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DIGITALISATION TO IMPROVE ORGANISATIONAL COMPETITIVE ADVANTAGE: A STUDY ON BBI EXPLOITATION

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Certificate of originality

I certify that the work submitted in this thesis is my original work and that, to the best of my knowledge, it reproduced no material previously published or written. Except where due acknowledgement has been made in the text, it also produced no material that has been accepted for the award of any other degree.

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Abstract

The increase of global competition in today's business environment has created a web of interconnectedness and interdependency between nations. This interconnectedness has induced competitiveness among nations, industries, and firms within the industries. The construction industry, in particular, appears to be facing a wide range of challenges and difficulties in its attempt to preserve the current level (or to improve its current level) of competitiveness for its survival and growth and to stay invincible in the market. These difficulties have significantly caused the construction industry to be criticised for its low profit-margins and relatively poor performance. The exploitation of digital technologies is expected to be one of the most reasonable methods, especially at the individual organisation level, of finding feasible pathways to enhance competitiveness in construction. There is evidence that shows digital data-driven approaches have a positive impact on organisational competitiveness and this provided the motivation to undertake this study.

The study is concerned with the exploitation of Building Information Modelling, Big Data Analytics, and the Internet of Things (BBI) for the competitive advantage of the construction industry. The methodology employed in this study is a combination of both semi-structured interviews and web-based questionnaire surveys, where the quantitative data was elaborated and expanded by the qualitative information. The study expands its boundaries to present a comparative study across four sectors: Construction, Retail, Finance, and Manufacturing within the UK.

The study first investigates the current level of exploitation in the above technologies as 'strategic tools' across four sectors, in the United Kingdom. The investigations established that the more firms exploit the technologies, the more chance they get to enhance their competitive edge. The relative level of exploitation for BDA and IoT was highest in the Retail sector. In Construction, the most exploited area in BIM was the 'effectiveness of the performance in daily tasks'. The highest exploited area for BDA in the construction industry was 'strategic leadership', while the 'efficacy of daily tasks' was the highest exploited area in Construction by using IOT. The investigations also revealed that BBI exploitation not only impacts individual organisational competitive advantage but also causes it. The role of synergistic exploitation of BBI in the enhancement of competitive advantage was a highlight in this study. It was revealed that these synergies enhance competitive advantages in higher levels than they are exploited individually. The study established a connection between the level of BBI exploitation and competitive advantage enhancements by highlighting their individual benefits and challenges. In the exploration of possible lessons learned from RFM sectors for the construction industry, 'Development of an organisational strategy' to exploit the technologies for organisational competitive advantage was prominent.

In the investigation of factors impacting BBI exploitation, and competitive advantage enhancement, the study demonstrates that there is not only a significant positive correlation but also causation from specific cultural and structural factors. For example, low power distance not only significantly impacts, but also significantly causes the ability to exploit technologies. Interestingly, organisation size had a bilateral correlation with exploitation. The quantitative data retrieved from statistical analysis predominantly aided establishing these correlations while more insights were received from qualitative data analysis. The findings lead to the development of an interactive strategic framework (https://bit.ly/366mZlc).

Management skills/ knowledge dimensions which managers at different levels need to possess to varying stages of the exploitation life cycle was a vital consideration of this study. The level of importance and the need for training in the skills/ knowledge dimensions indicate that the majority of senior managers believe that 'information management' and 'innovation management' are the two most important skills/knowledge dimensions that require the most training now and for the future. The findings lead to the development of an interactive skills- and-knowledge inventory (https://bit.ly/3mPg32q) for all three levels of managers. While these research outputs address the gaps in the literature, they make original contribution to the wider research discipline by emphasising 'how best to enhance individual organisational competitive advantage' by exploiting the above technologies.

The study recommends that the areas indicating the lowest level of exploitation need more efforts for improvement. BIM exploitation, for example, embracing new routines and processes, is an area that must be improved. The study also recommends that the synergistic exploitation of BIM, BDA, and IOT (BBI exploitation) gives a higher level of enhancement in competitive advantage than when they are exploited alone, and thus encourages such synergies. The strategic framework and the skills knowledge inventory together advocate 'how best' to enhance a firm's competitive edge by exploiting BIM, BDA, and IoT. Research to establish factors, other than culture and structure, that may impact on BBI exploitation is recommended. Devising a method to establish measurable outcomes of BBI synergistic exploitations is another area for future research. More comprehensive research is recommended on the impact organisation size has on BBI exploitation.

Keywords: Big Data Analytics, Building Information Modelling, Competitive Advantage, Internet of Things, Strategy.

Publications arising from the PhD Study

Journal Papers

- Madanayake, U. and Egbu, C. (2019). Critical analysis for big data studies in construction: significant gaps in knowledge. Built Environment Project and Asset Management. 9 (4), pp. 530-547.

Conference Papers

- Madanayake, U. and Egbu, C. (2017). A Systematic Review for the Challenges Related to the Implementation of Building Information Modelling, Big Data Analytics, and Internet of Things (BBI) in the Construction Sector. International Conference on Sustainable Futures- ICSF 2017. Bahrain 26 - 27 Nov 2017 Applied Science University Bahrain.

- Madanayake, U. and Egbu, C. (2018). A strategic approach to exploiting and implementing BIM, big data analytics, and internet of things (BBI) for competitive advantage in the construction industry. ARCOM Doctoral Workshop. Dublin, Ireland 09 - 09 Mar 2018.

- Madanayake, U. and Ganiyu, S. (2018). Research, data collection and ethical issues: lessons from hindsight. International Conference on Professionalism and ethics in Construction. London 21 - 22 Nov 2018.

- Madanayake, U. and Cidik, M. (2019). The potential of digital technology to improve construction productivity. 35th Annual ARCOM Conference. Leeds, UK 02 - 04 Sep 2019.

- Madanayake, U., Cidik, M., Egbu, C. and Adamu, Z. (2019). The impact of organisation culture on the effective exploitation of building information modelling, big data analytics and internet of things (BBI) for competitive advantage in construction organisations. International Conference on Innovation, Technology, Enterprise, and Entrepreneurship (ICITEE). Bahrain 24 - 25 Nov 2019.

- Madanayake, U., Seidu, R., Young, B. (2020) Investigating the Skills and Knowledge Requirements for IoT implementation in Construction. 5th North American International Conference on Industrial Engineering and Operations Management. Detroit, Michigan, USA, August 10-14, 2020.

Posters

- Madanayake, U, and Egbu, C. (2017). A strategic approach to exploiting and implementing BIM, Big Data Analytics, and Internet of Things (BBI) for competitive advantage in the construction industry. LSBU Postgraduate Research Summer School. London South Bank University 03 - 07 Jul 2017.

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Abbreviations

AEC	Architectural, Engineering and Construction
APP	Assets, Process, Performance
BDA	Big Data Analytics
BBI	Building Information Modelling, Big Data Analytics, and Internet of Things
BIM	Building Information Modelling
CITB	Construction Industry Training Board
DV	Dependent Variable
EU	European Union
ICT	Information and Communication Technology
IV	Independent Variable
IoT	Internet of Things
IT	Information Technology
MM	Mixed-Method
NBS	National Building Specification
ONS	Office for National Statistics
RFM	Retail, Finance, and Manufacturing
RICS	Royal Institution of Chartered Surveyors
SIC	Standard Industry Classification
SKI	Skills Knowledge Inventory
SKT	Skills, Knowledge and Training needs
SME	Small and Medium-Sized Enterprise
SPSS	Statistical Package for the Social Sciences
SSI	Semi-Structured Interviews
UK	United Kingdom
WBS	Web-Based Survey
WoS	Web of Science

Chapter One

1. Introduction

1.1 Introduction to Chapter One

The purpose of this introductory chapter is to provide a summary for the research on 'A strategic approach to exploiting BIM, Big Data Analytics, and Internet of Things (BBI) for competitive advantage in the construction industry`. The background explains the rationale and the literature on the potentials needed to exploit BBI for organisational competitive advantage. This was predominantly accomplished by reviewing the current state of knowledge and identifying the gaps in the literature. Subsequently, the chapter unfolds the study's aim and objectives. It explains the research design, its scope, and delimitations. This chapter also highlights the contribution to the body of knowledge and the value of undertaking this study. The last section of this chapter provides a brief guide to the thesis.

1.2 Background and rationale

1.2.1 Problem identification

The construction industry in the UK is currently facing uncertain market prospects due to the political and economic conflicts following the EU referendum and the COVID-19 pandemic. Now, more than ever, the construction industry in the UK is getting criticised for its poor performance (Allcoat, 2020), low productivity (Alade and Windapo, 2020), and low-profit margins (PwC, 2019). A report published outlining the industry's KPIs also highlighted that industry profitability remains under pressure (Office for National Statistics, 2020). When uncertainties and the challenges associated with them loom, construction stakeholders should prepare themselves to ensure that the industry can be sustained during these uncertain times. The preparation for such performance-productivity problems, financial meltdowns, and critical market conditions is greatly influenced by the competitiveness of construction firms collectively (Ng *et al.*, 2018). The role of construction firm in competitiveness is that, with the internal mechanism of a firm, one can structure the economic and management activities as 'manageable collective team efforts' within similar organisation cultural contexts- which are less effective at an industry or a project level (Ng *et al.*, 2018). Moreover, to be able to address the aforementioned problems in the industry, making an initiative through a group of firms producing close substitutes is the most effective medium (Porter, 1980b). The necessity to undertake this research in the area of construction organisations is further explained in section 2.4.3. Enhancing competitiveness is an effective strategy for firms to survive and grow within the market by outperforming their peer competitors mainly because 'competitiveness' is at the core of success or failure of firms that ultimately decide the success or failure of the industry (Porter, 1980b).

Enhancing competitiveness is also vital for firms in the construction industry as they are forced to compete for contracts with not only local practitioners but also practitioners from all over the world. With the increased globalisation and saturation of local markets, employing an export-import oriented strategy of providing construction services to emerging overseas markets has been inevitable (Ng *et al.*, 2018). The continuing globalisation spreading across the world has meant that the challenges and opportunities to the industry are increasing. Furthermore, the recent hype of globalisation has created a multitude of interconnectedness and interdependencies between nations around the world. This has given rise to competitiveness among nations, industries and firms within the industries (Flanagan *et al.*, 2007b). To maintain the competitiveness of an industry, firms must have a futuristic vision either for their 'survival' or 'growth' (Ambastha and Momaya, 2004).

One of the possible reasons for the existence of complexities and dynamisms around global construction competition is fast-evolving technology, especially information technology (Lu, 2006). Although the construction industry is considered to be one of the least digitised sectors (Mckinsey Global Institute, 2016), it is gradually coming to be considered a technology intensive-industry rather than a traditionally rooted labour-intensive industry (Lu, 2006). The evolving client requirements, technological advancements, development of complexities in construction projects, and inevitable globalisation have urged construction organisations to enhance their competitive position in the market.

The complexity and the rapid changes involved in the construction business environment have made it more difficult for the construction firms to maintain their survival. The survival and success of industries and their entities in such turbulent times increasingly depends on competitiveness (Ambastha and Momaya, 2004). Therefore, identifying the means of enhancing the competitive advantages of construction enterprises and the weaknesses that prevent them from being competitive in a turbulent market environment have become essential to sustain the development of the construction industry and its entities (Zee, 2002). Thus, the significance of pursuing competitive advantages in construction is becoming more apparent. This pursuance of competitive advantage in construction leads to the questions, how competitive advantage needs to be sought/ enhanced and in which scale/ level. The next section provides more insights into these two questions.

1.2.2 Identifying the scope of the research

The scope setting in this research is mostly confined by 'delimitations' consisting of four parameters namely: 1) Level of analysis/ unit of analysis; 2) Domain of organisations; 3) Geographical confinement and 4) Market sector(s). The following paragraphs explain these four parameters.

It is imperative to set the study scope explicitly, especially because the predominant research field of this study- 'competitiveness' is a relatively complex area comprised of different levels of analysis. From a macro level to a micro-level, competitiveness can be analysed at the national level, the industry level, an organisation level, and a project level. Setting a specific analysing level would not only provide more clarity into the understanding of competitiveness as a concept at a given level but would also provide coherence into the concentration of research efforts. This study confines its first parameter to analysing competitiveness at the individual construction organisation/ enterprise level as opposed to the industry or project level. Although many researchers stress the importance of project-level competitiveness, this study emphasises the fact that competitiveness at individual organisation level equally or sometimes significantly contributes to the construction industry competitiveness as much as project-level competitiveness (Ambastha and Momaya, 2004). A project is a temporary organisation, whereas an organisation is a continuing entity that creates the construction industry (Male and Stocks, 1991; Kale, 2002). Porter once stated "it is the firms, not nations, which compete in international markets" (Porter, 1996). The majority of variance in profitability could be attributed to firms' characteristics and actions (Arikan and Mcgahan, 2010). The literature also suggests that an evaluation of the competitiveness of construction organisations is imperative to sustain the growth of construction enterprises and the construction industry simultaneously (Arikan and Mcgahan, 2010). Considering these facts, the unit of analysis of this study is also set to be 'individual organisation'. Organisational capability is hypothetically measured in the organisational or sub-organisational units` ability to demonstrate competitive advantage. This demonstration ability is examined by the way organisations surpass and outshine the peer market competitors by pursuing a common mission or delivering a common project/outcome. To be able to understand the organisational context concerning competitiveness, at times, individual competencies, attitudes, agreements, and behaviours are also taken on-board. It allows the analysis of the individual's ability (with knowledge extent, skill sets, and values) to contribute to the "competitive advantage of individual organisation level". Thus, the unit of analysis is set primarily to be ‘organisation’. This is a key delimitation (choice) made by the researcher. However, the data related to individual perceptions incorporated in BBI exploitation are also utilised in the study. The key individuals include, but are not limited to, IT Managers, Architects, Directors, decision-makers, peer staff, etc. For, enhanced decision making, it is of paramount importance that the human dimension at a behavioural level, as well as technology, process and data, is considered. In that contingent, the cultural aspects of organisations should also be thoroughly studied. The prevailing status of organisation cultures and sub-cultures are hence investigated in-line with the intellectual traditions collectively drawn by seminal work in construction management literature.

The study limits its investigations to types of organisations in the UK construction industry according to SIC classification 2007. This includes, but is not limited to, organisations ranging from contractors to designers, and consultancy practices at different scales and sizes.

This study is geographically limited to the United Kingdom. One of the main reasons for this delimitation is that the UK is considered to be the quickest to embrace BIM, Big data Analytics and related technological aspects (PwC, 2019). According to HM Government (2014), although Scandinavian countries have had BIM regulations in place for almost a decade, the UK is now recognised by its peers as one of the leading nations in the exploitation of BIM technology and related processes with an internationally respected centrally-led programme. Moreover, BIM Level 2 is mandated across all centrally procured construction projects in UK. This has enabled the country to achieve a comparative advantage in certain construction services, primarily engineering and architecture while creating opportunities which are driven by technological change (HM Government, 2013). In April of 2016, the UK’s Government construction strategy declared that the construction industry in the UK would reach 20% savings on procurement costs, and this cost saving would be greatly attributed to BIM adoption across the country. Moreover, in terms of data-enabled ways of working, the UK is recognised as ‘being on the right track’. Concerning the usage of data-enabled technological solutions, the UK has moved from 39% to 48% in 2016 (NBS, 2016). Presenting facts in a similar vein, the European BIM Summit held in Barcelona (2015) divulged that, the UK government had saved £1.7 billion on major projects over the previous year (Giacomo, 2015). Nevertheless, The National BIM Survey reveals that the awareness and current usage of BIM in the UK remains second to Denmark and Canada (NBS, 2016). While BIM and other data-enabled systems are recognised to be ‘key agents’ for economic growth in both domestic and international construction markets, the government has also recognised a threat of markets beginning to close to UK business as other countries are rapidly adopting data-enabled technologies, looking for home grown expertise or sourcing their skills and capabilities from elsewhere in the world (NBS, 2016). This threat is predominantly coming from the dynamic emerging markets, where competition is greatly dominated by innovative digital technologies (HM Government, 2013). This indicates the need for the urgent development of digital capabilities and the need to progress the exploitation of BIM and other data enabled technologies, especially in the UK. Considering the above facts, the context of the study is limited to the United Kingdom.

The fourth limiting parameter is the market sector. It is essential to relate the study into a specific market sector as competitiveness is strongly influenced by the characteristics of a given market and its social, political, and economic conditions. The study encompasses not only the construction market sector but also a vast spectrum of different market segments. It includes lessons learned from the Retail, Finance, and Manufacturing sectors by arguing that, regardless of the specific market characteristics , enhancing competitive advantage possesses common features that can be applied to any industry. Most of these 'other sectors' are withstanding the challenging and turbulent economic environment, maintaining their profit margins at acceptable levels compared to construction. On this basis lessons could be learned from those other sectors and these could be adapted for the construction sector. The study, therefore, explores the extent to which BBI are employed as competitive tools in other sectors and deploys their success factors into the construction industry.

1.2.3 How competitive advantage can be enhanced

As outlined in the previous section, this study limits its investigations to competitiveness in UK construction organisations. Achievement and/ or enhancement of competitive advantage in organisations in general has received considerable attention over the past decades. Among the plethora of theories explaining how this could be done, three main schools are dominant: the competitive advantage and competitive strategy models (Porter, 1980b; Porter and Millar, 1985), the resource-based view and core competence approach (Prahalad and Hamel, 1990; Barney, 1991), and the strategic management approach (Chandler, 1962; Mintzberg, 1987). Out of these different approaches, pursuit of competitive advantage, via a strategic approach (Betts and Ofori, 1992) is the primary focus of this study. This is comprehensively explained in Section 2.2.

While a considerable body of knowledge in the field of the strategic approach to competitiveness has been developed, some essential issues have not been well addressed. For example, the common determinants of competitive advantage for construction organisations in general is something that is lacking in the construction management literature (Shen *et al.*, 2006). What factors may impact the journey of enhancing organisational competitive advantage and what can be employed as 'strategic tools' to enhance organisation competitiveness are a few other areas of concern that have not been fully addressed (Flanagan *et al.*, 2007a).

1. Introduction

Strategic management refers to a set of managerial decisions and actions that determines the sustainable performance of an organisation (Wheelen and Hunger, 2012). The initial thrust of the strategic management approach is to deal with the turbulence of the business environment for long-term survival and growth. The evolvement of strategic management is now often used as an approach for achieving a firm's competitive advantage. The five different definitions of (or approaches to) developing a strategy suggested by Mintzberg were employed as the basis of this research (Mintzberg, 1987b). The strategic management approach to enhance competitive advantage suggests that identifying the sources and tools of competitiveness in a firm helps improved understanding of the strategic use of these resources (Betts and Ofori, 1992).

IT capabilities play a vital role as an important source of obtaining sustainable competitive advantage for an organisation. Organisation capabilities related to IT are transferable and hence, if combined with other IT or non-IT capabilities, they have the potential to enhance organisational competitive advantage (Wade *et al.*, 2011). It has also been suggested that IT-enabled strategies have a significant impact on construction organisations competitiveness (Yahuza Kassim, 2010). A few of the values offered by the use of IT that may contribute to sustainable competitive advantage include an improvement in overall construction processes, enhanced collaboration by effective communication, and effortless information sharing thereby creating new construction business opportunities (Yahuza Kassim, 2010). For decades, the role of digital technology in enhancing competitive advantage has been one of the leading concerns for both academia and industry. The digital revolution has transformed the nature of organisational competition and affected every aspect of the current organisational structures. Deployment of digital resources as strategic tools and the strategic impacts of these digital resources on organisations' performance have been of interest to both academia and industry for decades (Irani, 2002; Kassim *et al.*, 2009b; Oyedele, 2016; Robson *et al.*, 2016; Wionczek and Sordo, 2019). Studies conducted in construction management literature have led to the suggestion that digital-enabled strategies could be used to gain organisational competitive advantage (Kassim *et al.*, 2009b). The main argument that rationalises this suggestion is that, digital resources do offer a strategic advantage to organisations through the efficient and cost-effective delivery of the organisation's value chain (Ahram *et al.*, 2017; Kassim *et al.*, 2009a; Roberts and Grover, 2012; Yahuza Kassim, 2010). However, most of these studies show a shortage of validated frameworks on which the studies were based. While a considerable amount of research is being conducted to explain the inconsistencies among the various studies about the impact of digital resources on organisation competitive advantage, the ascribed difficulties associated with conceptualising and methodological issues are not clearly documented. Due to the complex linkage between theoretical frameworks used for evaluating the value of digital resources and its contribution to organisational competitiveness, this study employed a multi-theoretical paradigm to conceptualise and model the enhancing competitive advantage through the use of digital resources as strategic tools.

The proposed concept in this study focuses on individually or synergistically (if possible) ‘exploiting’ Building Information Modelling (BIM), Big Data Analytics (BDA), and Internet of things (IoT) as ‘strategic tools’ for organisations’ competitive advantage. The rationale for the selection of these three digital resources as strategic tools is explained fully in Chapter Two.

The logical basis for the research inquiry is compiled based on two main observations:

Observation 01- There has been a growing interest in the adoption and exploitation of BIM, BDA, and IoT. It appears that a significant diffusion of BIM/BDA/ IoT adoption within UK construction practices is about to take place in the UK. In some areas that transition has already taken place. A UK survey predicts a 50% increase in BIM usage in 2020 and most of the industry using BIM within the next five years (NBS BIM survey 2018). The construction 2025 targets also focus on the use of big data and IoT strategies to improve sector productivity. With a widespread digital revolution predicted, systems and guidance must be in a methodical righteous path to ease this transition (Office for National Statistics, 2020).

Observation 02- A considerable number of authors suggest the beneficial use of combined technologies for organisational competitive advantage. However, there is a lack of research that informs ‘what exactly’ leads to competitive advantage. Although there is a plethora of research into BIM, a lack of research for its consolidation with big data analytics and internet of things is emphasised. This lack of research is quite significant concerning the factors that lead to competitiveness enhancement. A research conducted by Coates *et al.* (2019) indicates that no research has been undertaken, to date, investigating the ways in which strategy, policy, and procedure for digital technologies could be combined for competitive advantage enhancements.

Building upon the two aforementioned observations, this research looks at enhancing competitive advantage in the construction industry by exploiting BIM, Big Data analytics, and the Internet of Things. It is a form of prescriptive research aimed at providing recommended actions or choices and giving directions to the effective exploitation of BBI. The research ultimately develops a strategic framework for an organisation to use as guidance to achieve/ enhance competitive advantage to enable organisational survival and growth.

The research conducted in the accomplishment of this PhD study addresses the problems (See section 1.2.1) in the construction industry by emphasising the importance of ‘improving construction competitiveness’ through a strategic approach. The thesis presented herewith is a summarised report of a PhD study carried out to help construction organisations to improve their understanding and awareness of competitiveness through the strategic use of digital technologies.

1.3 Importance of this research

Despite the widespread acknowledgement of its importance, competitiveness remains a concept that is neither well understood nor easy to communicate (Flanagan *et al.*, 2007b). First, neither theories nor tools are available to provide sufficient references to know how competitiveness can be enhanced in construction organisations in general. How construction organisations could enhance competitiveness by exploiting information technologies is a grey area in construction literature. Although some theories and models are currently being used to explain competitiveness, no framework has been developed to communicate it to the practitioners effectively. This study therefore shows the applicability of general competitiveness theories and strategic management theories in the construction context by analysing empirical evidence.

Moreover, existing research into competitiveness at the construction firm level shows an imbalance, particularly in the choice of research methodology. The lack of empirical studies on the application of competitiveness theories into construction firms has been a significant concern in academia. Roger Flanagan emphasises that more empirical studies on construction firms' competitiveness must be initiated in the future (Flanagan *et al.*, 2007b). A study conducted by Flanagan et al. redressed this imbalance to some extent by devising a competitive index to measure the competitiveness in construction firms. The latter study, however, does not prove whether these competitiveness indicators help with mapping the long-term performance of construction firms. 'Will a contractor's performance be better if its competitiveness index is higher?' is yet an unanswered question. Among the available methods for enhancing competitiveness in construction, not much attention has been given to the competitiveness of firms other than contractors. For example, design firms and quantity surveying firms have not received much attention. This study bridges these gaps by generalising the competitiveness investigations into construction organisations in general. The author in this Ph.D. study believes that measuring competitiveness is not the ultimate purpose but enhancing the competitive advantage and achieving long-term survival and growth is.

Many research studies have been concerned with the implementation of BIM, big data analytics, and IOT, emphasising it as a costly endeavour. However, no consideration has been given to the development of an holistic framework focusing on the synergies of the three strategic tools through the 'exploitation' perspective. Some researchers see the synergistic approach as a worthless attempt because one cannot predict the extra costs for unforeseeable changes and the unpredictable timing of the actual occurrences of these synergies. The immeasurability of amounts of change and the present costs may be higher than the future costs for the same changes. Hence, the recurrent trend is to step forward in adopting and implementing B, B, I as strategic tools and thereafter maximising the exploitation potential for competitive advantage. There is a lack of research relating to BIM exploitation and its consolidation with big data analytics and the internet of things especially concerning complex projects. Research which was done by Liu *et al.*, (2015) indicates that no research has been conducted on the exploitation strategy, policy, and procedure or formative guidance to achieve for BIM, BDA, and IoT. This appeared as a significant gap in the current literature, so this study was designed to bridge this gap. To this end, the development of a strategic framework could help organisations, providing a guided approach to follow in achieving organisational competitive advantage.

1.4 Research aim and objectives

This research aimed to develop a framework for the improved exploitation of BIM, Big Data Analytics, and the Internet of Things as strategic tools for competitive advantage in construction organisations.

The study followed the six objectives listed below.

1. To critically review state of the art in the use of BIM, Big Data Analytics, and Internet of Things in the construction industry.

2. To investigate the extent of exploitation, benefits, and challenges associated with BBI in construction and its implications towards organisational competitive advantage.

3. Ascertain the impact of organizational size, culture, and structure on the effective exploitation of BBI in construction.

4. Investigate the extent to which BBI are employed as competitive tools in organisations in other sectors (including Retail, Finance, and Manufacturing) and explore possible lessons to be learned for the construction industry.

5. To develop a framework for improved awareness and understanding of the critical factors at play in the exploitation of BBI for competitive advantage in construction.

6. To explore skills and training needs for the effective exploitation and implementation of BBI for competitive advantage and, in this regard, develop a skills and knowledge inventory (SKI).

1.5 Research Questions

To facilitate the achievement of the intended objectives in this research, two research questions were formulated. The two research questions were ensured to be fact-oriented and information-gathering. These research questions were confirmed or refuted in the conclusion chapter.

1. What factors impact on a construction organisation's ability to exploit BIM, BDA, and IOT for competitive advantage?

2. In what different and complex ways do construction organisations maximise competitive advantage through the exploitation of BIM, BDA, and IoT?

1.6 An overview of the methodology

The research flow diagram (illustrated in Figure 1) encapsulates the work undertaken, including the overall methodology, methods used, and the results obtained from this research endeavour. Phase 1 explains how the research question, aim and objectives have been defined and how they lead to preliminary primary data collection This phase reviews the literature to identify construct variables for high-level concepts and to explore people's perception of research focus areas. Phase 2 uses a desk study towards the development of strategic Framework and Skills Knowledge Inventory (SKI) based on data collected in the previous phase. Phase 3 looks at providing overall conclusions regarding this research endeavour.

To address the industry problems as described in section 1.2.1, it is necessary to adopt a methodological approach that takes into account both ontological and epistemological viewpoints (Love et al. 2002). The study identifies 'organisational competitiveness' as a driver/ solution for many of the contemporary industry problems. The study was guided by the 'pragmatism knowledge claim' and categorised under the applied research category. The dominant purpose was in the tradition of explorative research. However, some aspects of descriptive and explanatory research traditions were utilised in objectives 3 and 4. Thus, an evidence-based empirical investigation was undertaken. A mixed-method approach was hence adopted. The methodology, literature review, semi-structured interviews and web-based questionnaire surveys were used to gather data. A desk study was used to develop the strategic framework for identifying the critical factors at play in BBI exploitation. These methods can be exploited to generate new knowledge, specifically in the field of construction management and technology diffusion bringing the theoretical insights into a real-life context with empirical verifications.

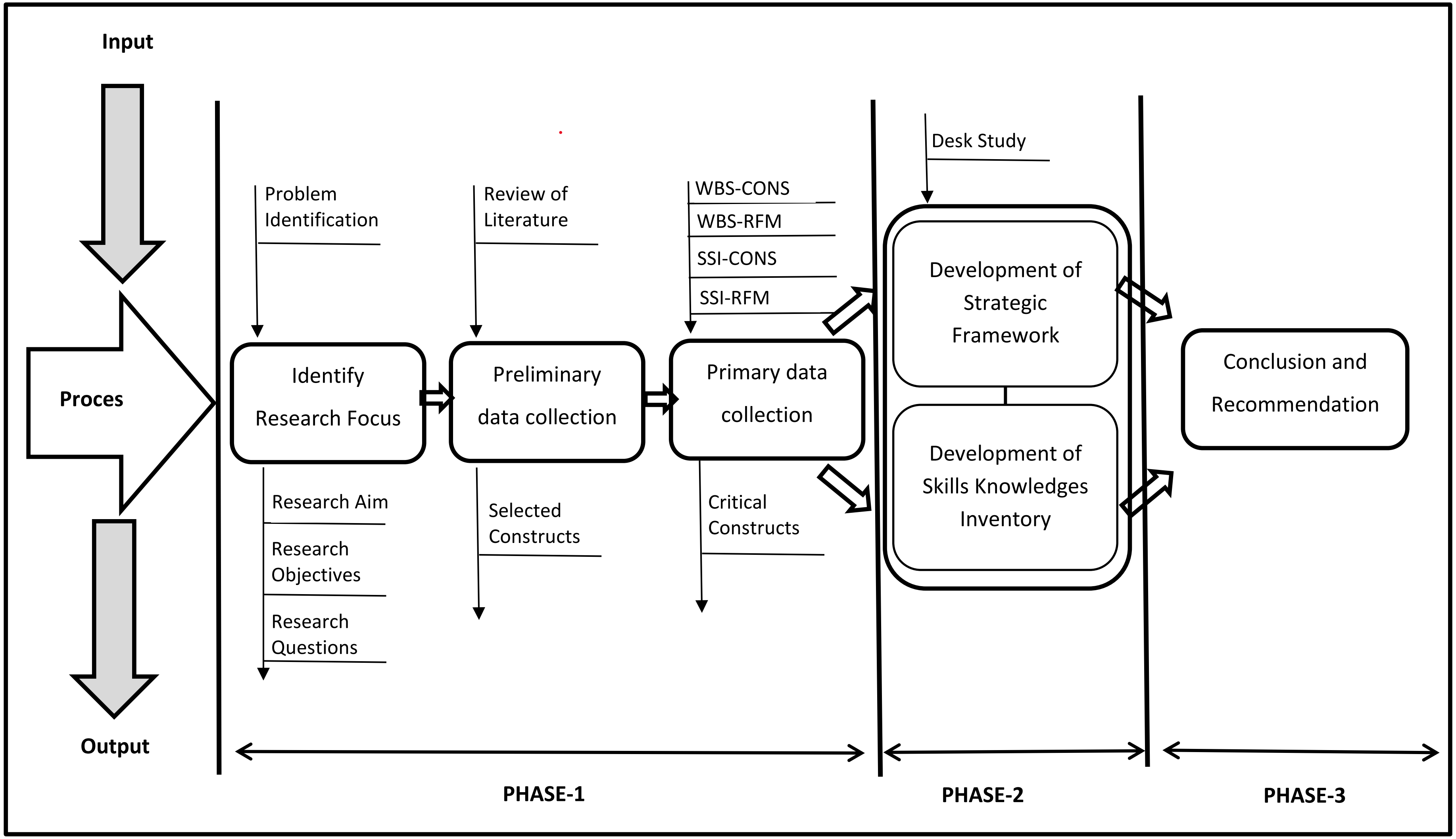

Figure 1- Research flow diagram

A summary of the research methods adopted (data collection, analysis, and validation) for completing each objective is illustrated in Table 1.

Table 1- Summary of the adopted research methods

Research Objective	Adopted Research methods/ instruments			
	Literature Review	Semi-structured interviews	Web-based surveys	Desk Study
1. To critically review state of the art in the use of BIM, Big Data Analytics, and Internet of Things in the construction industry.	√			
2. To investigate the extent of exploitation, benefits, and challenges associated with BBI in construction and its implications towards organisational competitive advantage.	√	√	√	
3. Ascertain the impact of organizational size, culture, and structure on the effective exploitation of BBI in the construction industry generally	√	√	√	
4. Investigate the extent to which BBI are employed as competitive tools in other sectors (Retail, Finance, and Manufacturing), and explore possible lessons for the construction industry.		√	√	
5. To explore skills and training needs for the effective exploitation and implementation of BBI for competitive advantage and, in this regard, develop skills and knowledge inventory (SKI).		√	√	√
6. To develop and validate a framework for improved awareness and understanding of the critical factors at play in the exploitation and implementation of BBI for competitive advantage in construction		√	√	√

The collected data was a combination of qualitative and quantitative data. The results were analysed through content analysis and descriptive statistical methods, and ‘triangulation’ was used to establish the quality and rigour of this scientific investigation.

1.7 An overview of the research findings

The results of the quantitative study depicted:

- that BBI exploitation leads to organisation competitive advantage enhancements;

- that exploitation of BBI as synergised strategic tools enhances competitive advantages in higher levels than when they are exploited individually;
- Individual years of experience and extent of technology use largely influence the organisational BBI exploitation levels;
- that the factors that most positively impact BBI exploitation in terms of organisation culture are the ability to take risks, ability to work collaboratively, competitiveness and being result-focused;
- that the factors that most positively impact BBI exploitation in terms of organisation structure are less formalisation and less stratification;
- that organisations can implement BIM, BDA, or IOT if they have sufficient leadership from senior leaders and if they have a strong initiative for skills and training;
- that organisations can determine that they have exploited BIM, BDA, or IOT if they are experiencing effectiveness and efficiency in their workflows after using BIM, BDA, or IoT;
- that organisations must have a contingency plan for data security, privacy, ownership, and skills-knowledge improvements through sufficient training incentives as they are the most challenging areas for effecting BBI exploitation;
- that organisations must be informed that BBI exploitation improves their competitive edge by enhancing areas inter alia; employee motivation, brand and reputation, technological capability, organisational profitability, organisational productivity, predictability and many more.

The results of the qualitative study depicted:

- that the development of a strategy is a must for the effective exploitation of BBI for competitive advantage. Things like access to data, data security, data privacy, an efficient supply chain, operational intelligence and target-based delivery are some of the critical strategic requirements;
- that there are dual-sided perceptions among professionals about the impact of organisation culture, structure, and size. For example, while some interviewees support the argument that collectivism enables BBI exploitation the same interviewees appreciate the importance of self-reliance on employees.

1.8 An overview of contribution to the body of knowledge

The contribution to the existing body of knowledge from this study is twofold:

First, the strategic framework developed (https://bit.ly/366mZlc) identifies the critical exploitation constructs, critical benefits, critical challenges, essential requirements of strategy, and critical competitive advantages. Moreover, the critical factors that impact effective BBI exploitation within the wider context of technology adoption in construction are established. This will assist constructors, consultants, designers, owners/clients, and developers in their investment decisions on potential BBI adoption, implementation, or exploitation. The developed Knowledge Skill Inventory (SKI) (https://bit.ly/3mPg32q) also assists in initiating the most important skills-knowledge and training needs suitable for different levels of job roles at different time scales.

Secondly, the research findings strengthen the reliability of the existing body of knowledge while confirming the rapid trend for BIM, BDA, and IoT use. In addition, the findings strongly emphasise that the synergistic use of BBI has the potential to enhance certain competitive advantages, which were merely vaguely identified in previous literature.

1.9 Structure of the thesis

After the introductory chapter, this thesis comprises six more chapters. It is noteworthy to mention that the structure of this thesis is shaped according to 'objective achievement'. All data collection, data analysis, and discussions related to each objective achievement are placed in corresponding chapters. Moreover, all objective-driven chapters (4, 5, 6) compare the similarities and differences of the research findings with the current state of knowledge.

Chapter Two

This chapter presents a comprehensive summary of previous research as a critical review of literature on topics that have been employed in the study. It also establishes a theoretical base for the research and helps the researcher in determining the nature of the research while establishing the 'variables' for the data collection. The objective-1 is fulfilled within this chapter.

Chapter Three

This chapter elaborates on the research methodology used in this study. A comprehensive overview of the research philosophy, design, and adopted research methods are discussed while providing pertinent justifications on method selection and sampling.

Chapter Four

An investigation into the extent of exploitation, benefits, and challenges associated with BBI in construction is discussed in chapter four. Moreover, the chapter explains how the construction industry exploits the concept of BBI in current practice. Achievement of Objective-2 and Objective-4 are explained in detail within this chapter. Data analysis and discussions related to objectives 2 and 4 are also placed here.

Chapter Five

Chapter five first explains the impact of organisation culture, structure, and size on the effective exploitation of BBI as a comparison study across sectors: construction, retail, finance, and manufacturing. This endeavour emphasises the direction and the strength of impact that the impact factors have on BBI exploitation and competitive advantage enhancements. The lessons learned from retail, finance, and manufacturing sectors which can be adapted to the construction industry are also presented remarking the achievement of objectives 3 and 4. Secondly, this chapter assembles the results of all the work undertaken concerning impact factors, exploitation, and competitive advantage and develops a strategic framework highlighting the critical factors at play in BBI exploitation for competitive advantage. The chapter explains the need for such a framework and the development of this strategic framework. Thus, Objective 5 is achieved here. The discussions aimed at the findings concerning the strategic framework are also presented in this chapter.

Chapter Six

Chapter six explores the skills and training needs required for effective exploitation of BIM, BDA, and IoT for competitive advantage. After analysing quantitative and qualitative data, the chapter concludes by developing an interactive Skills Knowledge Inventory (SKI) for the construction industry. Objective 6 is completed within this chapter, followed by a discussion aimed at the findings concerning the skills knowledge inventory.

Chapter Seven

The last chapter provides an overall conclusion of this research endeavour. The priority of this chapter is to explain the key conclusions and recommendations emerging from the findings in line with the research objectives and research questions. The contributions to the body of knowledge and recommendations for further research are also envisaged.

Figure 2 below illustrates the position of each chapter in the overall research endeavour and the contribution of each chapter to the research outputs. Accordingly, the next chapter presents a comprehensive summary of previous research on the topics that have been employed in the study, laying out the theoretical foundation for the research endeavour.

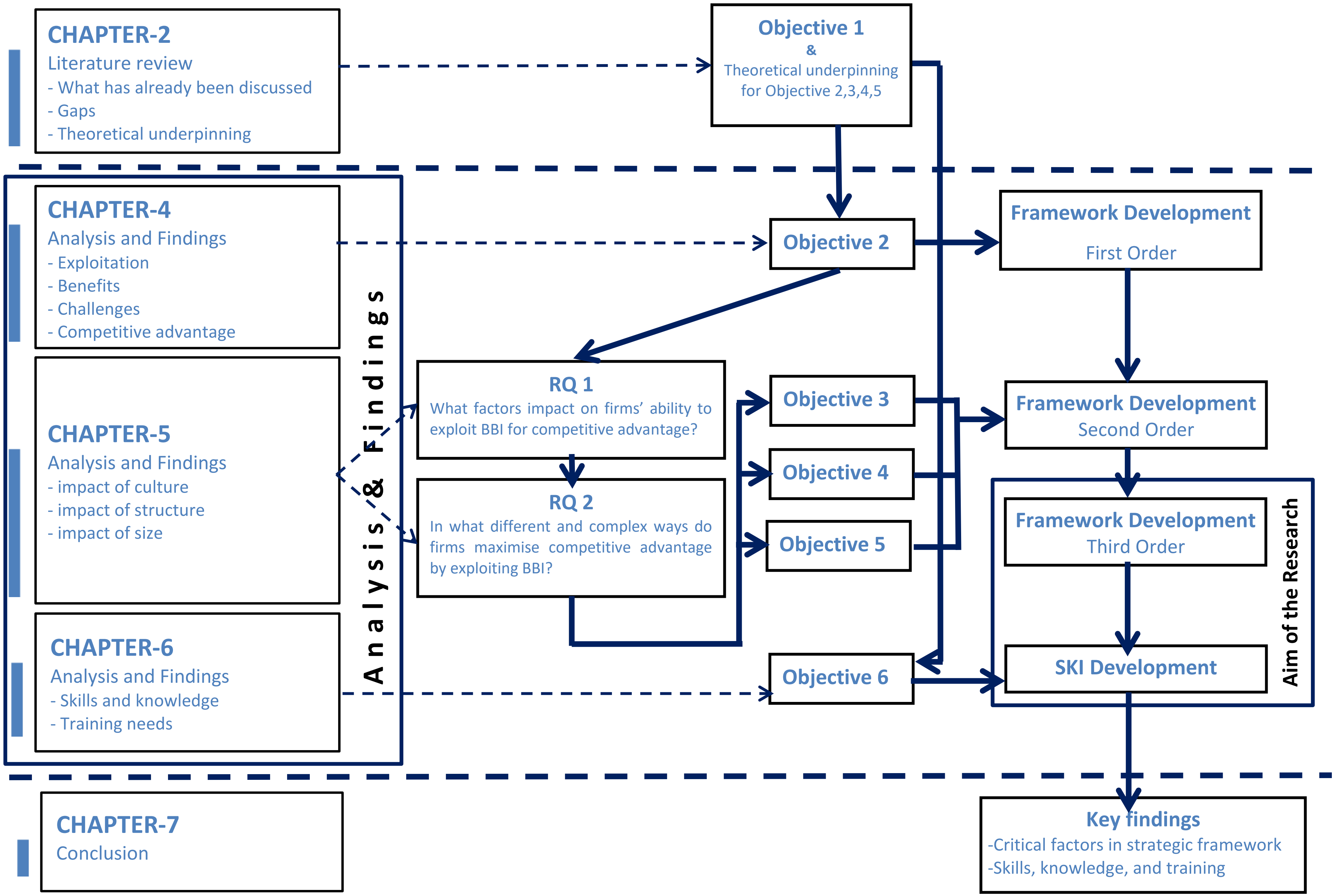

Figure 2- Position of each Chapter in the study and their contribution to strategic framework

Chapter Two

2 Review of Literature

2.1 Introduction to Chapter Two

The purpose of this chapter is three-fold. First, to summarise what has already been discussed in the field related to this study and to show how this study relates to that field. This includes ascertaining the state-of-the-art in the use of BBI and it leads to the achievement of the first objective. Second, to highlight gaps, problems, or shortcomings in existing research to show the original contribution that this thesis makes to the existing body of knowledge. Third, to identify the most relevant/ suitable studies, methods, and theoretical frameworks that can be applied to this research.

In meeting the above aims, this chapter presents a review of literature on subject areas relevant to three main issues of the research; 1) strategic management approach; 2) competitive advantage; and 3) 'exploitation' of Building Information Modelling (BIM), Big Data Analytics (BDA) and Internet of Things (IoT) in four sectors (construction, retail, finance, and manufacturing). First, the 'strategic approach' which has been recognised as fundamental to the success of any organisation is discussed concerning the problems stated in section 1.2.1 and the possible solutions outlined in section 1.2.3. This provides the conceptual foundation for this research. The 'strategic approach' provides the layout positioning for the construct variables employed in this research to achieve the aim of developing the 'strategic framework'. Second, 'competitiveness' is discussed as a part of the 'strategic approach' implying that competitiveness serves as the 'ploy' for the strategic approach. Third, the state of the art in the exploitation of each strategic tool; BIM, BDA, and IOT (achieving the first objective) and the factors that impact the skills/ knowledge required in exploiting BIM, BDA and IOT are discussed.

2.2 Establishing a 'Strategic approach' by which the exploitation of BIM, BDA, and IoT can be improved.

2.2.1 Addressing the problem and the possible solutions

As outlined in section 1.2.1, productivity in the UK construction industry has lagged compared to many other sectors. While productivity and performance growth since the Great Recession has been negative and sluggish (CIOB, 2016), the situation has got worse since post-referendum and post-pandemic economic falls. Further, the hype of globalisation has recently created the plethora of interconnectedness and interdependency of nations around the world which in turn induces competitiveness among nations, industries and firms within the industries (Flanagan *et al.*, 2005). To maintain the competitiveness of an industry, firms must have a futuristic vision either for their 'survival' or 'growth' (Ambastha and Momaya, 2004). Therefore, in response to the problems stated, the need for improving competitiveness among firms is manifested.

As a proactive solution for increased competition, the deployment of digital resources has been of interest to both academia and industry (See section 1.2.3). Building Information Modelling, Big Data Analytics, and the Internet of Things are such digital technologies that not only prosper from the revolution of the fourth industrial revolution but also prosper affordable living and work that are safer (Alade and Windapo, 2020). The deployment of these technologies was narrowed down into the scope of 'exploitation' to facilitate the investigations presented in this research. This is extensively discussed in section 2.5. In the 'management perspective', to accrue the beneficial use of these technologies a robust strategic approach is required. The next section is dedicated to explaining why a 'strategic approach' is needed in achieving the overall aim of this research and how the management process could be strategized using a renowned strategic planning model.

2.2.2 Strategic Management in general to construction

According to Dobson *et al.*, (2004), a strategy is a view that helps to position an organisation in an industry by being different and achieving competitive advantage via delivering unique value-added service to the customer. Having a similar view, Johnson *et al.*, (2008) state that strategy is the direction and scope of an organisation over the long-term, which achieves advantage for the organisation through its configuration of resources within a challenging environment, to meet the needs of markets and to fulfil stakeholder expectations. According to Mintzberg (1987), a strategy must provide for the creation and/or maintenance of competitive advantage in the selected area of activity. Strategic management allows organisations to be more proactive than reactive in shaping their future, to initiate and influence activities, and to exert control over its sustainability (David, 2011). According to Porter's renowned competitiveness strategy model (1985), a firm's competitive advantage comes from the competitive strategy if adopted. A strategic management approach has been explored by many researchers for its applicability to construction (Fellows, 1993; Newcombe *et al.*, 1990; Venegas and Alarcón, 1997; Warszawski, 1996). Although the above studies give different insights into ways of achieving competitive advantage, many criticisms also seem to appear to the contrary (Kale and Arditi, 2002). These criticisms are greatly attributed to the use of anecdotal or descriptive research approaches. The latter authors further emphasise the irony of 'stuck in the middle' discussed in Porter's strategy. Porter (1980, 1985) postulates that the contractors with a neutral strategy (aka 'stuck in the middle'), possess no competitive advantage. whereas Kale and Arditi (2002) explain how US markets achieve competitive advantage through a neutral strategy that falls between a narrow and a broad strategy. This has led to the dearth of rigorous empirical data that causes problems in a realistic understanding of competitiveness.

2.2.3 The connection between strategy, Information technology, and competitiveness

Harnessing the power of the digitalised data revolution is one major concern when considering potential solutions for contemporary issues in the construction industry. The need for a 'strategic approach' to this end is vital as it provides a layout that positions all required constructs that enable competitive advantage. The role of strategic management is not just fixing the foundations: it must also plan for a rapidly changing future, and look to shape new market opportunities for continuous improvement (Abiad and Bitter, 2009). Porter (1985) has highlighted technological change as a 'principal driver' for competition as it plays a major role in defining and sustaining industry structure as well as creating new industries. He also classifies technology as a powerful determinant of entry barriers as it has the potential to raise or lower economies of scale in any valued activity. However, the author claims that not all technological changes are strategically beneficial as they have similar probabilities to worsen a firm's competitive position as well as industry attractiveness. Firms leverage their IT investments by creating unique IT resources and strategically positioning them within their organisational strategy together with the human skills and knowledge required to execute the process (Clemons, 1986; Mata *et al.*, 1995). Nonetheless, any technological change has the potential to have a significant impact on a firm's competitive advantage. The implication between technology and competitive advantage is that technology significantly determines the relative cost position or differentiation of a firm. Technology also affects competitive advantage through 'changing or influencing the other drivers of cost or uniqueness' (Porter, 1985). However, a firm's technological success is always interdependent with a buyer's buying decisions (Abiad and Bitter, 2009).

The existing literature has extensively discussed the strategic impact of Information Technology (IT) in general on the organisations' competitive advantage. The impact of IT-enabled strategy on construction organisational competitiveness is comparatively significant among the other types of strategies, which may include improvement in overall construction processes and creating new business opportunities for construction (Yahuza Kassim, 2010). The literature has used different terms such as digitalisation, information, and communication technology (ICT), Information technology (IT) and technology, and even 4IR (Fourth Industrial Revolution) to establish the strategic importance of digital technologies in general in enhancing the organisation's competitiveness. The subsequent paragraphs critically review the literature that suggests the strategic deployment of digital technologies towards organisational competitive advantage.

The utilisation of IT in construction projects is found to enhance collaboration by supporting communication among project members and sharing information and documents, which is inherently a performance improvement (Nitithamyong and Skibniewski, 2004). The contribution of IT to the enhancement of an organisation's performance metrics such as productivity, profitability, cost, differentiation, and market share is acknowledged by various authors while the terms they have used in the investigation of this impact varies. "IT business value", "strategic value of IT", "strategic advantage", "competitive weapons", and "IT-dependent strategy" are all used. (Melville *et al.*, 2004; Wade *et al.*, 2011; Oh and Pinsonneault, 2007). Following the same direction, (Zhai *et al.*, 2009) bring out evidence that overall costs have been reduced or project performance has been improved with the use of IT in construction. Bharadwaj (2000) asserts that IT resources greatly support the delivery of the construction organisation's value chain, improve productivity and contribute to organisations' overall sustainability and ultimately improves their competitive position in the market. A study conducted by (Flanagan *et al.*, 2005) investigated the factors that influence the competitiveness of the construction sector and concluded that one of the most influential factors for construction competitiveness is the use of ICT. Firms are more likely to yield business benefits by marrying good management practices with IT investments (Stewart, 2007). For this research, technology/ ICT/ digitalisation are viewed as 'strategic tools' employed towards sustainable competitive advantage.

There is very little evidence to suggest that construction companies develop long-term technology strategies that look at the future needs to address their emerging business needs. Hence, this research to bridge this gap proposes a strategic approach to exploit digitalisation for the competitive advantage of the industry. The next section critically reviews the most suitable strategic theoretical underpinning for this research.

2.2.4 The most relevant strategic approach towards enhancing organisational competitive advantage- Mintzberg's 5 Ps of Strategy as 'strategic approach'

Considering all available theories around Strategic Management, Mintzberg's 5 Ps of Strategy (Mintzberg, 1987b) consisting of Plan, Ploy, Pattern, Position, Perspective was selected to take forward in this research for a number of reasons.

First, the 5 Ps help to view the strategic apex of an 'organisation' from different perspectives. Instead of trying to use the 5 Ps as a process to follow while developing strategy, this approach offers a variety of viewpoints that a firm should consider while developing a robust and successful strategy. Second, this model regards the strategic approach as not the exclusive domain of large companies. It is an equally important activity for all sizes and types of organizations looking for success. Third, as affirmed by Mintzberg (1987), the implementation of the 5PS approach specifically targets the improvement of ‘something’ to keep a business in a favourable position by taking advantage of the organisation’s strengths and capabilities. There is no point in developing a strategy that ignores the culture and capabilities of an organisation. This would be a waste of one of a company’s strengths. Fourth this approach acknowledges that a strategy to start something new or to improve something that exists should not only take into account the competitor's actions but should also acknowledge culture and other possibilities and developments within the organisation. The table below explains how Mintzberg's 5 Ps of Strategy is used towards research aim achievement.

Table 2- Adopting Mintzberg's 5p's Strategy to develop the 'strategic Approach' in this research

Mintzberg's 5 Ps of Strategy	Explanation as given by Mintzberg	How the theory was personalised to this research
Plan	A plan must be made before possible actions are taken. A plan could take place in a variety of different ways if managers are keen on improving something. Part of planning is dealing with the situation and understanding current capabilities (strengths, weaknesses, opportunities, and threats)	This research aims to develop a strategic framework to improve the ‘level of exploitation’ in BIM, BDA, and IoT. First, a situation analysis was carried out to see the current level of exploitation at the ‘plan’ level.
Ploy	A ploy puts an organisation in a favourable competition with other potential providers of those services. The strategy becomes a ploy when organisations look to outsmart/ outperform the available competitors.	Ploy defines ‘what’ puts an organisation in competition with other potential providers of those services. The choice of ‘ploy’ in this research is ‘improving exploitation levels’ of BIM, BDA, and IOT as strategic tools’. This study defines the nature of ploy according to a set of competitiveness determinants.
Pattern	An organisation is likely to make decisions/choices that have already been made in the past, again in the future. In such cases, past behaviour is a pattern that is included in strategy development. Evaluating the impact that organisational regular behaviours have on organisational success may reveal the patterns that need to be enhanced as well as changed for good.	The choices an organisation makes about its strategy rely heavily on its structure and scale. Just as patterns of behaviour can emerge as a strategy, patterns of thinking and behaviours will shape an organisation's capabilities. Therefore, this research investigates the impact that organisation structure and size have on BBI exploitation.

Position	This implies how an organisation may decide to position in the marketplace. In another way, it is the fit between the organisation and the environment, the interaction between the internal and external context and it helps you develop a sustainable competitive advantage.	By performing a full analysis of the environment, the challenges and the opportunities presented by exploiting BIM,BDA and IOT, an organisation can facilitate the development of a sustainable competitive advantage.
Perspective	Perspective can heavily influence the ways an organisation chooses to operate. How things are carried out on a daily basis may determine the extent to which the organisation leads in the market.	The ways an organisation will be able to or will choose to operate. This Perspective is derived from the culture (i.e. the ways of behaving and thinking) that are present within the organisation, in conjunction with its values and overall mission.

This research will focus on how construction organisations can maximise their competitive edge on technology/ digitalisation by formulating and implementing a strategic approach (as defined by Mintzberg 1987). The suggested strategic approach is consisting of different trajectories inter-connected to each other aiming towards enhancing competitive advantage. Among these trajectories, , 'ploy' is considered to be the core that glues everything else together(see Figure 3). The remaining Ps support the competitiveness enhancing process by addressing the two research questions as outlined in section 1.5 Table 2 explains how these Ps act as trajectories in the path to maximise competitiveness. The different perspectives of the strategic approach present a comprehensive view of 'competitive advantage' (or ploy). Enhancing competitiveness is not possible without regarding a plan, pattern, position and perspective. Chapters 4, 5 and 6 will follow the logic created by Mintzberg's 5 Ps of Strategy.

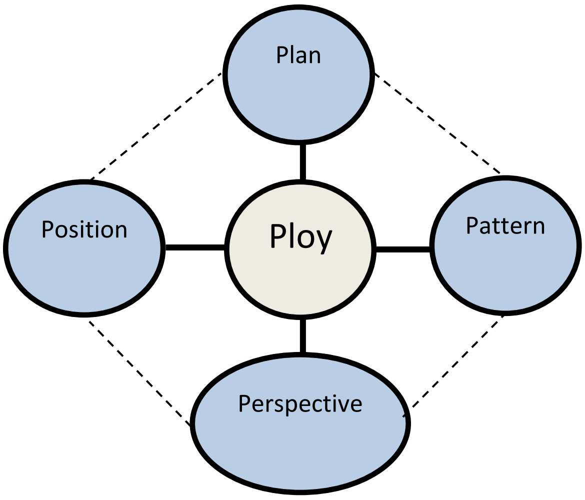

Figure 3- The 'ploy' centred strategic approach

2.3 The 'plan', 'position' and 'perspective'

As explained in the previous section, a strategy can be viewed as a 'plan' which is made before possible actions are taken. Planning requires analysing the current situation of the level of adoption and the state-of-the-art by understanding the organisational strengths, weaknesses, opportunities, and threats. With a 'position' perspective, what organisations can do to make their products unique in the marketplace could be understood. Positioning the niche market to be the strategic use of BIM, BDA, and IoT, this study looks at collecting data from four different sectors for two different time scales: now and for future (Figure 4).

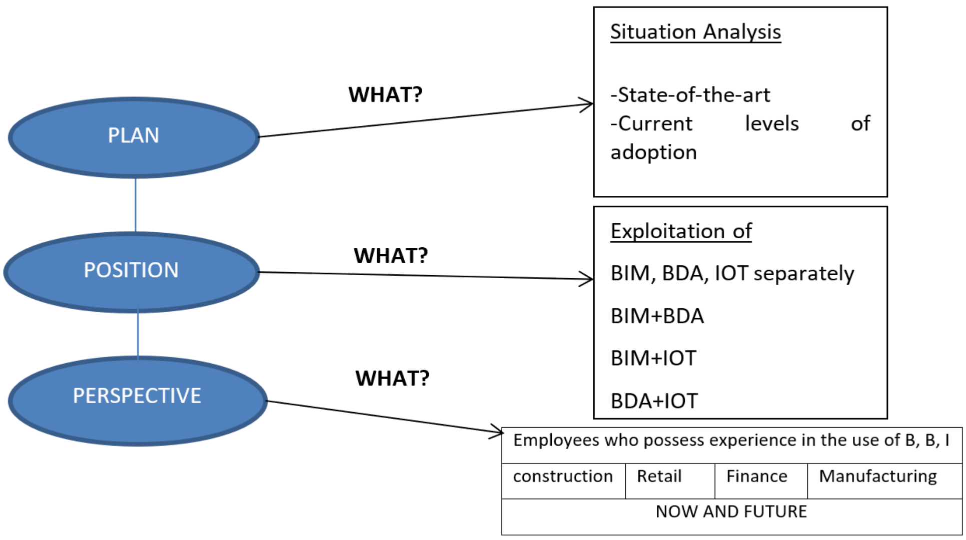

Figure 4- How 'plan', 'position' and 'perspective' are laid out in this study

The sectors were selected according to the availability of digital assets, digital usage, and digital workforce (Whyte, 2012) related to the use of the technologies. The digital assets refer to the investments of firms in hardware/ software/ data/ IT services, and investments in physical assets while digital usage refers to the extent to which firms interactively engage digitally with customers and suppliers via digital design, digital product development, digital construction/operation/facility management, digital marketing and digital payments (Whyte, 2012). Lastly, the sectors were chosen based on the workforce associated with digital technologies. The following sections explain the state-of-the-art in the use of BIM, BDA and IOT remarking the achievement of the first objective.

2.3.1 State-of-the-art in the use of Building Information Modelling

Eastman *et al.* (2008) define Building Information Modelling (BIM) as 'a verb or adjective phrase to describe tools, processes, and technologies that are facilitated by digital, machine-readable, documentation about a building, its performance, its planning, its construction, and later its operation. Thus, a 'building information model' is the adoption of such tools, processes, and technologies which enable a building to be represented in a digital, computable, and intelligent 3D form, where all relevant information required to be realised can be captured, stored, and managed for its exploitation.

The architecture, engineering, and construction (AEC) sector are leading in the implementation and exploitation of Building Information Modelling (BIM). According to the National BIM survey, in 2019, 62% of AEC practices were using BIM on some of their projects. Further, the literature confirms that the future usage will continue to be dominated by the AEC sector because the nature of BIM shows more focus on the built environment (Davies and Harty, 2012; Liu *et al.*, 2015a; Parker, 2017). BIM has a fairly wide range of applications in the manufacturing sector to increase the visibility of those products to potential customers (Volk *et al.*, 2014), but, among these manufacturing companies, the majority are manufacturers and suppliers of construction products. The minority, that is from completely different sectors (i.e. shipbuilding, tools, and equipment manufacturing), compared to the usage extent in construction is inconsiderable. Therefore, for the implementation and exploitation of BIM, no sector other than *construction* is considered.

Even though the construction sector has long been known for its lack of innovation and digitalisation, the advances in digital technology have created opportunities for increased productivity and efficiencies in construction, operations, and the maintenance of facilities (Infrastructure and Projects Authority, 2016). According to Digital Built Britain's agenda, the UK Government has been promoting the adoption of Building Information Modelling (BIM) as a method of facilitating collaboration and improving delivery efficiency and project quality especially in the construction sector (Abanda *et al.*, 2015). In May 2011, the Government Construction Strategy published by the UK government states that “Government will require fully collaborative 3D BIM (with all project and asset information, documentation and data being electronic) as a minimum by 2016” (Cabinet Office, 2011). With the proclamation of this mandate, the adoption of BIM processes in UK public sector projects showed an overall increase.

Although BIM awareness and BIM adoption have increased compared to previous years, the attitude among employees about BIM implementation does not show a considerable change (UK BIM survey 2019). The benefits of BIM have not been able fully captured. Among the results given by BIM regarding completed projects, a number showed increased profitability, and some resulted in operation and maintenance savings which had doubled since the previous year (Khosrowshahi and Arayici, 2012b). Furthermore, large firms showed high confidence levels in their skills and knowledge compared to medium and small firms. A link has also been discovered between confidence in BIM adoption and seeing the benefits of it (NBS, 2019). with those confident in their knowledge of BIM more likely to adopt it and see its benefits. This understanding has triggered the industry to exploit BIM as a strategic tool. This has also been acknowledged by academic literature highlighting the promising new directions of research that explore the synthesis of data from data capture, modelling, GIS, and the internet of things and that examine data over the futuristic life-cycle of buildings and infrastructure assets (Whyte, 2012).

There is growing and evolving research around the use of BIM as a strategic tool in the AEC literature across the international research community as the number of firms using BIM as a strategic tool and appreciating the value it brings to their work is growing (Succar, 2009, Dainty *et al.*, 2017, Arayici *et al.,* 2011). The discussions in this literature are focused on five main themes inter alia: BIM Lifecycle and Sustainability, BIM in Design and Construction, BIM Technologies, beneficial use of BIM, Professions, and BIM policies (Whyte, 2012). These studies reveal strong research interests around BIM, the gaps in knowledge, and possible directions for future research. Among this literature, BIM is highlighted as a 'strategic tool' poised to improve its efficiency/effectiveness and enhance collaboration at the organisation level. Although there is a plethora of literature around the strategic use of BIM, Jennifer Whyte (2012) in her annotated bibliographic working paper emphasises that there is, "a lack of empirical work that examines the use of BIM strategically". Hence this research addresses this gap in empirically investigating BIM in a strategic perspective.

A significant amount of attention has been paid to the identification of Building Information Modelling (BIM) benefits in both industry and academic spheres (McGraw Hill Construction, 2014). Most of these cases have proven that its benefits have influenced an increase in the adoption of BIM-related processes and workflows (NBS, 2016, 2019) and improved organisational competitive advantage (Eastman *et al.*, 2008; Kassim *et al.*, 2009b; Reza Hosseini *et al.*, 2018; Robson *et al.*, 2016).

To satisfy a part of objective 2 of this research, it is necessary to identify the benefits of BIM. Therefore, the researcher conducted several systematic reviews and bibliographic/ taxonomy analyses to capture BIM benefits. A systematic review has the potential to inform both practice and scholarship of the gaps existing in the literature. For practitioners, a systematic review can assist in their decision-making process for managerial challenges as the review itself provides some reliable knowledge bases through a range of findings (Denyer and Tranfield, 2009; Tranfield *et al.*, 2003). For scholars, a systematic review sheds a light on perceiving the robustness and rigour in research methodology for the given area as well as an idea generator for future research (Madanayake and Egbu, 2017).

The reviewed documents were collected from the Web of Science database (WoS). Figure 5 below shows the list of 'selected benefits' that emerged from the analysis.

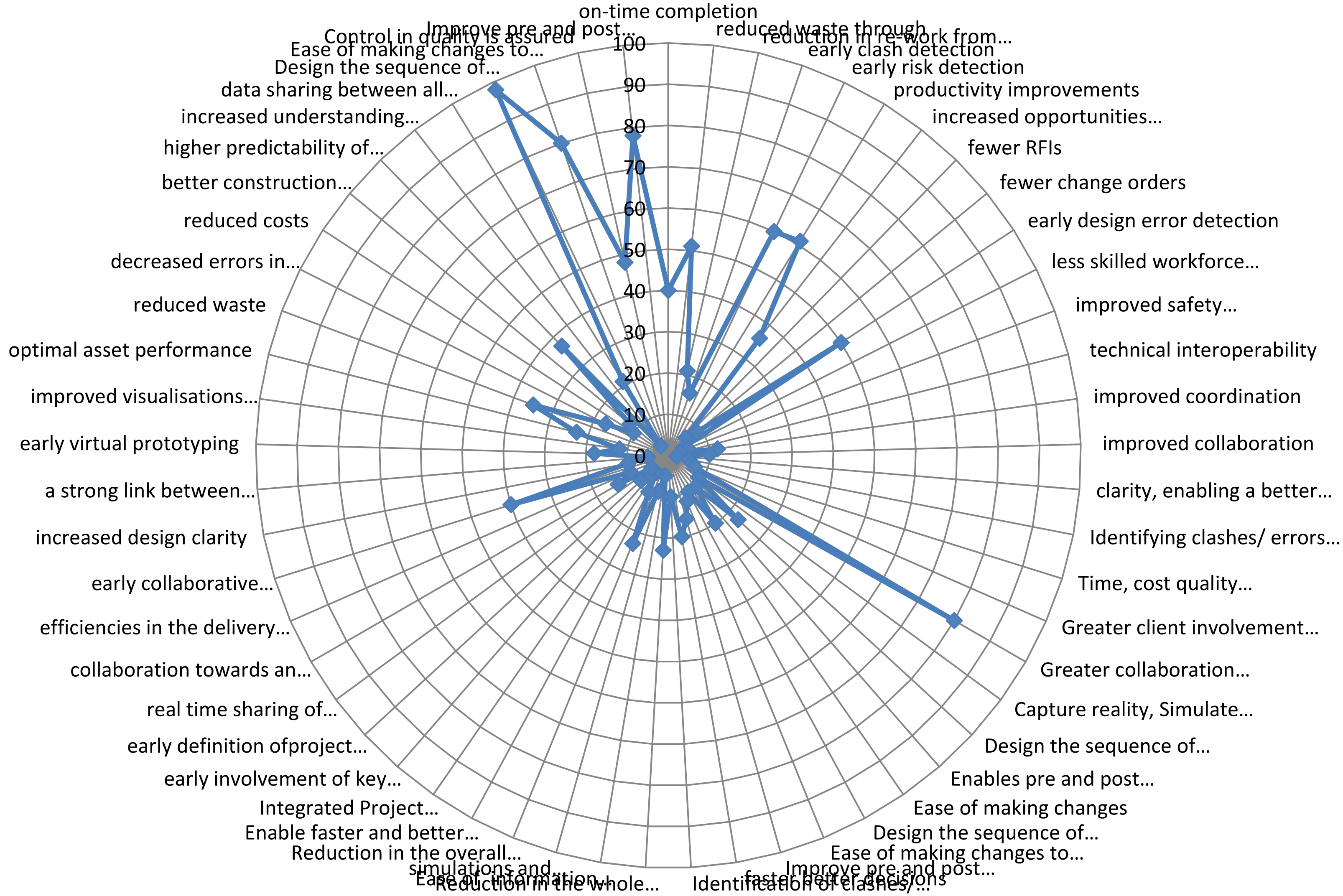

Figure 5- The frequency of citation for BIM benefits after text querying

Following the evaluation of the frequency of citation for BIM benefits, reduction in the whole life cost of built assets, ease of information abstraction, reduction in the overall time, and enable faster and better decisions through greater collaboration were selected.

Despite the benefits of BIM, numerous challenges are also acknowledged by authors to its wider adoption within the industry. Navendren *et al.* (2014) highlight that the challenges that hold back the progression of BIM implementation can be considered from three viewpoints: technological, organisational, and environmental. Newton and Chileshe (2012), revealed that the highest-ranked challenges of BIM implementation are: lack of understanding about BIM, education and training costs, start-up costs, and changing the way companies do business. The noticeable issues around risk and responsibilities include legal issues, cultural conflict, interoperability between the different format models, and habitual resistance (Ghaffarianhoseini *et al.*, 2017; Madanayake and Egbu, 2017). As BIM involves a massive amount of knowledge sharing, it can lead to legal issues regarding data ownership, copyright, and data protection (Azhar, 2011).

Using the same types of analysis (co-author analysis, co-citation analysis, Bibliographic coupling analysis, and co-occurrence analysis), the most cited challenges to BIM implementation/ exploitation were identified (**Error! Reference source not found.**). These challenges include lack of in-house expertise and therefore salary premium of employing personnel trained in BIM, hardware upgrading and software licensing costs, treating virtual as superficial and not trustworthy leading to a lack of client demand, and the general unavailability of vendor-neutral data formats and standard- Interoperability/ incompatibility.

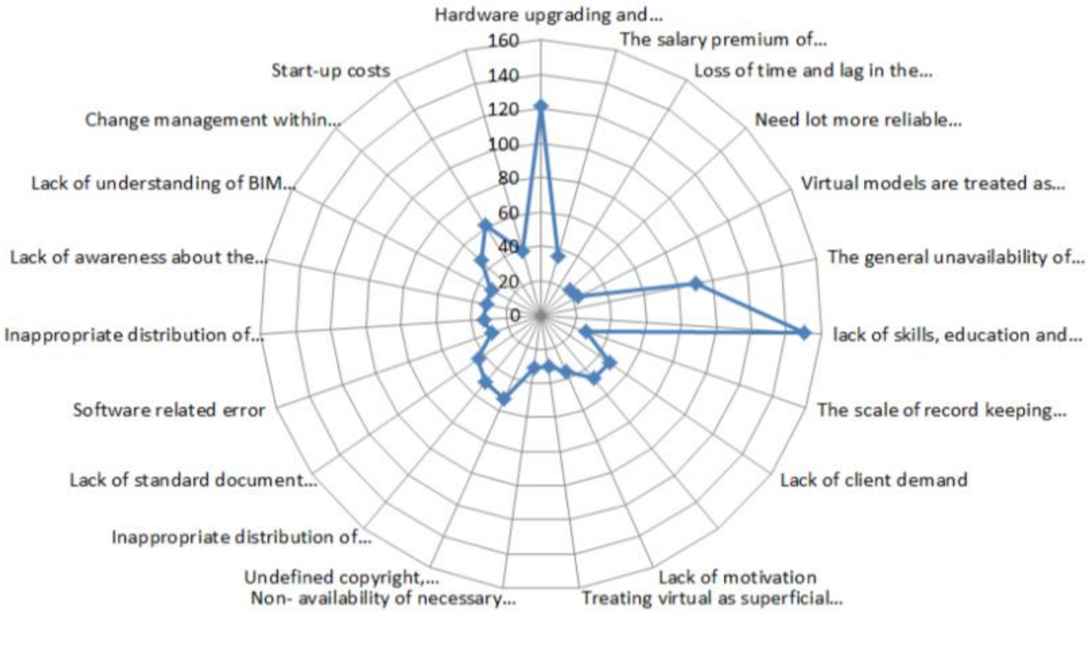

Figure 6- The frequency of citation for challenges for BIM after text querying

After an extensive review of literature, the most cited benefits and challenges to BIM were selected and labelled as ‘selected BIM benefits’ and ‘selected BIM challenges. These variables were fed into the questionnaire survey for further investigation. Data analysis of these variables is described in detail in section 4.3 of Chapter Four. This remarks the achievement of the BIM part of the first objective (as stated in section 1.4).

2.3.2 State-of-the-art in the use of Big Data Analytics (BDA)- in construction and other sectors

The definition of Big data has raised some confusion among researchers due to its rapidly evolving nature. Some authors explicate their understanding of big data focusing on what is, while others try to explain big data focusing on what it does. Either way, it is conspicuous that the definition of big data is related to the ‘size’ of the subject. The characteristics of big data as defined by Laney (2001) suggested that Volume, Variety, and Velocity (also known as 3V’s) are the three dimensions of data management. Volume refers to the magnitude that the data set occupies, velocity refers to the speed with which the data is produced and transmitted and variety is the various ways in which this data can be presented- i.e. structured, semi-structured, and unstructured data (Reyes *et al.*, 2019). This concept of 3V’s has subsequently been used as a framework by many authors to explain big data (Kwon *et al.*, 2014; Chen *et al.*, 2012). For example, Bi and Cochran (2014) advocate that information systems can be measured by their capabilities in dealing with the volume, variety, and velocity of data and their responsiveness in making decisions about system operations. The literature discusses an extended version of the aforementioned 3Vs by adding two more characteristics such as veracity and value (Wamba *et al.*, 2016). The rationale behind the addition of these two characteristics is that it reflects actionable ideas for delivering sustained strategic value, measuring performance, and establishing competitive advantages (Fosso Wamba *et al.*, 2015).

According to Manyika, Chui Brown, *et al.* (2011), “Big data” refers to datasets whose size surpasses the ability of typical database software tools to capture, store, manage, and analyse (Manyika *et al.*, 2011a). Big Data Analysis/ Analytics implies those various forms of data being managed, stored, and analysed to develop a prediction of relationships, trends, and possible future events to improve decision making (Reyes *et al.*, 2019). The analytics helps the acquisition of knowledge acting as a strategic tool for subsequent value adding workflows.

The direction of big data analytics in itself is quite extensive and includes a variety of specialisations such as data mining, machine learning, data warehousing, decision tree analysis, statistics, Natural Language Processing (NLP), data clustering, regression, etc. (Garyaev and Garyaeva, 2019). All these specialised dimensions can be categorised into predictive analytics, descriptive analytics, prescriptive analytics, inquisitive analytics, and pre-emptive analytics (Sivarajah *et al.*, 2017). Much of the existing work does not discuss big data analytics alone but synergises it with another technology/ concept/ process to ascertain the value of it. Figure 7 shows the complexity of these multidisciplinary fields to Big Data and their relevance.

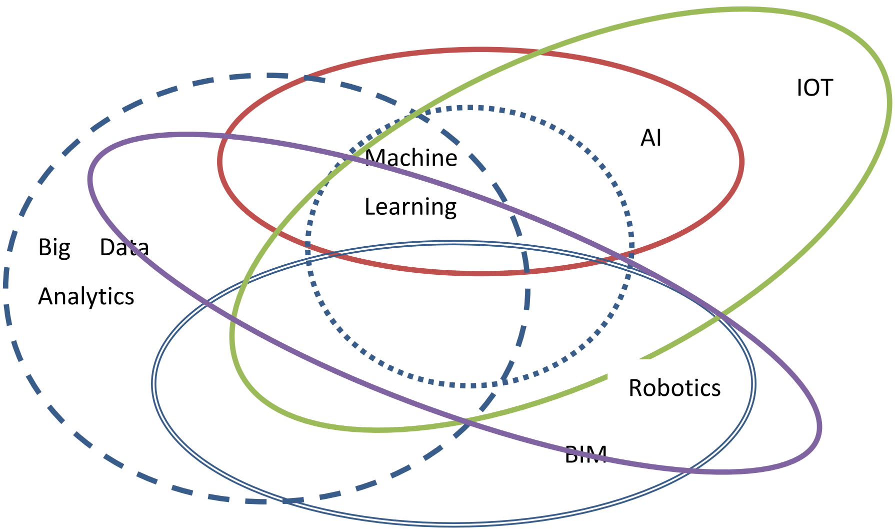

Figure 7- Multidisciplinary fields to Big Data

The construction industry in particular, as a result of its complex and fragmented nature, produces massive amounts of data (voluminous) in a variety of formats and standards and therefore the need for a systematic way of data analytics to manage such data is a high priority (Skillett, 2017). The use of BDA to analyse these large piles of data and extract knowledge that will allow making effective decisions for the adoption of sustainable practices in construction is becoming more important (Kopanakis and Mastorakis, 2016). However, the 'interoperability' of data has become a key issue within the construction supply chains consisting of different sub-sectors such as architectural, structural, energy, and real estate (Bilal *et al.*, 2016b). Many authors have spotted the beneficial use of big data in many sub-sectors of construction such as real estate property, construction, engineering, architecture, planning (BIS, 2013). For example, big data analytics helps the real estate and property sector with mapping data in research analytics, marketing and sales, corporate real estate, and facilities management (Eriksson *et al.*, 2017). In the architecture, engineering and construction sectors, particularly in organisational and project contexts, big data assists asset management, energy efficiency, risk assessment optimisation, research and analytics, designing, interactive mapping and visualisation, urban planning, sustainability/ carbon emission reduction, etc. (Akhavian and Behzadan, 2015). Big data analytics is also useful in keeping track and better management of resources, producing more accurate budget estimates, lowering project risks, and making the right choices (An, 2014). It has been widely accepted that in construction, material waste accounts for approximately 25% of a project's cost, and rework adds an estimated 10%. The use of big data is proven to reduce waste and re-work (Bilal *et al.*, 2016a).

In the construction sector, the use of big data integrated with BIM provides substantial benefits for resource optimisation including waste minimisation (Bilal *et al.*, 2016a), generative design (Boeykens *et al.*, 2016; Motawa, 2017), performance prediction (Alaka *et al.*, 2015), visual analytics (Han and Golparvar-Fard, 2017) and energy management (Koseleva and Ropaite, 2017; Reyes *et al.*, 2019; Sanyal and New, 2013). The Digital Built Britain report published by HM Government also states that the agendas of BIM and smart cities are closely aligned when wider BIM data are used to make better-informed decision making in line with model transport demands, air quality, energy consumption, and healthcare requirements (HM Government, 2015). , The construction industry is showing a tendency towards the use of IOT data, as well as BIM data, to produce insights through big data analytics.

As the number of companies that embrace big data remains high, it is also worth investigating their level of implementation and exploitation. Even though an increased adoption of BDA can be seen, many authors are in agreement that firms in construction have not yet exploited big data to its full potential (Reyes *et al.*, 2019) and hence more room for improvement exists (Love and Irani, 2004). To date, very little research has been done on the investigation of the extent to which these companies have implemented big data. Generally, big data analytics have been used for all stages of a construction life cycle- starting from the strategic definition (Kähkönen and Rannisto, 2015; Martínez-Rojas *et al.*, 2016), development of brief (Lee and Kang, 2015), concept design (Chen *et al.*, 2015), developed design (Whyte *et al.*, 2016), detailed design (Williams *et al.*, 2014), construction (Teizer, 2015; Wang and Cho, 2015; Yang *et al.*, 2015), hand-over and closure (Lu *et al.*, 2015), use (Han and Golparvar-Fard, 2017) and disposal (Liu *et al.*, 2015b). The state of the art in BDA is moving around data innovation, knowledge creation, effective knowledge management, and the development of internal data technological capabilities creating and improving sustainable competitive advantage which is translated to a superior market position (Kopanakis and Mastorakis, 2016).

A considerable amount of authors are in favour of the argument that Big data investments contain positive strategic associations with organisational performance and organisational competitive advantage (Brynjolfsson *et al.*, 2011; Brynjolfsson and Hitt, 1993; Brynjolfsson and Mcafee, 2014; Hitt and Brynjolfsson, 1996; Mcafee and Brynjolfsson, 2009). Many authors have acknowledged the fact that data can be used strategically to generate insights into business trends and hence can be employed as a strategic tool for business growth. For example, BDA allows for improved data-driven organisational decision making and innovative ways to organise and study all types of data (Yiu, 2012), thus, reinforcing asset performance optimisation, tracking and tracing for logistics, customer relationship management, and improvement in the management of many organisational aspects (Bean and Kiron, 2013).

Considering the Big Data Analytics usage in other sectors, the state of the art in big data suggests that the use of big data analytics is becoming a key basis of competition and growth for individual firms in many industries (Manyika *et al.*, 2011b).

There are specific industries that are benefiting from big data analytics the most. As explored by Marr (2018), the Healthcare sector is leading the exploitation of Big Data Analytics as the use of Big data is transforming the way illnesses are identified and treated. This has ultimately improved people's quality of life and has avoided preventable deaths. The second leading sector in the use of Big Data analytics is the 'Retail Sector' especially when looking at the fast-evolving buying and selling habits both online and offline (Marr, 2018). The retailers who have embraced a data-first strategy towards understanding their customers, signposting them to appropriate products, and parting them from their cash are reaping huge rewards. Then, it could use big data and analytics to create personalised material and products that excite and engage in-store visitors. This way, Big data, and analytics provide the insights needed to maintain customer satisfaction and repeat visits to stores. This simply means that data analytics is now being applied at every stage of the retail process (Marr, 2018).

On the other hand, the increasing levels of automation and the advances of robotics are dramatically transforming the face of manufacturing processes. This is not confined to modern manufacturing as data is still making a mark in traditional manufacturing environments by embedding data capturing devices in their equipment (Marr, 2018). This is the third leading sector as stated by Marr (2018). Retail and banking sectors remain in 5^{th} and 6^{th} positions overall (SAS, 2016).

Financial services including banking and insurance are also benefiting from data analytics; from fraudulent transaction detection to expanded trend analysis services for businesses. In insurance, data is already being used to help insurers set fairer and more accurate policy premiums, identify fraudulent claims, and improve their marketing efforts. Some insurance services are taking data collection a step further by offering discounts to a certain proportion of people who allow them to monitor the use of equipment (i.e. vehicles) via smartphone apps and in-product devices, allowing the insurer to observe the level of safety in driving. For the above-mentioned reasons, the use of Big Data in three sectors- Manufacturing, Retail, and Financing- was selected for further investigation in this research.

Despite the benefits accrued by employing BDA, it also appears that there are common challenges these sectors face. The shortage of talent necessary for organisations to take advantage of big data is one of the most impacting barriers almost all sectors face (Manyika *et al.*, 2011b). Ying Liu (2014) also acknowledges that the task of finding the right talent/skill to execute big data levers can potentially be daunting for retail executives. Data policies, technology, and techniques, organisational change and talent, access to data, and industry structure are a few other challenges faced by sectors in general (Brown *et al.*, 2012).

The mixed results as reported in the literature for the strategic business value of Big data established a reason to explore the benefits and challenges of BDA. The next section of this chapter is hence dedicated to the identification of big data benefits and challenges.

To partially satisfy objective 2 of this research (as outlined in section1.4), it is necessary to identify the critical benefits and challenges of BDA. Using similar analysing techniques, after an extensive review of literature, the most cited benefits and challenges to BDA were selected and labelled as 'selected BDA benefits' and 'selected BDA challenges. These variables are fed into the questionnaire survey for further investigation. Data analysis of these variables is described in detail in Chapter-4. This remarks the achievement of the BDA part of the first objective (as stated in section 1.4).

2.3.3 State-of-the-art in the use of Internet of Things (IoT)- in construction and other sectors

Internet of Things (IoT) refers to a system of connected physical objects via the internet (Marjani *et al.*, 2017). The 'thing' in IoT can refer to a person or any device which is assigned through an IP address (Garyaev and Garyaeva, 2019). A 'thing' collects and transfers data over the internet without any manual intervention with the help of embedded technology. It helps them to interact with the external environment or internal states to make decisions. From the end user's perspective, a typical IoT system consists of five major components according to the function of the IoT system, namely: 1) Devices or Sensors (terminal), 2)Networks (communication infrastructure), 3) Cloud (data repository and data processing infrastructure), 4) Analytics (computational and data mining algorithm), and 5) Actuators or User interfaces (services) (Jia *et al.*, 2019). From a technological perspective, IoT can be realised as the convergence of three major paradigms, namely: Things-oriented vision, Internet-oriented vision, and Semantic-oriented vision (Atzori *et al.*, 2010).

Several types of research profess the potential of IoT technologies such as Radio-Frequency Identification (RFID), GPS, Bluetooth, and Zigbee to improve the efficiency of construction sites ensuring that correct and sufficient data has been collected to make sound decisions, coordination and safety, making the construction activities easier and improving productivity. Anumba and Ruikar (2001) investigated the applicability of electronic commerce business models in the construction industry through internet and/or dedicated networks. Teizer *et al.* (2017) used a cloud platform to integrate real-time data that are collected in a construction site with IoT physical hardware which ultimately allowed the site staff to monitor the site activities with greater precision and safety. The use of smart machinery in construction has also been provided with distance sensors to avoid collisions and idling due to breakdown (Cazacliu and Roquet, 2009). The essence of IoT architecture therefore immensely helps the construction industry especially because the industry is characterised as a complex industry that has been exposed to 'digital disruption', and has long been criticised for its poor productivity and least digitised nature (Waterhouse and Philp, 2016).

The state of the art in IoT also highlights the advantage of coupling IoT with BIM. Hackitt (2017) states that BIM level-3 can only be fully realised with the help of IoT by facilitating more interconnected devices connected to BIM. Even though the widely accepted opinion is that BIM helps construction management, there is also a consensus that the degree of collaboration offered by Level 2 BIM is insufficient to bridge the gap of fragmentation and the inhomogeneous nature of the construction industry (Kassem *et al.*, 2016). The need for transformation into a more networked and integrated system fuelled by IoT technology is now seemingly envisioned to achieve BIM-level 3 (Heiskanen, 2017; Panuwatwanich and Peansupap, 2013). Companies in the Architecture, Engineering, and Construction sector in the UK have already initiated or planned to initiate technologies related to IoT especially fuelled by the Industry 4.0 scheme (Reinhard *et al.*, 2016).

Both researchers and practitioners have explored the strategic benefit of IoT in the construction industry. For example, several construction companies have launched IoT enabled devices to improve their operational efficiency, demonstrating the competitive edge and future tendency of IoT (Jia *et al.*, 2019). Barkai (2018) advocates that companies must innovate continually and invest in technologies such as IoT to improve efficiencies, be more competitive, and drive profitable growth. The latter author further indicates the importance of evaluating the return (i.e. new business opportunities, financial returns) that IoT promises to bring about before making any commitments.

Chui (2017) emphasises the strategic value of IoT as it drives a higher level of competitiveness and business advantage in the marketplace. The extent to which IOT gives this strategic value is commonly determined by the degree to which the new products or services establish a sustainable market advantage and provide effective barriers to entry against existing and future competitors (Barkai, 2018). Supporting the same notion, Nord *et al.* (2019) explain how IOT allows manufacturing organisations to exploit knowledge and experience gained during the development and deployment of new technology across business functions and product lines derived strategic value. Another strategic view expressed by Senna *et al.* (2019) implies that a robust strategic foundation of an organisation in-turn creates a higher level of innovation, operational optimisation, and market competitive advantage. The robustness of an organisation strategy toward IoT deployment has been acknowledged by many authors. A good IOT strategy should give greater potential returns and lower levels of uncertainty (Kanan *et al.*, 2018) and the organisation's innovation culture plays a vital role in it (Jassawalla and Sashittal, 2002). The organisation's innovation culture exhibits organisational ability to harness technical, financial, human, and organisational resources to harvest the future value of technology.

Similar to the case with BDA, the manufacturing industry is expected to gain the highest economic benefit as well as business efficiency benefits through the use of IoT (CEBR, 2016). Interestingly, retail businesses are experiencing a greater increase in revenues through IoT application than through BDA, which highlights the market difference between the two. Telecoms, retail banking, and professional services are earning the largest cost-saving at an average of 19% through the application of both BDA and IoT. The manufacturing industry reported the smallest cost savings, of approximately 13% (CEBR, 2016).

Like the effects of revenue growth, the cost savings achieved through investment in the IoT are less significant for some industries than through BDA. This can be attributed due to the length of time businesses in these sectors have been using IoT. The sectors which are experiencing the greatest gain may be the 'early adopters' and could, therefore, be benefiting through first-mover competitive advantage. Undeniably, it is not the adoption that counts when it comes to the 'exploitation', but the application that harnesses the benefits. However, some authors have stated that the sectors with the greatest rates of adoption are likely to experience the greatest benefits as a result of using BDA and IoT (Banafa, 2017).

In terms of exploitation, the number of analytics solutions organisations have implemented is further explored. This accounts for a level forward from adoption to successful implementation. In both BDA and IoT, telecoms had the highest adoption rate while Energy & Utilities and Retail Banking held second and third places. The survey has expanded to seek not only the current but also the prospective growth potential of BDA and IoT by analysing the amount of data stored per firm. The findings suggest that industries such as retail and investment banking, and telecoms are more likely to want to make greater use of big data in the future than other industries.

Considering the performance of the sectors so far, manufacturing, retail, and finance are sectors that have beneficial uses of BDA and IoT in common. Hence, the above-mentioned sectors are chosen for further investigation considering the research objective- 4. The subsequent sections are dedicated to quantitative and qualitative data analysis for these three sectors- *Retail, Finance, and Manufacturing.*

After reviewing the literature on IoT related benefits and challenges, the most cited benefits, and challenges of IoT were selected and labelled as 'selected IoT benefits' and 'selected IoT challenges. These variables are fed into the questionnaire survey for further investigation. Data analysis of these variables is described in detail in Chapter-4. This remarks on the achievement of the IoT part of the first objective and hence remarks on the achievement of the first objective (as stated in section 1.4). The reason for ascertaining the state-of-the-art in the use of BBI lies in the need for understanding the possibilities of BBI to address the problems stated in section 1.2.1.

2.3.4 The concept of BBI and why they (BIM, BDA, and IOT) are investigated together?

In the previous section, the state of the art in BIM, BDA, and IOT in construction and a few other sectors were discussed. In this section, the rationale for the collective selection of BBI as strategic tools is analysed. BIM, BDA, and IoT have been transforming the technology world for the past several years, and they are no longer a "nice to have" technology but a necessity for survival (Mayer-Schonberger and Cukier, 2012).

It has been widely accepted that the use of BIM, BDA, and IoT enables a futuristic view and thereby strategic development. The strategic view of the construction industry is about striving to become a highly efficient, quality-centred, socially responsible industry that aims to successfully deliver the requirements of current and future generations, BIM can play a strategic role in this transformation of the construction industry but it is naïve to assume that BIM alone can make such a big change. However, BIM along with other complementary strategic tools can provide the necessary impetus. Jang and Lee (2018) states that BIM helps an organisation to identify unique opportunities for itself and the product–markets which will give it a strong competitive position. Digital innovation has immensely impacted the construction industry, and correspondingly many organizations have introduced 'big data analytics' and 'Internet of Things' as an approach to gain 'competitive advantage' (Perner, 2015). BDA is now considered as a game-changer enabling improved business efficiency and effectiveness because of its high operational and strategic potential (Wamba *et al.*, 2016). There is evidence that a data-driven approach has a positive impact on enterprises' performance (Kopanakis and Mastorakis, 2016). A report published by the World Economic Forum stressed that the development and deployment of digital technologies and processes are crucial to the required transformation of the construction industry to enable cost savings. Particularly, the use of big data and analytics: algorithms generate new insights from the huge data pools created both on construction projects and during the operations phase of existing assets (WEF, 2016). Moreover, there is a drive to adopt BIM, big data and IOT within organisations which has triggered their use tremendously in the past few years. This drive is predominantly influenced by 'organisational competitive advantage'.

Literature suggests that BIM, BD analytics, and devices connected to cloud computing can be used to *improve productivity and enhance efficiencies in planning, design, and overall delivery of construction projects* (Raguseo, 2018) and hence back-up the combined investigation. Moreover, BIM and IoT have the highest potential to be effective when used together with data-driven approaches (Mansouri and Akhavian, 2018; Ahmed *et al.*, 2017).

The main reason for investigating BIM, BDA and IoT together is that *Businesses across all industries gain a competitive advantage* through big data analytics, the Internet of Things, and Building Information Modelling (Kelly, 2018). Notwithstanding the above discussions which support the argument that BIM, BDA, and IOT either create or enhance competitive advantage as separate strategic tools, there is a considerable amount of research in favour of the complementarity of these strategic tools claiming that the potential to maximise competitive advantage is more than when they are applied alone. In this section, how BIM, IoT, and big data go hand in hand and how organisations are obtaining benefits by using BIM, internet of things, and big data together are discussed.

(Eadie *et al.*, 2013a) Their study on BIM implementation framework states that the construction industry is dealing with a significant amount of multi-dimensional data arising from diverse disciplines throughout the life cycle of a facility. To this end, Building Information Modelling (BIM) is envisioned to systematically capture these multi-dimensional data and feed them into decision tree analysis to support multidisciplinary collaboration among stakeholders. High volumes of data produced through BIM and IoT are considered a *Valued Corporate Asset* that has a greater need to be systematically captured, stored, managed, and analysed for business intelligence.

This is when big data analytics assist (SAS, 2016). As the most recent evidence suggests the need for big data in BIM, the specification for production and management of data in certain formats for a BIM-enabled Common Data Environment (CDE) has recently been suggested by the construction regulating authority (BSI, 2014, 2015). However, several reports show that organisations tend to face challenges in managing the huge volume of data that is generated during the project delivery process (Lock, 2012; Russom, 2013). The reports further state that organisations face challenges in managing information, not just in terms of volume, but also in complexity as the data has linkages to various complex database. This can be seen specifically in design coordination and data retrieval during the operation phase of the building. Consequently, this non-traditionally structured data termed as “big data”, requires specialised infrastructure and relevant skills and that is when the need for ‘big data analytics’ emerges. The reports further highlight that the sources of these data are continuing to expand and have challenged the conventional analytical processes and existing systems to be transformed. The stress caused by this unfamiliar and hard-to-cope with situation resulting from the data complexity in BIM has been a major reason for calls for the need for big data analytics.

Another study conducted by Jiao *et al.* (2014) on an augmented big data analytical framework for BIM states that data generated by BIM contains a variety of formats ranging from 3D geometric encoded data to computer intensive compressed data (graphics and Boolean computing) in diverse proprietary formats which are intertwined. These various formats of data have presented numerous challenges to the stakeholders when handling with conventional data managing techniques, mainly because of their variance and volume. Hence the latter authors recommend the use of big data techniques like ‘MapReduce’ to collate the data into a federated BIM model. Similarly, a considerable amount of research has purported IoT improves the efficiency, accuracy, and effectiveness in the operation and management of construction aimed at guaranteeing a high quality of life and stimulating the innovation process and competitive advantage of firms (Giudice and Straub, 2011).

Moreover, the mainstream literature suggests that even though the entrance of IoT was laggard in comparison to BIM and related data analytics, the intake of IoT on BIM and related data analytics is advantageous (Han and Golparvar-Fard, 2017). Technological revitalisation leads to a survival of core competencies and capabilities of incumbent firms (Cooper and Smith, 1992). In terms of R&D management, the integration of different technologies is a compulsory capability for technological revitalisation. These capabilities are essential to creating value for customers (Del Giudice, 2016).

The impact and the role of the IoT on the construction business process management in terms of promotion of knowledge flow, innovation, and competitiveness are flowing in an improved direction (Al-Mashari and Zairi, 1999, 2000). The current business enthusiasm leads to an organisational culture characterised by a shared commitment to make *data central* to business decision-making. When data use is a value and practice, companies become more dynamic and profitable (Davenport, 2014).

The IoT and big data deployment in the built environment are growing exponentially, however, a gap exists in integrating these two to BIM in a systematic way through a strategic approach. The prime asset that ties these three strategic tools together is 'the Built Environment data'. When leveraging these Built Environment data to produce information, knowledge, and wisdom, there is a necessity for automating specific workflows as they will provide systematic guidance, and even transformation of current BIM processes, with the potential to enhance organisational competitive advantage. The Table 3 below presents a review of the literature showcasing the benefits of synergistic BBI exploitation towards enhancing competitive advantage.

Table 3- A review of strategic BBI exploitation towards enhancing competitive advantage

Synergistic Strategic Tools	**Area of discussion related to competitive advantage**	**Author (s)**
BIM and BDA	Multi- dimensional data produced in BIM can be harnessed by big data techniques to enhance multidisciplinary collaboration among stakeholders	(Eadie *et al.*, 2013a)
	An augmented big data analytical framework for varied formats and voluminous data generated by BIM	(Jiao *et al.*2014)
	BIM files can quickly get voluminous, with the processed natural language data this voluminous nature can be easily managed	(Lin *et al.*, 2016) (Marzouk and Enaba, 2019; Motawa, 2017)
	Use of customised cloud computing system for BIM data and querying components is an effective solution for BIM clash detection, quantity estimation and visualisation	(Jiao *et al.*, 2013a)

	Factor analysis and correlation matrix for Identifying the programme (4D BIM) delays and asset management	(Kim *et al.*, 2008);
	Data warehousing for querying partial BIM models query languages to improve construction productivity	(Chau *et al.*, 2003); (Koonce *et al.*, 1998); (Mazairac and Beetz, 2013)
	Use of data mining techniques for BIM design coordination	(Wang and Leite, 2013)
	Using BIM model and genetic algorithms to construction project planning	(Chen *et al.*, 2011); (Moon *et al.*, 2012)
	Big data for construction waste minimisation through BIM model	(Bilal *et al.*, 2015)(Lu *et al.*, 2015)
	Competitive advantage of BIM implementation in terms of cost and differentiation by a SWOT analysis	(Arayici *et al.*, 2011)
BIM and IOT	Use of Radio Frequency Identification (RFID) in augmented reality technology on BIM for operation and maintenance technology	(Zhong *et al.*, 2017) (Chu *et al.*, 2018); Williams *et al.*, 2015
	Use of social networking services for BIM models for multi-disciplinary users throughout construction lifecycle	(Jiao, Wang, *et al.*, 2013) (Gheisari *et al.*, 2014); (Dave *et al.*, 2018)
	Creating a network of sensors and software to monitor building performance for improvements	(Chiang *et al.*, 2015); (Yu *et al.*, 2013)
	Integrating BIM and IOT through open standards	(Dave *et al.*, 2018)
IOT and BDA	The real time data produced by adoption of big data in smart IOT technology helps identifying potential risks and minimise them, hence minimised risk	(Manyika *et al.*, 2011b);(Gandomi and Haider, 2015); (Jukic *et al.*, 2015)

	IOT helps generating large volumes of data while IoT helps storing and analysing these data at the real time in construction specific domain applications-i.e. Connected mobile technology to minimise construction Waste	(Burger, 2015)(Bell and Bell, 2016)(Bilal *et al.*, 2016a)
	Sensor devices and smart phones to collect data from large-scale dynamic and distributed environments	(Barnaghi *et al.*, 2013); (Wong *et al.*, 2014)
BIM, BDA, IOT	Big Data applicability is amplified further by many other emerging trends such as BIM,IOT	(Bilal *et al.*, 2016b); (Zheng *et al.*, 2019)
	The possible integration of IoT, big data, and relational exchange theories to explain complex behaviour of supply chains, organizations, people, and technology and likely to provide many benefits	(Mishra *et al.*, 2017)

Building Information Modelling brings all parts of a building design together into one integrated and collaborated system and it is no longer a collection of unconnected parts. When this system meets IoT, it is about creating a network of sensors and software to monitor things in the building like the movement of occupants in the building to adjust heating levels as people congregate and the position of the sun changes, the amount of lighting relative to natural light entering the building and levels of energy usage. These devices will gather, share, and transmit a huge amount of data in real-time for building operations people to deal with.

Though IoT and Big data evolved independently, they have now become interrelated. The role of big data in IoT is to process a large amount of data on a real-time basis and store them using different storage technologies (Jukic *et al.*, 2015). When organizations collect data for analysis purpose, IoT acts as a major source for that data, and Big data analytics is emerging as a way of analysing IoT generated data from “connected devices” which helps to take the initiative to improve decision making. Furthermore, the relationship between big data and IoT has shown convergence of the two technologies which aligns the technologies in the best possible way. A report published by SAS on BDA and IoT performance in the wider economy has evaluated the current-future adoption rate, current-future cost savings and reports the combined economic value of big data and the Internet of Things. Further, if IoT and big data separately give plenty of reasons for excitement, then combining the two technologies multiplies the anticipation. Finally, according to *loss aversion theory*, companies that do not adopt a BIM, BDA, and IoT strategy in the next 5 years are said to carry a risk of losing market share and momentum (Kelly, 2018).

This is the basic rationale for the selection of BIM, BDA, and IoT for investigation. This research looks at Building Information Modelling (BIM), Big Data Analytics (BDA), and the Internet of Things (IoT) as an integrated strategic approach consisting of three distinctive strategic tools that have mutual complementarities.

2.4 The 'ploy'-Enhancing Competitive Advantage

As explained in section 2.2.2 ploy puts an organisation in a favourable competition with other potential providers of the positioned services (Mintzberg, 1987b). According to Porter (1980), an advantage over competitors gained by offering consumers greater value, either through reducing prices or by providing greater service or by providing a different/ unique service is called 'Competitive advantage'. This understanding helps to create an argument that generating or enhancing (the existing) competitive advantage is the 'ploy' of strategic management. Building upon this argument, this section focuses on elaborating 'competitive advantage' in a broader perspective first and gradually narrows down to find the way to fit it into the research context which seeks to understand 'organisational' competitive advantage in construction.

Since the research aims to improve the level of exploitation for BIM, BDA, and IoT and enhance competitive advantage, insights gained into the concepts of 'competitive advantage' are required. An extensive critical review of literature is carried out to ascertain what had been published around general theories of competitive advantage. A sound literature review gives a good basic framework to proceed further with the investigation by clarifying the research problem and identifying likely variables (Sekaran, 2006). Thus, at the end of this section, the Determinants of (Organisational) Competitive Advantage (DCA) are established for further investigation.

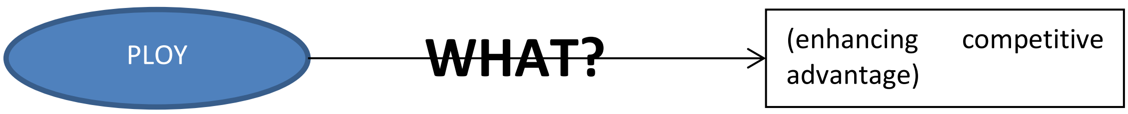

Figure 8- Use of 'Ploy'

2.4.1 Characteristics of competitive advantage in general

Competitiveness has been discussed by many researchers as a multidimensional concept that carries different characteristics. Terminologies such as ‘competitive advantage’ and ‘competitiveness’ are interchangeably used in the existing literature. Many authors have engaged in an intellectual debate on competitiveness and contributed to a wider understanding of the concept. For example, different levels of abstraction i.e. nation, industry, firm, project/projects, or individual. These different levels of competitiveness have been acknowledged by Moon *et al.* (1995). Waheeduzzaman and Ryans, (1996, P7) claim that “competitiveness is one of the most misunderstood concepts of the 1990s.” and hence draw a comprehensive picture of different perspectives of competitiveness acting both as a cause’ (sources of achieving a given status level) and ‘an outcome’ (the given status level) and states “Like beauty, the measurement, definition, and understanding of competitiveness belong to the eye of the beholder” (Waheeduzzaman and Ryans, 1996). Some researchers are of the opinion that the logical precision of a complex concept like ‘competitiveness’ does not matter as long as the result of it offers virtue. The general characteristics of competitiveness as purported by Boltho (1996), Porter (1990), Buckley *et al.* (1988), Cho *et al.* (2008), Momaya and Selby (1998), Teece *et al.* (1997b) and Lall (2001) imply that competitive advantage is: Multi-defined, Multi-measured, Multi-layered, Subjective, Relative, and Dynamic.

2.4.2 Competitive Advantage in Construction

The construction industry has long been viewed as a heterogeneous industry and has attracted many competitiveness studies over the past two decades. Among them, Porter’s theory for firm competitiveness has had a significant prevalence in the construction industry (Langford and Male, 2001; Betts and Ofori, 1992, 1994; Male and Stocks, 1991). A few recent studies also seem to incorporate Porter’s theory for competitiveness in the construction industry (R Flanagan *et al.*, 2005; Lu, 2006; Shen *et al.*, 2006; Puying *et al.*, 2017).

The Diamond (Porter, 1990), double diamond (Moon *et al.*, 1998), Total Value Competitiveness (TVC) framework and the APP (Buckley et al.,1988; Momaya and Selby, 1998) were the other organisational level frameworks renowned for their application in construction. The suitability of RBV has also been examined in the construction sector. Kale (2002) adopts RBV in his framework for identifying the sources of competitiveness in construction firms while Haan *et al.* (2002) conduct a comprehensive study on the validity of RBV theory in construction.

In terms of construction management research, several researches have given different explanations to competitiveness (Henricsson *et al.*, 2004; Lu, 2006; Shen *et al.*, 2006) influenced by many of the previous studies. It is manifested that the traditional economic theories which see competitiveness in economic indicators such as profitability, productivity, or market share are now considered to be insufficient to fully elaborate competitiveness in terms of sustained continuous improvement (Lu, 2006). Buckley *et al.* (1988) state that the true competitiveness of any level should not only reflect past performance but should also allow us to conceptualise and predict the potential and the improvement of future managerial processes. This supports Lu's (2006) argument confirming that traditional indicators can only measure the competitiveness of history with quantifiable nominal facts. Notwithstanding the latter fact, competitiveness needs to be viewed through facts beyond economic indicators such as performance, potential, and process, which enables linking the concept into management and operation research as well (IMD, 2004). This indicates that competitiveness can guide management on the ways that the competitive edge can be improved and how it can be sustained in the long-term. In this research, competitiveness is linked with construction strategic management. Strategic management overlooks a process for its long survival through sustainable performance. However, there is a paucity of empirical evidence of the co-relationship between competitiveness and strategic management which leads to sustainable performance. This can be attributed to the fact that the two concepts are widely criticised by different aspects and that they are also highly controversial by nature which denotes the difficulty of finding empirical evidence.

There has been a meticulous debate in construction between productivity and competitiveness (Ive *et al.*, 2004). Some researchers believe productivity to be the origin/source of competitive advantage and define competitiveness as a by-product of productivity which can be measured by labour productivity, capital productivity, or total factor productivity (Arditi and Mochtar, 2000; Chau and Walker, 1988). Nevertheless, the metrics and definitions used for both competitiveness and productivity are not well expressed. This issue is well exhibited in UK national statistics. The UK national statistics reveal that the construction industry is undergoing a decline in terms of productivity (Office for National Statistics, 2020). Surprisingly, this is not reflected in project performance figures provided by companies; instead, the figures show improvements in productivity on site and in the design office which leads to much confusion. However, there are researchers that looked into competitiveness beyond productivity in a much broader perspective stating that the measures of competitiveness should be more informative than productivity measures (Cattell *et al.*, 2004). The latter authors further highlight the vitality of thinking outside the traditional box- changing the focus onto the effectiveness of project management, the achievement of quality levels, innovations, and technology advancement. It is also acknowledged that measuring industrial productivity is troublesome and, more importantly, is problematic and difficult in the construction industry (Ive *et al.*, 2004).

2.4.3 Definitions, key schools of thoughts on firm-level Competitive Advantage in construction

Before looking into the firm-level competitive advantage, which is crucial; one must first make some fundamental distinctions between markets that the industry is made of and organisations (firms). The essence of the firm, as Coase (1937) pointed out, is that it displaces market organisation. This is mainly because, with the internal mechanism of a firm, one can organize certain types of economic activity as a joint team effort in ways one cannot using markets and therefore it is very important to study competitive advantage at a firm-level instead of market/ industry level (Teece and Pisano, 1994). Porter (1980) defines an industry as a group of firms producing products that are close substitutes for each other. Furthermore, according to Porter (1998), 'it is the organisations, not nations, which compete in international markets, and hence they have received greater interest from many researchers focusing on individual firms and their strategies for operations and resource planning. Langford and Male (2001) explicate the industry as an arbitrary boundary within which firms compete to produce comparable products. A project is a temporary entity, while a firm is a continuing organisation that creates the built environment (S. Kale, 2002; Male and Stocks, 1991) where such a firm's competitiveness can foster competitiveness for a given industry (Shen and Tan 2005). Thus, to understand the dynamism of an industry, it is vital to study the competitiveness at the firm level. Firm level competitiveness can be defined as the ability of a firm to design, produce and or market the products or services superior to those offered by competitors (Rugman and D'Cruz, 1993). Having established the importance of competitive advantage at the firm level, the section next presents an overview of key schools of thought on firm-level competitiveness and the application of them to construction.

The different characteristics, different abstraction levels and different definitions have led to forming different schools of thoughts around the competitive advantage. Among these, seven main schools of thought can be identified specifically in organisational (firms') competitiveness literature. These are, Porter's diamond framework based on the process-based theory (Porter, 1985); Resources Based View-RBV (Barney, 1991) Core Competency view-CCV (Prahalad and Hamel, 1990; microeconomic theory-MET (Dewan and Min, 1997); Total Value Competitiveness Framework-TVC (Flanagan *et al.*, 2007b); APP framework (Buckley *et al.*, 1988; Momaya and Selby, 1998), and strategic management approach (Chandler, 1962; Mintzberg, 1987).

As noted by Buckley et al., (1988), competitiveness can be determined by three distinctive perspectives; the extent to which an entity performs well, the types of assets possessed, and the management process. This framework is known as APP (Assets, Process, and Performance). APP framework suggested by, Buckley et al. (1988) provides a richer and more comprehensive view on sources of competitiveness, their relevance and performance concluding that there are three categories of competitiveness sources, each with a different focus. These sources have been categorised under 'Asset', 'Processes', and 'Performance' on the spectrum of all levers of a firm (i.e. strategic, tactical, and operational) (Ambastha and Momaya, 2004). On the other hand, the APP framework integrates resources (as acknowledged RBV) to performance through processes addressing the complete dynamism of firm-specific competitiveness which gives a robust basis for the professionals providing a better understanding of how competitiveness is paired with strategy (Momaya, 1998; Shee, 2002). Competitiveness includes both efficiency (reaching goals at the least possible cost) and effectiveness (having the right goals) (Buckley et al., 1988, p 195). The authors concluded that all three perspectives must be included to reach a satisfactory view of a nation's, industry's, or firm's sustainable competitiveness.

A study conducted by Ambastha and Momaya (2004) has provided an example of tools that can help professionals in the selection of the right framework or a model. According to Ambastha and Momaya (2004), in terms of competition, firms can be divided into two categories: survival and growth. Which implies firms seek to introduce or enhance competitive advantage for either survival in the market as a mean of escaping from a crisis or to maintain the stability and growth (Ketels, 2016; Buckley et al., 1988). Influenced by their work, a matrix was developed to illustrate the suitability of APP for this research (Figure 9). For firms that are in crisis which seek survival, frameworks like TVC could help in achieving operational excellence. For firms who seek growth opportunities (i.e. innovation) with a robust strategic intent, more complex frameworks like APP would help.

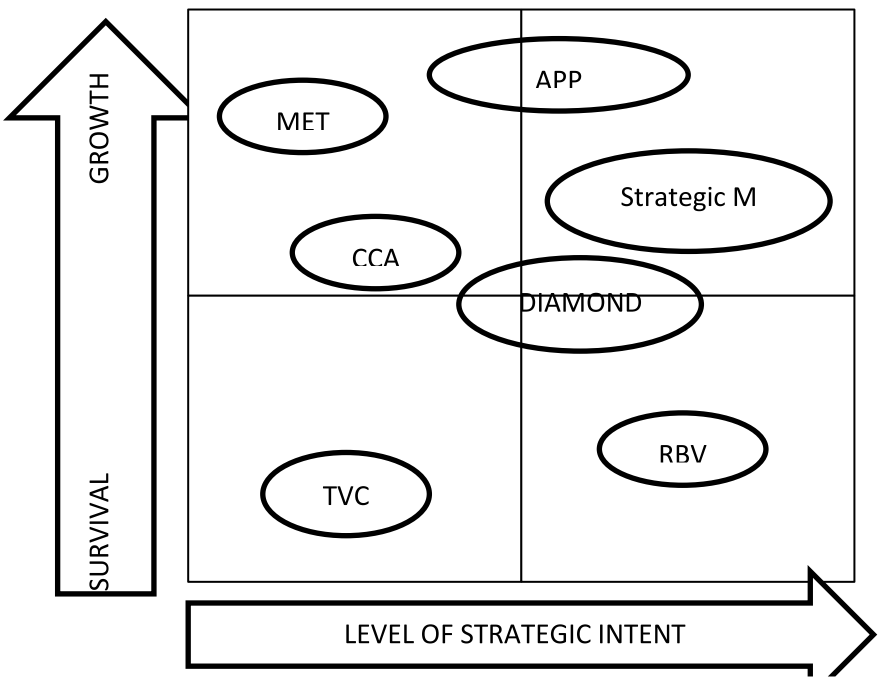

Figure 9- The position of different competitiveness theories for organisational growth and strategic intent

Given the aim of this research and due to the complex linkage of how ICT resources utilisation may impact on organisational competitive advantage, the APP Framework is the most useful and relevant framework to aid the identification of determinants of competitiveness concerning different hierarchical levels within a firm. A further APP framework is emerging from the construction background. A review of existing literature yields an array of sources/ indicators of competitiveness considering the APP framework and shows that there have been fewer studies on assets and more studies on processes and performance. This highlights the importance of processes and performances, as identified in the literature review earlier.

Thus, for this research, Buckley *et al.'s* (1988) APP Framework is selected and employed to describe competitiveness at the organisational level and is thus carried forward as the 'operational definition' (or the framework) for the development of 'determinants of competitiveness'. Thus, based on the above extensive review of literature the following definition for firm-level competitive advantage is concerned in this study:

''A firm can achieve competitive advantage by its internal assets when converted to performances by a particular management process'' The APP framework is further explained in the next section.

2.4.4 Determinants of Competitive Advantage through APP framework

In Buckley *et al.'s* (1988) APP Framework, competitiveness includes both efficiency (reaching goals at the lowest possible cost) and effectiveness (having the right goals). To reach the right goals, three categories are required. The first category, Assets, represents the components of a firm habitually known to be sources of competitiveness. However, these assets are "dormant factors unless they are transformed into 'performance' by 'processes'" (Momaya, 1998, p 41). This framework was used for both the understanding and measurement of competitiveness (Ambastha and Momaya, 2004; Momaya, 1998).This school of thought was later employed for the development of World Competitiveness Formula by the WEF and the IMD in 1993 (IMD and WEF, 1993) and was also adapted by Momaya (1998 and 2004) to introduce a logical sequence between assets, process and performances which was later renowned among construction management researchers (Ambastha and Momaya, 2004).

Assets

These assets can be tangibles or intangibles (Ambastha and Momaya, 2004). The assets have also been acknowledged as 'resources' by Barney's (1991) Resource-Based View which focuses on the firm-specific internal resources. It is mainly based on Barney's (1991) seminal work on 'distinctive competences' and on Penrose's (1959) early argument that a firm is a collection of resources and its performance depends on its ability to use them (Ambrosini, 2003).

Leonard Barton in her book of 'Wellspring of knowledge (1995)' indicates four dimensions of core capabilities; physical systems, skills, managerial systems, and values. Moreover, she reveals that implementation often implies some level of change in the users' work. This ambiguously suggests that people are more receptive when they have contributed to its design. Since, the study itself intends to implement a strategic approach to be competitive among the peers, scrutiny about core capabilities is essential (Leonard, 1995).

Processes

Competitiveness processes are those processes which help to convert the assets/ resources into performance. These can also be related to the management (administration) of the company (Siudek and Zawojska, 2014). The core processes include strategic management processes, human resources processes, operations management processes, and technology management processes. The competitiveness process can be viewed as a balancing process that complements traditional functional processes such as operations management and human resources management. It enhances the ability of an organization to compete more effectively.

Performances

Performances denote the performance outcome relative to that of competitors (Siudek and Zawojska, 2014). Many authors have presented performances as 'measures' or 'indicators' against a benchmark or peer competitors (R Flanagan *et al.*, 2005; Flanagen *et al.*, 2007; Puying *et al.*, 2017).

Followed by thorough investigations, 110 determinants (Determinants of Competitive advantage (DCA) were initially identified. These initial determinants were then reduced after going through a frequency of citation (FOC) analysis and were categorised into three broad categories as assets, processes and performance, as defined by the APP framework and finalised to receive 21 Selected Determinants of Competitive Advantage. The full list of (21 nr) competitive advantage determinants can be found in Chapter-4.4.1. These determinates were fed into a questionnaire survey to capture the extent to which BIM, BDA, and IoT help to enhance organisational competitive advantage and finally to obtain critical competitiveness determinants (CDCA). The statements used for the questionnaires in the effort of investigating the level of enhancement of the above competitive advantages are explained in Chapter- 05.

2.5 The ‘plan’- Exploitation

2.5.1 An operational definition of Exploitation to be employed in this study

As a part of the ‘plan’ stage, first, a situation analysis was carried out to see the current level of exploitation in all four sectors. A situation analysis is simply an analysis of an organisation's internal and external environment to understand the organisation's capabilities, and business environment (Mintzberg, 1987b). To be able to understand the level of current exploitation, an operational definition for ‘exploitation’ in terms of digital technology is a necessity.

In the innovation management literature, different researchers have presented different propositions about the number of stages required for an innovation to reach its success. Some authors advocate three-stage models incorporating idea generation, adoption, and implementation (Shepard, 1967) while some authors interpret innovation in multi-stages: i.e. 12 stage model (Hage *et al.*, 1974). Rothwell and Gardiner (1985) assert that the stages: implementation and exploitation cannot be characterised as incremental stages as they can also act as two independent stages of innovation. Implementation is the carrying out, execution, or practice of a plan, a method, or any design, idea, model, specification, standard, or policy for doing something (Khosrowshahi and Arayici, 2012a). As such, implementation is an action which operates parallel to ‘exploration’ enabling something to happen.

Zahra and George (2002) describe exploitation as a combination of ‘use’ and ‘implementation’ where organisational core competencies and harvesting resources have major roles. The latter authors also argue that transformation and exploitation capabilities are likely to influence organisational performance and yield sustainable competitive advantage. They define

> *“exploitation as an organisational capability is based on the routines that allow firms to refine, extend, and leverage existing competencies or to create new ones by incorporating acquired and transformed knowledge into its operations” (Zahra and George, 2002:190).*

Cohen and Levinthal (1990) offering a similar view in line with absorptive capacity assert a firm’s ability to value and assimilate and apply new knowledge is exploitation. The primary emphasis of exploitation is that it is an organisational capability that is based on the routines that allow firms to refine, extend, and leverage existing competencies and create new ones by incorporating acquired and transformed knowledge into its operations (Cohen and Levinthal, 1990). These routines are referred to as structured and systematic procedures that allow firms to sustain the exploitation of knowledge over a long period. Egbu (2004) through an innovation-based view defines innovation as the successful 'exploitation' of ideas, where the idea is new to the unit of adoption and hence explains the closer link between innovation and exploitation. Exploitation also reflects the firm's ability to yield and incorporate knowledge from its operations (Tiemessen *et al.*, 1997). Exploitation can be systemised by the persistent creation of new goods, systems, processes, and knowledge or new organisational forms (Spender, 1996). From an ontological perspective, exploitation is evident when innovative firms use their strategies to capture knowledge from their market, competition, and customers, and such captured knowledge are used to create new competencies to create sustained competitive advantage (Zahra and George, 2002). Similarly, the existence of the aforementioned routines that allow firms to target and deploy their knowledge to enhance existing initiatives or encourage and create new initiatives within a firm equally create sustained competitive advantage (Rumelt, 2005). Similarly, (Martin and Reddington, 2009) on their study on human resource management viewed exploitation as the operational capacity and routines to use its new, transformed knowledge of products/services to refine and expand on existing services and/or combine existing and new knowledge to produce a transformed business model of greater strategic value to the company. Teece and Pisano (1994) emphasise the notion that competitive advantage requires both the 'exploitation' of existing internal and external firm-specific capabilities particularly in technological capabilities and of developing new ones. This notion has also been acknowledged by many other classical authors (Penrose, 1959; Teece, 2003; Wernerfelt, 1984).

In addition to the mainstream literature on exploitation, there is a vast body of knowledge which considered 'exploration' and 'exploitation' as two concepts that go hand in hand. One such study conducted by March (1991) purports "*exploitation includes such things as refinement, choice, production, efficiency, effectiveness selection, implementation and execution"* (p71). Thus, it implies that 'implementation' is a component of exploitation. The argument made in March 's (1991) study is, both exploration and exploitation are critical for organisational success as conducting exploration alone, to the exclusion of exploitation, would not reap the intended benefits.

Building upon the literature, this research suggests that for an organisation to create or enhance competitiveness, it must have the ability to exploit the positioned services. In the context of 'strategic tools'- BIM, BDA, and IoT, 'exploitation' implies a combination of pre-planning and post-planning processes that help them to operate properly. In other words, it requires both inputs/ enablers and outputs/results. This exploitation includes strategic leadership, analysing requirements, gathering all resources and infrastructure, goals,, policy standards, installation, configuration, customisation, running, testing, systems integrations, user training, delivery, and making necessary changes. The word "deployment" is also used to mean a similar idea in literature. Moreover, there is a wide body of literature supporting the constituents of exploitation identified by Zahra and George in the context of technology/ digitalisation/ ICT (Ruikar *et al.*, 2007; Yasin and Egbu, 2010). However, there is little coverage of BIM (Arayici *et al.*, 2012), BDA (Kache and Seuring, 2017; Akhavian *et al.*, 2015) and IOT (Dave *et al.*, 2018; Woodhead *et al.*, 2018) in construction literature. Thus this research adopts exploitation as a dimension that may influence organisational competitive advantage by exploiting the potentials of these strategic tools by refining, extending and leveraging existing capacities, practices or routines and then creating new uses, practices, routines, services or products (Zahra and George, 2002), effectiveness and efficiency (March, 1991) and implementation of senior management leadership, required resources and infrastructure (human and non-human), intended goals, standards and policy initiatives. Chapter 4.2.3 lists the constituents used to explain the collective term ‘exploitation’. These constituents were worded and presented separately to reflect and match the context of each strategic tool (BIM, BDA, and IoT).

Once the strategic tools are positioned in such a way that they distinguish themselves from their competitors and deliver value to specific customer segments, the next step is to evaluate the patterns from the past. One way of evaluating the pattern involves identifying the factors impacting exploitation. This may include people and skills (Hollen *et al.*, 2013), organisational culture (March, 1991; Angel, 2006), structure (Javed *et al.*, 2018), technology tools (Abdul Kadir *et al.*, 2005) which are discussed in the next section.

2.6 The pattern- The factors (at high abstraction level) that impact on the exploitation of BBI for competitive advantage

2.6.1 Selection of higher abstraction level impact factors

According to Mintzberg (1987), patterns are the strategies that have been implemented before. Studying the past patterns triggered by behaviours within an organisation (i.e. organisation culture, structure) helps an organisation to identify what worked well, what achieved the intended results and what did not go as planned. A critical look at the strategic management literature, especially in technology exploitation, reveals that some key factors are of great significance for the integration of a strategic approach with BIM, BDA, and IOT exploitation. Further, it is also noticeable that these factors are viewed from different perspectives.

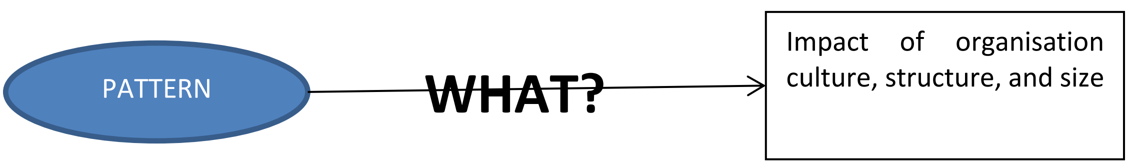

Figure 10- Use of 'Pattern'

With the comprehensive emphasis received from the literature, the factors having an impact on the exploitation of BBI for competitive advantage were categorised to reflect three lenses on a higher abstraction level. These include theories of a firm; organisational strategy that influences competitive advantage; and BIM, BDA, and IoT implementation/ exploitation (innovation diffusion).

First, the factors impacting on technology/ digitalisation intake have appeared in literature in the organisational context (also known as theories of firm). DeCenzo and Robbins (2013) define an organisation as a systematic arrangement of people brought together to accomplish specific goals. Beijerse (1999) in his renowned organisational design model highlights strategy, culture, and structure as the three main factors that impact organisational performance. On a similar view, Zheng *et al.* (2010) focused attention on organisational strategy, structure and culture playing an important role in the effectiveness of organisations.

Second, researchers have stressed the importance of factors around organisational strategy when improving organisational performance for competitive advantage. Ismail *et al.*, (2012) identifies internal factors that impact strategy implementation concerning site safety and technology deployment as organisation structure, organisation culture, leadership, company resources, strategies, rewards, and staff motivation. Chandler (1962), in his ground-breaking work, "strategy and structure", highlighted the impact of organisational structure in the determination of the basic long-term goals and objectives of an enterprise, and the adoption of courses of action and the allocation of resources necessary for carrying out these goals. Miller (1983) scrutinises that there is an intrinsic association between strategy formulation and structure of the organisation. In the scrutiny of economic perspective, the world economic forum, in their Industry Transformation Framework, has also mentioned the need for transformation in the construction industry concerning the areas of strategy, people, structure, and culture at the company level (WEF, 2016) to be able to foster innovation.

Third, a critical look at the literature on BIM implementation/ exploitation, BDA implementation/ exploitation, and IoT implementation/ exploitation reveals that some key factors are of great significance for competitive advantage. Although the BIM/BDA/IoT implementation studies show various approaches and viewpoints on factors (i.e. drivers, barriers, challenges, benefits, and other issues) by the researchers, the most cited factors can be divided into five main fields as people, technology, process, organisation, and policy. Some authors expand the organisation category as strategy, structure, culture, and training and resources. The findings of the study conducted by Aibinu and Papadonikolaki (2016) brought the attention to how various procurement methods impact on successful BIM implementation. A study conducted by Arayici *et al.* (2011) on a systematic approach for building information modelling (BIM) implementation for architectural SMEs at the organisational level highlighted people, process and technology as factors that led to capacity building through improvements in process, technological infrastructure and upskilling for BIM implementation.

After a comprehensive investigation into the three types of literature above, it is clear that 'organisational culture' and 'organisational structure' play a vital role in the context of organisational behaviours, organisational strategy for competitive advantage, and the exploitation of BIM BDA and IoT. Further, one of the main reasons why many organisations struggle to attain advantages out of technologies is that, rather than considering digital initiatives as part of their core strategy, organisations treat them as separate endeavours (Fuchs *et al.*, 2018). These organisations most often isolate technology implementation from strategy and keep their workflows, processes, cultures, and structures unchanged. Fuchs *et al.* (2018) further suggest that to deliver differentiated digital value, companies should create cultural teams that support an agile way of working in which core operating units are integrated with the IT/ digital units.

It is interesting to see the commonality of these three factors when viewed in the three lenses. It is also interesting that there is no agreed significance reported in the literature regarding the impact of organisational size on technology/digitalisation implementation. Instead many researchers highlight drivers and strategies, both commonalities and differences can be found among construction firms of different sizes (Meng and Brown, 2018; Reza Hosseini et al., 2018). The complexity and lack of agreement have influenced this research to investigate the impact of organisational size. Thus, the three main factors that impact the exploitation of BIM, BDA, and IoT for organisational competitive advantage are established and this yields to the development of the initial conceptual framework (Figure 11). In summary, there are five main reasons for choosing organisation ***culture***, ***structure,*** and **size** for this study as impact factors, namely: -

I. According to Theories of a firm, to maximise or create organisational competitive advantage, "soft" assets like values, culture, and structure are required to be formed in such a way that it addresses the determinants of competitive advantage.
II. Many organisations treat digitalisation (initiation, adoption, implementation, exploitation) as a set of technology-lead processes and most often isolate it from strategy and keep their workflows, processes, cultures, and structures unchanged. Consequently, they struggle to take full advantage of digitalisation as their existing unchanged strategy inhibits them from benefitting. Culture and structures are two main components of every organisation

strategy- hence there is a serious impact from them on BBI exploitation which is worth investigating.

III. To exploit a technology (or an innovation), particularly technologies which contain digital features like BIM, BDA, and IoT, much change is required from organisation internals such as structure and culture. Indeed, a recent consultation document published by the Department of Trade and Industry notes that the UK will not reap full economic benefits unless the economic, legal, institutional, and cultural obstacles to innovation are identified and eliminated (Department of Trade and Industry, 2016).

IV. The research coincides with a time in the UK construction industry where 99% of businesses are SMEs being criticised for being, relatively, the least digitised industry. Consequently, a dilemma has emerged as to whether the sluggish nature of digitalisation in construction is caused by the dominance of small firms- hence the question arises of whether firm size has an impact on the exploitation of digital technologies. Despite that, few studies to date have provided empirical evidence to compare BBI exploitation among small, medium, and large construction firms, therefore, a gap is identified in the body of existing knowledge.

V. Generally, any sector must tackle organisations' structural, strategical, cultural, and talent challenges to maximise the benefits of big data (Manyika *et al.*, 2011a). BIM and IoT inherently produce 'big data'

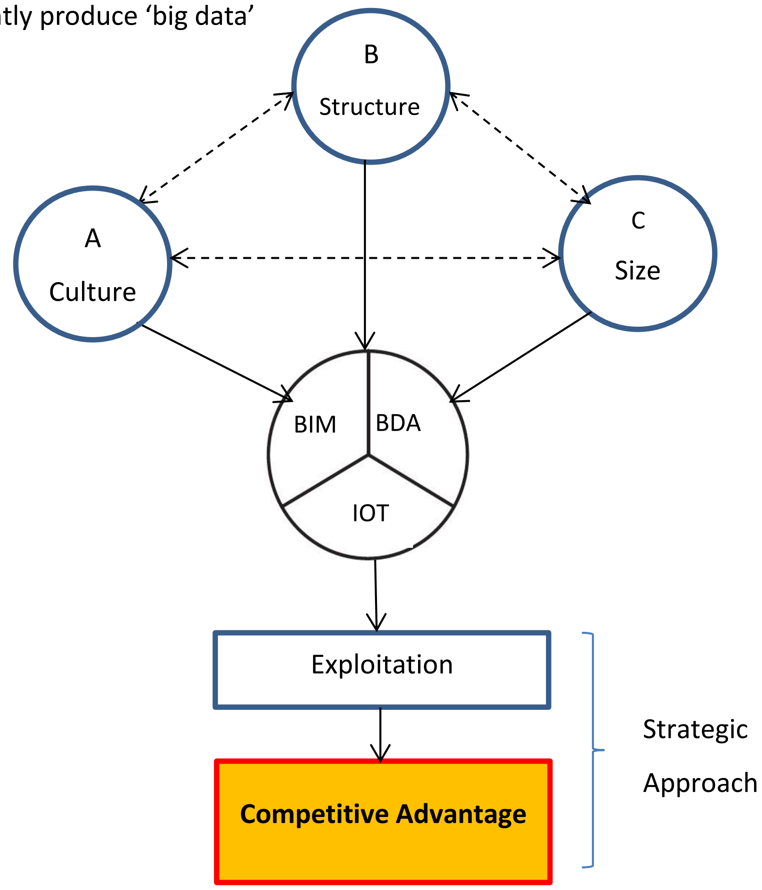

Figure 11- Conceptual framework for factors impact on BBI exploitation

Even though ‘skills’ and ‘training needs’ are also identified as higher abstraction level factors that impact BBI, this research chooses to present skills and training needs as an ‘inventory’. After establishing the three factors (at higher abstraction level) that impact on the exploitation of BBI for competitive advantage, the next step is to derive the construct variables for these high-level factors.

2.6.2 Organisation Culture and its impact on the exploitation of BBI for competitive advantage- Establishing CULTURE variables

A culture is a competitive advantage for an organization as it cannot be replicated by its competitors, for its historical legacies are embedded in cultures. Nevertheless, a culture also acts as a significant barrier for change with its anchored historical beliefs. (Johnson *et al.*, 2014). Mainstream construction management literature has long since recognised the implications of organizational culture on organisational performance (Hofstede 1980; Handy, 1985). However, some studies showed that there is no impact on the success of a project even if cultural differences existed (Nummelin, 2005).

Given the diverse nature of literature on organisation culture, the impact of culture on the successful implementation of Building Information Modelling, Big Data Analytics, and Internet of things (BBI) in the construction sector is questionable, especially with the paucity of empirical data in this area. There has been a vast amount of research undertaken into the role of culture within today’s organisation and technological innovations. However, no study has addressed the cultural implications with BIM, Big Data Analytics, and the Internet of Things as a synergistic strategic approach.

Among many of the renowned authors who studied organisation culture, Hofstede (1980) has defined culture as ‘‘the collective programming of the mind which distinguishes one group from another’’. Having said that, Barthorpe *et al.* (2000) encapsulate the current research literature on organisational cultures and simply explicate culture as ‘‘what we are and what we do as a society’’. Notwithstanding, Holden (2002) expounds culture in the light of knowledge management. He appraises culture as a variety of common knowledge and an intellectual resource that can be managed through knowledge management. Edgar Schein elucidated an organisational culture as ‘the basic assumptions, behaviours, and beliefs that are shared by members of an organisation, that operate instinctively and define in a basic presumed way on organisation’s view of itself and its environment (Schein, 2004). Robert E. Quinn and Kim S. Cameron coined another well-known cultural model- the Competing Values Framework (CVF) which is one of the most influential and extensively used models in the area of organisational culture research. According to Cameron and Quinn (2006), there are four types of organizational culture: Clan, Adhocracy, Market, and Hierarchy. Market-oriented cultures are results-oriented, with a focus on competition, achievement, and “getting the job done most efficiently”. This shows a similar characteristic of Hofstede’s (Hofstede *et al.*, 2010) concept of masculinity. Clan oriented cultures are family-like, with a focus on mentoring, nurturing, and ‘doing things together’ (Cameron and Quinn, 1999) which resembles femininity and collectivism. Adhocracy oriented cultures are dynamic and entrepreneurial, with a focus on risk-taking, innovation, and ‘doing things first’; showing similarities with masculinity and low uncertainty avoidance in Hofstede’s culture model (Cameron and Quinn, 2006).

Among the aforesaid views, Hofstede’s cultural model is selected for the investigation in this research, and thus construct variables for ‘organisational culture’ are established in line with the aforesaid model. Hofstede (1980) perceived culture in 4 dimensions, namely, power distance, uncertainty avoidance, individualism/collectivism, and masculinity/femininity. This four-dimensional model of culture provides a lens in evaluating the impacts of culture on organisational competitive advantage. Even though Hofstede’s culture model is pitched for national cultures, it contains close relationships between the stages of development in organisational life cycles as the measurements were controlled with samples from a single organisation (Smircich, 1983). Further, the methodology and philosophical paradigms employed for cross-cultural research justifies the suitability of this model for this research. Hofstede’s research into national culture is through the careful collection of data from large stratified samples, which he analyses with statistical techniques designed to suppress subjective interpretations (Hofstede, 2002). The dimensions of his model purport to be universally applicable. One out of two strands in this research also holds positivist epistemology which seeks generalisability through responses from a stratified sample hence the methodological similarities give strong seemliness and felicity to deploy Hofstede model as a basis for culture investigations in this study. Finally, this model shows the characteristics of a ‘Parsimonious model’ with the least assumptions and variables but with the greatest explanatory power (Williamson, 2002).

Table 4- Construct Variables for organisation culture

Cultural Dimension	Statement Used to explain each construct variable
Power distance	The impact of empowering employees, enabling them, and including them in decision-making
Uncertainty avoidance	The impact of having clear job responsibilities and job security

Individualism	The impact of individuals to be independent and self-reliance in daily tasks
Collectivism	The impact of group/ teamwork
Femininity	The impact of a friendly and sociable working environment
Masculinity	The impact of competitive, result-focused, and risk-taking work environment

Power Distance

Power distance studies the basic differences of equality/inequality among superiors and subordinates within an organisation (Wu *et al.*, 2001). Power distance generally affects the upward communication in such a way that operational level employees in a high power distance culture may be afraid of expressing their opinions to their managers (Zairi and Al-Mashari, 2005). Alternatively, power distance is also defined when less powerful members within an organisation expect and accept that power is distributed unequally (Steele and Murray, 2004). High power distance may lead to a very autocratic, controlling type of leadership (Table 5), whereas a low power distance may give rise to a more democratic approach and place more emphasis on the empowerment of the peers (Hofstede, 2001). Numerous authors suggest the positive effect of autocratic organisation culture on technology adoption in general (Engelen *et al.*, 2014; Fikret Pasa, 2000) as the leaders with their implicit influence establish strategic directions that technologies could carry for organisational success. However, there are also studies in favour of low power distance that encourage subordinates' 'voice' and 'input' to a similar extent as top-level managers (Auh and Menguc, 2007; Calantone *et al.*, 2010; Chen and Huang, 2007).

Table 5- A comparison between high and low power distance organisations

Low Power Distance	**High Power Distance**
Decentralized decision structures; less concentration of authority	Centralized decision structures; more concentration of authority
Flat organization pyramids	Tall organization pyramids
The person in a superior position is generally a resourceful democrat; sees self as practical, orderly, and relying on support	The person in a superior position is generally well-meaning autocrat or friend-like; sees self as a benevolent decision-maker

Subordinates expect them to be consulted by superiors when decision making and day-to-day activities	Subordinates expect to be told what needs to be done in day-to-day activities

Source: (Hofstede, 1991; Triandis and Hofstede, 1993)

Uncertainty Avoidance

The second dimension of Hofstede's culture framework is uncertainty avoidance, which refers to people's tolerance for ambiguity (Wu *et al.*, 2001). This tests the extent to which people are flexible when coping with uncertain circumstances. An organisation which has high uncertainty avoidance may lead to a more bureaucratic and controlling management with highly formal rules and procedures (Table 6) whereas low uncertainty may lead to a more laissez-faire management (Akiner and Tijhuis, 2008). Members of high uncertainty avoidance cultures placed a premium on job security, career paths, retirement benefits, etc. Several authors see high uncertainty avoidance as a positive effect towards technology assumptions as the job roles and responsibilities were expected to be very clear with detailed instructions, and subordinates' initiatives were tightly controlled (Furnham and Furnham, 2006; Hofstede, 2011; Merkin, 2006). On the other hand, some authors are in favour of lower uncertainty avoidance cultures as they are the ones that carry greater readiness to take risks and less emotional resistance to change which are considered essential requirements of technology exploitation (Akiner and Tijhuis, 2008).

Table 6- A comparison between high uncertainty avoidance and low uncertainty avoidance in organisations

Low Uncertainty Avoidance	**High Uncertainty Avoidance**
The leader's role is mostly transformational	The leader's role contains a degree of hierarchical control
No pressure for hard-working (unless needed) and embracing challenges/ risk hence people remain in the comfort zone	The emotional need to be busy; the inner urge to work hard
Innovative ideas and behaviours are encouraged	Out of the box ideas and behaviours are not encouraged; resistance to innovation
Motivation by achievement and esteem or Belongingness	Motivation by security and esteem or belongingness
Weak loyalty to the employer; short average duration of employment	Strong loyalty to an employer; long average duration of employment
Top-level managers are only for strategy-related tasks	Top-level managers' involvement in operations in common

Source: (Hofstede, 1991; Triandis and Hofstede, 1993)

Individualism/ collectivism

The third dimension, individualism-collectivism, refers to the orientation of people into groups. This explores relationships between the individual and the group or collective. Members of the collectivist approach would tend to have a greater emotional dependence on their organisations and the organizations would be more likely to assume greater responsibility for its members (Hofstede, 2001). Moreover, collectivists may have collective goals, favour group decisions, possess a sense of harmony, and have concern for others in contrast to individual goals. On the other hand, members of the individualist approach expected to remain independent from their organisations as well as all other collective societies within the organisation. Individualists' primary concern are themselves and their immediate families. The nature of individualists may lead to a more competitive type of management, whereas high collectivism may give rise to a more consultative style. Furthermore, in a collectivist culture, a strong 'we' sensemaking/ spirit can be seen and that spirit is based on the relations within groups (Hofstede, 1980). Highlighting another interesting point, Hofstede (1980) states, in most collectivist cultures, saying no to one's request or opinion is very rare as it is confrontational. Instead, the group members may use more polite ways such as 'you may be right' or 'we will think about it'. Similarly, the word 'yes' should not necessarily be seen as approval, but as maintenance of the communication line. Many authors are of the view that collectivism influences collaboration and therefore is an effective solution for micro-level fragmentation within organisations (Demchenko *et al.*, 2013; Sepasgozar *et al.*, 2013). Collaboration and teamwork have long been considered to be a prerequisite for the exploitation of BIM (Lin *et al.*, 2017b; Schweigkofler *et al.*, 2018), BDA (Gandomi and Haider, 2015; Mishra and Sharma, 2015; Russom, 2013) and IOT (Banafa, 2017), hence collectivism has positive implications for BBI exploitation. However, literature also supports the idea that individual-focused cultures encourage a more competitive type of environment which are designed for agile target achievement, hence it is healthy for organisational competitive advantage (Franke *et al.*, 1991; Mobley *et al.*, 2005b). Moreover, knowledge and skill development (Eriksson *et al.*, 2017; Green, 2016; Waterhouse and Philp, 2016; WEF, 2016) which is a necessity in every digital technology exploitation can be better fostered by improving individual skill development/ training programmes rather than collective training (Egan, 1998).

Table 7- A comparison between collectivist and individualist

Collectivist	Individualist
Level of education provides access to higher status groups	Level of education provides merely self-respect or self-economic value

The organisation contains a family-like atmosphere; Employer-employee relationship is moral	The organisation is one big business deal/ contract made between employer and employee
Discrimination at work is not tolerated as inclusivity is appreciated; report teamwork	Work is reported individually and therefore discrimination is bound to happen
Hiring and promotion decisions take employees' in-group into account	Hiring and promotion decisions are based solely on individual skills and rules
Overall management is clustered for managing each collective group	Overall management is managing individuals
Managers chose duty, expertness, and prestige as life goals	Managers choose pleasure, affection, and security as life goals

Source: (Hofstede, 1991; Triandis and Hofstede, 1993)

Masculinity/ femininity

The fourth dimension describes achievement-related values concerning the tasks that represent the duality of the sexes, but it is not related to the sex/gender of the worker (Wu *et al.*, 2001). Hofstede suggests that the masculinity/femininity dimension affects the meaning of work in people's lives. This dimension concerns the extent to which individuals tend to support male or female favoured goals. High masculinity may give rise to a macho type of management, whereas high femininity may lead to a more empathetic considerate type of leadership. Masculine culture has a higher emphasis on assertiveness and the acquisition of money and other material things. Feminine cultures stress relationships among people, concern for others, and interest in the quality of the work environment. Many of the authors are of the opinion that organisations with a balance of masculine and feminine approaches, get more of the strengths and less of the downsides of each, as both masculine and feminine approaches have their strengths and limitations (Good *et al.*, 1994). On the same view, Gavious *et al.* (2012) state that, in terms of technology, 'inclusive cultures' get better results out of technology. The latter authors further emphasise, when an organisation is dominated by either masculine or feminine approaches, there is a risk that the downsides of that approach will emerge. Nevertheless, there is a proportion of authors that claim an organisation must follow one approach between masculinity and femininity as an organisation culture that cannot be more task-oriented and more interpersonal at the same time (Helson, 1979).

Table 8- A comparison between masculinity and Femininity

Masculinity	**Femininity**

Success, material value and progress are key concerns	Caring for others and preservation are key concerns
Business value and the levels of success that the relationships can add are of more concern	Relationships between each other are highly valued
Assertive, ambitious, and tough	Everybody is modest
Workflows are big and fast	Workflows are small and slow
Differences between gender roles are more rigid	Differences between gender roles are more fluid

Source: (Hofstede, 1991; Triandis and Hofstede, 1993)

Hofstede added another two dimensions; Long-term/Short-term Orientation, and indulgence/Restraint as an extended version of his four-dimensional culture model. Degrees of long-term orientation portray whether decisions are made to benefit present situations or have long term goals and impacts. Finally, indulgences scores relate to whether a member of a culture looks to be instantly rewarded or gratified. However, for this research, these two dimensions are not considered.

2.6.3 Organisation Structure and its impact on the exploitation of BBI for competitive advantage- Establishing STRUCTURE variables

Organisational structure plays a key role in the exploitation of digital technology (Khosrowshahi and Arayici, 2012b; Wade *et al.*, 2011; Zheng *et al.*, 2010) because it can facilitate the coordination of all the elements inside the organisation so that the latter can fulfil its objectives (Mintzberg, 1987b). Miller (1985) observes that there is an intrinsic association between strategy formulation and the structure of an organisation and hence the structure is an important factor that impacts the strategy, because the structures facilitate or constrain how the process and relationships work in strategy formulation (Johnson and Scholes, 2002). Anumba *et al.* (2002) emphasise the impact of organisation structure on the competitive advantage of construction through concurrent engineering. The structure of an organisation directly impacts the overall effectiveness and ultimately the success while the number of layers required in any given hierarchy is a product of the organisation's mission (Jaques, 1985). Burns and Stalker (1961, 2009) purport that, for an organisation to achieve maximum performance and compete with its rivals its structure must fit with the dynamism of the environment caused by technology adoption. To exploit digital technology, firms must design structures and systems that facilitate the flow of information so that the organisation can create, accumulate, integrate, and disseminate, and hence manage, this resource effectively (Grant, 1996; Nonaka, 1994).

Even though there are a large number of studies reported analysing how the traditional variables defining the structure of an organization (i.e. formalisation, complexity, and centralisation) influence organisational performance, no study has examined the link between the aforementioned traditional characteristics of organisational structure and competitive advantage in light of BBI exploitation. The key construct variables for organisation structure are established in the next paragraph after exploring a few renowned structure models.

One of the most prominent researchers in the area of bureaucratic structure is the German sociologist Max Weber (Weber, 1947) who specified four characteristics of bureaucratic structure. Second, Mintzberg’s structure of five configurations describes organisation structure as simple structure, machine bureaucracy, professional bureaucracy, and adhocracy (Lundberg and Mintzberg, 1991). Other recent models include the chart structures (hierarchical, matrix, horizontal/flat, network, divisional line organisation, team-based), hypertext model (Nonaka and Takeuchi, 1995), and the federated structures (Handy, 1992). In addition to the above forms ‘hybrid’ forms can also be seen (Baskerville and Dulipovici, 2006). These hybrid forms imply that the organisations try to reconcile the basic formal characteristics of traditional structures, such as functional or divisional forms (Lundberg and Mintzberg, 1991) with other characteristics that are closer to adhocratic, flexible structures.

On large scales, discussions emerging from the literature suggest, organisational structures are multi-dimensional and heterogeneous which need a strategic positioning to understand the correct route. Hence, in this research, the researcher adopts Hage's (1999) four-dimensional organisation structure model as it simplifies the different complex dimensions into four (Aiken and Hage, 1968; Hull and Hage, 1982). Hence the construct variables for organisation structure are established for further investigation (Table 9).

Table 9- Construct variables for organisation Structure

Construct variables for organisation Structure	The statements used to describe the construct
Centralisation	The impact of centralised decision making, authority and flow of communication at the top management without employees’ participation on achieving the best possible use
Formalisation	The impact of having highly formal rules and procedures on achieving the best possible use

Stratification	The impact of having a substantial number of states, layers, levels of professional roles on achieving the best possible use
Complexity	The impact of having a substantial number of specialised job roles, divisions/ units on achieving the best possible use

Centralisation

Centralization is described as "the extent to which decision making power is concentrated at the top levels of the organisation" (Caruana *et al.*, 1998, p. 18). In opposition to centralisation, decentralization is the distribution of authority and decision-making units throughout an organization (Bloisi *et al.*, 2007). Hence, centralisation encourages hierarchical organisational structures by focusing decision making at the top while decentralisation encourages sharing the responsibility with lower-level individuals (Auh and Menguc, 2007).

Even though the idea of 'where power is coming from' has bi-polar attributes by nature, some authors discuss this issue as one dimension and the extent to which the power is placed on the top of the organisation determines how bureaucratic an organization is (Pugh *et al.*, 1968, p. 76). Numerous attempts have been made to find the effect of centralisation on the organisational performance which concluded with completely different implications. Findings of Connor (1992) suggest that the high specialisation of personnel in organisations caused by the size of the organisation (especially being large) makes the structure less centralised and therefore it improves performance. Supporting the same argument, several researchers (Ouchi, 2006; Pertusa-Ortega *et al.*, 2010) have indicated the positive effect of the involvement of more members of an organisation (from different levels) in organisational decision-making processes, as a variety of ideas and opinions emerge that help in problem solving in various areas including 'technology'. Auh and Menguc (2007) emphasise the need for decentralisation by highlighting the negative impact of centralisation for organisational technology exploitation, as in centralised structures, management tends to overlook the diverse cognitive resources of human capital, and therefore, diverse and creative ideas are more likely to be excluded from decision-making processes. These employees who are excluded from decision-making may think about their inability to influence their work environments and, consequently, become reluctant to come up with creative ideas and become less innovative and less active (Dedahanov *et al.*, 2017). Furthermore, centralisation reduces the quantity and dilutes the quality of knowledge and ideas retrieved for problem-solving in radical innovations (Kimberly *et al.*, 1988). Such knowledge, ideas, and creativity are prerequisites for BIM implementation (Gu and London, 2010). In a similar view, Chen *et al.*, (2010) and Chen and Huang

(2007) suggest that lower-level employees have limited autonomy in highly centralised organisations and therefore technology adoption is adversely affected, because technology in its very structure is a continuously evolving innovation that seeks creativity. Hence, decentralized structures provide more flexibility to exchange ideas within organisations (Calantone *et al.*, 2010) allowing individuals to express their opinions during the innovation process which helps in technology adoptions. Lovelace (1986) concludes that 'an organic matrix and decentralised structure will provide the 'creative individual with sufficient freedom to be creative'. Since, creativity, free motion of thinking and communication (Ones *et al.*, 2017) are treated as prerequisites of innovation implementation and exploitation processes, such a structure is in favour of technology exploitation (Hameed *et al.*, 2012). However, Leavitt, (2004, p. 40) argues that hierarchical structures that promote centralisation enable the big and complicated tasks to be performed effectively than when they are managed by different units (i.e. in a flat structure through decentralisation.

Formalisation

Formalisation refers to "the degree to which rules define roles, authority relations, communications, norms, sanctions, and procedures" (Aiken and Hage, 1968). Organisations with low formalisation are categorised as organic organisational structures, whereas those with high formalisation are categorised as mechanistic organizational structures (Alexander and Randolph, 1985). Pierce and Delbecq (1977) emphasise the positive influence lower-level formalisation has on innovation adoption and implementation, as highly formalised managements specify work routines rather than permitting individuals to decide how things are done (Agarwal, 1993). Moreover, excessive rules and regulations restrict individuals from being part of a team as the opportunities for integration and communication are limited; therefore less collaboration limits the creation and sharing of new knowledge (Pertusa-Ortega *et al.*, 2010). A similar perspective has been drawn by Tang *et al.* (2013) bringing attention to the fact that excessive rules and regulations grounded in a higher level of formalisation hinder innovation behaviour essential for firms in digitalisation. Hindrances include work-related stress (Dubinsky *et al.*, 1992; Journal *et al.*, 1993; Michaels *et al.*, 1996). Creating innovative and creative behaviours in an organisation is an enabler for creating new uses out of existing ones- which is a dimension in exploitation (Zahra and George, 2002) Having highly structured routines and systems impedes the development of this innovative and creative behaviour (Chen *et al.*, 2010) as it prevents individuals from seeking several sources of information and engaging in more sense-making approaches to their jobs rather than following a pre-defined set of actions (Gilson and Shalley, 2004). Further, a low focus on work rules allows more room to focus on stimulating creative behaviours and idea generation with openness (Damanpour, 1991). A prerequisite common for BIM, BDA, and IoT exploitation is the trial and error behaviour- this behaviour is not encouraged by highly formalised systems (van der Panne *et al.*, 2003).

The literature has also reported positive implications of high-level formalisation in organisations. For example, having highly formal rules mitigates the workplace ambiguity while giving them confidence and conformity in their job roles and responsibilities (Hartline *et al.*, 2000) Jansen *et al.* (2006) see a clear difference between variation-seeking behaviour and structured behaviour and rejects the idea that formalisation impedes variation-seeking behaviours, instead he mentions that knowing your limits and scopes makes it easier to go beyond the limits. (Lichtenthaler, 2009).

Stratification

Stratification refers to the difference in high- and low-level status within an organisation's hierarchy. These differences imply salary, prestige, level of control, etc. (Donaldson, 2014)**.** Stratification is also an indication of who is in the top tier and who is in the low tier of an organisation's hierarchy (Chandler, 1962).

According to Egbu (2000), the excessive amount of preoccupation required to maintain status and the lack of freedom for creative thinking in high stratification organisations hinders innovation. The greater the disparity in the rewards/ opportunities between top and bottom status levels, the more limited mobility between them (Pertusa-Ortega *et al.*, 2010). This limited mobility results in not only limited communication (Bezweek and Egbu, 2009) but also higher time consumption for information to pass through many levels (Bezweek and Egbu, 2012) and hence hinders organisation performance as it gives rise to certain problems such as delays and distortion of information. Highly stratified organisations tend to apply highly formalised rules and hence restrict innovative behaviour (Tang *et al.*, 2013). On a similar view, Kanter (1983), highlights how 'elevator mentality' adversely impacts on innovation capability in organisations as they are formed by a highly stratified structure that reflects the large differences between upper and lower management levels.

Having a neutral perspective, Child (1974, 1975) highlights the balanced association a top-down-dictate has on organisational performance. Further, Dedahanov *et al.* (2017) emphasise the importance of dividing the organisation structure into different strata to make task delegation easier.

Complexity

Complexity refers to the amount of occupational specialisation and task differentiation within an organisation (Egbu, 2000). For an expanded definition, complexity also refers to the degree of differentiation within the organisation in terms of horizontal (number of functions), vertical (number of hierarchical levels), spatial (number of operating sites), or personal (number of occupational specialists with distinctive blocks of knowledge) in nature (Ford and Slocum, 1977). In short, the level of complexity represents the extent to which an organisation is vertically and horizontally distributed internally and externally. Two main organisational stratifications are divisional and functional. In a divisional hierarchy, similar activities are grouped into a division (e.g. housing, infrastructure, etc). In a functional hierarchy similar functions are organised into departments (e.g. manufacturing, finance, sales, engineering, etc.) (STAMP, 1981).

A high level of complexity is said to facilitate the initiation stage of the innovation process (Egbu, 2000) while a low level of complexity facilitates the implementation stage of the innovation process (Ones *et al.*, 2017; Simonton *et al.*, 1992). Integration is another element of organisational complexity (Tang *et al.*, 2013). Integration is described as the extent to which different units and employees of a firm communicate and work interrelatedly (Germain, 1996). Integration between business units, departments, or job roles fosters the interaction of both horizontal and vertical communication (Hameed *et al.*, 2012; Willmott, 1981), information-sharing, collaboration, and coordination between units (Song *et al.*, 1997)which are enablers for technology exploitation. Moreover, a higher level of geographical distribution facilitates the dispersion of diverse mindsets across units/branches and helps employees to consider different perspectives (Brown and Eisenhardt, 1995) as having a diversified perspective is said to be a prerequisite for the implementation of new products, tools, and technologies. Thus, organisations with a higher level of complexity are more likely to seek new technologies, processes, techniques, and/or product ideas (Calantone *et al.*, 2010).

However previous empirical studies have also reported a negative association between complexity and organizational innovation performance. For example, Bloisi *et al.*, (2007) reported that having a large number of operating business units or a large number of functional departments does not make a firm cooperate to generate and screen new ideas for new products; instead, employees in such firms become reluctant to seek and implement new technologies, processes, techniques, and product ideas because of a human's intrinsic reluctance to embrace complexity. Since companies become innovative by utilising the capabilities of employees to innovate (Sethi, 2000)and not by the physical distributions, the reluctance of individuals to generate and implement new ideas inhibits organisational innovative technology performance.

A thorough review of the general literature on technology/ IT/ ICT/ BBI exploitation reveals a meagre amount of empirical research on how the above four structural variables impact upon BBI exploitation separately. The situation is even unfavourable in technology exploitation literature with a construction industry perspective. From an innovation perspective, Zaltman *et al.* (1973) have noted that the aforementioned four structural variables contain contrasting effects at the initiation and implementation stages of the innovation process (the so-called ‘innovation dilemma’) (Egbu, 2000). Hence this research, with its originality, investigates the impact of organisation structure on the exploitation of BBI in chapter 05.

2.6.4 Organisation size and its impact on the exploitation of BBI for competitive advantage- Establishing SIZE variables

Typically, the structure of the construction industry is unequally distributed in terms of firm size. The Federation of Small Business (FSB) states that over 99% of businesses in the UK are SMEs, and the Department for Business Innovation and Skills suggest that 99.9% of UK construction contracting businesses are SMEs (BIS, 2013). About 95% of construction firms employ fewer than eight people (Egbu, 2000). This explains the reasons why quite a lot of construction research, such as Barrett and Sexton (2006); Davey *et al.* (2004); Hardie and Newell (2011); Shelton *et al.* (2016) Thorpe *et al.* (2009) are focused on the use of innovation/ innovative technologies in small firms rather than on large firms. This imbalance has been a cause for fragmentation and hence reflects the economic situation of the construction industry. In general, the construction industry requires relatively low capital investment, possesses relatively low barriers to entry and relatively low threats of new entrants (Betts and Ofori, 1993). Despite this, construction SMEs find it difficult to enter the market for larger projects, particularly within the public sector. Proving the latter fact, 40% of construction SMEs were failing to win nine out of ten public sector contracts and more than half reported their success rate falling over the last five years (Construction Excellence, 2016). This is partly due to the issues around financing and passing through competitive bidding procedures. The government has attempted to tackle this situation by introducing standardisation (i.e. PAS91), introducing strategies to improve accessibility to public projects, and the use of digitalisation (HM Government, 2015) but the amount of empirical evidence for improvements is insignificant.

With government intervention, the construction industry is jointly working towards an inclusive and multi-beneficial digitalisation of the sector. From previous sections on the state-of-the-art in BIM, BDA, and IoT, it was informed that these technologies are now becoming increasingly pervasive in today's business environments and are, in many ways, providing a competitive edge to construction organisations. However, the set-up costs, maintenance costs, and the level of expertise associated with these innovative technologies suggest that small size construction organisations, especially those with fewer than ten employees, should proceed with caution. When it comes to digital transformation and digital exploitation, several aspects can be sensitive for organisation size. For example, figuring out a business strategy before investing in technology is one key aspect that may depend on the availability of workforce and turnover within an organisation (Bosch-Sijtsema *et al.*, 2017). Building capabilities for the workforce of the future is another aspect that may heavily depend on the number of employees and availability of funds (Ammar *et al.*, 2003). On the other hand, some would argue that having a less complicated organisation structure with a manageable amount of employees is a key to digital transformation success (Caputo *et al.*, 2019). Either ways, the process of creating and managing digital information about a built asset require standardisation and hence why this research proposes a framework along with a SKI. This proposition has given rise to investigation of the impact of 'organisation size' on the exploitation of BBI.

Inherently, small, medium and large firms have their own characteristics and hence technology exploitation patterns for large construction firms are not necessarily appropriate for small firms and vice versa (Cohen and Klepper, 1996). The non-construction literature has highlighted a significant impact of organisational size on technological application, not necessarily in terms of the level of exploitation but for the differences in the approach of application. For example, Wagner and Hansen (2005) identified a significant difference in the application of technology and innovation for timber made product manufacturing. Kumar *et al.* (2012) explored the differences and similarities of small and large firms in food manufacturing in terms of their strategic orientation towards innovative technology adoption. Further resources and capability differences between small and large firms are highlighted by Hewitt-Dundas (2006). These comparative studies offer a sound grasp of innovative technology adoption/ implementation/ exploitation in firms of different sizes.

As brought to light by the literature, there are several measures available to measure the size of an organisation. Construction research has been employing a range of measures such as Net Assets (Akintoye and Skitmore, 1991; Ammar *et al.*, 2003), number of employees (Love and Irani, 2004; Nam and Tatum, 1997; Marsh and Mannari, 1981; Nor and Egbu, 2010), turnover (Kamal and Flanagan, 2012), the geographical distribution of branches (Child and Mansfield, 1972; Ford and Slocum, 1977) and payroll (Duff and Makin, 1990). Volume of subcontracted work, scale of operation, and capital to labour ratio are considered to be some measures that have not gained much popularity (Penrose, 1955).

The European Union divides companies into micro-, small-, and medium-sized enterprises (collectively termed SMEs) (Commission of the European Communities, 2003). The main criterion for this division is the number of employees, but the balance sheet, and/or annual turnover is also used to classify a company to one of the size categories. According to the European Union, company size categories are defined as follows: micro-enterprise: staff < 10, turnover < € 2 million, and/or balance sheet < € 2 million; small enterprise: staff < 50, turnover < €10 million, and/or balance sheet < € 10 million; medium-sized enterprise: staff < 250, turnover < € 50 million, and/or balance sheet < € 43 million (Commission of the European Communities, 2003).

The use of net assets has its limitations, associated with variation in company accounts (Egbu, 2004). The number of employees has also been criticised for its subjectivity for the method of contracting service delivery. Because a variation can be expected in numbers employed for companies with approximately the same turnover.

Turnover is also not entirely satisfactory, as it contains errors caused by the possible unbalanced yearly distribution of the assets. However, Bates (1920) and NewBould and Wilson (1977) have alluded, that the choice of measure opted for organisation size studies does not matter in practice, and a degree of flexibility can be allowed as most measures are highly correlated with each other. An important note for researchers is given by NewBould and Wilson (1977) they assert that it is important that the researchers choose only one measure considering the practical limitations.

Despite the availability of a wide range of organisation size measures, it is noteworthy that each of them has its merits and demerits. For this research, the author has chosen 'the number of employees' because of the accessibility of this data. This research coincides with a period during which the location context of the study (United Kingdom) is undergoing a withdrawal agreement between the European Union (EU) and the UK. Consequently, many of the EU establishments are bound to be abolished. The main definition used for firm size concerning turnover is established by the EU, which is likely to be redundant. However, the annual turnover is also used as an alternative measure of size because of the availability of this data and to corroborate the two measures.

People and their skills are also considered to be factors impacting organisations' ability to exploit technology to maximise competitive edge (Hollen et al., 2013). However, given the nature of the objectives of this research, the skills and knowledge dimensions are treated separately to develop a SKI (See section 2.8).

2.7 Strategic framework development

2.7.1 Need for the development of a strategic framework

The prevailing need for the exploitation of BIM, BDA, and IoT was extensively discussed in section The 'plan'- Exploitation. The rationale for studying these three strategic tools together was also discussed in the same chapter. When compared to Retail, Manufacturing, Finance, and other industries, the application of BIM, BDA and IOT as strategic tools in the built environment shows a poor uptake rate. Many of the industry practitioners are in agreement that the construction industry needs to embrace digitisation. This has also been discussed in the 'problem statement; in Chapter-1; presenting the real need to conduct this research. Moreover, the most common sentiment is that using digital technologies is merely a case of adhering to government mandates. Without digital technologies, there's no sort of survival attitude established in the industry. Most of the construction industry has not recognised the strategic business value of these three strategic tools.

The recent advances in BIM, BDA and IoT have disseminated the utilisation of digital information in the construction industry. Nevertheless, the practical effectiveness of these utilisations to stand out of the competitors is difficult to justify at this stage. Even though previous efforts in the BIM implementation and in-kind frameworks have decently addressed the BIM/BDA/ IoT variables, comprehensive issues in terms of their effectiveness towards competitive advantage need to be further developed. To provide consistent and accurate information to make a good decision on the investment in BBI and to maximise competitive advantage, an understanding of the strategic influence (Arikan and Mcgahan, 2010), benefits-challenges (Azhar, 2011) and impact factors (Abdul Kadir *et al.*, 2005), is a necessity. Moreover, exploitation of technology today presents a new and unique set of challenges for the construction industry, owing in large part to the cultural complexity, scheduling, and financing of today's organisations (Alade and Windapo, 2020). Thus the literature supports the need for a framework to identify these constructs at the exploitation of BBI. The framework proposed in this study addresses not only the challenges but also the benefits, and the way organisations need to structure their culture and structure to be able to enhance competitive advantage by identifying the critical considerations. This will assist constructors, consultants, designers, owners/clients, and developers in their investment decisions on potential BBI adoption, implementation, or exploitation.

There is a vital need to understand what impact the exploitation of BIM, BDA, and IoT will be able to make to the organisations. The exploitation of these strategic tools would enable the industry to withstand impact factors and respond to potential changes. Such identification offers an opportunity to bring empirical knowledge and evidence to develop this framework. This research establishes that investing in BIM, BDA, and IoT is a decision for both immediate (current) and long-term futures (future). The findings of the research discover the potential competitive advantage synergies BIM, BDA, and IoT could offer the construction industry. Implementing and exploiting is a value-added decision for construction industry professionals. The case remains, however, that, to-date, there are no developed tools available addressing the critical factors in play for BIM, BDA, and IoT, hence the majority of the strategic decision-makers are reluctant to invest in BIM, BDA, and IoT without knowing the competitive edge they offer. Thus, it is important to assist professionals in the construction industry in identifying the critical factors that impact, as well as relate to, the exploitation of BIM, BDA, and IoT. This would then support the decision to continue or abandon the exploitation of BBI.

2.7.2 The theoretical models aimed at enhancing construction competitive advantage by exploiting BIM, BDA, and IoT

Improving the competitive advantages of construction organisations has long been an interest in the international construction management research community. In attempting to achieve the aim of this study, it is essential to study the frameworks that have already been developed in the subject area. An ample amount of research has been done on the objective of developing frameworks in enhancing/ improving the competitive advantage of construction. The frameworks of competitiveness found in the literature can be divided into three categories: those frameworks that measure competitiveness, provide understanding for competitiveness, and integrate the understanding and measurement.

Ng *et al.* (2018) developed a framework for improved understanding of the competitive advantages of construction firms in developed countries, where the theoretical foundation was Porter's 'diamond framework', but this framework lacks the internal focus of an organisation. Another study used the extended version of Porter's framework- the Hexagon Framework to understand the construction industry's competitiveness (Ericsson *et al.*, 2005). This framework provides an explanation of the different facets of competitiveness based on Porter's Diamond, but a major drawback of this framework is the conflict between the use of five forces to analyse an individual company, versus a broad industry. Another issue includes the need to assess all five forces equally when some industries aren't as heavily impacted by all five. Some other studies looked at measuring competitiveness in construction based on the framework suggested by the World Economic Forum (WEF) (Flanagan *et al.*, 2007a) (Puying *et al.*, 2017; Shen *et al.*, 2006). Even though the latter frameworks are well equipped to measure competitiveness, by regulating market competition, promoting best practice in the whole industry, they do not address the pressing need to explore the mechanisms for a construction industry to foster competitive advantage for all its firms.

Among these frameworks on enhancing construction competitive advantage, many of the key questions specific to construction competitive advantage remain unanswered. For example, ‘how can the pre-established theories/ frameworks be adapted for a particular strategy or a particular hierarchical level or the use of a particular strategic tool of a firm with different capabilities and resources?’ remains unanswered. Further, it is also important to note the cause-and-outcome relationship between the measurement of competitiveness and the understanding and explanation. Many of the existing frameworks do not differentiate between the factors which determine the competitiveness of a nation (i.e. causes of competitiveness) and the indicators that are used to measure its competitiveness (i.e. outcomes). For further discussion, there appears to be an imbalance in the research methodologies adopted in these framework developments. Although there have been sufficient theories on the competitiveness of firms over the past decades, when it comes to practically applying them in construction, it seems that apart from a very few empirical studies, many researchers have adopted anecdotal methods that cannot guarantee the reliability as they haven’t been based on facts and figures drawn from empirical shreds of evidence.

Hence, having identified the above weaknesses of existing theories and frameworks, this research focuses on differentiating the outcome and causes relationship and integrates competitiveness with strategy and functional processes. This research combines the relevant theoretic propositions as explained in previous sections and tests a resulting high-level theoretical model (Figure 11). The study begins with the ‘strategic approach’ and develops it through Mintzberg’s 5p’s model. According to this model, plan, position, ploy, pattern, and perspective are considered as 5 pillars that shape the story of this research endeavour. As explained in section 2.5.1, skills and training needs are presented as a separate inventory.

This initial theoretical model moves towards a much-detailed theoretical model, indicating a wide range of causal relationships which constitute several propositions. For a detailed list of propositions including tested and concluded directions along with theoretical underpinning and data analysis, please see Chapter Four and Chapter Five.

2.8 Skills, knowledge, and Training needs for construction professionals

2.8.1 Skills and knowledge- The difference between each other

As explained in section 1.2.1, a shortage of skilled professionals especially in the areas of BIM, BDA, and IoT has long been a disturbing problem in the construction industry. In recent years, many of the industry's professionals, researchers, and policymakers have raised concerns about a steep rise in the shortage of skills in construction. To address these issues in a meaningful way, the `right' skills and knowledge base for construction personnel is crucial (Egbu, 2004). Moreover, as outlined in section 2.5.1 and 4.2.3.1, to be able to exploit BIM, BDA and IoT, training and upskilling is quite crucial. This has been manifested in one of the construct constituents for exploitation (EXP-3 Our technology-specific team is appropriately selected with the right skills and they are receiving proper training).

According to a resource-based perspective, knowledge is perceived to be an organisational resource, principally intended for economic exploitation (Egbu, 2004). Egbu (2004) defines knowledge, as the ideas, wisdom, and facts managers acquire through experience, theory, and practice; the acquisition of which gives them an ability to understand. Nonaka and Takeuchi, (1995) view knowledge in two ways: tacit and explicit where the tacit knowledge exists within an individual and is intuitive and unarticulated while explicit knowledge can be articulated and structured, fixed-content, externalised, and conscious. Katz and Shapiro (1986) view knowledge as the 'potential' waiting to be combined with the skill to convert into a 'performance'.

Skills on the other hand according to Boyatzis and Richard (1982) in their write-up on the "Competent Manager", define skill as an ability to perform a specific job or task. Bringing in a similar observation, Newton and ůConsultant (1983) and Toor and Ofori (2008) explain skill as the ability to perform a job to a stipulated calibre. Prahalad and Hamel (2007) introduce 'competency' as a harmonised combination of multiple resources and skills that distinguish a firm in the marketplace.

There is a vast amount of literature in favour of the fact that skills and knowledge complement one another, where skills are supported by underlying knowledge to effective or superior performance (Egan, 1998; Egbu, 1999; Holti *et al.*, 1999). Katz and Shapiro (1986) laying out a similar notion state skill is an ability to translate knowledge into action. On the contrary, there is also a considerable amount of research that lays out the disconnection between knowledge and skills. , Katz and Shapiro (1986) reject this notion and affirm that skill is not necessarily inborn and it can be developed and improved through continuous training to be able to convert into a meaningful 'performance'. In a similar vein, Winterton *et al.* (2006) refer skill to the ability to apply knowledge to specific situations and is developed through experience, practice, and a combination of sensory input and output.

There is a general acceptance in competitive business environments and project-based industries like construction that knowledge is an important organisational asset that gives competitive advantage which also contributes to organisational innovations and project success (Egbu, 2004).

The literature on knowledge, skills, and training needs is too complex to reduce to a linear categorisation as there are recurrent overlaps in the way people see them. For example, the researchers who see knowledge and skills as an organisational asset denies the fact that they are important aspects of organisational strategy. On the other hand, the researchers who see the strategic potential of knowledge, skills, and competencies also see it as a tool for promoting innovation capability. However, there are general strands of thought that may be linked in correspondence to the previously mentioned dichotomy.

Considering the aforementioned views, a consensus of agreement amongst researchers to the notion that 'skills' and 'knowledge' complement each other whereas the level of effectiveness of an action/ performance is a standard by which a skill is judged is manifested. For that reason, in this research, skills, and knowledge are treated as a single concept that describes a manager's job dimension.

2.8.2 Skills and knowledge- relevant literature for technology management

Having clarified the complementary nature of knowledge and skills, it is then worthwhile to explore the existing body of knowledge around skills, knowledge, competencies, and the training needs for general construction management. There are several research streams into the understanding of skills, knowledge, and training needs in construction. These research streams can be classified into two main categories such as organisational strategic management and innovation diffusion.

The importance of skills and training-needs in organisations has been emphasised by many classical researchers in organisational strategic management perspectives (Drucker, 1999; Lundberg and Mintzberg, 1991). In the same research stream, there is also literature that stresses the idea that distinctive organisational capabilities can provide a competitive advantage and generate rents only if they are based on a collection of routines, skills, knowledge and complementary assets that are difficult to imitate (Teece and Pisano, 1994). Whetten and Cameron (2015) unveil an important point that general management skills are interrelated and overlapping. This idea is also exhibited in the list of skills employed in this research and has also been accepted by many other researchers as no effective manager performs one skill or one set of skills independent of the other (Egbu, 1999; Winterton *et al.*, 2006). For example, to develop or improve leadership as a skill/ knowledge it is inevitable to use a combination of several skills- communication, problem-solving, decision making to different extents. However, this nature has been optimistically reviewed by authors for its flexibility in managing diverse situations (Newton and ŏConsultant, 1983). Gammelgaard and Larson (2001) in their study on managerial skills deduced a list of managerial skills which has a less standardised nature and a high situational specificity. According to Jaques' Stratified Systems Theory, managers' ability to change and assimilate new skills and knowledge is based on their potential capabilities and cognitive ability (Jaques, 1985). Hence, it is convincing that skills and training to improve skills are two main aspects of an organisational strategy which helps in maximising organisational competitive advantage.

On the other hand in the innovation diffusion literature, Rogers' (1995) classical theory explains technology adoption and innovation diffusion in terms of (1) actor categories, (2) adoption decision stages and influence modes, and (3) the role of opinion leaders. His explanations cover the importance of skills and knowledge at each of these three contexts. The author further highlights that for an innovation to reach its maximum potential, regardless of the adoption stage, and the type of actor, skills and knowledge are two main essentials. Many other authors have also described organisational technology adoption and diffusion patterns in terms of leadership skills, knowledge dimension, and amount of training required (Deng *et al.*, 2014; Katz and Shapiro, 1986).

Having discussed the general construction management literature around skills and training in construction, research efforts are put into the identification of areas that need more training and the level of importance of different skills of professionals from different levels. Literature emphasises the type of skills knowledge required by senior-level managers. Cognitive skills, as emphasised by Jaques, include analytical ability, logical thinking, concept formation, inductive and deductive reasoning (Bass and Stogdill, 1990). This ideology implies that conceptual ability is related to managerial effectiveness, more specifically at the higher-level managerial positions.

Mid-level managers are also required to have a certain level of cognitive complexity to be able to organise information to maintain the overall effectiveness of the organisation. For a tactical level manager to effectively exercise leadership and add value to subordinates, he/she must show a level of complexity, which is higher and has a longer time-span of control than that of the subordinates supervised by him/her (Jaques, 1985).

The needs and uses of skills and knowledge to managers at three hierarchical levels for organisations are well recognised and documented. In the context of this research, skills for three levels of managers need to be understood based on activities or patterns of behaviour which managers are required to undertake to accomplish a given desired outcome through the implementation and exploitation of BIM, BDA, and IoT. Since, BIM, BDA, and IoT are three distinctive strategic tools that represent a form of innovation, Innovation Diffusion theories and strategic management theories are referred to as forming a structure of the skill set.

One of the earliest researchers in construction skill management: Heller and Porter, (1966) explored managerial skills by collecting data from American and British managers and concluded the higher-ranked skills as follows:

i. Dealing with people
ii. Leadership
iii. Motivation
iv. Communication.

The lower-ranked skills are the ones concerned with the functional specific technical demands of the job. Management expert Henry Mintzberg suggested ten primary roles and behaviours that can be used to categorize a manager's role into three different functions such as leadership (or interpersonal), informational and decision making (Lundberg and Mintzberg, 1991). (Lundberg and Mintzberg (1991) further state that degree of importance, level of application, and training requirement are likely to differ in different jobs as the job descriptions mostly come with the scope of work.

Katz (1955) suggests that following three basic managerial skills can influence effective management. The author further states that competence in each of the three skills is a must for all managerial levels, although the degree of importance may vary according to the manager's job role. For example, the higher the hierarchical level, the greater the need for conceptual skills. Moreover, the lower the hierarchical level, the higher the need for more technical and human-related skills. The identified three managerial skills are:

i. Technical Skills (involves specialised knowledge and use of tools, equipment, and techniques of the specific discipline)
ii. Human Skills (ability to work with people by appropriately controlling them and working in collaboration with them)
iii. Conceptual skills (visualising the organisation, identity/position of the business within the industry and social-political interventions to create an overarching strategy for continuous business improvement)

Another similar perspective has been drawn by Whetten and Cameron (2015) listing the ten most cited skills of highly effective managers. The skills are:

i. Delegating authority
ii. Communication (verbal and non-verbal)
iii. Problem identification, synthesising and solving
iv. Time management and stress management in a competitive business environment
v. Managing individual decisions
vi. Motivating and influencing peers/ subordinates
vii. The clarity in vision mission and goal setting accordingly

viii. Self- awareness
ix. Team building
x. Conflict Management

Mumford (1987, 1995) explains the roles and responsibilities of construction managers and highlights the following three skill types as the most important skill areas.

i. Long term strategic vision and change management in a dynamic business environment
ii. Analytical abilities and decision making
iii. Interpersonal skills

Sunindijo (2015)has also identified the skill difference depending on the organisation's structural level. The most important general management skills and knowledge that emerge from this study were classified under three main categories as listed below:

i. Financial Business Management (strategic perspective, the value proposition of the business)
ii. Operational Management (day-to-day operations/ tasks)
iii. Interpersonal skills (people related)

In construction, the innovation strategies identified by Egbu (2004) include top management support, strategic vision, innovation culture, long-term focus, knowledge sharing, and transfer and education and training. Further, innovation diffusion requires consideration of both leadership skills and operational skills (Kanter, 2005). On a similar perspective, Rahman and Ayer (2019) assert non-technological skills required for BIM adoption such as analytical and problem-solving, communication, initiative, planning and organizational, and teamwork skills are some of the most critical skills for BIM professionals to have to resolve the most common people and process-related issues that can arise in BIM projects.

De Carvalho and Rabechini Junior (2015) and Zuo *et al.* (2018) highlight the importance of distinguishing soft and hard skills in general construction management which helps the project managers to understand not only the technicality but also the importance of solving people-related issues among various stakeholders so that the mutual understanding can be achieved. The latter authors further affirm those skills can be broadly divided into specific skills and general skills. Specific skills refer to knowledge and lead directly to the construction projects while general skills provide much of the foundation for developing project management skills. According to this the main skills set are:

i. Soft Skills (leading, communicating, negotiating, and problem-solving, Teamwork, collaboration, Conflict management, Achievement motivation, Cognitive skills, Adaptability, Self-control, Negotiation, Social awareness, Building trust, Influencing, Cultural awareness, Empathy, emotional intelligence, Coordination, Delegation, Perceived role, and responsibilities)
ii. Hard Skills (task-specific skills that describe the job role)

On a similar vein Ahadzie (2007)argued that behavioural measures of skills can assist construction project management professionals in contributing more effectively to projects. Behavioural competencies can be grouped into two main types:

i. Task performance behaviours (more technical focus and job-specific) and
ii. Contextual performance behaviours (job-related acts that assist in organisational effectiveness)

Teece *et al.* (1997a) state strategic planning and promoting competitive advantage in construction organisations requires organisations to develop firm-specific, difficult to imitate combinations of organisational, functional, and technological skills. Hence, in the context of three strategic tools (BIM, BDA, and IoT), all these types of skills are considered for inquiry. An analysis of management skills and the knowledge base for BBI implementation and exploitation commences with data on managers' perceptions of the relative importance of each skill/ knowledge and then moves on to the need for current and future training. There are several bodies (CITB, RICS, etc) that effectively provide training for both general managerial and technology-specific roles in construction management and look into research; but no study has looked at the three strategic tools in a holistic view. There are skill features that are common to each technology which can be categorised as general management skills and also unique features specific to each technology according to the theory of strategy as defined by Henry Mintzberg (1990). Burgoyne (1994) in a similar view states that although managerial jobs are the same at a high level of abstraction, they are different at a detailed level of resolution. The rapidly changing nature of construction, competitive environment, and the increased use of digital technologies urge the industry to widen the sectoral skills and knowledge not only to general management but also to these sophisticated technology-specific skills and knowledge.

It appears that there is an agreement between many of the authors on the most important skills as strategic vision, people-related skills, and operational skills. A consensus amongst authors can also be seen in that the relative importance of general management skills and knowledge varies across managerial levels and managerial jobs.

2.8.3 Need for the development of skills-knowledge inventory

As explained in section 1.2 of Chapter One, a shortage of skills/ knowledge in construction towards competitiveness improvement has been of concern both in practice and academia. The literature for BBI exploitation also establishes ‘skills and training need’ as an important constituent (2.5.1 and 4.2.3.1). Drilling into this need more specifically, there is a clear distinction between the skills required by different levels of managers to support the overall strategic benefit of BBI exploitation. Moreover, skills may also vary depending on the adoption level (i.e. implementation/ exploitation) as well as time scale (i.e. current/ future). The common features are discussed under the above sections as ‘general management skills’. In addition to that, technology-specific skills are crucial in the technical execution of technologies. The Construction Industry Training Board (CITB) has pointed out that the need for construction education, training, and qualification must take account of the particular problems such as the special nature of specific technologies and also common features (CITB, 2013).

Therefore, in this research, a better understanding of the job role of three different levels of managers, and the skills and knowledge they need and bring to their work to be able to exploit BIM, BDA and IOT should reflect both common features and special features. This supports the overall strategic benefit of BBI exploitation. Keeping this fact at the forefront, this research investigates and evaluates job dimensions of three levels of managers so that: -

1. The most important skills and knowledge dimensions can be identified, and this identification could be of help to improve awareness and acquisition of relevant skills and knowledge for individual managers and it could lead to an increase in job satisfaction.
2. The identification of current and future training needs helps organisational strategic level managers to revisit their organisational strategy to include required training programmes, not only for now but also for the next five years. This could help advance career prospects.
3. The identification of the most important skills and knowledge could help in the selection and recruitment of the right calibre of personnel that matches the technology uptake.
4. With improved awareness of the required skills, knowledge, and with sufficient training organisations could maximise their efficiencies, effectiveness, and competitive advantage.

A few renowned authors have also made efforts in developing BIM competency models (Succar and Sher, 2014) and competency-based knowledge model (Motawa and Almarshad, 2013). Australian Construction Industry Forum in collaboration with Building SMART has also made efforts in the development of a BIM knowledge and skills framework. This Framework is designed to guide and assist all industry stakeholders in the adoption and implementation of BIM (Australian

Construction Industry Forum and Australasian Procurement and Construction Council, 2017). However, this framework lacks the focus of organisational perspective on how skills and knowledge vary depending on different hierarchical levels and the level of benefit realisation for competitive advantage through BIM adoption (i.e. implementation and exploitation). Thus, many of these studies appear to focus on the industry as a whole and are limited to BIM adoption or implementation only. Hence, this research addresses the gap of introducing a Skills and Knowledge Inventory that will enable differentiating each managerial role in each stage of adoption. A great deal of commitment has been made to capture the BIM specific skills required by managers.

2.8.4 Skills/ knowledge dimensions related to Building Information Modelling (BIM)

Lack of skills, knowledge, expertise, and competencies in BIM has been a long-discussed topic in construction literature. Eadie *et al.* (2013) conducted a comprehensive literature review on BIM implementation and identified the lack of BIM expertise at both project and organisational level as one major reason why BIM is not used on some projects. While there is a wide acceptance of this issue highlighting the 'lack of skills' as a major barrier for BIM implementation (Becerik-Gerber and Kensek, 2010; D. K. Smith and Tardiff, 2009; Liu *et al.*, 2015), some authors highlight the difficulties in training BIM skilled professionals considering the high costs (Wu and Issa, 2014). Further, the extent to which 'BIM training programmes' are encouraged at organisational level has also been identified as a critical success factor for BIM adoption as well as implementation (Won and Lee, 2010). The UK Government together with the UK BIM Alliance has introduced an agenda on how the UK is addressing BIM and digital working skills shortages and how academia responds to these challenges (Kemp and Saxon CBE, 2016). Thus, all facts suggest that the skill gap for BIM is critical and needs to be addressed. Having understood the skill gap for BIM implementation, it is then worthwhile looking into the types of skills required for different job roles. Table 10 below summarises some of the skills identified in literature.

Table 10- Skills/ knowledge areas for Building Information Modelling in construction literature

Author(s)	**Knowledge/ skill areas**
(Rahman *et al.*, 2016)	3D modelling and designing (use of software), Comprehensive planning, Design research, facility management, sustainability standards, New business development, space planning, MEP are common skill areas for both BIM managers and project managers

(Rahman and Ayer, 2019)	Non-technological skills- Problem-solving skills, analytical skills, ability to work as a team member, Communication skills
(Bosch-Sijtsema *et al.*, 2019)	BIM skills can be classified into (1) personal traits like attitude or behaviour- good communication, leadership, commitment, cooperativeness, problem-solving, ability to make demands, patient, critical approach, curious, handling criticism, change-oriented, strategic, flexible. (2) knowledge – conceptual and theoretical- different needs for professional groups, construction process, design; production; project management; 3D modelling; computer technology/IT, architectural, civil engineering (3) skill – procedural and applied knowledge- Creating virtual model, model quality control, quantity take-off; manage model-based information; simulate scheduling, cost estimation, collision check, risk analysis, project logistics, BIM requirements, goals setting, determining metrics, procurement, coordination with the client for delivery
(Succar *et al.*, 2013)	BIM competencies can be classified into core competency, domain competency, and execution competency. For example- if creativity is under the core-competency group, the core activity is related to the activity of design conceptualisation in a domain competency, and the operation skill is the use of "ArchiCAD" software and its execution.
(Aibinu and Venkatesh, 2014)	Quantity Surveying skills such as, taking off, cost modelling, cost reporting, estimating and 4D BIM, simulate scheduling
(Cao *et al.*, 2014)	Coordinate between contractors and subcontractors, Ensure quality control, Site logistics, Cost estimation, resource allocation
(Bosch-Sijtsema *et al.*, 2017)	clash detection, quantity surveying, and developing 3D models, Cost estimation, Resource plans/staffing plans, coordination for delivery.

(Sacks, Rafael, Eastman, Charles M., Lee, Ghang, Teicholz, 2018)	Clash detection/design reviews, Quantity take-off, Site utilisation planning, Site logistics, Cost estimation, programme planning and coordination, Generation of procurement plans, asset management
(Hartmann *et al.*, 2008)	Visualization/3D presentation, Cost estimation, procurement strategy
(Becerik-Gerber and Rice, 2010)	Developing/designing a 3D model, handling As-built model, Cost estimation, facilitate communication in projects, create information channels between supply chain partners
(Eadie *et al.*, 2015)	Developing/designing a 3D model, Coordinate between contractors and subcontractors, Schedule time planning, prepare for facility management
(Barison and Santos, 2011)	Six main BIM competencies that managers must have: aptitude, education, experience, skill and ability, knowledge, and attitude

Considering the above views and conducting a thorough review of literature, the most cited set of skills/ knowledge (by conducting systematic reviews) were devised combining both general and BIM specific skills for BIM. The final list of skills can be found in Chapter-6. Please see Chapter- 6 for data analysing and the development of Knowledge Skill Inventory (SKI) refining after mixed methodological data analysis.

2.8.5 Skills/ knowledge dimensions related to Big Data Analytics (BDA)

The increased use of digital technology has caused a proliferation of data and has impacted the application of big data analytics to drive a smart project and asset management. However, many researchers from the construction domain have identified 'lack of skills and training' as a major barrier for implementation as well as the exploitation of big data analytics (Reyes *et al.*, 2019). Mikalef and Krogstie (2019) examined the level of maturity in terms of data analytics skills for technical and business profiles in construction and found out the differences between those that have invested more in human capital and those that are lagging behind. This investigation helped to identify a major skill-gap that exists in the industry. The authors also deduced that success of big data analytics initiatives is seen to be a result of multiple skills including that of technical, human related and business-related analytics skills. Admittedly, unlike BIM, Big data is a technology that has been widely embraced by many other sectors than construction; hence the variety of skills for big data are explored not limited to construction but also looking at other sectoral literature (i.e. manufacturing, retail).

By conducting a critical review of literature, it is convincing that the authors are in an agreement that while there is a lot of work regarding the identification of the technical skills associated with big data analytics in construction, there is little work on the managerial skills as well as on soft and collaborative skills (Mikalef and Krogstie, 2019). Interestingly, the vast majority of researchers have also looked into job advertisements to identify the skill demand in construction related to data analytics (De Mauro *et al.*, 2018; De Mauro *et al.*, 2016). Ransbotham *et al.* (2015)in his review article highlights the significance of the role of managerial skills to realise benefits out of Big Data. The rationale given in that review was that managers in this era need to be fully aware and knowledgeable about modern technologies to be able to apply them to their business goals. This issue has been raised by several recent articles in which big data skills would help in forming the business case (Eriksson *et al.*, 2017). To this end, domain knowledge/ technical knowledge around big data and foreseeing ways in which data science can help resolve business issues are widely accepted to be important for contemporary managers.

Table 11 lists out some of these skills/ knowledge areas identified from construction literature. These data analytics skills/ knowledge areas have been credited as enablers for firms to identify previously unobtainable insight and allowing them to gain a competitive edge over their rivals by acting on this insight.

Table 11- Skills/ knowledge areas for Big data in construction literature

Author(s)	**Knowledge/ skill areas**
(Marzouk and Enaba, 2019)	Integrating BIM and data analytics through algorithm techniques, data visualisation
(Reyes *et al.*, 2019)	Big data business case, data security, and disclosure, data accessibility, personalisation, standardization, opportunities for sustainable construction through big data
(Safa and Hill, 2019)	Accuracy of data, data storage
(Mikalef and Krogstie, 2019)	*Technical skills*- Exploratory data analysis, Data visualization, Machine learning techniques, Data mining, Data modelling. *Business and project management skills*-Enterprise architecture of big data, Big data strategy formulation, understanding how to apply analytics for business problems.

	Soft skills- Identifying situations requiring participative group problem solving and to utilise the proper degree and type of participation, Cross-disciplinary collaboration
(Caputo *et al.*, 2019)	work motivation and social competencies, human resources' organizational behaviour
(Ram *et al.*, 2019)	Big data's role in improved management decisions, ways of maximising efficiencies through big data, BD–BIM integration, facilitating integration and management of information for the whole building lifecycle
(Mikalef *et al.*, 2018)	Both technical and managerial skills are equally important. For technical skills- data architecture, big data engineering, and big data analytics. For managerial skills- strategic thinking, ability to take data, and to be able to understand it.
(Kopanakis and Mastorakis, 2016)	Statistics, analysis and machine learning for technical skills and economic benefits of big data, decisions making for management skills
(Motawa, 2017)	Knowledge capturing through BIM digital data for monitoring and maintaining building performance
(Eriksson *et al.*, 2017)	The use of open data for smart city construction
(Akhavian *et al.*, 2015; Akhavian and Behzadan, 2015, 2018)	Data-driven construction simulations for construction project performance monitoring
(Bilal *et al.*, 2016b)	Data visualisation, Cost implications for Big Data in
(Tambe, 2014)	Technical skills like Hadoop skills
(Ajayi *et al.*, 2019)(Bilal *et al.*, 2016a)	Producing prediction model through big data
(Ahmed *et al.*, 2017)	How big data could be utilised for FM and discipline-special skills as well as the relevant technological skills
(Sivarajah *et al.*, 2017)	Skills related to analytics skills to make sense of Big Data and data interpretation skills
(Gandomi and Haider, 2015)	Various types of big data analytics (text analytics, audio analytics, Social media analytics, and predictive analytics)

Considering the above views and conducting a systematic literature review, the most cited set of skills/ knowledge were devised separately for BDA. This list can be found in Chapter-6. Please see

Chapter- 6 for data analysing and the development of Knowledge Skill Inventory (SKI) refining after mixed methodological data analysis.

2.8.6 Skills/ knowledge dimensions related to the Internet of Things (IoT)

Models generated by integrating multiple entities (things) often exchange knowledge, combine different skills and capabilities, exploit ideas from outside the company's boundaries, accelerate new product development, and achieve a significant innovation output (Dave *et al.*, 2018). Sectors thriving towards this integration often suffer from the scarce IoT management capabilities, low-technological knowledge, and IoT skills of staff (Scuotto *et al.*, 2016; Li *et al.*, 2019). Firms who are capable of using their IoT capabilities are likely to become more powerful and competitive as their know-how and skills are central to product differentiation and cost minimisation (Porter, 1980a). Calling attention to a global issue, Dunaway Virginia *et al.* (2019) identified the disruptive nature of IoT hinting at a major increase in unemployment issues in society. The latter authors advocate that the employees who are lacking IOT skills may end up losing their jobs as an effect of automation of daily activities. Nonetheless, this rising unemployment rate can be overcome with education and training for the required skill/ knowledge areas. In a similar vein, the latest industry 4 strategy framework has also identified that a lack of digital skills and training is the biggest challenge facing engineering and construction companies to implement industry-4.0 (Reinhard *et al.*, 2016).

The literature suggests a variety of skills/knowledge areas ranging from technical skills to managerial skills. SAS in their survey for skills and resources that are most useful in their IoT projects identified being able to manage those bought-in skills and the ability to work collaboratively with the external consultant as the most important skill in IoT adoption into an organisation (CEBR, 2016). The next three most important skills as identified by SAS were: process automation, engineering skills to address sensor performance, data reliability, and adapting people tasks to the new technology. Their conclusion was the skills required represented both technology and cooperation (CEBR, 2016).

Although the immediate job of IoT is to connect the unconnected, the value is realised only when the data is analysed and used to derive insights. Therefore, the skills required to develop and improve must cover the entire IoT journey from sensor technology to decision making including data quality, data privacy, data management, analysis, and distribution considerations (Scuotto *et al.*, 2016). Data analytics and governance skills are also critical to IoT and this is why the data managers are included at the beginning of IoT projects (Marjani *et al.*, 2017). On the technical side, Nord *et al.* (2019) emphasise the importance of integrating new technologies into existing technologies, managing data/ network complexity, networking, data security, and policy requirements. On the other hand, a considerable amount of authors have also acknowledged the need for "soft skills" associated with culture and leadership, such as collaboration, education, and changes to various approaches (Borgia, 2014). Change management has also been stressed as IoT adoption often needs restructuring in the organisational setting (Jia *et al.*, 2019). 'Design thinking' is another skill/ knowledge mentioned by a few authors where the users, or user experiences, are allowed to drive design where behavioural theory is exhibited with technological expertise (Santoro *et al.*, 2018). This human-centric process encourages client involvement in the initial stages.

The key skills affecting the construction sector to implement and exploit IoT have been highlighted in several recent reports and academic literature, which were used in the questionnaire surveys for further investigation. It is apparent that the adoption of IoT is a huge advantage to the construction industry. To reap these benefits, organisations, regardless of their sector, are anxious to tap into the right talent and required skill sets (Barkai, 2018). The literature suggests, this skill set will have to be more than just coding/ programming; but will have to have skills such as intuitive problem solving which helps to see the big picture, recognising dynamics of construction, and realising their responsibility to keep up (Freel, 2005). Contributions from existing literature assisted in developing the selected list of IoT skills. A full list of these skills/ knowledge areas can be found in chapter 6. Please see Chapter- 6 for data analysing and the development of Knowledge Skill Inventory (SKI) refining after mixed methodological data analysis.

2.9 Summary to Chapter Two

The predominant theoretical underpinning for this study focuses on planning, positioning, establishing a perspective, setting-up a ploy, and identifying the patterns to instigate the strategic approach to exploit technologies. In line with the aforesaid theoretical foundation, 'exploitation', 'competitive advantage', benefits and challenges, and impact factors were established. The paucity of research and the complexity of behaviours into the holistic view of latter perspectives were the mainsprings to empirically investigate this complex phenomenon. To be able to empirically investigate this complexity, a systematic, theoretical approach must be employed. The systematic approach analyses the principles associated with a branch of knowledge as well as the most appropriate methods applied to the field of study. Therefore, the next chapter explains how the researcher systematically designed this study to ensure valid and reliable results that address the research aims and objectives.

Chapter Three

3 Research Methodology and Methods

3.1 Introduction to Chapter Three

A research methodology is the skeleton of a scientific study, basically consisting of research philosophy/ paradigm and design. The research methodology is a generic term for "the combination of techniques used to inquire into a specific situation; and methods are individual techniques for data collection, analysis, and so on" (Easterby-Smith *et al.*, 2002). A robust methodology elaborates on the logical assumptions, gathers rich data, and results in acceptable solutions for the research question while placing the study in the appropriate theoretical position. Every research goes through a research process that leads to an effective data collection and analysis process (See Figure 12). Before reaching the core of methodology, there are important layers of the onion that need to be peeled away. This chapter describes these layers based on the theoretical and practical perspectives specific to the research methodology adopted in this research geared to answer the research questions stated in section 1.5. Each subdomain concludes with a justification for selection and debate around the application in construction management.

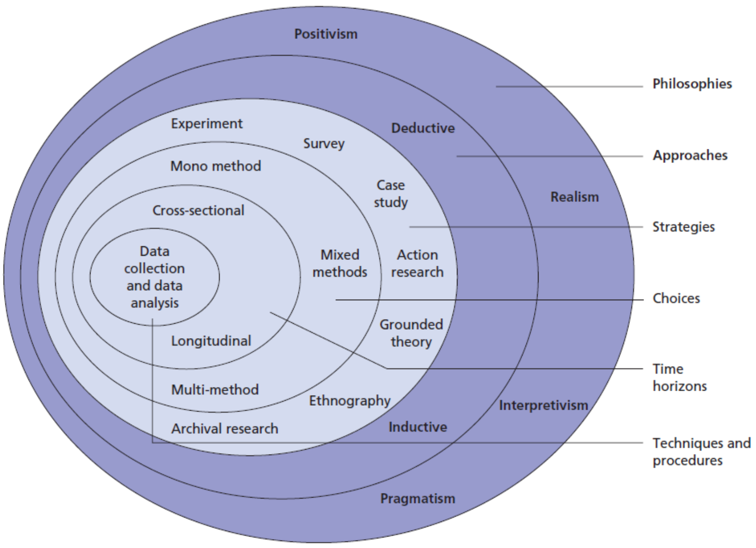

Figure 12- Research Onion

Source: (Saunders *et al.*, 2009)

3.2 Research Methodology

The research methodology is the entire research process that leads to the achievement of the research aim. According to Figure 12 research onion, this includes the philosophical assumptions of worldviews, approaches employed, the strategy of inquiry/ research methods, choices, time horizons and techniques/ procedures for data collection, analysis and validation which are discussed in subsequent sections in light of the applicability to this research.

3.3 Research philosophical position and paradigms

Research philosophy is important because research is simply developing new knowledge in a field by making important assumptions about how the researcher views the world. These assumptions are the base of all the remaining layers of the onion, research design, strategy, and methods (Saunders *et al.*, 2009). It has a significant impact on the output as it decides not only what the researcher does, but also the understanding of the researcher on what is investigated. The research philosophy and paradigms adopted herein are in-line with the research aim, objectives and research questions, established in sections 1.4 and 1.5 respectively.

3.3.1 Ontological position of this research

First, ontology refers to the sort of things that exist in the social world (state of being of this world) and assumptions about the form and nature of that social reality (Guba and Lincoln, 1994). Social reality is distinct from biological reality or individual cognitive reality, representing as it does a phenomenological level created through social interaction (Berger and Luckmann, 2016). The ontology questions whether or not social reality exists independently of human understanding and interpretation. For instance, whether there is a shared social reality or 'multiple context-specific realities'.

The study identifies 'exploitation' of Building Information Modelling (BIM) or Big Data Analytics (BDA) or Internet of Things (IoT) or all three of them as drivers for Competitive Advantage in organisations and seeks to diagnose the possibilities of using BBI (BIM, Big Data Analytics and Internet of Things) as strategic tools. As stated in the research aim; this study predominantly looks at 'improving the understanding' of the exploitation of Building Information Modelling (BIM), Big Data Analytics (BDA), and the Internet of Things (IoT) for the 'competitive advantage' of the construction industry. Hence, the researcher first acknowledges the existence of 'competitiveness' in the social world but acknowledges that different organisations are differently competitive in their social realities. Thus, there are multiple context-specific social realities to 'competitiveness'. This is known as relativism as opposed to realism (Louis *et al.*, 2006). In relativism, the truth evolves and changes shaped by the context. Moreover, the truth can only be viewed in a similar context created by the meanings and experiences of people using the 'emic' approach. The researcher sees the problem that needs to be addressed in this research as an ideology between society and technology (Science). The society is either regulatory or subjected to radical change. The society in this research is viewed in a radical way; a constant conflict is seen as humans attempt to live a preferred life free from the domination of societal structures (post-modernism) (Burrell and Morgan, 1982). Because an external reality for 'competitiveness' or 'BBI exploitation' independent of what people may think or understand it to be (realm) cannot be captured, it is understood via the human's interpretation (idealism) of it and the socially constructed meanings they have given to it.

BIM, BDA, and IOT are strategic tools that help to maximise the competitive edge. But, without taking the measures of competitiveness in consideration, evaluating the level of competitiveness enhancement would be difficult. To that end, the researcher devotes some effort in defining the determinants of competitiveness as it exists in the social reality. Further, the researcher views 'competitiveness' as a reality that can be understood via the human mind and socially constructed meanings and therefore seeks perceptions of people (or social actors related to it) with the way they understand it to carry out the research (i.e. models developed to view competitiveness, responses to questionnaire surveys and interviews posing questions about the exploitation process of BIM/ BDA/ IoT and how employees perceive it to be true within their organisations). The technologies (BBI) are also treated as human-made realities; hence, one way to understand this reality is by socially constructed meanings. Thus, the research employs '*relativist'* ontology.

3.3.2 Epistemological position of this research

Second, epistemology is concerned with the nature of knowledge and ways of knowing and learning about social reality (the means and conditions for knowledge). The way we can know about the social reality is heavily dependent on the ontological perspective (the nature of the objects of knowledge) and determining what exists and its nature depends on how we can know. A firm may claim that they are the most competitive firm in an industry and how they go about maximising their competitiveness is via exploiting BIM. Another firm may claim the same but via a different technology. This implies that in the real world, there is a competition between firms. But it can only be understood by talking to major clients, referring to recognised competitiveness indexes or benchmarking the competitive performance against established 'determinants of competitiveness'. This leads to the 'emic' epistemology of investigating how people involved in the scenario think; how they perceive and categorize the world, their rules for behaviour, what has meaning for them, and how they imagine and explain things (Creswell, 2007).

Some authors claim that it is difficult to accept a single philosophical position or an approach to address all construction management research problems. However, the interpretive approach plays a vital role, particularly in identifying construction management related problems (Wing *et al.*, 1998). This implies that the researcher uses managers' perceptions to make sense of the extent of BBI exploitation, the nature of the factors that impact effective BBI exploitation, benefits, challenges, and competitive advantages which could be achieved through the exploitation of BIM, BDA, and IoT.

Since the researcher has identified that the nature of reality relies upon social actors, the ways of knowing about this reality is only through human interactions. The two main perspectives for knowing the social reality are 'positivism' and 'interpretivism'. 'Constructivism' and 'naturalistic' are terms commonly referred to in the literature and sometimes in an inconsistent way for 'interpretivism' (Guba and Lincoln, 1994). The 'constructivism' identifies the basic principle that reality is socially constructed; a 'relativist' position holds the view that there is no external reality independent of human consciousness (Robson, 2002). Unfolding the two research questions, and as explained in the previous paragraph, the epistemological perspective of this research is 'constructivism' or 'interpretivism', as to know how it appears to humans as an understanding of human behaviour around organisational cultures and structures is also at the centre of the strategy of inquiry. Therefore, participants' perceptions within an interpretivism philosophy are providing the best way of collecting social phenomena in natural settings. BBI implementation is a human construct, and the success or failure of implementing BBI is dependent upon the perspective of the individuals or groups affected. This often involves social interactions that give rise to social phenomena. The successful implementation factors are defined by the latter affected groups. The research tacitly identified not to be rigid but to be flexible enough to explore many ways of achieving a competitive advantage. Hence, it further confirms that the likely approach that fits best with the research is interpretivism and social constructivism with the subjective position. The researcher follows the social constructionist world view in which 'innovative technology' is subjectively understood by human beings, and the reality is constructed by institutionalised cultural norms (Giddens, 1984). A constructionist stance supports a researcher in observing people's understanding of their lives and of situations and issues that are complex and multiple (Lincoln et al., 2011).

In summary, this research seeks to investigate the attempts made by humans to gain knowledge about 'competitiveness' at a relativist ontology and emic approach of epistemology, based on how they have been understood as 'subjective knowledge' (not as 'objective knowledge') influenced by opinions. Anything subjective is subject to interpretation. Subjectivity guides everything from the choice of topic that one studies, to formulating hypotheses, to selecting methodologies, and interpreting data (Berger and Luckmann, 2016).

3.4 Research choice

According to Figure 12, following the establishment of a philosophical assumption, it is vital to make the right selection of research approaches employed, the strategy of inquiry/ research methods, choices, time horizons, techniques/ procedures for data collection, data analysis and validation which are underpinned by predetermined philosophical views. These are discussed in subsequent paragraphs.

This research deploys the 'mixed method' (MM) as opposed to the mono method.

Construction management has been subjected to a higher dominance of positivism and quantitative methods over many years. Interestingly, the applicability of the latter made in recent research is questionable, and hence research today in respect of the same discipline seems to embrace methodical pluralism (Dainty, 2007). Strong pluralism unambiguously states the appropriateness or relevance of application and adds more rigour to the findings rather than when they are collected and analysed alone (Burrell and Morgan, 1982). However, this does not imply the inadequateness of the single/mono method. The mixed-method choice is the most suitable choice considering the nature of this research. This is explained in subsequent paragraphs.

The problem investigated here is the lack of competitiveness in the construction industry, which leads to lower productivity and lower profit margins (research gap described in Chapter-1). According to Wionczek and Sordo (2019), lack of competitiveness in an industry is a social problem. As a practical solution, the exploitation of BIM, BDA, and IoT is expected to improve competitive advantage (See Chapter-1). However, the extent to which these technologies enhance competitiveness as well as the extent to which BBI exploitation is supported in the organisational context is still unknown. In the investigation of this research gap, it is important to conduct a situation analysis first to determine the extent to which BBI is being implemented and or/ exploited in construction organisations, the benefits accrued and the challenges faced throughout the process. The first intention of MM design to this end is to decrease the deficiencies and biases that come from any single method. In other words, the strengths of one method may compensate for the weaknesses of another. The results from one method are used to enhance, augment, and clarify the results of another (methodical and data triangulation). For example, quantitative data helps to identify the areas in which construction firms have mostly exploited the technologies while qualitative data provides more insight as to why, how, and on what basis firms exploit those areas the most.

According to the research aim, it is required to develop a strategic framework for improved exploitation of BIM, BDA, and IOT while the development of SKI buttresses the framework when used together. Qualitative research seeks to 'explore issues' (Creswell 2014) or 'understand phenomena' (Flick 2006) that 'individuals or groups ascribe to a social or human problem' (Creswell 2009 p.3). Quantitative research is a 'means for testing objective theories by examining the relationships among variables' (Creswell 2009 p.3), and mixed-method research considers both qualitative and quantitative approaches to answering a particular problem. In the development of the two outputs, understanding phenomena to explore prevailing issues, and testing existing theories are equally important. In this way, quantitative data helps to determine the critical factors while qualitative data provides more elaboration and expansion to that level of criticality.

The qualitative data is typically collected in the participant's setting where collected data are inductively attributed from general themes while the researcher is making interpretations of the meaning of the data. This approach allowed the researcher to identify the key themes around the questions and cross-check whether they matched with quantitative data, and if not to expand the quantitative findings. A quantitative study, on the other hand, tests theories by examining the relationship between variables identified by the literature. These variables are measured, typically on instruments, so that numbered data can be analysed using statistical procedures. This approach involves assumptions about testing theories deductively, building in protections against bias, controlling for alternative explanations, and being able to generalize and replicate the findings (Creswell, 2009). This research assumes that a case represents a group, and that quantity identifies some specific characteristics of that group, and the results inform how generalizable the findings are. The quantifiable attributes tell something about how pressing an explanation was within the group surveyed. The number can give a sense of the commonality of experience but also of the dominant narratives related to a specific topic and the culturally available explanations--which may lead to very different interpretations. Moreover, the kind of replicability, as well as the statistical generalisability, which involves questions about the ability to infer population values from survey responses, is very important when developing a framework for a target audience. Once the general themes are finalised through the qualitative study, comparison with the variables of the quantitative study provides more elaboration and expansion to the findings. Hence, thirdly, these combined characteristics of MM design- exploring key themes and generalisability are vital in producing the framework as established in the research aim.

Fourth, a major advantage of MM research is that it enables researchers simultaneously to ask confirmatory and exploratory questions, and therefore verify and generate theoretical framework in the same study. This study develops a strategic framework that explain, predict, and understand the phenomena around how an organisation can maximise their edge by exploiting B,B and I. In short, it is a generalised statement that brings together the interrelated concepts, definitions, and propositions that explain or predict the means of competitive advantage and the factors impacting the whole process by specifying relations among the variables. The quantitative study helped verifying the inter-relations between variables while the qualitative study helped developing a deep and broad base of knowledge in the discipline with ideas, concepts and themes emerged from the qualitative data collection. The MM strategy also encourages thinking 'outside the box' (Brannen, 2005) as well as generating new perspectives and innovative insights. It allows a 'fit' with the political currency accorded to 'practical inquiry' that speaks to policy and policymakers, and that informs practice (Hammersley, 2000).

Fifth, in the receiver's perspective, MM's strategy allows a researcher to speak to the audience in more than one language. It is vital to speak in multiple languages in a society where the growth of strategic and practically oriented research meets the needs of users. This supports research dissemination as well. This may be a technical language that pitches the experts and a language that is easily communicated and understood by the public, that is words and numbers that work for everyone.

Finally, according to Teddlie and Tashakkori (2006), qualitative research methodologies are used to explore why or how a phenomenon occurs, to develop a theory, or describe the nature of an individual's experience, while quantitative methodologies address questions about causality, generalizability, or magnitude of effect (Fetters *et al.*, 2013). With the use of both qualitative and quantitative data, when one research question seeks to explore why and how 'competitiveness' occurs when using BBI, the other research question seeks to look at causality, generalizability, or magnitude of the effect of BBI exploitation for competitive advantage.

The sample for the qualitative data collection was smaller than that for the quantitative data collection. This is because the intent of data collection for qualitative data is to locate and obtain information from a small sample but to gather extensive information from this sample; whereas, in quantitative research, a large N is needed to conduct meaningful statistical tests. The potential threat to validity in using this convergent approach is that unequal sample sizes may provide less of a picture on the qualitative side than the larger N on the quantitative side (Creswell, 2014). Since the MM design in this study used exact similar concepts or variables on both sides, although the sample size is unequal, it may yield comparable and easy to merge findings. Hence, the **convergent**

side-side, by comparison, is chosen. In this research, the individuals interviewed were not included in the questionnaire survey sample. However, the sampling strategy for each method was the same; hence the validity of comparison remains the same while the 'qual' study helps to expand the findings of QUAN study in a comprehensive manner.

3.5 Triangulation of MM design

The data collected from different data sources can be triangulated by examining evidence from the sources and using it to build a coherent justification for themes (Naoum, 2012). If themes are established based on converging several sources of data or perspectives from participants, then this process can be claimed as adding to the validity of the study (Creswell, 2014). Simply put, triangulation is a method of cross-checking the relevance and significance of issues or testing out arguments and perspectives from different angles to generate and strengthen the evidence in support of key claims' (Simons 2009 p.129). It is also a way of finding the convergence among multiple and different sources of information to form themes or categories in a study' (Creswell and Miller 2000 p.126). The literature suggests four types of triangulation (Love et al. 2002) as data triangulation, investigator triangulation, methodological triangulation, and interdisciplinary triangulation.

For this research, methodological and data triangulation is used as a way of approaching the research questions from different angles (Mason 2002). This is supported by the rationale for the mixed method design in section 3.2.2. The literature suggests that the rationale of mixed-method research is underpinned by the principle of triangulation, which implies that researchers should seek to ensure that they are not over-reliant on a single research method and should instead employ more than one measurement procedure when investigating a research problem (Bryman 2008). More specifically, this study used multiple methods to cross-check the internal validity of the findings.

Elaboration or expansion (Creswell, 2014)is often employed when there is a requirement for the data analysis of one method to exemplify the data analysis of others. Further clarified, it is one type of data analysis that adds to the understanding being gained by another. In this research elaboration and expansion in QUAL analysis was used to elaborate on how patterns/trends revealed in quantitative studies could be elaborated and expanded by qualitative means. The data analyses from both beasts are juxtaposed and generate complementary insights that together create a bigger picture.

3.6 Type of Implementation process

The type of implementation/ form of integration used in this methodological triangulation is Convergent parallel mixed methods in which the researcher collects and analyses both QUAN and QUAL data separately and then converges or merges both data types to provide a comprehensive analysis of the research problem in the form of comparing the results to see if the findings confirm or disconfirm each other (See Figure 13). In this design, the researcher collected both QUAL and QUAN data at approximately the same time. Following data collection, the researcher analysed the two databases separately, and the findings were compared. In the data interpretation stage, both phases of the study were examined and combined to draw the conclusions- the data were merged to develop a single instrument. The information produced was integrated into the interpretation of the overall results. It is viable to compare the two databases if necessary because they are typically drawn from different samples, and "*the strategy intends to determine if the qualitative themes can be generalized to a larger sample"* (Creswell, 2014, p277). The sample in the qualitative phase is not included in the quantitative phase as this would introduce undue duplication of responses.

The final inferences are based on the results of both strands of the study. The second strand of the study is conducted to confirm/disconfirm the inferences of the first strand. Moreover, each strand is further used to explain findings derived from each opposing strand. Contradictions or incongruent findings are explained or further probed in this design.

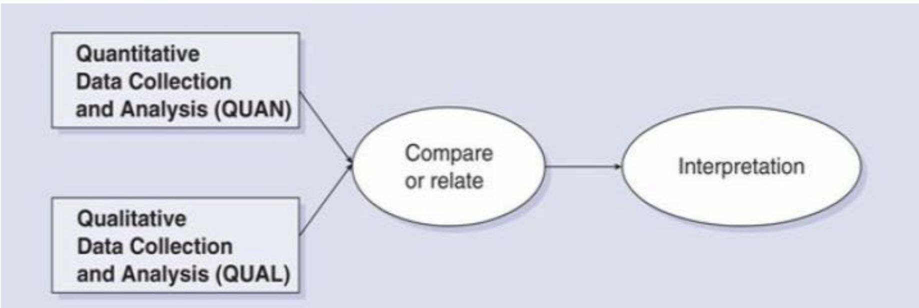

Figure 13- Convergent parallel mixed method

Source: (Creswell, 2014)

The key assumption of this approach is that both qualitative and quantitative data provide different types of information. In qualitative, often detailed views of participants are gathered while numerical scores on instruments are gathered in quantitative, and together they yield results that will either be the same or different. It builds on the historic concept of the mixed methodical idea from Campbell and Fiske (1959), who felt that a psychological trait could best be understood by gathering different forms of data.

As suggested by Creswell (2014), this research uses side-by-side comparison where the researcher will first report the quantitative statistical results and then discuss the qualitative findings (e.g., themes) that either confirm or disconfirm the statistical results. Since the research holds value-based axiology, any contradictions and contrasts are added to the final findings. This function of the research is known as elaboration and expansion.

The two databases were unequal where the QUAN study consisted of a larger sample while the 'qual' study consisted of a comparatively smaller sample. The data were collected concurrently from each database. Table 12 summarises the choice justification based on different grounds.

Table 12- Convergent parallel mixed method justified based on different grounds

Outcomes Expected	merge the two databases to show how the data convergent or diverge and to see how each method explains the other while expanding the findings of other
How the Data Will Be Used Together (or Integrated)	two are independent and the data collection and analysis proceeds for each database separately. Comparing and integrating different perspectives drawn from quantitative and qualitative data
Timing of the Data Collection	two databases are collected concurrently, at roughly the same time
The Emphasis Placed on Each Database	Qual-QUAN (QUAN is dominant as the sample size is large)
Single Researcher or Team	Since the research is conducted by an individual researcher with a limited amount of given time, collecting multiple forms of data at the same time in a convergent approach is the most suitable

The strategy intends to develop better measurements with specific samples of populations and to see if data from a few individuals (in the qualitative phase) can be used to explain the findings of a large sample of a population (in the quantitative phase). By this method, the researcher can analyse the qualitative data to develop new variables, to identify the types of scales that might exist in current instruments or to form categories of information that will be explored further in a quantitative phase. However, as suggested by Creswell (2014) it is ensured that the individuals for both samples are not the same.

Inferential analysis particularly in qualitative data is not referred to statistics. But referred to the techniques that allowed to use the samples to make generalisations about the populations from which the samples were drawn- or inferring from a sample to a population. The inference mode used in Qual study is 'induction'. Collected QUAN and QUAL data are integrated only in the last stage. Therefore, it is partial integration (not full integration at every stage- See Figure 14). Both strands are conceptualised, methodised and analysed separately until the inferential stage where the results derived from each study are compared and merged.

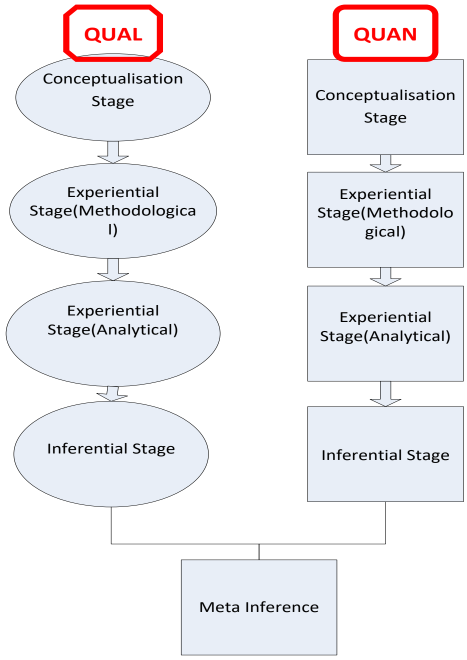

Figure 14- QUAL-QUAN strands and integration

In this research, the QUAN method is treated as dominant (main) while the 'qual' method is treated as secondary. Therefore, lesser resources of time are being devoted to the qual method in terms of data collection and also in the analysis phase and the writing up while many resources are dedicated to QUAN research data collection, analysis, and writing up (qual- QUAN).

3.7 Contextualisation

The research topic does not specifically state that the question it intends to answer through this research is in the context of the United Kingdom. The problem investigated here is global; therefore, the inferences and implications made in the conclusion may be applied in different contexts in terms of nations. However, for the feasibility and viability selections, the researcher selects the United Kingdom as the context of data collection and construction organisations (generally) in the United Kingdom as the 'unit of analysis'. Nevertheless, the researcher, through this research makes attempts to 'conceptualise' a phenomenon within a pre-defined context (UK) that can be applied to a wider context. .

3.8 Research Tradition

This research employs applied tradition as it explicates the research problem that the study is going to address. Moreover, it enables us to build, test, or make a connection to well-established theories (i.e. APP theory for competitive advantage, Hofstede's culture theory, etc.) to provide a solution to the aforesaid problem (Neuman, 2011). Scrutinising the 'purpose' of this research, as suggested by Neuman (2011), exploratory studies are an ideal fit for subject areas that are comparatively new and under-researched. As Neuman (2011) purports, some research studies may contain multiple purposes. However, in all cases, the dominant purpose needs to be clearly stated and thereby the tradition can be identified. Since implementation and exploitation is a relatively new and under-researched area, this study is 'explorative' as a counter purpose. However, the study predominantly contains aspects of 'descriptive- predictive' and 'explanatory' traditions as well. Since the study attempts to predict the future skills/knowledge training needs, it has some predicative features. Looking at the sample of data collection, the research follows an 'across-tradition', as many cases (within a single unit of analysis- organisations) were used for investigation. Again, since the study does not employ a case study approach, the time dimension was not a dominant concern. The data was neither collected at a single point of time nor at a series of times at regular intervals. Hence, the time dimension is excluded from the tradition.

3.9 The logic of inquiry (research approach)

In this study, both deductive and inductive approaches are used at different stages. The research starts with a comprehensive literature review to explore the existing theories and variables to represent several concepts. The researcher studied what others have done in the same research discipline and gone through the existing theories of phenomenon. A broader view of general theories helps to narrow this down into more specific hypotheses (Deductive at first stage- See Figure 15). This shows the deductive nature in the first stage. In the second stage, the research moves from specific observations to broader generalisation and theories by establishing construct constituents for each concept. Data collection starts with qualitative interviews and quantitative surveys in-parallel, which shows the inductive nature of identifying concepts. Conclusions change and evolve continuously as more qualitative data is collected. Both qualitative and quantitative studies moves from specific observations about individual occurrences to broader generalisations. The correlations between factors identified from broader literature are further explored to establish a theoretical framework. Further, it uses identified concepts and investigates deductive relationships. The theories built are interpreted as a strategic framework and a Skill Knowledge

Inventory (SKI). The relationships between concepts (the proposed theory) are tested by looking for facts that support or deny the suggested relationship (deductive at the last stage) (see Figure 15)

Accordingly, this study aims to uncover the main strategic factors that lead to the competitive advantage of construction firms, by using BBI as strategic tools, develop a framework, and validate it. The twofold strategy used to achieve the aim is as follows:

1. To inductively identify critical criteria that drive the competitive advantage of construction firms through qualitative methods; and
2. To deductively establish the relevance of each of the identified criteria and establish the underlying factors through quantitative methods

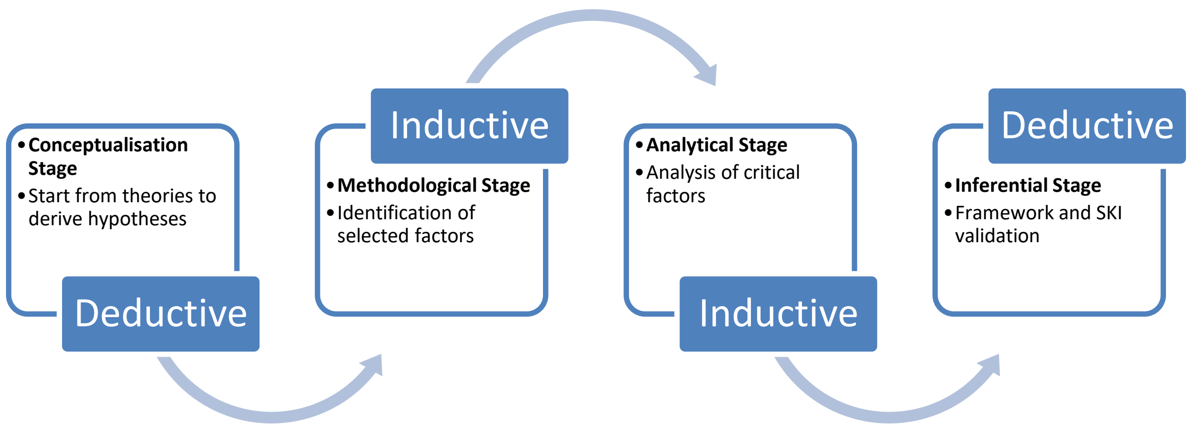

Figure 15- Deductive/ inductive approach

3.10 Data collection methods

Research methods adopted in this research predominantly depend on the research objectives and the logic of the study. The main research methods employed in the research include literature review, semi-structured interviews, and structured questionnaire surveys. As stated in section 3.3, this research employs subjective reality- relativism where the data is collected through an 'emic' approach. The emic approach uses phenomenology where the data is collected through lived experiences. Even though quantitative research is deductive and realist in nature, the questionnaire survey used in this research seeks the phenomenon of inquiry (not the objective reality of attic approach).

The key idea with this design is to collect both forms of data (qualitative and quantitative) using the same or parallel variables, constructs, or concepts. For example, to investigate the impact of organisational culture on BIM exploitation, the same set of constituents that define organisational culture was used in both qual and QUAN methods. The ethical clearance was obtained before conducting the first interview and there were no ethical concerns raised (Formal ethical clearance letter along with the ethics application can be found in Appendix A

3.10.1 Semi-structured interviews used for the qualitative study (QUAL)

3.10.1.1 Justification for the selection of semi-structured interviews for the current research

The researcher seeks opinion research via semi-structured interviews (see Appendix B for interview template) to identify the extent of their exploitation in BIM, BDA, IoT, and the extent to which organisational culture, structure, and size impact on the exploitation of BIM, BDA, IoT. The skills/ knowledge dimensions and training required by all levels of managers to implement and exploit BIM, BDA, and IoT were also explored through interviews. More priority was given to the strategic managers given the nature of strategic management includes addressing the issues related to strategic decision making around the implementation and exploitation of technologies. Bryman (1988) explains that personal interviews are advantageous if probing questions are involved, visual demonstrations are required or when instant feedback is desirable. To this investigation, these interviews were used to probe the dynamics around implementation and exploitation of BIM, BDA, and IOT and how these technologies can be appropriately exploited to maximise organisational competitive advantage. Further, semi-structured interviews are suitable for this research because:

- It helps to throw up tentative hypotheses established
- It is a way of establishing significant variables for isolation and examination
- Resource area is under-researched; hence interviews help to be more explorative
- It acts as a 'mapping' exercise to inform the research design and implement the quantitative part of the study.
- It strengthens some interpretations in the inferential stage.
- It describes in rich detail, phenomena as they are situated and embedded in local contexts.
- It allows identifying contextual and setting factors as they relate to the phenomenon of interest
- It helps to determine how participants interpret "constructs'' (variables) and allocate them according to the priority given by them.

Conducting interviews provides a greater understanding of human cognition while giving insights into perception, meanings, and definitions of situations and constructions of reality (Punch 1998). Considering that, an interview helps to see and answer a research question from the perspective of the interviewee and to understand how and why they have this perception. This leads to an epistemological discussion as established in the philosophical assumptions section. The literature affirms an interview is predominantly based on the type of questions, mode of conduct, and the number of participants involved. The type of question can be within the range of highly structured (closed-ended) to unstructured (open-ended). The questions involved in this research contained semi-structured questions where the questions were structured into certain variables/ concepts but the respondents were still given a certain amount of flexibility. Semi-structured interviews for this study were conducted face-to-face and through online platforms. The literature suggests, conducting group interviews is another popular technique if data collection is specifically in construction management research, as it helps to obtain their perspectives on a single phenomenon while improving the richness of data with group dynamics and synergy. However, the latter technique was not deployed for this research as the requirement is to gather rich information from a widespread sample (scattered participants from different organisations, and not a high number of participants from a single organisation).

3.10.1.2 Sampling Strategy for semi-structured interviews

Data sampling plays a vital role in the credibility of the overall outcome of the research. However, it is not practical to gather data from the whole population; thus an 'accessible population' is used in many studies to represent the whole population (Teddlie and Tashakkori, 2006). Sampling informs a systematic technique of capturing this representative group. The literature suggests that non-probability sampling is used in exploratory research while probability sampling allows for statistical methods, eliminates population parameters and bias, and must have a random selection of units. As described above, the latter was rejected due to the given reasons in this data collection method.

First, the sample population was selected to provide a good balance between all sizes of organisations and to represent four sectors (Construction, Retail, Finance, and Manufacturing). This enabled comparisons of similar work in other industries and the extraction of possible lessons learned to bring into the construction industry. The reason behind the selection of these four sectors is explained in section 2.3. Further, doing so ensures maintaining the consistency of the research. From a different point of view, firms that perform well in one domain (BIM) are seemingly not doing well in another domain (BDA or IoT). The qualitative data generated through the interviews will be reported at appropriate intervals throughout the study.

The researcher has chosen annual turnover as the measure to determine the size of the firm. In the interest of identifying different markets, this research segments the unit of analysis (organisations) into micro, small, medium, and large. The firms were categorised as per SIC classification. The reason for the selection of firms in all sizes is that it is generally accepted that the 'competitiveness' which is the heart of this research does not always come from the big players. Moreover, sophisticated innovative technologies like BIM, BDA, and IoT have been proven to be adopted in many micro- SME organisations. However, most of the interviewees represented large organisations. Within the unit of 'organisation', subunits were segmented based on organisation hierarchy (strategic, tactical, and operational).

Random sampling was not a feasible option given the newness of the areas and the existence of specialists in the areas of inquiry. Therefore, *non-random, or non-probability purposive sampling, stratified before sampling* is applied here. The reason for this purposive judgmental selection is that, BBI is a relatively under-researched, new area. The literature suggests that there is only a handful of firms that have the potential to implement or have already implemented BBI and therefore the sample needed to be selected objectively to achieve specific objectives (Fink, 2010). Not forgetting the bias and errors it can create (Teddlie and Tashakkori, 2006), purposive sampling helped to capture the most suitable professional experts who have practically dealt with the technologies of inquiry. These expert opinions are required to produce the proposed strategic framework. Forty-three people who directly work with these technologies were interviewed individually. The Snowball method was used to grow the sample to reach 43 industry practitioners; 6 to represent each other sector (Retail, finance, and manufacturing) and 25 to represent the construction sector. The reason why most of the respondents were from construction is that, since the study is aiming to improve the understanding and awareness of BBI in construction, the priority was given to construction.

Every participant was sourced from different firms or different business units of the same firm. LinkedIn Online Professional network as well as events organised around central London i.e. BIM alliance forum, BIM for infrastructure by Bentley, IOT Breakfast brief, etc.) were key means of sourcing potential interviewees. These methods offered a huge success in judgementally selecting and inviting the most suitable participants for interviews.

3.10.1.3 Process of conducting semi-structured interviews

For this research, 43 semi-structured interviews were conducted within a time frame of 4 consecutive months (April-August 2018). Many of the open-ended questions were placed at the beginning of the interview to understand the broader context of implementation and exploitation issues. These unstructured open-ended questions were used to get the maximum out of experts who had a comparatively wide knowledge around the three domains, so that it could be ensured that research took into consideration all the possible angles beyond the researcher's own axiological bias. It also ensured that any important factors missed in the proposal were added after these open/free discussions. However, it is also worthwhile mentioning that the 18 respondents from RFM sectors had no knowledge of BIM, therefore the BIM questions were not included in RFM interviews. By using the semi-structured method, the researcher prevented any form of prior assumptions about the criteria that lead to successful BBI implementation. The scope was then narrowed down to a certain extent in the middle part of the interview and closed-ended questions were used at the end (interview templates can be found in Appendix B). However, it was noticed that many of the interviewees kept backing-up their answers even for the closed-ended questions by elaborating their views, which shows their interest in the topics questioned. The questions were aimed not only at current practice but also on suggestions for future practice; because the industry is rapidly moving forward, and innovations are evolving at a rapid pace.

The researcher used a digital voice recorder for face-to-face interviews while online interviews were recorded in the application itself which allows downloading the audio/video file. It was also ensured that notes were taken at the same time, as keeping records of an interview is part of the artistry (Bryman, 2001) as well as the back-up technique for an unexpected data loss. Later, all 43 audio files were transcribed to text by the researcher. An online transcribing tool was used initially, but since the accuracy was subjective due to the background noise and the frequency of technical terms, names usage, the researcher had to double-check and review the transcripts for required amendments. Most of the technical terms were non-identifiable by the online transcribing tool described above. This resulted in the researcher transcribing each audio file by herself. The interviewee reference number (I#) was used as an identifier when quoting some of the important points that emerged from the interviews.

3.10.1.4 Data analysing process for semi-structured interviews

Qualitative data analysis is a process of resolving data into its constituent components, to reveal its characteristic elements and structure (Dey, 2003). The qualitative analysis referred to in this research was mainly based on the interview transcripts. The transcripts were then analysed through coding and thematic analysis by version-21-Nvivo software to derive critical variables to feed two research outputs. Miles and Huberman, (1994) introduced data reduction, data display, and concluding the basic steps of qualitative data analysis. This study also followed the same sequence for analysing the in-depth qualitative data. The collected data was filtered through a data reduction process. First, the data was grouped into wider themes, and then it was narrowed down to specific codes. The data was presented through diagrams and graphs, which were drawn using Mind manager, MS Visio, Auto CAD, and MS Excel. This exercise partly helped to produce 'Proposed Strategic Framework' and 'Proposed Skill-Knowledge Inventory'. The rest of the data used in the framework and SKI was from the web-based questionnaires, discussed in the next section.

3.10.2 Web-based questionnaire survey (WBS) used for the quantitative study (QUAN)

3.10.2.1 Justification for the selection of web-based questionnaire survey (WBS) for the current research

To obtain a wider opinion, the questionnaire survey method was applied to collect data from a larger range of participants, and thus, the WBS is a high resourced quantitative study. The web-based questionnaire survey was conducted in parallel with the interviews. The main purpose of the questionnaire surveys is to identify the correlations between impact factors, competitive advantage, exploitation, and confirm or reject pre-set tentative hypotheses. These findings subsequently helped to develop the strategic framework and Skills/knowledge Inventory. The questions are directed to seek not only a reflection of the behaviours and performances of their current organisation but also their perception of the subject areas because an organisation is an entity comprising its individuals involved (Pathirage *et al.*, 2007).

The web-based questionnaire was an inexpensive, less time consuming, and user-friendly method of collecting data for wider opinion. Moreover, it is possible to be delivered to a person's address while providing opportunities for easy follow-ups. It also provides greater geographic flexibility and a fast, cost-efficient response and respondents have more time to think about the questions before replying. These advantages also justify the use of WBS in this study.

3.10.2.2 Sampling Strategy for web-based questionnaire surveys

The selection of respondents via random sampling was not feasible. The sample was non-random purposively selected to represent four sectors. The main reason for the rejection of random sampling is that addressing the issues around BBI requires more specialist knowledge and experience. More technical and empirical evidence was needed to improve validity and reliability as well. The surveys, therefore, targeted professionals who possess an acceptable amount of experience and/or involvement in these areas and who work for companies that have adopted at least one of these technologies in the UK. Moreover, exploitation of BBI is a relatively new area that has not yet become business as usual in construction; therefore, the firms who currently use BIM/ BDA/ IOT were purposively selected. First, a list consisting of organisations that use at least one of these technologies was created with the help of multiple sources. Thereafter, a non- random purposive judgemental sampling method was adopted to design the sample frame. This considers that 'the individuals within the chosen organisations are selected and then all of the units of interest are sampled within this selection' as suggested by Teddlie and Tashakkori (2006). The unit of interest was based on their profession, limited to their experience and/ or involvement for these technologies. The selected list of construction organisations consisted of 50 construction practices in the UK. The method used to select the organisations is described in the next paragraphs.

3.10.2.3 Sample size calculation for the web-based questionnaire survey

The sample for questionnaire surveys was homogenous, and comprehensive, and was a true representation of small, medium, and large construction organisations within the UK construction industry. The questionnaire was distributed among all four sectors (Construction, finance, retail, and manufacturing) aiming to ascertain the views of practitioners at all three hierarchical levels.

It was extremely difficult to get a single source of a database that contained organisations that use at least one of the three technologies (BIM, BDA, or IoT). There were a couple of consultant companies who were willing to offer such reliable databases at an agreed subscription price. However, due to financial limitations, those options had to be rejected. Therefore, the selection of active members of accredited technological bodies was used as the sampling strategy. From different sources, 50 construction organisations were identified. The requirement was to identify firms in all four sectors that use at least one of the B, B, and I technologies. For the construction sector, the following selection criteria were used.

- Members of COMIT (Commercial IT)
- Nominations/ shortlisted/ winners of Techfest 2017 and 2018
- Nominations/ shortlisted/ winners of New Civil Engineers 100 awards

It is widely accepted that the firms registered under these three databases are leaders in technology in construction. This method does not limit the selection to only large firms. Firms of every size and type were included. However, since this is purposive sampling more priority was given to 'Constructors' which include main/ sub-contractors and developers. The type of organisation was defined according to the Standard Industry Classification (SIC-2007). These classifications can be seen in section 4.2.2 of data analysis. Thus, the list of companies purposively selected for the questionnaire survey includes companies of every size and represents 6 distinctive company types as defined in Primary UK SIC. The sample was then subjected to stratification. It implies the division of the population into subgroups, classes, or strata. This involves dividing the whole population into representative parts. In this case, the stratification of all construction companies into micro, small, medium, and large organisations was performed. The size was determined according to the annual turnover among many other indicators (i.e. number of employees, profit margin, geographical distribution). This resulted in the identification of 8% of micro firms, 18% of small firms, 12% of medium firms, and 62% of large firms. To be able to cover the entire sample, SIC 2007 classification was used in the questionnaire survey. This can be found in Appendix C- organisation type question.

Having arrived at the population sample (50 organisations) the next stage was deciding whether the survey for the study should include all elements of the population or whether it should be targeted at certain elements of the population. Although the study aims at a strategic approach, the target population was not confined to strategic management. Managers from all levels were targeted in this study. The researcher adopted proportionate stratification of the population sample before the collection of sample individuals. Following to the stratification of construction organisations, the sample was re-stratified into three levels according to the job roles listed below. This wider selection helps to generalise the findings. This is a generally accepted method of categorising levels of management in construction. Random sampling is applied after applying stratification.

- Senior Management (i.e. Executives, strategic managers, senior managers) (60%)
- Middle-level Management (i.e. Tactical managers) (20%)
- Lower level Management (i.e. Day-to-day operational managers) (20%)

Most importantly, a great effort has been devoted to identifying the most suitable individuals for the study given the fact that they have some sort of involvement/ experience in the implementation or exploitation of BIM or BDA or IoT. It is also assumed that these managers are aware of the culture and the structure of the organisation. Further, according to Mintzburg's (1987) view on organisational strategy- the five-Ps-plan, pattern, position, perspective, and ploy need to be executed at all levels of an organisation, therefore strategy cannot be viewed through strategic level managers in isolation. However, more priority was given to senior-level managers. The 'senior level' category was 60% of the total respondents whereas the other two categories represented 20% each. With the number of organisations selected (N=50), it was not feasible or acceptable to select one person to represent each organisation. Hence, approximately, 12 individuals from each organisation were selected.

To get the individual contact details, different publicly accessible sources were used. Construction news- www.cnplus.co.uk; Forecasting analysis and modelling environment (FAME) Bureau Van Dijk U.K- Updated version September 2018; LinkedIn; Global Database.UK; Lexis Nexis World Compliance™ and British Telecom directory were some of them. To sum up the sampling strategy, the target number of questionnaire distribution was 605 with a margin for error and the expected response rate was 30%-35%. However, the study could not achieve this response rate because of several reasons which have been described in later sections.

The same sampling method was adopted in the selection of RFM (Retail, Finance, and Manufacturing) sectors were stratified in different proportions. However, most of the organisations in RFM sectors were large.

3.10.2.4 Process of conducting web-based questionnaire surveys

The questionnaire was highly structured where only close-ended questions were employed to facilitate the respondents' opinions (See Appendix C for the questions included in the WBS). The variables used in questionnaires were derived from the literature (see Chapter Two). The questionnaire was divided into six sections: personal information, exploitation, benefits, and challenges Impacting factors for BBI, competitive advantage and skills-knowledge and training needs for BBI exploitation, where ALL questions were set to be 'compulsory/ required' for the questionnaire to be 100% complete. This means that none of the questionnaires were recorded as completed unless all questions were answered. If an item/question was missed by chance, the respondents automatically got an error message saying that it could not continue without completion of the missing item. Therefore, there were no partly completed non-usable responses received.

Because it cannot be ensured that the respondents may use all three technologies at their workplace, separate questionnaires were designed and tailor-made according to their use. This resulted in developing and distributing eight questionnaires separately. The eight questionnaires include WBS1) BIM only; WBS2) BDA only; WBS3) IoT only; WBS4) BIM +BDA; WBS5) BIM+IoT, WBS6) BDA+IoT; WBS7) BIM+BDA+IoT and WBS8) RFM sectors. The first seven questionnaire surveys (WBS1- WBS-7) were distributed among construction professionals depending on their use of technology. Another separate questionnaire survey was distributed among retail, finance, and manufacturing (RFM) professionals (which resulted in 8 surveys in total) who directly involve the use of BDA and/ or IoT as part of their job role. The total number of 405 and 195 questionnaires were sent out for construction and RFM sectors, respectively. With the margin for error, it was expected to receive a response rate of 30%-40% from both sector segments.

The same set of questions was employed for both sector segments where BIM questions were omitted for RFM sectors. Pre-populated parameters were used to capture the organisation size, technology use, and other identifiable information.

Before distributing the survey, the questionnaire had been piloted and reviewed through several academic staff and peer colleagues at the School of Built Environment and Architecture, London South Bank University for feedback on clarity and readability to ensure the questionnaire was professional and formal with rich and appropriate content (internal validity). The questionnaire was distributed within the UK as a ‘web-based online survey’ through JISC (Formerly known as Bristol Online Survey-BOS). Since LSBU has a license for JISC it was the most cost-effective tool for the researcher.

The survey did not use public URL options. Instead, a specific respondent list was created using an appropriate sampling strategy. By doing this, the researcher was placed in control of who can complete the survey. Further, the researcher chose not to keep the survey anonymous but to capture information in the responses that would identify which response was provided by which respondent and track who has and who has not completed the survey. For this purpose, the pre-population parameters technique was employed. This way, it was able to keep track of who had and who had not completed the survey and send reminders to the ones who had not.

Manual email sending was done for sending invitations but for sending reminders, Ms. Office outlook ‘mail merging’ facility was used. This substantially helped to reduce the time it takes for sending emails, by allowing the researcher to send 405 personalised emails in a shorter space of time by defining the changing labels in advance. After 2 rounds of email reminders were sent, the final option used to increase the number of responses, was personal contact with the respondents who had not completed the survey. Although this was not completely successful, it helped to increase the number of responses. ‘Piping’ was also used in the survey to address every respondent from their names, this way it was possible to maximise the number of respondents.

The questionnaire return was requested within three weeks and two follow-ups were issued after two weeks as a reminder. It appeared that the questionnaire distributed among construction professionals received a higher response rate (28.4%) than for the RFM sectors (26.15%) resulting in 115 and 51 number of successful returns. Generally, it is accepted that surveys that are distributed internally (i.e. to employees within one organisation) have a much higher response rate than those distributed to external audiences (i.e. industry practitioners). The acceptable response rate for internal surveys will generally be 30-40% on average, compared to an average 10-15% response rate for external surveys (Baruch, 1999). Therefore, being external surveys, both response rates appear to be acceptable. Among the 7 questionnaires distinguished for the adoption of three different technologies, the highest number of responses was received from WBS-1- Exploitation of Building Information Modelling (BIM) For Competitive Advantage in the Construction Industry. The questionnaire did not get any non-usable responses as the questionnaire was designed to make all questions compulsory. The responses do not mark as 100% completed until they complete all questions.

The 7 questionnaires for the construction sector were launched in November 2018 and was closed in April 2019. The questionnaire for the RFM sector was launched in April 2019 and closed in May 2019. The reason for keeping the construction sector questionnaire for that long was due to the low response rate and the difficulty in sending reminders for a large sample of 405. Also, the time that the construction questionnaire was launched and distributed was closer to the festive/ holiday season (Christmas) for the industry practitioners. For those reasons, the questionnaires were kept alive for a maximum of five months. However, it was interesting to see that the return speed in RFM sectors was quite fast compared to the construction sector. Wåhlberg and Poom (2015) claim that possibly, people who would not initially respond to a questionnaire voluntarily would complete various items if they were forced to after the second or third reminder. This seemed to be true as it was noticed that the response rate was increased every time reminders were sent out. To address the generalisation, the respondents were categorised into three groups: early respondents, late respondents, and non-respondents. The late respondents are the people who responded after the follow-ups. Miller and Smith (1983) explain that late respondents are often like non-respondents. Therefore, the researcher closed the questionnaires after a maximum of five months without giving the respondents ‘time-at-large’ to answer.

3.10.2.5 Data analysing process for web-based questionnaire surveys

Quantitative data collected from 8 web-based questionnaires were then analysed together to facilitate a comparison between cases. The questions consisted of nominal and ordinal data only. Both nominal and ordinal data are categorical. Ordinal data is most often used to compare the available categories/attributes. Many of the closed questions in the web-based questionnaire surveys aimed to identify the respondents’ corresponding organisational attitude, performance, and behaviours towards the use of BBI for competitive advantage. For ordinal questions, the respondents were given with a Likert consisting of a 0-5 scale/ 0-4 scale of answers (for example, 1- Not seen as a challenge at all, 2-Very Low level of challenge 3-Low level of challenge, 4-High level of challenge, 5-Very High level of challenge). The main reason for using different Likert scales (4-point and 5-point) in this study was because in certain cases in which a specific user opinion is essential, the exception rule needs to be applied. For example, when questioning respondents about the extent to which their companies exploit BIM, to be able to reach the expected objective, more specific opinion is required, and therefore 4-point scale is most ideal. The blurred line between low and high level of exploitation is exempted and replaced with ‘to somewhat extent’ to force a choice when a respondent has more complicated opinion. 5-point Likert scale on the other hand is useful when certain opinions are required to be categorised in to two extreme poles and a neutral option connected with intermediate answer options. All ‘impact investigation’ questions used 5-point Likert scales as they tend to produce better distributions of data by measuring all possible attitudes towards an issue.

The collected qualitative data was supported by quantitative analysis; their central tendency (mode, median, and mean) and the statistical dispersion was considered while analysing the data. The t-test was used to evaluate the differences in means between the groups (i.e. different job levels and different experience levels). The study also used judgemental multi-variate regression analysis to derive the Cronbach's alpha coefficient test, Pearson's correlation coefficient, relevance index score, and factor analysis to examine the reliability of the questionnaire and also to ascertain the impact of given factorial data through SPSS. The results will show the critical strategic factors to include in the 'improved strategic framework' and 'improved SKI'.MS Excel 2010 was used to present the processed data. As, Punch (1998) explains that conclusions should be in the form of propositions and they need to be verified, finally the conclusions were articulated with verifications.

3.10.2.6 Methodological Challenges and limitations of web-based surveys

One of the main limitations seen as a cause for the low response rate in the questionnaire surveys was the length of the questionnaire and the complexity of the questions. The questionnaire contained a few lengthy grid questions that required a considerable amount of thinking and concentration. However, such questions helped to capture the intended richness of the investigation. This challenge was however dismissed in the questionnaire for RFM sectors as it contained fewer number questions, because of omitting BIM related questions. Further, in construction, giving the respondents the free choice to select the applicable link out of seven links also seems to be complicated which is another cause for the low response rate. Having all compulsory questions is another such cause. Because, the survey does not count any of the partly completed questionnaires as 'completed', the ones who stopped in the middle of the questionnaire and hit the 'submit' button (and never returned to complete it) were lost. Errors in survey research design can occur in the areas of respondent selection, survey questions, and administration (Neuman, 2011). Such errors can also cause a low response rate. However, the causes can be considered as inevitable challenges rather than errors. Generalisation in survey findings is a critical issue in scientific research because many surveys end up with low response rates. Therefore, proper attention must be paid throughout the survey.

3.11 Validity and reliability of scientific research

Based on the assumptions purported by Bryman (2008), this research is a 'scientific research' because it is;

- Purposive (The main purpose of the research is to improve exploitation levels of BBI leading to enhanced competitive advantage and all other research procedures follow this purpose)
- Testable (the research tests set of hypotheses to understand and find out the relationship between dependent and independent variables-i.e. relationship between culture and BIM exploitation)
- Replicable (if similar methods and procedures for data collection and analysis are used as compared to this study, it is very likely that similar findings may result)
- Rigorous (the research is underpinned by good theoretical knowledge and laid methodology which is reliable and valid)
- Parsimony (As well as the research data collection and analysis, the interpretation of findings also follows a simplistic approach that is understandable for the target audience)
- Generalisable (The findings obtained from the research are applicable and acceptable worldwide. For example, the research findings of this organisational setting are applicable for another organisational setting of almost similar nature)

Scientific knowledge about the world is based upon empirical observation. These observations are used to develop a theory to help us to describe, understand, and predict how our world works (Bryman, 2008). Neuman (2011) refers to reliability and validity as ideas that help to establish the 'credibility' of scientific findings. Further, the author claims that reliability in general aims towards the consistency or replication of research findings in similar conditions, while validity evaluates the truthfulness of findings. In another perspective, Gibbs (2007)purports that qualitative validity means that the researcher checks for the accuracy of the findings by employing certain procedures, while the researcher's approach is consistent across different researchers and different projects. Creswell (2014) affirms that chance, bias and confounding are the three main threats to validity. Miles & Huberman (1994) identify the essential considerations that need greater thought concerning reliability, internal validity, and external validity. Based on the latter three considerations a review into the validity and reliability of this research is explicated in subsequent paragraphs.

Commencing from the research questions established in section 1.7, the questions are reliable because they are easily understood and unambiguous. The theoretical concepts in the research area were at an appropriate abstraction level to be able to itemise and breakdown into key construct constituents. The higher abstraction level theoretical concepts (when broken down to constituents) clearly show what data is required to answer them and how the data will be obtained.

The two research questions are interconnected in a meaningful way geared towards the research aim. In terms of internal validity, the questions are interesting, meaningful, and worthwhile to the research effort. They define the scope and delimitations and confirm external validity as well.

The role of the researcher in the entire research endeavour is explicated at every stage of the research. The literature review provides the gaps and a full account of theories and concepts relevant to research questions from the existing body of knowledge hence providing the reliability and construct validity. While the congruence between research problems and features of the study design assures the internal validity, the deployment of peer reviews and piloting the study design with peer experts affirm the external validity.

Internal validity is used for establishing causal relationships while external validity is about the generalisation of findings (Neuman, 2011). The study presented in this Ph.D. study is generalisable as it makes general conclusions/claims based on the research findings, rather than making them specific to the research context. The data collection is reliable because it is collected from a reliable sample that is a true representation of the target sample population. The collected data is rich and shows its linkage to emerging theories. The data comply with the researcher's assumptions, worldview, and theoretical orientation stated in section 3.3. Given the capacity to 'operationalise' the theoretical concepts formulated in literature, the validity of research data is secured (Mason, 2002). The adopted research methodology is meaningful facilitating parallelism of findings across multiple data sources. The findings are reliable because they exhibit a coherence where the concepts and the construct variables within them are systematically related to each other. Moreover, given the level of the discussion presented to explain the results and the extent to which results are transferable and able to be compared with extant literature, the findings are internally and externally valid. The level of consistency in data collection, connection to previous theories established, the sequence of narration, applicability, and facilitation for further testing corroborate and verify the internal validity of findings and conclusions.

The two research outputs (see section 7.2.6) are reliable because of the reliability of findings as explained in the previous paragraph. Errors were checked for statistical analysis and thematic analysis to maintain internal validity.

3.12 Summary to Chapter Three

This chapter outlined the systematic approach employed in this study explaining the principles associated with the branch of knowledge and the most appropriate methods applied to the field of study. The research aim was to develop a strategic framework for improved exploitation of Building Information Modelling (BIM), Big Data Analytics (BDA), and the Internet of Things (IoT) as strategic tools for competitive advantage in construction. The researcher made *relativist ontology and emic epistemolog*y to dictate the research method choices. The adopted research design was a mixed-method approach, which was further explained in terms of purpose, triangulation technique, number of strands or phases, type of implementation, and temporal aspects such as priority, function, and contextualisation. Fulfilling the research aim required understanding of the extent of BBI exploitation, the impact of organisation culture, structure, size, and the implications of skills and training needs. Thus, empirical evidence-based practical investigation (applied) was undertaken. The next chapter commences these empirical investigations by presenting the data analysis, and discussions derived from semi-structured interviews, and web-based questionnaire surveys. The method of 'triangulation' was used to evaluate the quality and rigour (reliability and validity) of the research.

Chapter Four

4 BIM, BDA and IoT exploitation and their leads to competitive advantage

4.1 Introduction to Chapter Four

Before developing a strategic framework for the improved exploitation of BBI, it is important to conduct a situation analysis to determine the health of the industry (ies) of inquiry. Situation analysis refers to a collection of methods that managers use to analyse an organisation's internal and/ or external environment to understand the organisation's capabilities concerning the competing business environment (Mintzberg, 1987b). As described in sections 2.2.4 and 2.5.1 of Chapter Two, conducting a ‘situation analysis’ is a part of Mintzberg’s 5 P’s strategy ‘plan’.

This chapter is supported by both qualitative (semi-structured interviews) and quantitative data (web-based questionnaire survey). The data collection process for interviews and web-based surveys can be found in section 3.10.1 and section 3.10.2 respectively. The construct variables used in questionnaires and the operational definitions used in the higher abstraction level constructs are explained in Chapter Two. A thorough review of the literature was conducted to better understand what has already been discussed, gaps in the literature, and theoretical underpinning of technology ‘exploitation’ (Refer section 2.3 in Chapter Two). Further, it allowed working hypotheses to be formulated. In the fulfilment of objective 2 outlined in section 1.4 of Chapter One, the following are the expectations that are met in this chapter.

i. Investigate the extent to which BIM, BDA, and IoT are being exploited in construction, retail, finance, and manufacturing
ii. Investigate the extent to which the benefits are being accrued and the extent to which challenges are seen to be challenging for BBI in construction, retail, finance, and manufacturing.
iii. Investigate how exploitation, benefits, and challenges lead to competitive advantages

Figure 16 below shows the position of Chapter-4 in the study and its contribution to framework development.

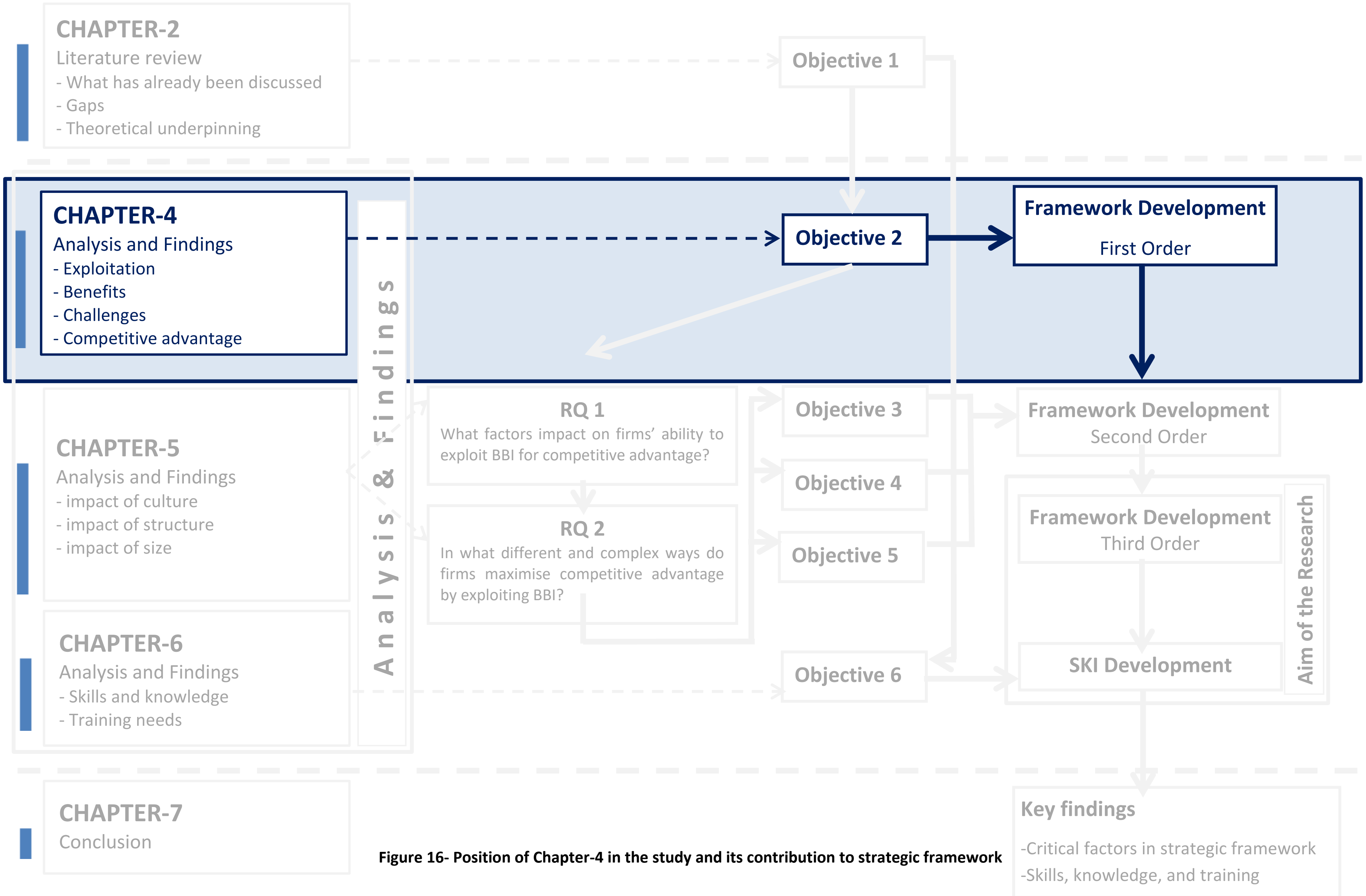

Figure 16- Position of Chapter-4 in the study and its contribution to strategic framework

4.2 The extent to which BIM, BDA, and IoT (BBI) are being exploited in construction, retail, finance, and manufacturing

4.2.1 Preparing the data for quantitative analysis

To commence the analysis, first and foremost, the demographics of the sample population are presented at aggregate and disaggregate levels for the segmented population (as mentioned in Chapter Three) using descriptive statistics and frequencies. This will be followed by investigating the extent to which BIM, BDA, and IoT are being exploited in construction. The disaggregation was carried out for each strategic tool (BIM, BDA, and IoT), on account of organisation category, organisation size, and respondents' category of the job role. All data analyses presented here onward were computed using IBM SPSS Statistics version 26. The data outputs were retrieved from 'spv.' format and were documented using Ms. Excel. The entire data set for the construction sector resulted in 526 variables for analysis. A full list of coded variables along with the questions can be found in Appendix C**.**

4.2.2 Descriptive Statistics for different segments

This section presents descriptive statistics for the population demographics from four sectors (construction, retail, finance, and manufacturing) with respect to the following variables:

1. Distribution of respondents according to the sector
2. Organisation category
3. Company size
4. Job role
5. Company-wise BBI adoption
6. Individual BBI use as a part of your current job role
7. Individual experience in BBI use

With reference to the responses received, the majority of responses were from construction (Figure 17). The reason for the imbalance between Retail, Finance, Manufacturing vs Construction could be a result of unequal sample sizes used for questionnaire distribution.

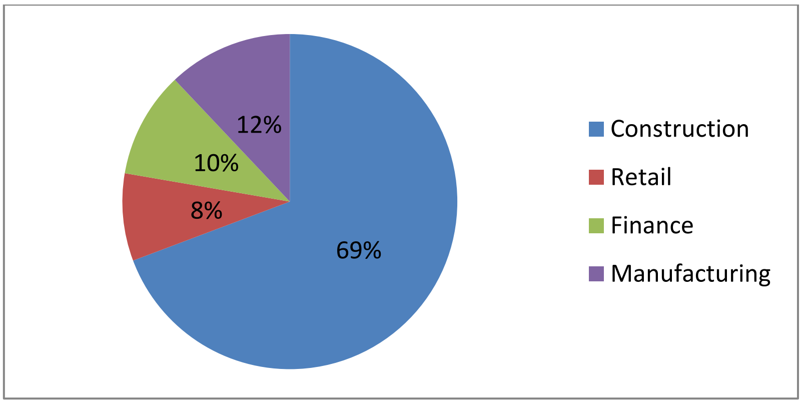

Figure 17- Distribution of respondents according to the sector

Next, descriptive statistics for 'organisation category- ORGCAT' were explored. This categorisation is applied for construction only. No categorisation was used for RFM sectors in terms of their organisation type as it is not practical to introduce common categories for more than one sector.

The categorisation was made according to SIC-2007 as below.

1. Development of building projects
2. Construction of residential and non-residential buildings
3. Civil engineering (e.g. construction of roads, railways, bridges, tunnels, utility projects)
4. Specialised construction activities (e.g. demolition, groundwork, electrical, plumbing, mechanical, scaffolding, finishes)
5. Architectural and engineering activities (e.g. building designing, drafting, urban planning and landscaping technical testing and analysis, technical consultancy)
6. Project management services related to building projects
7. Other professional, scientific, and technical activities (e.g. quantity surveying, environmental consultancy)

Many respondents in construction represented the 'Construction of residential and non-residential buildings and Civil engineering' (20%) category. Parallel to the organisation category, the researcher used the variable ORGTYP as a prepopulated parameter to source the type of the organisation as an already known data. A pre-populated parameter is used to pre-populate the information already known about individuals or groups. This was feasible because all organisations were purposively sampled. The distribution of ORGTYP shows that the organisation type that most of the respondents belong to out of all the organisation types prepopulated for construction is 'Main Contractor'.

The stratification for the 'size of organisation' was done after sampling (please see chapter 3 for sampling strategy) and that resulted in most of the organisations from the entire population being 'large'. In RFM sectors, all respondents were from large organisations (see Table 13).

Table 13- Frequencies for organisation size

	Construction		Retail		Finance		Manufacturing	
Org. Size	**Frequency**	**Percent**	**Frequency**	**Percent**	**Frequency**	**Percent**	**Frequency**	**Percent**
Micro	4	3.5	0	0	0	0	0	0
Small	6	5.2	0	0	0	0	0	0
Medium	12	10.4	0	0	0	0	0	0
Large	93	80.9	14	100.0	17	100.0	20	100.0
Total	**115**	**100.0**	**14**	**100.0**	**17**	**100.0**	**20**	**100.0**

The sample population was stratified for the individual job-level before sampling. The stratification involved three hierarchical levels in the organisation they currently work for. The respondents were majorly from the 'senior management' category (see Table 14). As mentioned in the sampling strategy for quantitative data collection in section 3.10.2.2, the researcher made the decision to make the population biased towards large organisations and senior managers.

Table 14- Frequencies for the job role

Job Role	**Construction**		**Retail**		**Finance**		**Manufacturing**	
	Frequency	**%**	**Frequency**	**%**	**Frequency**	**%**	**Frequency**	**%**
Senior Management (i.e. Executives, strategic managers, senior managers)	68	59.1	7	50.0	8	47.1	7	35.0
Middle-level Management (i.e. Tactical managers)	34	29.6	6	42.9	7	41.2	7	35.0
Lower level Management (i.e. Day-to-day operational managers)	13	11.3	1	7.1	2	11.8	6	30.0
Total	**115**	**100.0**	**14**	**100.0**	**17**	**100.0**	**20**	**100.0**

The purposive selection of organisations (see 3.10.2.3) allowed the researcher to identify whether each organisation currently uses B, B, I, or not in their current practice. In that attempt, the researcher purposively selected organisations that use at least one of the technologies of the inquiry. In the attempt to investigate the extent of exploitation for BIM, BDA, and IoT, the survey first used a screening question to see how many of the population use BIM, BDA, and IoT as a part of their job role. Because the questionnaire contained questions that are specific to each technology a person who does not involve a specific technology in his role may not be capable of answering the questions related to that particular technology. This would screen the population according to their ability to answer the questions and they were directed to a suitable questionnaire survey depending on their individual use. For RFM sectors, the respondents were involved in the use of BDA and IoT only. For construction, the majority of the respondents claimed that they used BIM (Table 15).

Table 15- Screened according to individual use in BIM, BDA, and IoT

WBS	B, B, I use	Construction	Retail	Finance	Manufacturing
WBS-1	BIM Only	31	0	0	0
WBS-2	BDA Only	12	2	3	6
WBS-3	IOT Only	9	0	0	0
WBS-4	BIM + BDA	20	0	0	0
WBS-5	BIM + IoT	16	0	0	0
WBS-6	BDA + IoT	9	12	14	14
WBS-7	BIM + BDA +IoT	18	0	0	0
Total		***115***	***14***	***17***	***20***

Contingent upon the above data, the questionnaires that were offered for RFM sectors did not contain questions on BIM. Therefore, it is important to highlight that RFM sectors do not provide any contribution to BIM-related analyses. Once the respondents were directed to the correct WBS, the questionnaire then asked the respondents about the extent to which they use B, B, I as a part of their current job role (the variables of inquiry include: UBIMEXT, UBDAEXT, UIOTEXT) and their years of experience in the use of BIM, BDA, and IoT: BIMEXPERI, BDAEXPERI, IOTEXPERI. According to Table 16; Table 17; Table 18, while all BIM users were represented in the construction industry, the majority of respondents from construction used BIM to a greater extent (35.7%) compared to BDA (13.9 %) and IoT (16.5%). Considering the construction industry alone, between BDA and IoT, it is reported that BDA has higher percentages for the values: 'To a very little extent' and 'To somewhat extent' compared to IoT. This implies that the extent to which construction respondents use BDA and IoT is low compared to BIM use.

Table 16- The extent to which respondents use BIM

	Construction	
Extent of BIM use	**Frequency**	**%**
To a very little extent	5	4.3
To somewhat extent	39	33.9
To a greater extent	41	35.7
Total	85	73.9

In the discussion of all four sectors at the cross-section of BDA use (see Table 17), retail and manufacturing sectors are leading as they use BDA to a greater extent 57.1% and 45.0% respectively. Retail is an industry that heavily depends on its customer base with highly personalised marketing strategies. That being the case, for retailers, analysing big data can create opportunities to provide better customer experiences. This can be a possible reason for retailers to exploit BDA to a greater extent than the other three sectors. The qualitative findings presented in section 4.2.3.2 provide more comprehension for better discernment.

Table 17- The extent to which respondents use BDA

The extent of BDA use	Construction		Retail		Finance		Manufacturing	
	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
To a very little extent	14	12.2	0	0	8	47.1	2	10.0
To somewhat extent	29	25.2	6	42.9	8	47.1	9	45.0
To a greater extent	16	13.9	8	57.1	1	5.9	9	45.0
Total	**59**	**51.3**	**14**	**100.0**	**17**	**100.0**	**20**	**100.0**

When considering all four sectors in the cross-section of IoT use (see Table 18), only manufacturing beats the IoT use of construction. As explained in 2.3.3 the state-of-the-art in the exploitation of IoT in manufacturing facilitates the production flow, by IoT devices automatically monitoring the development cycles remotely managing the warehouses and inventories. This could be a beneficial reason why the manufacturing sector greatly exploits IoT compared to the other sectors.

Table 18- The extent to which respondents use IoT

	Construction		Retail		Finance		Manufacturing	
The Extent of IoT use	Frequency	%	Frequency	%	Frequency	%	Frequency	%
To a very little extent	13	11.3	3	21.4	7	41.2	5	25.0
To somewhat extent	20	17.4	8	57.1	6	35.3	5	25.0
To a greater extent	19	16.5	1	7.1	1	5.9	4	20.0
Total	52	45.2	12	85.7	14	82.4	14	70.0

The years of experience in the use of BIM, BDA, and IoT (see Table 19) shows that manufacturing respondents have more experience in BDA compared to the other three sectors. There were no respondents from any of the sectors who have 11-20 years of experience in the use of IoT. However, respondents from the retail sector possess more experience in the use of IoT than the other sectors.

Table 19- Percentages for the years of experience in the use of BIM, BDA, and IoT

	Sector	Less than 1 year %	1-5years %	6-10years %	11-20 years %	Total
BIM	**Construction**	7.0	25.2	27.0	14.8	73.9
BDA	**Construction**	14.8	26.1	7.0	3.5	51.3
	Retail	0.0	42.9	57.1	0.0	100.0
	Finance	0.0	82.4	17.6	0.0	100.0
	Manufacturing	0.0	35.0	60.0	5.0	100.0
IoT	**Construction**	10.4	18.3	16.5	0.0	45.2
	Retail	21.4	42.9	21.4	0.0	85.7
	Finance	11.8	52.9	17.6	0.0	82.4
	Manufacturing	20.0	20.0	30.0	0.0	70.0

4.2.3 Identify the extent to which Building Information Modelling, Big Data Analytics, and Internet of Things (BBI) are being exploited in four sectors

A great effort was devoted to the identification of construct variables for exploitation factors for BIM, BDA, and IoT in section 2.5. Based on the definition for 'exploitation', a list of construct variables was derived for the exploitation of BIM, BDA, and IoT separately. The factors were formed to reflect both 'inputs'/ 'enablers' and 'outputs/ results'. Having more than one outlook has been acknowledged as a good practice constituent development for individual and cluster competitiveness by Temporal (2005). For example, support and leadership from senior management, BIM tools, and workflows can be classified as inputs while performance efficiency and effectiveness in daily tasks can be classified into results.

Section 2.5 presented a review of the literature on which the construct variables for exploitation were based. These construct variables were carried forward for the web-based questionnaire survey (WBS). Please see Appendix C for the full list of variables and the corresponding questions. Although additional technology-specific phraseology was added, the variables remain common for all three technologies: BIM, BDA, and IoT.

4.2.3.1 Quantitative data analysis for BIM, BDA and IoT exploitation comparison for four sectors

Preliminary analysis- Assessing normality

The variables: EXPBIM, EXPBDA, EXPIOT were used to investigate the extent to which each sector exploits BIM, BDA, and IoT. A full list of questions and variables can be found in Appendix C. Normality tests (Shapiro-Wilk and Kolmogorov-Smirnov[a]) were carried out to see the normality of the data distribution. The percentage trimmed mean within the range of 3%-5%. implies that the data distribution for all four sectors are near-normal. Since a significant difference cannot be seen between the original mean (3.11) and trimmed mean (3.12), no further investigation is required for these data points (Pallant, 2011). From the 'descriptive', it was convincing that distributions are not 'perfectly normal'. For example, EXPBIM1 shows a positive kurtosis value of .586- indicating that the distribution is rather peaked (clustered in the centre) with long thin tails. Negative kurtosis value shown in EXPBIM2 indicates that the distribution is relatively flat (too many cases in the extremes). With fairly large samples, like in this study, skewness 'will not make a substantive difference in the analysis' (Tabachnick and Fidell, 2007). Moreover, for large samples, having a skewness and kurtosis z-value between -1.96 and +1.96 is considered to be acceptable (Löfgren *et al.*, 2013). All skewness and kurtosis z-values for the variables of inquiry for this section are neither below -1.96 nor above +1.96. The reliability test (Cronbach-alpha) was also performed on exploitation variables and it resulted with alpha values: 0.910 (Construction), 0.842 (Retail), 0.770 (Finance), and 0.829 (Manufacturing) which indicate a good level of internal consistency.

Descriptive and Inferential statistics for EXPLOITATION variables

The questions related to the level of exploitation for BIM, BDA, and IoT in four sectors can be found in Appendix C. According to Garland (1991), the five-point scale forces the indifferent respondents to make a choice, resulting in a 10% reduction in the 'importance' categories and an 8% increase in the 'unimportant' categories. The other 2% of this shift is found in the 'don't know' category. In this study, in the investigation of the extent to which each exploitation variable is achieved, a four-point Likert scale is used (without the mid-point). This helps to prevent the respondents from being un-opinionated (which falls in to 'don't know' category) (Garland 1991).

The four-point Likert scale was first given with values ranging from 1-4, where 1- Not at all apply, 2- To a very little extent, 3- To somewhat extent and, 4- To a greater extent. When the sum of each variable is computed, the higher the sum (or the mean value), the higher the extent to which it is being exploited.

Influenced by Jaafar *et al.* (2018)'s scoring system used in their study on Construction Accidents, a similar scoring system was developed (Table 20) to determine the selection criteria for 4 point Likert data. The scoring system indicates all scores falling into a certain criterion in the scoring system represent the relevant level in the 'selection criteria'. The selection criteria used to determine the 'critical' exploitation represent the mean score between 3.25 - 4.00 which indicates that the exploitation occurred to a greater extent.

Table 20- Overall suitability scale

Mean interval scale	Mean value scale

1.00–1.74	Not at all apply
1.75–2.49	To a very little extent
2.50–3.24	To somewhat extent
3.25–4.00	To a greater extent

Level of Exploitation for BIM, BDA, and IoT

Table 21 presents a side-by-side comparison of how four sectors differently exploit BIM, BDA, and IoT. Because Likert scales produce ordinal data, as much as the mean is important, it is also important to calculate the median (the number found exactly in the middle of the distribution) which is a measure of central tendency. It simply shows what the 'average' respondent might think, or the 'likeliest' response for each variable. Mean on the other hand is the same as an average.

For BIM, all data are transpired from the construction sector. Looking at the BIM column along with construction, EXP7 (The individuals who work with BIM manage to perform their daily tasks more effectively) has received the highest mean score of 3.65 out of the responses for BIM exploitation. This means that the majority of the respondents are in agreement that they have greatly been able to perform their daily tasks more effectively. This is the only variable that has received the highest median score of 4.00 out of the mean scores for BIM exploitation. BIM enables more flexibility to design changes or documentation without any hassle to the project team. This reduces the required coordination time and manual checking for errors. This leaves the project team with more time solving real design related problems. This may be the reason why respondents believe that BIM helps to manage daily tasks more effectively. The second highest mean score for construction reports from EXP1 (The senior management of our company gives the required strategic leadership and support on the entire BIM process) and EXP9 (After adopting and diffusing BIM within the organisation, the company is gradually beginning to operate more efficiently than before) record a similar mean score of 3.59. Meaning, the 'average' respondent believes, (or the 'likeliest' response) that the support they receive from senior management on organisational BIM process is greater than the rest of the measures of exploitation. Inspection of construction sector medians for BIM exploitation suggests (EXP7, EXP1. and EXP9: Md= 4.00) that the majority of respondents are in agreement that EXP7, EXP1, and EXP9 are the areas in which they think their organisations have exploited BIM.

Comparing the overall findings for BDA: the retail sector is in the lead. Most respondents in construction believe that their senior management is offering the required leadership to the entire BDA process which enables them to exploit BDA. But concerning the deployment of required resources/ infrastructure to enable BDA use, the manufacturing sector is taking the lead. In the search for the highest mean score in BDA mean scores, the manufacturing sector is perceived to be the sector that is gradually beginning to operate more efficiently than before after using BDA (EXP9). The area in which the finance sector exploits BDA the most is strategic leadership. The respondents from the finance sector believe that their senior managers have understood the value of Big Data Analytics and thus are giving them their utmost support leading to the exploitation of BDA. But the respondents from the retail sector believe that the way they most exploit BDA is through the employees of their organisations. For example, well thought out recruitment of staff with the right skills and training. On the other hand, respondents in the manufacturing sector believe that they are exploiting BDA more on the results side. For example, after adopting and diffusing BDA within their organisation, they have noticed that their company is gradually beginning to operate more efficiently than before. When the average of total statistics is calculated, it is revealing that the extent to which the Construction sector is exploiting BDA is comparatively less than Finance, Retail and Manufacturing. This lays the foundation to seek lessons from these RFM industries and investigate ways they can be applied to construction.

For the exploitation of IoT, the retail sector remarks the highest sum of mean scores. An inspection of the descriptive statistics data for IoT in construction clearly shows that there is no exploitation variable in construction for IoT that reports 4.00 of a median score. However, EXP7 (The individuals who work with IoT manage to perform their daily tasks more effectively, (M= 3.42) and EXP9 (After adopting and diffusing IoT within the organisation, the company is gradually beginning to operate more efficiently than before, M= 3.27) are the ones that have scored highest in terms of mean scores for construction. A considerably lower level of exploitation is reported in construction with regards to IoT exploitation compared to BIM and BDA. Therefore, based on the findings, it appears that the retail sector is accomplishing the expected results by exploiting IoT. The finance sector is exploiting IoT most based on in its results. Creating new uses for its users, an increase in performance efficiency, and leveraging existing individual competencies on technology are the areas in which the respondents from the finance sector are exploiting IoT. The situation is quite different in retail as the exploitation of IoT is influenced by senior management. The individuals who work with IoT in manufacturing companies believe that they extend and leverage their existing individual competencies on technology more than anything else. Looking at the mean of the sum of statistics, it informs that the extent to which Construction has exploited IoT is comparatively less than Finance, Retail and Manufacturing. This also implies that there is room for lessons learned from RFM sectors.

Table 21- Descriptive statistics for BIM, BDA, and IoT Exploitation

	Construct Variables for EXPLOITATION	**Mean Values**											
		Construction			**Retail**			**Finance**			**Manufacturing**		
		BIM	**BDA**	**IoT**	**BIM**	**BDA**	**IoT**	**BIM**	**BDA**	**IoT**	**BIM**	**BDA**	**IoT**
EXP1	The senior management of our company gives the required strategic leadership and support	3.59	3.65	3.26	N/A	3.57	3.67	N/A	3.41	3.36	N/A	3.35	3.50
EXP2	We are deploying required resources/ infrastructure to enable the technology use and they are properly stored in such a way that allows access to all members involved	3.27	3.08	2.83	N/A	3.07	3.00	N/A	2.76	3.14	N/A	3.15	3.36
EXP3	Our technology-specific team is appropriately selected with the right skills and they are receiving proper training	3.32	3.26	3.26	N/A	3.07	3.25	N/A	3.47	3.00	N/A	3.00	3.14
EXP4	We have set realistic technology goals (i.e. short term/ medium term/ long term)	3.27	2.92	3.00	N/A	3.14	3.25	N/A	2.94	3.00	N/A	2.65	3.29
EXP5	We are using appropriate standards and policy initiatives that help selection, execution, and refinement technology workflows	3.27	2.98	2.94	N/A	3.29	3.17	N/A	3.12	2.50	N/A	3.35	3.29
EXP6	The individuals who work with technology typically create new uses for them	3.31	3.05	2.90	N/A	3.43	3.75	N/A	3.18	3.21	N/A	3.30	3.50
EXP7	The individuals who work with technology manage to perform their daily tasks more effectively	3.65	3.25	3.42	N/A	3.50	3.75	N/A	3.18	3.00	N/A	3.65	3.43
EXP8	The individuals who work with technology extend and leverage their existing individual competencies on the technology by incorporating the new system into their regular job role	3.32	3.27	3.13	N/A	3.50	3.75	N/A	3.71	3.07	N/A	3.40	3.71
EXP9	After adopting and diffusing technology within the organisation, the company is gradually beginning to operate more efficiently than before	3.59	3.27	3.27	N/A	3.36	3.75	N/A	3.29	3.14	N/A	3.75	3.29
EXP10	After adopting and diffusing BIM within the organisation, the company embraces new routines and processes to use the system in a better way	3.21	3.10	2.92	N/A	3.21	3.17	N/A	3.18	3.29	N/A	3.05	3.29
	Sum of statistics	**33.8**	**31.83**	**30.93**	**N/A**	**33.14**	**34.51**	**N/A**	**32.24**	**30.71**	**N/A**	**32.65**	**33.80**

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Considering the definition for ‘exploitation’, level of exploitation shows an interesting dynamism between construct variables for exploitation in different sectors. The situation analysis is hence successful in the interest of determining which sector exploits what and to what extent. In an overall observation, for BDA and IoT, the level of exploitation in FRM sectors is higher than in construction. This remarks on the need to explore the best practice lessons learned from the RFM sectors.

Having known the extent to which BIM, BDA, and IoT has been exploited in four sectors, it is worthwhile to check whether the differences between predefined groups are statistically significant. These groups include individual job role; the extent of BIM/ BDA/ IoT use; and years of experience in BIM/ BDA/ IoT. Organisation size-ORGSIZ is comprehensively investigated in Chapter-5 together with exploring likely associations between ORGSIZ and all other variables.

First, to compare the perceptions of BIM exploitation between the senior, middle and lower-level management (Job Role- JOBR) in construction, Kruskal-Wallis H test was utilised. The Kruskal-Wallis H test is a rank-based nonparametric test that can be used to determine if there are statistically significant differences between two or more groups of an independent variable on a continuous or ordinal dependent variable (Gray, 2012). This test allows the comparison of the scores of continuous variables for three or more groups. The reason why Kruskal-Wallis was employed as opposed to the Mann-Whitney U test is that the Mann-Whitney U test only allows the for comparison between two groups. Since all variables of inquiry in comparing groups have more than two groups, the Kruskal-Wallis H test is the most suitable. The hypotheses set for this analysis are as presented below:

HO: the mean ranks of the three groups for BIM exploitation are equal.

HA: the mean ranks of the three groups for BIM exploitation are not equal.

As shown in Table 22, there are no significant differences between the three groups. For example, for EXP1, there is no significant difference ($H = 3.408$, $p = .182$, $df = 2$) found among the three categories of participants (senior, middle level, and lower level management). The null hypothesis is rejected and concludes that medians of all EXPBIM variables are not equal. Even though the null hypothesis (H0) is rejected as a result of all p-values being higher than the significance level of 0.05, there is no statistically significant difference in the way three organisational hierarchies have responded to the extent of BIM exploitation. This means that even though different levels of managers see the organisational BIM exploitation differently, this difference is not statistically significant.

Table 22- Kruskal Wallis Test for BIM exploitation by Job Role

Test Statistics[a,b] for Building Information Modelling (BIM)- Construction										
	EXP1	**EXP2**	**EXP3**	**EXP4**	**EXP5**	**EXP6**	**EXP7**	**EXP8**	**EXP9**	**EXP10**
Kruskal-Wallis H	3.408	1.742	1.302	2.045	2.244	.243	.732	.909	.701	2.644
df	2	2	2	2	2	2	2	2	2	2
Asymp. Sig.	.182	.418	.521	.360	.326	.886	.694	.635	.704	.267
a. Kruskal Wallis Test										
b. Grouping Variable: Please select the category that best describes your current job role- JOBR										

Kruskal-Wallis H test was performed to see whether there was a difference in the way respondents have answered based on their level of experience in BIM. The hypotheses set for this analysis are as presented below:

H0: the mean ranks of the 6 groups of the level of experience for BIM exploitation are equal.

HA: the mean ranks of the 6 groups of the level of experience for BIM exploitation are not equal.

The Kruskal-Wallis H test showed that there was a statistically significant difference in few BIM exploitation variables: EXP1, EXP5, EXP7 and EXP9 between the different groups classified according to years of experience in BIM (Table 23). Interpreting the one with the highest difference (EXP9): $\chi2(2) = 13.371$, $p = .004$, with mean rank exploitation of 37.50 for less than one year, mean rank of 33.07 for 1- 5 years, mean rank of 48.55 for 6-10years and mean rank of 52.41 for 11-20 years. This simply means that there is a statistically significant difference in the way participants have responded for BIM exploitation depending on their years of experience in the above domains. Hence for the aforesaid variables, the null hypothesis (H0) is rejected while the alternative hypothesis is accepted as the differences are statistically significant. This implies that an individual's years of experience do have the potential to make a change in the organisational level of exploitation.

Table 23- Kruskal Wallis Test for BIM exploitation by years of experience

Test Statistics[a,b] for Building Information Modelling (BIM)- Construction										
	EXP1	**EXP2**	**EXP3**	**EXP4**	**EXP5**	**EXP6**	**EXP7**	**EXP8**	**EXP9**	**EXP10**
Kruskal-Wallis H	8.246	6.024	2.897	6.325	10.661	2.981	8.999	5.514	13.371	6.174
df	3	3	3	3	3	3	3	3	3	3

Asymp. Sig.	.041	.110	.408	.097	.014	.395	.029	.138	.004	.103
a. Kruskal Wallis Test										
b. Grouping Variable: How long have you been using Building Information Modelling? BIMEXPERI										

In a similar fashion, the Kruskal-Wallis H test was performed to see whether there was a difference in the way respondents have answered based on respondents' extent of BIM usage. The hypotheses set for this analysis are as presented below:

H0: the mean ranks of the 4 groups of the extent of BIM usage for BIM exploitation are equal.

HA: the mean ranks of the 4 groups of the extent of BIM usage for BIM exploitation are not equal.

As shown in Table 24, the only variable that reports having a significant p-value of less than 0.05 is EXP5- We are using appropriate standards and policy initiatives that help selection, execution, and refinement of BIM workflows. Which means, there is a statistically significant difference in the continuous variable (extent of using appropriate standards and policies that help selection, execution and refinement of BIM workflows) across the four groups of BIM usage extent (Gp1, n= 0: I do not use at all; Gp2, n=5: To a very little extent; Gp3, n=39: To somewhat extent; Gp4, n=41: To a greater extent), X^2 (df=2, n=85) = 11.515, p = .003. An inspection of the mean ranks for EXP5 for the groups suggests that the greatest BIM use group (To a greater extent) had the highest BIM exploitation (mean rank 51.67) with the lowest BIM use group (33.50) reporting the lowest. The greatest BIM use group in EXP5 (to a greater extent) recorded a higher median score (Md= 4.00) (Table 24) than the other two groups, which both recorded median values of 3.00. For all other continuous variables, there is no statistically significant difference across four groups of BIM usage extent. Hence, for EXP5, the null hypothesis (H0) is rejected.

Table 24- Kruskal Wallis Test for BIM exploitation by the extent of BIM use

Test Statistics[a,b] for Building Information Modelling (BIM)- Construction										
	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6	EXP7	EXP8	EXP9	EXP10
Kruskal-Wallis H	3.433	3.434	1.837	3.664	11.515	1.906	4.655	1.560	4.090	3.283
df	2	2	2	2	2	2	2	2	2	2
Asymp. Sig.	.180	.180	.399	.160	.003	.386	.098	.458	.129	.194
a. Kruskal Wallis Test										
b. Grouping Variable: Please select the extent to which you use BIM as a part of your current job role-UBIMEXT										

The important take-aways from this section of analysis are:
In Construction, although job role does not make any difference for the way firms exploit BIM, it was determined that there are no statistically significant differences between three groups of the job role for the level of BIM exploitation. Significant differences were found across years of BIM experience with strategic leadership, using appropriate standards, effectiveness in daily tasks, and setting realistic targets, and efficiency. Such differences were also found between the groups of the extent of BIM use. Thus, an individual's experience in BIM and the extent to which BIM is being used by everyone could make a difference in organisations' BIM exploitation levels.

After discovering whether there is a significant difference in the way firms exploit BIM in construction depending on different groups, it is obligatory to perform the same analyses for BDA and IoT. For these analyses, a side-by-side comparison of four sectors is performed. To check whether there are any statistically significant differences between the groups (individual job role- JOBR; the extent of BDA/IoT use- UBDAEXT/UIOTEXT; and years of experience in BDA/IoT- BDAEXPERI/IOTEXPERI), Kruskal-Wallis H test was utilised. Organisation size- ORGSIZ is comprehensively investigated in Chapter-5 together with exploring likely associations between ORGSIZ and all other variables. The hypotheses set for this analysis are as presented below:

HO: the mean ranks of the three groups for BDA exploitation are equal.

HA: the mean ranks of the three groups for BDA exploitation are not equal.

Table 25 reveals the results for the level of exploitation related to BDA. To have a significant difference in the results across three groups, the p-value must be less than 0.05. In construction, it can be grasped that there is no significant difference (Ex: EXP1: $H = 1.937$, $p = .380$, $df = 2$) found among the three categories of participants (senior, middle level and lower level management). Further, all p-values in construction are higher than the significance level of 0.05, it could be deduced that medians of all exploitation variables for construction are not equal hence null hypothesis is rejected. Even though the null hypothesis (H0) is rejected, there is no statistically significant difference in the way the three organisational hierarchies have responded to the extent of BDA exploitation in construction. However, the Retail sector shows a significance in EXP8 while Manufacturing shows a significant p-value in EXP1 and EXP3. This means that in retail, depending on the level of job role, the extent to which certain job levels who work with technology manage to perform their daily tasks more effectively than others.

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Table 25- Kruskal Wallis Test for BDA exploitation by Job Role

Test Statistics^{a,b} for Big Data Analytics (BDA)											
Sector		**EXP1**	**EXP2**	**EXP3**	**EXP4**	**EXP5**	**EXP6**	**EXP7**	**EXP8**	**EXP9**	**EXP10**
Construction Sector	Kruskal-Wallis H	1.937	1.017	0.294	0.815	0.938	2.513	1.4	1.292	2.518	4.108
	df	2	2	2	2	2	2	2	2	2	2
	Asymp. Sig.	0.38	0.601	0.863	0.665	0.626	0.285	0.496	0.524	0.284	0.128
Retail Sector	Kruskal-Wallis H	0.813	0.208	1.267	0.098	1.264	2.986	4.524	6.894	3.307	1.168
	df	2	2	2	2	2	2	2	2	2	2
	Asymp. Sig.	0.666	0.901	0.531	0.952	0.532	0.225	0.104	0.032	0.191	0.558
Finance Sector	Kruskal-Wallis H	0.735	0.375	0.079	3.803	1.735	2.331	0.658	1.024	4.262	2.689
	df	2	2	2	2	2	2	2	2	2	2
	Asymp. Sig.	0.693	0.829	0.961	0.149	0.42	0.312	0.72	0.599	0.119	0.261
Manufacturing Sector	Kruskal-Wallis H	6.37	1.008	8.746	0.131	4.593	0.976	0.805	0.735	2.052	1.239
	df	2	2	2	2	2	2	2	2	2	2
	Asymp. Sig.	0.041	0.604	0.013	0.937	0.101	0.614	0.669	0.692	0.359	0.538
a. Kruskal Wallis Test											
b. Grouping Variable: Please select the category that best describes your current job role- JOBR											

Thereafter, the Kruskal-Wallis H test was performed to see whether there was a difference in BDA exploitation based on respondents' years of experience. The questionnaire used 6 groups of years namely: not at all; less than one year; 1- 5 years; 6-10 years; 11-20 years and more than 20 years. The hypotheses set for this analysis are as presented below:

H0: the mean ranks across 6 groups of years of experience for BDA exploitation are equal.

HA: the mean ranks across 6 groups of years of experience for BDA exploitation are not equal.

The Kruskal-Wallis H test showed that there was a statistically significant difference in EXP4 (We have set realistic Big Data goals (i.e. short term/ medium term/ long term) across six different groups (in construction) classified according to years of experience in BDA (Table 26). Interpreting the one which has this significance, (EXP4): $\chi2(2) = 9.099$, $p = .028$, df=3, with mean rank exploitation of 23.24 for less than one year, 30.88 for 1- 5 years, 32.25 for 6-10years and 47.63 for

11-20 years. This simply means there is a statistically significant difference in the way participants have responded for BDA exploitation in construction depending on their years of experience. Hence the null hypothesis (H0) is rejected, with EXP4 in construction being significant.

EXP6, EXP7, and EXP8 in Retail show a statistically significant difference (Table 26) depending on respondents' years of experience. EXP8 is the only variable in Manufacturing that rejects the null hypothesis whereas, in Finance, EXP1, EXP5, and EXP6 are the ones that show a significant difference influenced by respondents' years of experience in BDA.

Table 26- Kruskal Wallis Test for BDA exploitation by years of experience

Test Statistics[a,b] for Big Data Analytics (BDA)											
ORGSEC		**EXP1**	**EXP2**	**EXP3**	**EXP4**	**EXP5**	**EXP6**	**EXP7**	**EXP8**	**EXP9**	**EXP10**
Construction Sector	Kruskal-Wallis H	6.595	4.004	4.155	9.099	5.203	2.132	4.499	2.434	3.194	1.794
	df	3	3	3	3	3	3	3	3	3	3
	Asymp. Sig.	0.086	0.261	0.245	0.028	0.158	0.545	0.212	0.487	0.363	0.616
Retail Sector	Kruskal-Wallis H	0.203	1.471	0.079	3.507	0.316	4.688	6.617	4.504	2.006	1.077
	df	1	1	1	1	1	1	1	1	1	1
	Asymp. Sig.	0.652	0.225	0.779	0.061	0.574	0.030	0.010	0.034	0.157	0.299
Finance Sector	Kruskal-Wallis H	4.898	2.239	0.529	2.788	4.886	5.088	3.363	0.025	2.292	1.687
	df	1	1	1	1	1	1	1	1	1	1
	Asymp. Sig.	0.027	0.135	0.467	0.095	0.027	0.024	0.067	0.873	0.130	0.194
Manufacturing Sector	Kruskal-Wallis H	3.760	2.735	1.433	4.356	1.154	2.368	2.446	6.531	1.371	3.354
	df	2	2	2	2	2	2	2	2	2	2
	Asymp. Sig.	0.153	0.255	0.489	0.113	0.562	0.306	0.294	0.038	0.504	0.187
a. Kruskal Wallis Test											
b. Grouping Variable: How long have you been using Big Data Analytics? BDAEXPERI											

In the same manner, the Kruskal-Wallis H test was performed to see whether there was a difference in the way respondents have exploited BDA across different extents of BDA usage based on respondents' experience in BDA. The hypotheses set for this analysis are as presented below:

H0: the mean ranks of the 4 groups of the extent of BDA usage for BDA exploitation are equal.

BIM, BDA and IoT exploitation and their leads to competitive advantage

HA: the mean ranks of the 4 groups of the extent of BDA usage for BDA exploitation are not equal.

As shown in Table 27, the only variable that reports having a significant p-value of equal or less than 0.05 in construction is EXP1- The senior management of our company gives the required strategic leadership and support on the entire Big Data Analytics process. Which means, there is a statistically significant difference in the continuous variable (extent to which senior management provide their leadership) across the four groups of BDA usage extent (Gp1, n= 0: I do not use at all; Gp2, n=14: To a very little extent; Gp3, n=29: To somewhat extent; Gp4, n=16: To a greater extent), X^2 (df=2, n=59) = 5.967, p = .050 (Table 27). At p= 0.05, the differences between the four groups have only a 5% probability of occurring by chance alone. An inspection of the mean ranks for EXP1 for the groups suggests that the greatest BDA use group (To a greater extent) had the highest BDA exploitation (mean rank 37.00) with the lowest BDA use group (22.57) reporting the lowest. The greatest BDA use group in EXP1 (to a greater extent) recorded a higher median score (Md= 4.00) (Table 27) than the other two groups, which both recorded median values of 3.00.

In Retail, EXP6, EXP7, and EXP8 show a statistical significance while in Finance EXP1, EXP2, EXP7, and EXP9 are statistically significant. Lastly, none of the construct variables in Manufacturing were statistically significant in the search of respondents' opinions on the firm-level of exploitation based on individual BDA use.

Table 27- Kruskal Wallis Test for BDA exploitation by the extent of BDA use

Test Statistics^{a,b} for Big Data Analytics (BDA)											
ORGSEC		**EXP1**	**EXP 2**	**EXP 3**	**EXP 4**	**EXP 5**	**EXP 6**	**EXP 7**	**EXP 8**	**EXP 9**	**EXP1 0**
Construction Sector	Kruskal-Wallis H	5.967	2.79	1.08	4.801	1.862	1.032	2.311	1.732	1.114	2.718
	df	2	2	2	2	2	2	2	2	2	2
	Asymp. Sig.	0.05	0.248	0.583	0.091	0.394	0.597	0.315	0.421	0.573	0.257
Retail Sector	Kruskal-Wallis H	0.203	1.471	0.177	3.507	1.264	4.688	6.617	4.504	2.006	0.077
	df	1	1	1	1	1	1	1	1	1	1
	Asymp. Sig.	0.652	0.225	0.674	0.061	0.261	0.030	0.010	0.034	0.157	0.782
Finance Sector	Kruskal-Wallis H	10.171	9.240	0.889	2.019	4.080	5.543	9.756	2.967	6.933	5.543
	df	2	2	2	2	2	2	2	2	2	2
	Asymp. Sig.	0.006	0.010	0.641	0.364	0.130	0.063	0.008	0.227	0.031	0.063

Manufacturing Sector	Kruskal-Wallis H	2.942	0.297	1.671	0.623	1.366	0.713	4.153	1.155	2.324	2.707
	df	2	2	2	2	2	2	2	2	2	2
	Asymp. Sig.	0.230	0.862	0.434	0.732	0.505	0.700	0.125	0.561	0.313	0.258
a. Kruskal Wallis Test											
b. Grouping Variable: Please select the extent to which you use BDA (Big Data Analytics) as a part of your current job role- UBDAEXT											

The important take-aways from this section of analysis are:
In Construction, it was determined that there are no statistically significant differences between the three groups of the job role for the level of BDA exploitation. However, such differences were found across years of BDA experience (only with setting realistic targets) and across the range of extent of BDA use (only with strategic leadership).

Based on the above takeaways, it is convincing that individual experience in the use of BDA and the extent to which individuals use BDA can make a significant change in the extent to which organisations exploit BDA. This has been incorporated into the strategic framework.

After perceiving whether there were statistically significant differences between two or more groups of an independent variable (s) on BDA exploitation, it is then worthwhile to perform the same analyses for IoT exploitation. First, the three groups of independent variable- JOBR was presented for the inquiry. The likely associations between ORGSIZ and all other variables are comprehensively analysed in Chapter-5. The hypotheses set for this analysis are presented below:

HO: the mean ranks of the three groups for IoT exploitation are equal.

HA: the mean ranks of the three groups for IoT exploitation are not equal.

The Kruskal-Wallis H test (Table 28) showed that there was a statistically significant difference in IoT exploitation (in construction) between the three different organisation roles (senior, middle and lower) in particularly EXP4, EXP5 and EXP6 in descending order ($P > 0.05$). Interpreting the one with the highest difference: IMPIOT4 (setting realistic IOT goals): $\chi 2(2) = 8.192$, $p = .017$, df=2 with a mean rank exploitation score of 25.06 for Senior Management, 34.04 for Middle-level Management and 11.17 for Lower-level Management. This means, at $p= 0.017$, the differences between the four groups have 1.7% probability of occurring by chance alone. Hence the null hypothesis is rejected particularly for EXP4, EXP5, and EXP6, as there are significant differences across three JOBR groups. Results for RFM sectors reveal that only EXP6 shows a statistically significant difference between the three job role groups in Manufacturing on IoT exploitation.

Table 28- Kruskal Wallis Test for IoT exploitation by Job Role

Test Statistics[a,b] for the Internet of Things (IoT)											
ORGSEC		**EXP1**	**EXP2**	**EXP3**	**EXP4**	**EXP5**	**EXP6**	**EXP7**	**EXP8**	**EXP9**	**EXP10**
Construction Sector	Kruskal-Wallis H	0.684	0.341	2.516	8.192	6.85	6.417	2.847	1.381	4.589	3.049
	df	2	2	2	2	2	2	2	2	2	2
	Asymp. Sig.	0.71	0.843	0.284	0.017	0.033	0.04	0.241	0.501	0.101	0.218
Retail Sector	Kruskal-Wallis H	2.200	0.000	1.883	0.570	0.166	1.059	3.667	3.667	3.667	0.930
	df	2	2	2	2	2	2	2	2	2	2
	Asymp. Sig.	0.333	1.000	0.390	0.752	0.920	0.589	0.160	0.160	0.160	0.628
Finance Sector	Kruskal-Wallis H	2.762	2.215	0.000	2.167	0.991	1.051	1.444	0.599	2.889	0.173
	df	2	2	2	2	2	2	2	2	2	2
	Asymp. Sig.	0.251	0.330	1.000	0.338	0.609	0.591	0.486	0.741	0.236	0.917
Manufacturing Sector	Kruskal-Wallis H	2.971	2.889	3.987	1.403	1.898	10.214	0.799	2.763	4.051	5.663
	df	2	2	2	2	2	2	2	2	2	2
	Asymp. Sig.	0.226	0.236	0.136	0.496	0.387	0.006	0.671	0.251	0.132	0.059
a. Kruskal Wallis Test											
b. Grouping Variable: Please select the category that best describes your current job role- JOBR											

Kruskal-Wallis H test was performed to determine if there were statistically significant differences between 6 sub-groups of the independent group variable- 'years of experience in IoT- IOTEXPERI' (Table 29). The hypotheses set for this analysis are presented below:

H0: the mean ranks of the 6 groups of the level of experience for IoT exploitation are equal.

HA: the mean ranks of the 6 groups of the level of experience for IoT exploitation are not equal.

The Kruskal-Wallis H test revealed that there was no statistically significant difference in IoT exploitation variables across the 6 groups of the level of experience in construction and retail; as none of the p-values are equal or less than 0.05 (Table 29). However, EXP2, EXP4, EXP7, and EXP8 show significant differences in finance sector as the Sig. values are less than 0.05. The null hypothesis is therefore rejected for those variables only. This means that the years of experience respondents have on IoT has an influence in different levels of IoT exploitation in firms.

Table 29- Kruskal Wallis Test for IoT exploitation by years of experience

Test Statistics[a,b] for the Internet of Things											
ORGSEC		**EXP1**	**EXP2**	**EXP3**	**EXP4**	**EXP5**	**EXP6**	**EXP7**	**EXP8**	**EXP9**	**EXP10**
Construction Sector	Kruskal-Wallis H	1.034	1.155	1.952	2.356	0.03	2.748	0.26	0.823	1.926	0.178
	df	2	2	2	2	2	2	2	2	2	2
	Asymp. Sig.	0.596	0.561	0.377	0.308	0.985	0.043	0.878	0.663	0.382	0.915
Retail Sector	Kruskal-Wallis H	5.500	0.000	0.400	1.222	4.458	3.667	3.667	1.222	1.222	0.792
	df	2	2	2	2	2	2	2	2	2	2
	Asymp. Sig.	0.064	1.000	0.819	0.543	0.108	0.160	0.160	0.543	0.543	0.673
Finance Sector	Kruskal-Wallis H	1.015	10.689	5.417	7.944	3.375	1.663	8.667	6.598	4.153	3.209
	df	2	2	2	2	2	2	2	2	2	2
	Asymp. Sig.	0.602	0.005	0.067	0.019	0.185	0.435	0.013	0.037	0.125	0.201
Manufacturing Sector	Kruskal-Wallis H	1.651	4.574	0.350	2.341	1.088	1.857	3.619	1.246	1.403	2.653
	df	2	2	2	2	2	2	2	2	2	2
	Asymp. Sig.	0.438	0.102	0.839	0.310	0.581	0.395	0.164	0.536	0.496	0.265
a. Kruskal Wallis Test											
b. Grouping Variable: How long have you been using Internet of Things? IOTEXPERI											

Very much correspondingly to IoT exploitation by years of experience, the Kruskal-Wallis H test which was carried out also revealed that there were only a few statistically significant differences in IoT exploitation variables across the 4 groups of the extent of IoT use. They are: EXP3, EXP7 in Finance and EXP2, EXP7 in Manufacturing (Table 30). Therefore, the null hypothesis (H0) is rejected for those above variables in Finance and Manufacturing.

Table 30- Kruskal Wallis Test for BDA exploitation by the extent of IoT use

Test Statistics[a,b] for the Internet of Things (IoT)											
ORGSEC		**EXP1**	**EXP2**	**EXP3**	**EXP4**	**EXP5**	**EXP6**	**EXP7**	**EXP8**	**EXP9**	**EXP10**
Construction Sector	Kruskal-Wallis H	1.316	1.886	0.037	3.05	2.37	2.193	0.029	0.03	0.316	0.619

	df	2	2	2	2	2	2	2	2	2	2
	Asymp. Sig.	0.018	0.389	0.982	0.218	0.306	0.334	0.985	0.985	0.854	0.734
Retail Sector	Kruskal-Wallis H	0.516	0.000	1.913	1.833	2.615	0.407	1.833	1.833	1.833	2.615
	df	2	2	2	2	2	2	2	2	2	2
	Asymp. Sig.	0.773	1.000	0.384	0.400	0.271	0.816	0.400	0.400	0.400	0.271
Finance Sector	Kruskal-Wallis H	0.701	3.487	7.429	1.006	0.548	5.121	6.397	2.982	0.181	1.265
	df	2	2	2	2	2	2	2	2	2	2
	Asymp. Sig.	0.704	0.175	0.024	0.605	0.760	0.077	0.041	0.225	0.914	0.531
Manufacturing Sector	Kruskal-Wallis H	0.475	6.529	0.474	2.823	1.061	0.371	7.622	2.990	0.594	0.760
	df	2	2	2	2	2	2	2	2	2	2
	Asymp. Sig.	0.789	0.038	0.789	0.244	0.588	0.831	0.022	0.224	0.743	0.684
a. Kruskal Wallis Test											
b. Grouping Variable: Please select the extent to which you use IoT as a part of your current job role - UIOTEXT											

The important take-aways from this section of analysis are:

The individual Job role has some level of influence on the IoT exploitation levels within firms in construction. This influence was significant towards setting IoT goals, using appropriate standards, and creating new uses for individuals. As with BIM and BDA there was a statistically significant difference in exploitation levels between the different levels of IoT experience and different extent of IoT use in construction. Considering the commonalities between BIM, BDA, and IoT the strategic framework was updated (see Figure 28*).*

4.2.3.2 Qualitative data analysis for BIM, BDA and IoT exploitation- comparison of four sectors

Semi-structured interviews were carried out with professionals in four sectors with similar question areas as presented in the quantitative study. The two main requirements of qualitative analysis are: capturing the alternative interpretations for BBI exploitation and capturing the possible lessons learned from RFM sectors on the strategic exploitation of BDA and IoT for competitive advantage of the construction industry.

Content analysis was employed (using NVivo version 12) in analysing the data to unravel themes emerging from the peoples' perception towards, level of exploitation, benefits, challenges, and competitive advantages. The content analysis fosters developing analytic constructions of the data to examine patterns in communication in a replicable and systematic manner; especially in technology innovation studies, when a deep exploration to a phenomenon is required (Howard and Björk, 2008). One of the key advantages of using content analysis is the ability to analyse social phenomena in its own non-invasive nature, in contrast to simulating social experiences or collecting survey answers (Goulding, 2002). These analytic data constructs are then used towards the creation of evidence-based categories and then the relationships between key categories are analysed. The data were collected from the perceptions of participants emerging from their experience/ observations in organisational contexts.

First, 'initial open coding' was carried out to establish different themes that emerge in large quantities of qualitative data. Second, 'focused (or selective) coding' was carried out to summarise the pre-identified open coded themes n to categories. 'Axial coding' is the third step followed to develop themes of higher abstraction levels. Finally, core categories are developed by studying the content of underlying categories and codes emerging from axial coding. If recurrent themes/issues were found, then they were followed-up on which can, and often, does lead grounded theorists in unanticipated directions. When using 'content analysis' in a social constructionist stance, the questions continually raised include: "How?“; "Why?“; "Under which conditions?“; "With which consequences?" "How do people construct beliefs?"; "How do they manage the claimed circumstances?"; "Why do they think, feel, and act the way that they do?"; "Under which conditions do they think, feel, and act that way?"; "What are the consequences of their beliefs, feelings, and actions?" (Charmaz, 1990). These questions were raised when analysing data in the first step- open coding. The first step- 'open coding' was conducted, as much as possible, in such a way that the codes and categories reflect emerging ideas rather than merely describing topics. A major strength of the grounded theory method is the fact that it involves open-ended and flexible questions (Charmaz, 1990). This was reinforced as analysis and data collection moved along simultaneously allowing the researcher to follow up on ideas at the same time as they are created. The subsequent chapters explain the ideas that emerged from the data (broken down into constantly refining series of questions) when proceeding with the Grounded Theory approach.

The questions (asked in the interviews) related to this chapter include the following:

1. *Please can you describe the extent to which your company is using BIM/BDA/IoT if at all?*

- *(if no), what do you think about the companies that use BIM, BDA/IoT?*
- *(If no), is there a reason that prevents your company from using BIM/BDA/IoT?*

2. *Can you please explain to me how BIM/BDA/IOT exploitation has been realised in your company? Has it planned and implemented strategies to achieve some specific business goals? (strategic, tactical, operational, and short, medium, long-term)*

3. *Does employing BIM/BDA/IoT provide a competitive advantage to your company over your peer competitors?*

- *(If yes), how has it given your company a competitive advantage? Can I ask you to kindly explain that with a few examples please if any?*
- *(if no), If not for competitive advantage, are there any other reasons for your company to use BIM/BDA/IoT?*

In line with the three questions above, Question 1 and Question 2 were analysed in this section. Thus, the exploitation of BIM, BDA, and IoT in construction was first analysed. All 25 respondents that were interviewed mentioned that their companies do show some form of BIM use. When the level of exploitation was questioned, they described how they believe that their companies exploit BIM in different ways. It is convincing that exploitation can mean many things concerning the depth and breadth of the use. While some participants explained the number of projects in which they use BIM, some explained the certification/ awards they received from the accepted bodies:

> *'We use BIM in almost all our projects. Our company is claimed to be one of the first companies in the world to be awarded the BIM accreditation, which will enable us to demonstrate compliance with BIM standards internationally. We use BIM across a wide range of sectors, including in the residential, infrastructure, retail, education, and art markets. We have reached BIM level-2 but that is only the first step"*

Some of the respondents highlighted their exploitation level as to the way they currently operate BIM/ BDA/ IoT in the delivery process. The fact they emphasised is that the extent to which a firm exploits the technology or not is not merely an adoption but the way it is embedded into the organisational operations.

> *"We have fully integrated BIM into our business with an inspired initiative. "Digital Engineering" is not just for specialists, but rather all members of staff. We are using it not only for the design but also for the procurement process, tendering process and post-contract process as well"*

A considerable amount of opinion was received from interviewees in favour of how BIM helps perform daily tasks more effectively. Out of the 25 interviews conducted in construction, 8 interviewees see their organisations as operating towards BIM 'exploitation' (according to the definition given by the researcher/ interviewer). Moreover, they see the effectiveness that BIM has offered in their daily tasks in different ways. Some see that BIM improves effectiveness by 'helping to create more unified delivery teams while allowing the supply chain to see beyond their activities to a more holistic view of the client's objectives' (I-6) while some see the achievement of BIM Level-2 maturity as an enabler, making their daily tasks more effective (I-1).

The analysed semi-structured interview data realised that opinions given by interviewees are quite complex compared to the constituents established in the questionnaire survey. Out of the 25 interviews conducted in construction, every viewpoint was different from each other in terms of big data exploitation'. For example, I-1 believes that his company is exploiting big data mainly because they are trying to combine different data sets by successfully managing information to get the value of the data integration and analytic-pieces coming together within there. On the other hand, I-2 states that the company he works for does not use the term 'big data', instead, they use large piles of information to look at patterns of use, space utilisation and analysing data to create useful information for them to make business decisions, and he believes that to be the exploitation of data. I-14 holds a different perspective as his company is effectively using big data for its macro-enabled dashboards. However, 4 out of 15 interviewees (from construction) mentioned that they receive the required support and guidance from senior leadership although they do not see their companies as exploiting the technology in the highest form.

Almost all the interviewees believe that their companies are on the journey of making sense of IoT systems but that they have not, to date, fully exploited IoT. This resembles the quantitative data that reports no significant median score equal to 4.00. However, almost all interviewees mentioned that they use IoT in some form. Two interviewees mentioned that they use the Internet of things integrated with BMS in every building project they do. I-11 revealed that their company is slowly buying into the idea of 'connected devices' and it makes their day-to-day tasks more efficient and effective as IoT has been useful in supply replenishment, remote operation, Construction Tools and Equipment Tracking, Equipment Servicing and Repair-Sensors in machines and Power and Fuel Savings. Three more interviewees (I-14, I-17, I-19) took the same stance, that IoT has enabled long term savings in some areas of operation.

Table 31 summarises all codes that were analysed concerning Question 1 from the data collected from 25 interviewees in construction. The data were analysed using NVivo. This gives an understanding of what exploitation means in practice, especially on what basis interviewees claim that their organisations exploit BIM/ BDA/ IoT.

Table 31- Coding for the extent of BIM/BDA/ IoT exploitation in the construction

Open coding	**Category**
'the extent of exploitation- on what basis?'	

•number of projects BIM/BDA/IoT is being applied (or capital projects) •being an early adopter •diversity of application (different sectors) •Number of schemes that possess BIM deliverables •Being an industry-leading company in terms of BIM use	**Adoption rate**
•Maturity level achieved •compliance with BIM/BDA/IoT standards •Firms being BIM verified by acceptable bodies •Having an award-winning BIM/BDA/IoT projects	**Accreditation**
•Having dedicated BIM/BDA/IOT champion for every project •Having a highly BIM/BDA/IOT -skilled workforce •Availability of up-to-date software, hardware, and equipment •Availability of training and education for BIM/ BDA/IoT	**Input Capacity**
•Gaining efficiencies out of BIM/BDA/IoT •Ability to deliver BIM/BDA/IoT projects according to client requirements •Level of benefits experienced out of BIM/BDA/IoT •Number of company KPIs met with BIM/BDA/IoT •fully reap the benefits associated with the long-term asset management not only the contractors but also clients	**Degree of output achievement**
•The quality of data management for effective decision making •not limiting to creating models but seeking unlocking knowledge and insight, creating the platform for true collaboration •Integrating (fully) building data to develop efficient methods of delivery and operation •the ability to build and connect the 'virtual' world of BIM to the real world •Make BIM/BDA/IoT available not just for specialists, but rather all members of staff •Digitising work in such a way that it applies to our health and safety business plus environmental business •Generation of information at the end that helps decision making •Building both capability and capacity for BIM/BDA/IoT maturity •applying BIM/BDA/IoT smart city approach and realising wide-ranging social, economic, and environmental benefits.	**Effectiveness of the operational process**

•helping other people in the supply chain to get to use their information more effectively •successfully demonstrating the ability to exchange models efficiently and effectively with other consultants and contractors. •more off-site manufacturing •creating a new set of rules for BIM/BDA/IoT •ability to deliver projects from inception to completion. •Using BIM not only for the design but also for procurement, tendering, and post-contract process •Collaborating with other disciplines and to share models developed the design and execution of schemes •using BIM/ BDA/ IoT for enhanced multi-disciplinary approach within project delivery •Creating an industry-leading common data environment (CDE) to be fully BS 1192-compliant •The extent to which making BIM business as usual. •Embedding BIM/BDA/IoT across the business as part of how people work •Working with leading digitally oriented companies •involvement of online and face-to-face training suite tailored specifically to each employee's role and level of competency	

Drawing from the themes emerging from the interviews (in Table 31), it can be deduced that the way firms in construction exploit BIM, BDA and IoT can be categorised into six broad categories inter alia: 1) Adoption rate, 2) Accreditation, 3) Input capacity, 4) Effectiveness of the operational process, 5) Degree of output achievement, and 6) Age of adoption. These were incorporated in the framework development.

The coding was extended to 'selective coding' and 'axial coding' to see what else would emerge from this question. Thus, the answers revealed the following categories and themes as well:

- what influenced or enabled the use of BIM/BDA/IoT (government push, client demand, increased competitiveness, the requirement for transparency, survival in the market)
- what are the benefits and challenges/barriers associated with BIM/BDA/IoT (core and custom benefits/ challenges; process related, people related, technology-related)

Once the level of exploitation was appreciated, the same population of construction was questioned with the strategic influence they have towards BIM/ BDA/ IoT exploitation (***Question 2)***. Most of the interviewees identified the 'development of a business case/ business model as a critical driver to initiate the strategic approach towards BIM/ BDA/ IoT. This business case must have a focus on the value added to the lifecycle of a built asset: design, construction, and operation phases. Table 32 below presents a summary of these qualitative findings via open coding and selective coding.

Table 32- Selective coding for strategic influence

Open and Selective coding	Key Themes
'strategic influence on BIM/BDA/IoT exploitation'	
having the right data, the right processes, and the right culture	Resource allocation and structuring
tailored to meet the requirements of our clients.	Understanding and meeting client requirements
Focusing on changing the surrounding environment with easier systems rather than changing the people	Resource allocation and structuring
partnering with industry leaders.	Building internal and external partnerships
Establishing a unique in-house consultancy and external consultancy team as well.	Mobilisation
Research & development	Review and control
Training and upskilling, creating champions	Resource allocation and structuring
Collaborating with professional bodies within the industry (i.e. UK BIM Alliance)	Building internal and external partnerships
Collaborating with academics and supply chains to identify new ways of working.	Building internal and external partnerships
Following the right standard protocol	Mobilisation
Fully engage with the client and understand their technology requirements	Understanding and meeting client requirements
Recognising the value and benefit (internal and external) of implementing a technology process	Development of a business case

Recognise the need for a definitive technology plan to support delivery, drive efficiencies, and profitability through the business whilst reducing risk and adding value on the projects we deliver.	Development of a business case
Evaluate the capability of consultants and supply chain as a prerequisite to implementation	Resource allocation and structuring
Cultural change- change of behaviours, attitudes, and beliefs.	Resource allocation and structuring
Creating a road map to see where we are now and where we want to be in the next few years. Identify how much we gain from it in return for the investment- the business case	Setting the strategic objectives
Setting- up a cross-office network to share ideas and knowledge and develop a standard set of templates.	Building internal and external partnerships
Implementation of technology is deemed beneficial to delivery where BIM is to be used.	Development of a business case
Improving awareness for the technologies	Resource allocation and structuring

It is conspicuous that although the strategic approach to exploit technologies varies from firm to firm, the fundamentals of their strategic approach shows some similarities. The analysis captures these similarities and then categorises them into some common themes. These include: 1) Development of a business case, 2) Building internal and external partnerships, 3) Setting the strategic objectives, 4) Resource allocation and structuring, 5) Understanding and meeting client requirements. 6) Mobilisation and 7) Review and control.

The same ***Question-2*** was asked of the Retail, Finance, and Manufacturing sectors, and this section analyses and presents these qualitative data. Considering the synergistic view of BDA and IoT, the theme most commonly discussed among the RFM professionals, which can also be counted as a lesson learned from RFM sectors is the organisational 'strategy' towards competitive advantage for the exploitation of BDA and IoT. The subsequent section explains this 'strategic influence with quotes from the interviewees. Further, the theme 'strategy' has influenced the development of the conceptual strategic framework promoting the synergistic concept of BIM, BDA, and IoT (BBI).

To identify the possible themes coming out of the data and to analyse the most frequently used word nodes, 'Coding query' and 'text search query' were employed. NVivo version 12 was utilised to get all content coded to case nodes with required attributes. The searches resulted with Word-clouds, Tree-maps, and Cluster analyses. Among these outputs, cluster analysis was quite useful in identifying the words that co-occur, as they are clustered together. The number of references for each theme were also displayed during this query. Among the outputs provided by text search querying, Word Tree was useful in exploring the contexts in which each word or phrase occurs (Figure 18). The word tree displays the results as a tree with branches representing the various contexts in which the word or the phrase occurs. This allowed for finding the recurring themes or phrases that surround the word of inquiry. The subsequent paragraphs describe the aspects of 'lessons learned' from the Retail, Finance, and Manufacturing sectors in order.

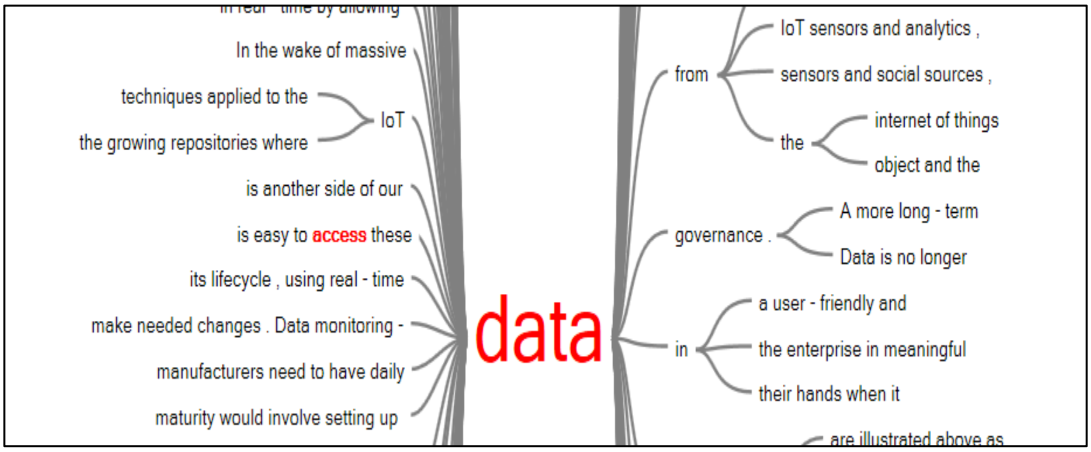


Figure 18- Word Tree resulted from a text search query for data access

Many of the RFM interviewees were in agreement that *Access to data* is a key factor in the development of Big data strategy (I-42, I-40, I-38). Having direct access to customer data comes with great responsibility. At a time where customer data is fast becoming very personal, maintaining the customer data's safety and security is crucial. Once the access to data is obtained, the data must be captured and understood to produce valuable insights. To this end, identifying initial patterns using data visualisations and identifying the core determinates of process performance using correlation analysis are useful analytical techniques (I-33, I-36, I-38, I-40, I-42). Hypothesis significance tests, and artificial neural networks are some other analytical techniques that would help to derive insights (I-39, I-41). The analytical side of data was mentioned by participants from Manufacturing (I-27, I-30) and Retail (I-32, I-35, I-36) as well. Having the right access to data helps to make the service more personalised and that is an important enabler mentioned by almost all six manufacturing interviewees (I-38, 1-39, I-40, I-41, 1-42, I-43). Further, data access and analytical tools applied to a larger cross-section of the enterprise, both in terms of across functions and across designations was also emphasised (I-41). Operational Intelligence is another striking point that goes along with making valuable insights out of big data. This entails, capturing product knowledge before it is lost. Maintaining large volumes of structured data and archiving them for future use serves as an aid to ensure that the mistakes which were made in the past are not repeated. Operational intelligence is a must-consider aspect when deciding on the right analytical technique. Thus, ‘access to data’ and ‘appropriate data analytics’ were selected as a part of the strategy formulation taken forward for the final strategic framework.

Data Democratization and data integration are other aspects that help to move away from the siloes. A move from a feudalistic model of access to data, to a more democratic method was a need highlighted by many of them. The service capacity of new and advanced machinery- equipment is limited when they are operated in silos. Value comes from connecting and analysing large volumes of data originating from data points spread across the whole production process. A fully connected production system enables the creation of fully automated production lines. Benefits of this connectedness are exponentially greater than silo-robotics or traditional production systems. To that end, the ability of computer systems or software packages to exchange data streams with each other and make use of those data is important. This was viewed in the lens of IoT, which is all about the connection between computing devices and cloud which enables data integration. Any company that is working on an IOT system may need to integrate multiple services within the same project, and possibly with third-party APIs. With IoT, this aspect of development becomes more complex and crucially important. There must be an integrating role to see the bigger picture and make sure integration runs smoothly. This can be resolved by assigning a dedicated integration specialist. The integration specialist is responsible for understanding and documenting the complete flow of interaction between cloud and mobile app development.

The data analysis also discovered new uses and/ or opportunities for individuals who use the technologies. While at certain times this will naturally result as a part of the process, in some circumstances the data handler must purposely look for *new uses*. This is the only way to *continuously improve* the data management. Once the IoT technology is proven, the next stage is to identify opportunities to improve organisational growth (i.e. improve efficiency to meet demands). Once a clear growth path is created, the next stage is to find ways to obtain further benefits (i.e. cost savings). Then expand from there to additional forms of data and perform analytics that contribute to top-line revenue in maximising a competitive edge. Continuous improvement is, therefore, a key to success.

Once the data were harnessed to generate valuable insights, enabling a higher level of maturity in big data strategy would involve setting up data-sharing and analysing sandboxes with key business partners, vendors, and even customers by building up a collaborative business partnership (I-41, I-43). This has been highlighted by many interviewees from all sectors including construction (I-43, I-44, I-27, I-32, I-33, I-36). A senior manager from the retail industry explained that their big data strategy is more focused on maximising ‘competitiveness’ among peer retailers.

> *"To be more competitive means helping our customers on saving their money on everyday items they want and need. We use our expertise as food makers and shopkeepers to ensure that our brand products offer the best possible quality at the best possible price, serving our customers better. So, the first thing is getting access to their data. i.e. buying preferences. And then we apply data analytics to discover customer insights. We listen to our customers that way. We also make sure that we treat their data with regulated data privacy and security policy. We aim to offer customers a one-stop-shop and give them more of what they want on a shopping trip. So, we continue to innovate and change the way we do business by introducing new things every week. We develop our operational process based on this. Offering innovative uniqueness with what the shoppers appreciate-Simplify and speed up" (I-32).*

According to 'I-35' from the retail sector, inviting collaboration among formerly walled-off functional units, and even seeking information from external suppliers and customers to co-create products and technology solution providers must be one of the key aspects of every big data strategy. More integrated data platforms now allow companies and their supply chain partners to collaborate during the design phase as well as the operational and in-use phase. And this is a crucial determinant for improving the competitive edge of any company regardless of the sector (I-29, I-31, I-35, I-37, I-40, I-43). Interestingly, collaborations with supply chain actors have also been emphasised as a strategic requirement by construction professionals during the interviews. Leveraging Partnerships has also been identified as a key aspect of strategy development. This was mentioned by many interviewees from all three sectors. Some of the professionals see it as a way of sharing risk. "Mutual contracts should also be considered as opportunities to share the innovation risk between parties – awarding all parties involved for their successful outcomes (I-33).

> *"When formulating the strategy, we think about how we are going to leverage existing assets and capabilities to optimise our position within the technology stack. The best way is to do it by partnering. Say, a software company, for example, well-positioned to build up talent and capabilities in hardware or is preferable to form strategic partnerships with other players, such as hardware companies, service providers, and systems integrators, perhaps advertising and marketing companies. A company must have a network of collaborative partnerships to spread their wings" (I-35)*

Thus, *establishing collaborative partnerships* is another lesson learned from RFM sectors.

Security-mindedness is an important organisational strategy consideration to repel evolving security threats and vulnerabilities (I-33). This is equally important as data privacy is to be included in the strategy and thus an important lesson learned from RFM sectors. It was recommended that when designing long-sighted systems high-profile security must be taken into account. Following very basic and well-accepted security practices could prevent such security issues to some extent. Cheap devices, and second-hand firmware that had not received security patches allows hackers to perform fraudulent activities. Performing sensitivity analysis to consider worse case scenarios would help to keep a back-up plan for worse situations.

> *"We have been beaten by data privacy and security quite a lot of times as we have made countless mistakes. It is always trial and error. You need to safeguard the data or otherwise, you must be prepared to take the risk of losing them overnight" (I-41)*

In terms of an IoT strategy, many of the interviewees mentioned that their IoT strategy is formulated predominantly around their IoT deployments that offer a rapid return. This IoT deployment enables manufacturers to realise digital transformations from several perspectives: efficiency, automation, customer-centricity, competitive benefits and the advantages which are offered by using data across the manufacturing value chain and to tap into new revenue sources (I-42). Identifying a clear and realistic business outcome is a key opinion given by many interviewees.

> *"We have an Outcome-Focused Industrial IoT Strategy. We have few stages of performing that. First, we manage the Information chaos by getting access to the most important data. Decision-makers can access the data itself and the defining metadata to organise and translate a wide array of scattered data into a coherent information strategy. Furthermore, automation of this capability through intelligent technologies, such as machine learning, can help scale collection and connection and help identify potential actions. (I-41)*

Some of the interviewees view the latter idea as 'finding the right business model'. Changing from product selling to solution selling is a big step towards maximising competitive edge. Having a proper business model aligned with an overall business strategy will answer 'How to make money out of IoT data'. For big data, on the other hand, many believe that a target-based approach is the key to success. Almost all retailers mentioned that they are working towards pre-set targets that is in-line with their short -term business objectives. This is vital to maintain the balance between supply and demand. Thus, the 'development of an outcome (or target) based business model' is the next theme emerging from the qualitative data, taken forward to the strategic framework.

Given the granularity of resources available, the requirement for a structured resources management plan is at the core of a strategy. Understanding the value-added ability of every resource would help to decide the resource management plan (I-32). At an organisational level, the process development is a key consideration in a strategy. This may include Building Capabilities (I-

36) as well as structuring the process (I-26, I-27, I-31). The most effective big data process development strategies identify business requirements first (I-26, I-27, I-31, I-37) and then tailor the infrastructure, data sources, and analytics to support the business opportunity (I-37). Therefore, the development of a structured resources management plan' is an important lesson learned.

Predictability is the aspect that has the highest frequency of mentions in response to the lessons learned from RFM sectors. The most important aspect of big data that adds to a competitive advantage is its greater predictability. The analytics reveal patterns and behaviours of buyers which help to predict possible future buying habits. The case is equally valid for IoT as well. In manufacturing, 'predictability' was the main theme mentioned by almost all interviewees. As a part of the content analysis, the words that frequently appear before and after the word 'predictability' were observed. By looking at the word tree, it was able to identify 'predictive maintenance' as the area of concern that possesses the most prominence (Figure 19). The size of the font indicates the number of times the word or phrase was found in the perception narrations. For high value or businesses critical machinery maintenance and repair, 'haphazard' or 'run-to-failure' approach may not be appropriate. Modern 'Smart manufacturing factories' contain sensors installed throughout the manufacturing process; these sensors send a consecutive stream of data back to the cloud. This data can then be analysed, and patterns identified. Predictive algorithms monitoring real-time sensor data can predict/ flag upcoming breakdowns well in advance. This way, preventative maintenance can then be scheduled into predicted downtime. This would also allow the machinery to shut down before further damage is caused in a worst-case scenario. Repair costs could also be minimised by this method.

Predictability was emphasised by the interviewees from the finance sector as well. Finance services are complex as they are linked with many other sectors. This 'complexity' needs to be accurately understood and taken into account at the outset so the true nature of the service is understood, and any predictive precautions could be undertaken in the initial stages. This was viewed as predictive action planning/ contingency planning by financial professionals. Thus, capturing the *'predictability'* of data assets is a major advantage to be able to harness the data.

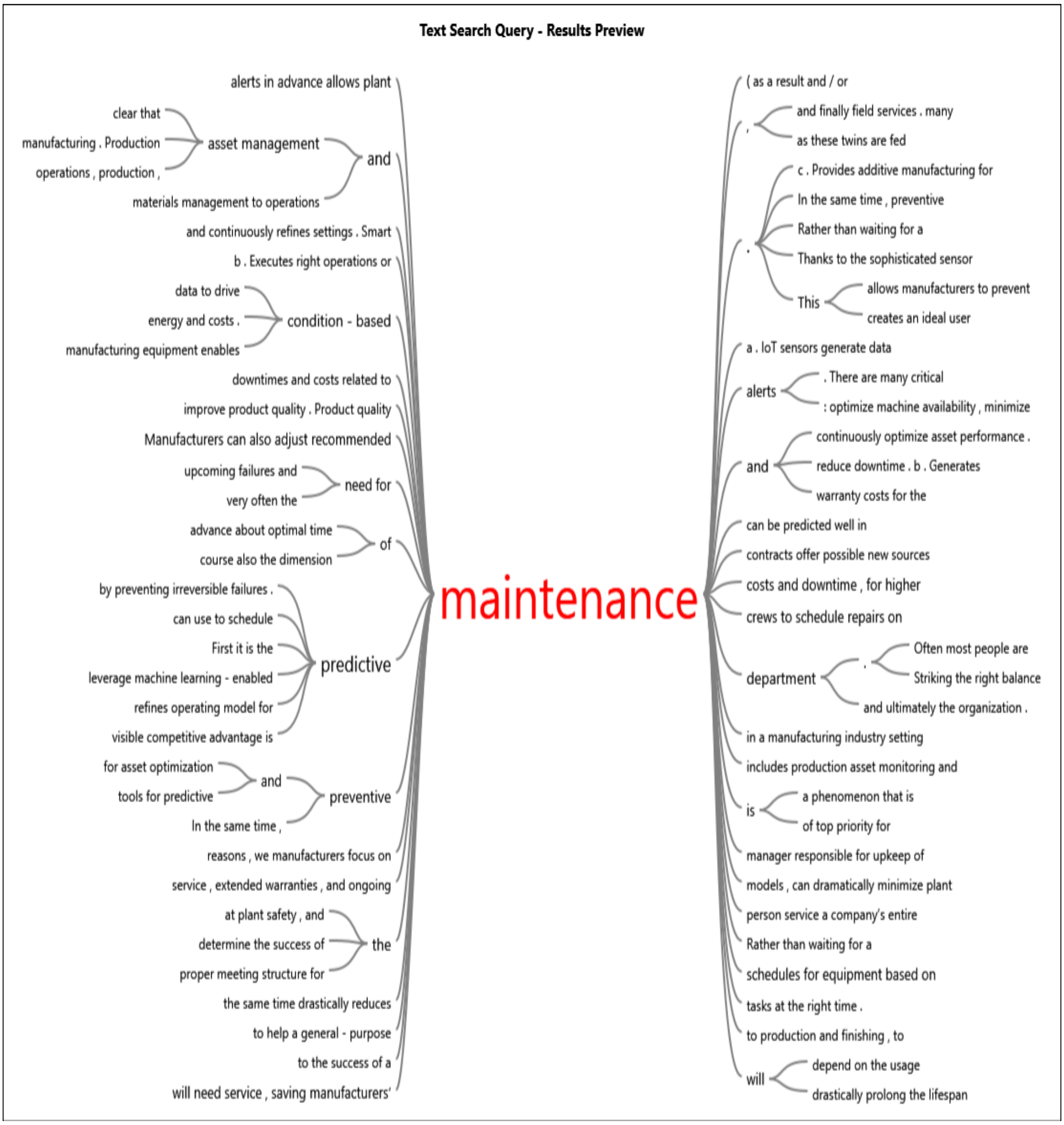


Figure 19- Word Tree resulted from a text search query for predictive maintenance

Creating digital replicas of physical assets helps data to be transmitted seamlessly between the original and the twin, creating an accurate digital representation of how the device is operating, the user's behaviour, a

nd the device's performance. This allows analysis of a vast amount of data in a practice-based virtual platform to make mistakes and learn from them for the best way forward. Once these patterns of errors are understood, predictive algorithms can notify product users of potential problems before their device breaks down. '*Use digital twins'* is therefore a recommended practice.

The use of *smart mobile devices* was manifested together with the advantage of creating digital twins, as societies are quickly getting used to touch-enabled smartphones and tablets. This is driving a huge change in the way companies operate and communicate internally as well as externally. Ignoring this smart device demand for access to manipulate Big Data information and insights via their mobile device is a survival-shortening decision for retailers.

The ability to take ownership of every activity and exhibiting the accountability for every process level of the flow is another crucial point mentioned by the interviewees from all sectors. Appointing an appropriately skilled and knowledgeable individual who will take responsibility for decision making and approvals is another important part of the strategy. This could also be called appropriate leadership. I-41 gives a different image to this idea as '*data governance'*.

> *" Data is no longer a dashboard that provides a picture of past success and failure. With the introduction of forward-looking, predictive analytics tools, manufacturers are quickly realising that data's value as an asset should be evaluated and managed strategically and that is what we do during the data governance stage. To be able to use governance wisely, people are expected to be accountable for what they produce" (I-41)*

A noticeable concern was raised for systematically scaling and speeding the workflow. Real-time decision making requires organisations to use Big Data information promptly. To be able to make timely decisions the data must be processed, and the results need to be released at the required speed and scale. This was a point on which interviewees across the three sectors had controversial views. Some see the need to scale-up the processes while some see the disadvantage of scaling into unmanageable limits. Hence, *scaling and speeding up to manageable limits* was considered as the lesson learned.

A mistake that many technology implementors make is using conventional marketing strategies for BDA and IoT related marketing. IoT marketing requires an IoT-specific strategy. The market for IoT related products may not be the same as for traditional versions of it. No matter how great (or smart) the concept is, the marketing professionals must know how to tell potential customers about it. Investing in IoT without investing in an IoT strategy is not a worthy investment. Therefore, *context-specific marketing strategy* is another important aspect.

Finally, a common cultural aspect raised by many of the professionals was, getting many people as possible involved to spread the awareness and knowledge about BDA and IoT exploitation faster. According to professionals, in-practice, breaking down an IoT or BDA project into small project teams is one of the biggest mistakes manufacturers make. Getting everybody involved in the holistic view of the project must be a part of the organisational competence development strategy. Every organisation must initiate ways of getting every employee involved and let them play with the new solutions. This can be expanded to the supply chain as well. Working with suppliers (on an IOT project) can bring the best practices and guidelines based on their real-life experience.

Thus, the findings for exploring possible lessons from RFM sectors on strategically exploiting BDA and IoT for competitive advantage to the construction industry could be summarised into the following categories: Access to data, Data democratization, and data integration, Appropriate data analytics, Creating new uses for continuous improvement, Establishing collaborative partnerships, Attention to High-profile security failures, Development of outcome/ target based business model, Structured resources management plan, Predictability, Use digital twins, Use of smart mobile devices, Data governance, Scaling and speeding up to manageable limits, Context-specific marketing strategy and Getting as many people as possible involved to spread the awareness and knowledge.

Given the findings from RFM sectors and the construction sector, a rich picture of the 'strategic approach' and the 'lessons learned were' established. These were used towards strategic framework creation. This remarks on the achievement of the part: 'level of exploitation' in objective- 2 and the investigation of the extent to which BBI are employed as strategic tools in organisations in other sectors in objective-4 (as stated in section 1.4).

4.3 The extent to which the benefits are accrued from the exploitation of BBI and the extent to which the challenges are challenging for BBI

4.3.1 Identify the extent to which benefits, and challenges associated with Building Information Modelling (BIM), Big Data Analytics (BDA) and Internet of Things (IoT) are benefiting and challenging in construction, retail, and Manufacturing sectors

4.3.1.1 Establishing the variables for benefits

The mechanism used in the attempt to identify construct variables for benefits and challenges for BIM, BDA, and IoT is discussed in detail in section 2.3 of Chapter Two. Unlike exploitation construct variables, benefits and challenges variables could not be considered as common variables for BIM, BDA, and IoT. As a result of this, a list of construct variables was derived for benefits and challenges for BIM, BDA, and IoT separately. Table 33 shows the set of construct variables (after applying the data reduction technique) used for benefits and challenges of BIM, BDA, and IoT respectively which were fed into the questionnaire survey. All variables were coded for the ease of data handling.

Table 33- Input Variables for benefits and challenges of BIM, BDA, and IoT

Building Information Modelling (BIM)			
Code	**Benefits**	**Code**	**Challenges**

BENBIM1	Reduction in the whole life cost of built assets.	CHBIM1	Lack of in-house expertise and therefore salary premium of employing personnel trained in BIM
BENBIM2	Ease of information abstraction through simulations and collaborated visualisation techniques	CHBIM2	Hardware upgrading and software licensing costs
BENBIM3	Reduction in the overall time, from inception to completion of construction (with less need for rework and early risk/ clash detection)	CHBIM3	Treating virtual as superficial and not trust worth- thereby lack of client demand
BENBIM4	Enable faster and better decisions through greater collaboration	CHBIM4	The general unavailability of vendor-neutral data formats and standard- Interoperability/ incompatibility
Big Data Analytics (BDA)			
Code	**Benefits**	**Code**	**Challenges**
BENBDA1	Time and cost reduction (Big Data tools offers more efficient ways of storing, managing analysing them)	CHBDA1	Getting meaningful insights using big data analytics
BENBDA2	Identification of important information (through advanced analytics) improves the quality of decision making	CHBDA2	Lack of in-house expertise and therefore training and education costs for data-centric roles
BENBDA3	Minimising potential risks with foresighted situational awareness & predictability	CHBDA3	legal issues regarding data ownership, copyright, and data protection
BENBDA4	New product/ service innovation (knowing client needs and habits)	CHBDA4	Insurance, uncertainty, and issues with cybersecurity and privacy of data
Internet of Things (IoT)			
Code	**Benefits**	**Code**	**Challenges**
BENIOT1	Cloud connection allows real-time data sharing which contributes to quicker information sharing as well as completion of a task.	CHIOT1	Lack of standardised guidelines, policies and contractual aspects embedded in current procurement and legal structures

BENIOT2	RFID data helps to mitigate the effects of any downstream delays/ failures in any type of performance and thereby performance optimisation.	CHIOT2	Privacy and security of transferred data
BENIOT3	Remote/ automated operation and usage monitoring for control purposes (e.g. energy generation, storage, distribution, and usage monitoring for energy conservation)	CHIOT3	Lack of IoT specific experts/ professions and Lack of skills, knowledge, and training
BENIOT4	Improved worker safety (i.e. real-time information with historical data provided by GPS helps tracking, tracing, and monitoring fleet through RFID IOT sensors	CHIOT4	Issue of compatibility and connectivity when sharing data in multiple formats

4.3.1.2 Quantitative data analysis for B, B, I benefits and challenges

Preliminary analysis- Assessing normality and reliability

All benefits and challenges variables were subjected to normality tests (Shapiro-Wilk and Kolmogorov-Smirnov[a]) to see the normality of the data distribution. Methods used in determining the data normality are similar to the methods described in section 4.2.3.1. Although the distributions are NOT 'perfectly normal', with fairly large samples, like in this study, skewness 'will not make a substantive difference in the analysis' (Tabachnick and Fidell, 2007). Further, according to Pallant (2011), violation of the assumption of normality is quite common in large samples. Hence no corrective actions were taken towards maintaining normality. However, appropriate precautions were taken to employ statistical analysis that suits such non-normal data distributions (i.e. non-parametric tests at certain data points).

Because the variables are used towards strategic framework development, it is imperative to check the internal consistency of the data. Cronbach's alpha is the most common measure of internal consistency ("reliability"). It is mostly used when multiple Likert questions exist in a survey/questionnaire that form a scale and determining if the scale is reliable. The reliability of the questionnaire was tested using Cronbach's alpha analysis. The results of the reliability test are presented in Table 34. From the results, it appears that Cronbach's alpha is 0.800 and 0.684 for BIM benefits and challenges respectively. These indicate an acceptable level of internal consistency.

Table 34- Reliability statistics for BIM benefits and Challenges

Reliability Statistics			
BIM Benefits		**BIM Challenges**	
Cronbach's Alpha	N of Items	Cronbach's Alpha	N of Items
.800	4	.684	4

Correspondingly, a preliminary analysis was executed for BDA and IOT across four sectors. The 'descriptive' revealed no significant difference between any of the benefit/ challenge variables of inquiry.

Descriptive and Inferential statistics for Benefits and Challenges variables

BIM Benefits and Challenges

After having an understanding of whether the questions related to these 2 variables have reliably measured the same latent variables (benefits AND challenges), it is imperative to see the extent to which the listed benefits accrue/ could accrue/ obtained from the exploitation of BIM and then to see the extent to which the listed variables are seen as challenges for BIM as stated by each participant. To identify most beneficial benefits, the questionnaire was rated using a 5-point Likert scale ranging from 1 (No benefit is obtained at all) to 2 (Very Low level of the benefit obtained), 3 (Low level of the benefit obtained), 4 (High level of the benefit obtained) and 5 (Very High level of the benefit obtained). Similarly, to identify the challenging level, a 5-point Likert scale ranging from 1 (Not seen as a challenge at all) to 2 (Very Low level of challenge), 3 (Low level of challenge), 4 (High level of challenge) and 5 (Very High level of challenge) was utilised. The Likert scales therefore imply, the higher the mean score, the higher the level of benefit/ challenge. The rationale for using different Likert scales (4-point and 5-point) in different questions can be found in section 3.10.2.5.

Table 35 shows the overall beneficial and challenging level of selected benefits and challenges from the mean-value descriptive analysis. A full list of questions and variables can be found in Appendix C. It is appears that BENBIM4 has the highest mean value and hence is considered to be the benefit that has the highest level of the benefit obtained. When considering the median also it can be concluded that BENBIM4 is the one that the respondents are in the agreement of 'Very High level of the benefit obtained'. Meaning- construction professionals believe that the most beneficial use of BIM is that it enables faster and better decisions because of its collaborative nature. BIM in its nature is a collaborative system leading to better communication. When better communication is in place, the construction process is streamlined and made more efficient facilitating better decisions. Increased collaboration also helps speed up the construction process.

Table 35- Descriptive statistics for BIM benefits and challenges

Construction								
	BENBIM1	**BENBIM2**	**BENBIM3**	**BENBIM4**	**CHBIM1**	**CHBIM2**	**CHBIM3**	**CHBIM4**
Mean	3.45	4.39	4.21	4.55	4.07	3.71	3.18	3.21
Median	3.00	5.00	4.00	5.00	4.00	4.00	3.00	3.00
Std. Deviation	1.006	.709	.803	.664	.842	.884	.966	1.059

Jaafar *et al.* (2018) in their study on Construction Accidents in the Malaysian Residential Construction Industry, has utilised a scoring system for scales in 5 point Likert data and purports to use the scores that fall into certain criteria in the scoring system as the ‘selection criteria’. Influenced by the latter, the scoring criteria adopted in this research is shown in Table 36.

Table 36- Overall suitability scale

Mean interval scale	**Mean value scale**
1.00–1.80	No benefit/challenge is obtained at all
1.81–2.60	Very Low level of benefit/ challenge obtained
2.61–3.40	Low level of benefit/challenge obtained
3.41–4.20	High level of benefit/challenge obtained
4.21–5.00	Very High level of benefit/challenge obtained

As shown in Table 36, the selection criteria used to determine the ‘key’ benefits and ‘key’ challenges are the mean scores between 4.21 - 5.00 which represents a Very High level of the benefit obtained. This means, all benefits and challenges that show a mean score between 4.21 - 5.00 were selected and taken forward for the strategic framework. The benefits and challenges which were chosen as key benefits and challenges for BIM are listed below:

- Enable faster and better decisions through greater collaboration (BENBIM4)- Very High
- Ease of information abstraction through simulations and collaborated visualisation technique (BENBIM2)- Very High
- Reduction in the overall time, from inception to completion of construction (with less need for rework and early risk/ clash detection) (BENBIM3)- Very High

BDA Benefits and Challenges

Succeeding in the identification of key benefits and key challenges for BIM, key benefits, and challenges for BDA are identified using the same technique. The Likert scale used for these variables is the same as for BIM.

Table 37 reveals the overall benefit and challenge level for each variable according to computed mean values from the descriptive analysis. BENBDA2 and CHBDA3 have the two highest mean values which fall into the criteria of 4.21–5.00 (Very High level of benefit/challenge obtained) as defined in Table 36. The respondents believe that BDA largely helps the capture of important information for decision making. The importance of such information lies in the consistency and continual growth. By uncovering this consistency, organisations could create new business opportunities, optimise current operational efforts and predict future trends for actionable insights and thereby make informed business decisions. This would ultimately generate more revenues. The biggest challenge for creating such insights is confusion around data ownership, copyright, and data protection.

Table 37- Mean value comparison for BDA benefits and challenges between the four sectors

	Mean Values for BDA benefits and Challenges			
	Construction	**Retail**	**Finance**	**Manufacturing**
BENBDA1	3.78	4.36	4.29	4.15
BENBDA2	4.31	4.36	4.12	4.50
BENBDA3	4.10	4.29	4.00	4.15
BENBDA4	3.63	4.21	4.12	4.00
Avg mean	***3.96***	***4.31***	***4.13***	***4.20***
CHBDA1	2.24	2.50	3.06	2.80
CHBDA2	3.98	3.21	3.65	4.05
CHBDA3	4.27	3.71	3.71	4.15
CHBDA4	3.90	3.93	3.94	4.05
Avg mean	***3.60***	***3.34***	***3.59***	***3.76***

According to the average of means, the construction sector benefits the least from BDA while the Retail sector benefits the most out of BDA. All benefits and challenges that show a mean score between 4.21 - 5.00 were considered as key benefits and challenges in a strategic framework. The benefits and challenges which were chosen as key variables for the benefits and challenges of BDA are listed below:

- In Construction, Identification of important information decision making (BENBDA2) is the most beneficial area of exploiting BDA. Further legal issues regarding data ownership, copyright, and data protection (CHBDA3) are reported to be the most challenging area when exploiting BDA.

- In Retail, all benefits remark a high level of benefit accrual.
- In Finance, the use of BDA gives time and cost reduction (BENBDA1) in higher scales.
- In Manufacturing, Identification of important information decision making (BENBDA2) was the most beneficial area of exploiting BDA while legal issues regarding data ownership, copyright, and data protection (CHBDA3) is the most challenging area.

IoT Benefits and Challenges

A similar procedure was carried out for IoT benefits and challenges as well. From the descriptive analysis in Table 38, it can be perceived that CHIOT2 and CHIOT3 are the ones that have the highest mean value which falls into the criteria of 4.21–5.00 (Very High level of benefit/challenge obtained) in construction. In Manufacturing, privacy, and security of transferred data (CHIOT2)seems to be the most challenging area. All other variables fall in the criteria 3.41–4.20 (High level of benefit/challenge obtained). The benefits and challenges which were chosen as key variables for the benefits and challenges of BDA are listed below:

- Privacy and security of transferred data (CHIOT2)- Very High
- Lack of IoT specific experts/ professions and Lack of skills, knowledge, and training (CHIOT3)- Very High

Table 38- Mean value comparison for IoT benefits and challenges between the four sectors

	Mean Values for IoT benefits and Challenges			
	Construction	**Retail**	**Finance**	**Manufacturing**
BENIOT1	3.65	4.00	4.07	4.00
BENIOT2	3.58	3.83	3.93	3.79
BENIOT3	4.15	4.00	3.86	4.00
BENIOT4	4.02	3.83	3.93	3.71
Avg mean	***3.85***	***3.92***	***3.95***	***3.88***
CHIOT1	3.92	3.75	3.5	4.14
CHIOT2	4.62	3.92	4	4.29
CHIOT3	4.25	3.83	3.5	3.79
CHIOT4	3.71	3.67	3.86	4.00
Avg mean	***4.13***	***3.79***	***3.72***	***4.06***

Considering the average mean scores, just as with BDA, construction is the sector that least benefits from IoT. The finance sector benefits the most from IoT. All BEN and CH variables were compared together to give some insight into the complexity of benefits and challenges related to BIM, BDA, and IoT in construction. Table 39 compares all BEN, CH variables according to their mean scores as well as the group mean scores based on benefits and challenges separately. Given the benefits and challenges variables only, Table 39 reveals that BIM is the strategic tool that respondents have accrued most benefits (M= 353), as well as seen as most challenging (M= 301) compared to BDA and IoT.

Table 39- Mean comparison of all BEN, CH variables in construction

BIM				BDA				IoT			
Variable	**Mean**	**Sum**	**Mean of sums**	**Variable**	**Mean**	**Sum**	**Mean of sums**	**Variable**	**Mean**	**Sum**	**Mean of sums**
BENBIM1	3.45	293	353	BENBDA1	3.78	223	233	BENIOT1	3.65	190	200
BENBIM2	4.39	373		BENBDA2	4.31	254		BENIOT2	3.58	186	
BENBIM3	4.21	358		BENBDA3	4.10	242		BENIOT3	4.15	216	
BENBIM4	4.55	387		BENBDA4	3.63	214		BENIOT4	4.02	209	
CHBIM1	4.07	346	301	CHBDA1	2.24	132	212	CHIOT1	3.92	204	215
CHBIM2	3.71	315		CHBDA2	3.98	235		CHIOT2	4.62	240	
CHBIM3	3.18	270		CHBDA3	4.27	252		CHIOT3	4.25	221	
CHBIM4	3.21	273		CHBDA4	3.90	230		CHIOT4	3.71	193	

4.3.1.3 Qualitative data analysis for B, B, I benefits and challenges

To further explore some emerging themes from the benefits and challenges, interview responses were taken into consideration. The comments received from interviewees were thematically linked to the questionnaire survey responses and hence allowed for a deeper understanding of some of the emerging issues. The broader indication of key themes and issues highlighted enabled the researcher to deduce that collaboration and access to information are two major benefits for BDA and IoT as well. Following two quotes from manufacturing help to strengthen this argument.

> *"Innovation is a collaborative and creative process. Innovative technologies like Big Data and IoT are based on collaboration because they create embedded knowledge that is used to enable innovation. The quality of knowledge heavily depends on how effective the collaboration is within and among teams. Creating high performing collaborative teams is no longer an option. It is now a necessity. Without collaboration, you are not going forward. Our company has made a strong case that this process can be engineered. For example, one of our laboratories that uses IoT wearable devices can reliably measure the potential productivity of teams. Ideally, feedback and learnings from IoT devices like these can*

dynamically help teams improve their creative productivity. I think the knowledge created from the collaboration is distinctive and therefore difficult to imitate" (I-40).

"Success in manufacturing depends on being able to quickly access information to make the right production and supply chain decisions. The ability to analyse equipment failures, production bottlenecks, supply chain deficiencies, etc., enable better decision-making" (I-40).

Early risk detection is another area which is critical to BIM, but not critical to BDA and IoT according to the quantitative study. A closer observation of qualitative data suggests that the ability to identify risks is a major benefit to both BDA and IoT exploitation. The following quotations help in strengthening this fact.

"It's helping manufacturers predict future events, foresee risk" (I-40)

"Using such environments and tools can allow manufacturers to eliminate the risk from decision-making processes" (I-39)

"Big Data technology enables improved supply chain transparency and risk mitigation. By analysing historical data, risk mapping, and scenario planning, businesses can assess the likelihood of issues and their potential impact, allowing them to implement effective early warning systems and mitigate risk" (I-32).

Concerning the connection between benefits and exploiting BIM, BDA, and IoT, this was described as a "very efficient way of working". There is a strong connection between the 'time-saving' and 'minimising delays' aspects offered by BIM, BDA, and IoT use.

Considering the above qualitative data concerning benefits common to BIM, BDA, and IoT in all four industries, following higher abstraction level themes could be identified by thematic analysis.

- Cost-Effectiveness
- Visualisation
- Collaboration
- Efficiency
- Risk mitigation
- Accessibility to information

Common to all three strategic tools (BIM, BDA, and IoT), a major challenge highlighted by the interviewees was lack of skills, expertise, and related training opportunities. This was a matter of concern for all industries.

> *"Lack of adequately trained professionals is one of the major reasons why we are not making money out of it" (I-34)*

> *"Lack of in-house skills and training makes our job more difficult. I do not see this as a concern in our company recruitment, especially being this is the ideal time to recruit staff with the necessary skills. Having Savvy employees is an asset especially during the recession because it makes a company more agile in their response to and adoption of BIM or Big Data or any technology. It will allow taking advantage of lower aggregate training costs" (I-17)*

Looking forward to the challenges faced by the companies in the exploitation of strategic tools, another major challenge mentioned by most of the interviewees from all four sectors, particularly in construction is lack of data-related standards.

> *"When our staff looks up the record of a customer, we experience that the external data exchange is significantly more challenging for our company. Not having proper standards shows that we are not in serious need of improvement. A major reason for this difficulty is the variation in how organisations capture and use the information to link records. So, l*ack of data standards hinders our day-to-day productivity*" (I-33)*

Thematic analysis of qualitative data on challenges received from all sectors on challenges could be summarised into four main themes as listed below.

- Standards
- Skills and training
- Data security and privacy
- Data ownership

This remarks on the achievement of objective- 2 and objective-4 (as stated in section 1.4) both quantitatively and qualitatively. The reasons giving rise to investigating the extent of exploitation, benefits and challenges associated with BBI lies in the requirement for conducting a situation analysis as a part of the 'strategic approach' (section 2.2) suggested in this research. Further, the comparison study between all four sectors is attributed to the requirement of exploring the possible lessons for the construction industry. According to Mintzberg's strategic perspective on 'Ploy' as described in Section 2.4, it is necessary to investigate an organisation's ability to put themselves in a favourable competition with other potential providers of the positioned services (Mintzberg, 1987b). The next section looks at the potentials that BBI holds to put an organisation in a favourable position.

4.4 Level of enhancement in competitive advantages by exploiting BIM, BDA, and IoT in four sectors

4.4.1 Quantitative analysis to the level of enhancement in competitive advantages in four sectors

Like all previous construct variable identifications, a great effort was devoted to the identification of determinants of competitive advantage. Section 2.4.3 of Chapter Two explored various definitions for competitiveness both in-general as well as specific to the construction industry and a list of determinants for competitive advantage was gathered in section 2.4.4. ‘Competitiveness’ is a concept that is neither well understood nor easy to communicate with people. The literature reveals that ‘competitiveness’ is an abstract concept, embracing almost everything that leads to the long-term performance of a firm. Despite its complex and vague nature, widespread acceptance is what is important. According to (Flanagan *et al.*, 2007b) direct assessment of organisational competitiveness is not feasible. Alternatively, it can be assessed by the factors that impact on organisations' ability to gain competitive advantage and the factors that formulate competitiveness.

The identified determinants of competitive advantages are listed in Table 40 and were categorised into three broad categories as assets, process and, performance. These determinants (Table 40) were fed into the questionnaire survey to capture the extent to which BIM, BDA, and IoT help in maximising organisational competitive advantage.

Table 40- Construct variables for organisation competitive advantage

Selected Determinants of Competitive advantage			Code
By achieving the best possible use of BIM/ BDA/ IoT			
Assets	1	Employees’ satisfaction/ retention was enhanced	COMP1
	2	Appropriate skills and intellectual assets of people were identified and promoted	COMP2
	3	The company brand and reputation were enhanced	COMP3
	4	The existing technological capability was enhanced	COMP4
	5	The effect of plant and material was enhanced	COMP5
	6	Source of finance-Financial capital and financing ability was increased	COMP6
Process	7	The company governance was upgraded	COMP7
	8	Company marketing and production operation tasks were made easy and efficient	COMP8
	9	Training and education were improved	COMP9
	10	Organisational culture and structure were enabled	COMP10
	11	Company business strategy and alliances with collaborative partnering was improved	COMP11

	12	Research and development were improved	COMP12
Performance	13	Company profitability was increased	COMP13
	14	Company productivity was increased	COMP14
	15	Performance efficiency and predictability was increased	COMP15
	16	The market share and the rate of market penetration was increased	COMP16
	17	Customer loyalty and retention were improved	COMP17
	18	Differentiation/ uniqueness in services was enhanced	COMP18
	19	Cost was reduced	COMP19
	20	Speed and quality of delivery was enhanced	COMP20
	21	The ability to add value to society, corporate social responsibility and sustainability was enhanced	COMP21

When using Likert-type scales it is imperative to calculate and report Cronbach's alpha coefficient for internal consistency reliability for any scales or subscales one may be using (Tabachnick and Fidell, 2007). The closer the Cronbach's alpha coefficient is to 1.0 the greater the internal consistency of the items in the scale. As reported in Table 41, the Cronbach's alpha values for all competitive advantage variables across four sectors are above the acceptable level. This indicates a good internal consistency of the items in the scale, it does not mean that the scale is unidimensional. The reason to have unequal N of items is that Construction has a set of (21 no) additional competitive advantage variables for BIM which the other three sectors do not have.

Table 41- Reliability Statistics for competitive advantage variables

Construction		Retail		Finance		Manufacturing	
Cronbach's Alpha	N of Items	Cronbach's Alpha	N of Items	Cronbach's Alpha	N of Items	Cronbach's Alpha	N of Items
.943	63	.736	42	.875	42	.782	42

After checking the 'Cronbach's Alpha if Item Deleted' values for all the above variables, it is conceived that the deletion of items does not help much in the increment of Cronbach's alpha value. Hence no item was deleted with the intention of improving the internal consistency.

The questions around competitive advantage used a Likert scale to estimate the individual opinion on the level of enhancement of a list of competitive advantages as a result of using BIM, BDA, and IoT. The question was phrased as: "*Considering your organisation's assets, process and performance please indicate the level of enhancement for the following competitive advantages by exploiting BIM, BDA, and IoT*".

The scale of rating the determinants of competitive advantage range from 1 to 5 according to the level of enhancement:- 1-No enhancement at all, 2-Very Low level of enhancement, 3- Low level of enhancement, 4- High level of enhancement, and 4- Very High level of enhancement. According to the value assigned for the question, it can be perceived that the higher the mean score, the higher the level of enhancement. The respondents were requested to rate the level of enhancement of each construct variable (of competitive advantage) taking into consideration the BIM exploitation, BDA exploitation, and IoT exploitation separately.

Many of the previous researchers who investigated the level of improvement in such similar determinants have used the standard deviation method or mean rank method. However, considering different critiques around these methods, for this section of the research, the level of enhancement index was also employed to cross-check with the mean method. This index has been used by many authors of similar investigations (Sangole and Ranit, 2015; Assaf and Al-Hejji, 2006). The analysis of the data ensures that the weighted average is used ranking each determinant. The Likert data were transformed to the relative level of enhancement index (LEI) for each factor as listed in Table 40. The relative level of enhancement index (LEI) was calculated using the formula shown below.

Equation 1- Formula for Level of Enhancement Index

$$\frac{5(n5) + 4(n4) + 3(n3) + 2(n2) + n1}{5\,(n1 + n2 + n3 + n4 + n5)} \text{ X } 100$$

As illustrated in Table 42, different sectors show different levels of enhancements for different competitive advantages. Highlighting the important findings for each technology domain, from the exploitation of BIM in construction, the highest level of enhancement (97%) appears to have been received for COMP15 (Performance efficiency and predictability were increased - By Exploiting BIM). This means that the exploitation of BIM has largely enhanced the construction Performance efficiency through the predictable nature of BIM. For BDA and IOT, even though the highest enhancement could not be seen in construction (when compared with 4 sectors), COMPBDA15 (performance efficiency) and COMPBDA20 (Speed and quality of delivery) were rated as the highest within construction itself.

By exploiting BDA, retail and manufacturing sectors enhance speed and quality of delivery (COMP20) at higher levels than the other two sectors. A similar situation can be seen in company productivity (COMP13) as well. Retail and manufacturing sectors enhance their company productivity at higher levels than others by exploiting BDA.

IoT on the other hand generally shows the highest level of enhancement in Speed and quality of delivery (COMP20). For COMP20, the finance sector shows the lowest level enhancement.

Table 42- Level of enhancement indexes for competitive advantage variables in four sectors

Code	Competitive Advantage	Level of Enhancement Index (LEI)								
		BIM	BDA				IoT			
		Construction	Construction	Retail	Finance	Manufacturing	Construction	Retail	Finance	Manufacturing
COMP1	Employees' satisfaction	66%	67%	74%	76%	75%	68%	72%	73%	74%
COMP2	Skills and intellectual assets	69%	71%	71%	64%	66%	71%	72%	66%	76%
COMP3	Brand and reputation	72%	78%	80%	68%	79%	82%	75%	71%	73%
COMP4	Technological capability	74%	76%	70%	78%	78%	78%	88%	67%	74%
COMP5	The effect on plant and material	77%	78%	96%	81%	83%	80%	83%	77%	71%
COMP6	Source of finance	60%	60%	69%	59%	65%	62%	55%	59%	64%
COMP7	The company governance	54%	58%	73%	69%	68%	58%	62%	71%	67%
COMP8	Company marketing	62%	75%	89%	78%	79%	73%	73%	70%	66%
COMP9	Training and education	79%	76%	71%	72%	72%	76%	80%	60%	73%
COMP10	Organisational culture and structure	75%	70%	76%	75%	69%	74%	77%	69%	73%
COMP11	Company business strategy and alliances	67%	69%	86%	69%	75%	68%	62%	73%	79%
COMP12	Research and development	66%	69%	74%	72%	71%	73%	70%	56%	73%
COMP13	Company profitability	80%	75%	79%	80%	76%	74%	78%	81%	77%
COMP14	Company productivity	94%	95%	96%	92%	96%	92%	93%	84%	96%
COMP15	Performance efficiency through predictability	97%	96%	96%	87%	95%	94%	90%	84%	96%
COMP16	The market Share	72%	72%	67%	84%	82%	69%	73%	80%	76%
COMP17	The customer loyalty	80%	77%	76%	80%	81%	78%	78%	73%	73%
COMP18	Differentiation/ uniqueness	74%	89%	80%	92%	90%	92%	92%	89%	91%
COMP19	Cost reduction	87%	84%	81%	82%	83%	80%	72%	71%	64%
COMP20	Speed and quality of delivery	96%	96%	97%	92%	97%	95%	97%	84%	94%
COMP21	The ability to add value to the society	82%	79%	96%	93%	95%	81%	97%	87%	96%

Mean of LEI sums	**75%**	**77%**	**81%**	**78%**	**80%**	**77%**	**78%**	**74%**	**77%**

BIM, BDA and IoT exploitation and their leads to competitive advantage

Another important finding that emerged from this chapter is that the exploitation of BBI as synergised strategic tools enhances competitive advantages at higher levels than when they are exploited alone. This was investigated using WBS (RFM) and WBS (CONS). It was observed that the mean scores of COMP variables for respondents who have already adopted all three strategic tools were higher than the ones who have adopted them alone (one or two).

All companies purposively selected for the quantitative study in construction currently use at least one of the strategic tools- BIM/ BDA/ IoT. For RFM sectors, all companies use at least one out of BDA and IoT. Hence, discovering whether there is a difference in the achievement of competitive advantage between ‘use’ and ‘non-use’ groups of the technologies is not possible. However, the level of enhancement in competitive advantages could be compared between individuals who use one strategic tool over more than one strategic tool. This would help in drawing inferences on whether it is more competitively advantageous to exploit technologies with their synergies or not. Table 43; Table 44 and Table 45 show these data for BIM, BDA and IoT respectively.

As presented in Table 43, the synergistic use of strategic tools offers a higher level of enhancement in competitive advantages for construction. Meaning- the use of BIM alone gives the least competitive advantage enhancement while the synergistic exploitation of BBI gives the highest competitive enhancement. In the ascending order of lowest degree of enhancement to the highest degree of enhancement in competitive advantages by exploiting BIM, it can be presented as below.

BIM+BDA = BIM+IoT < BIM only< BIM+BDA+IoT

Table 43- Mean values for the level of enhancement of competitive advantages by exploiting BIM

Variable	**Variable Description**	**Level of competitive advantage enhancement by exploiting BIM- Mean values**			
		Construction Sector			
		BIM only	**BIM+BDA**	**BIM+IoT**	**BIM+BDA+IoT**
COMPBIM1	Employees’ satisfaction	3.35	3.25	3.13	3.39
COMPBIM2	Skills and intellectual assets	3.52	3.55	3.13	3.61
COMPBIM3	Brand and reputation	3.65	3.45	3.44	3.72
COMPBIM4	Technological capability	3.71	3.60	3.75	3.78
COMPBIM5	The effect on plant and material	4.00	3.55	3.88	3.94
COMPBIM6	Source of finance	2.97	2.75	2.94	3.28
COMPBIM7	The company governance	2.71	2.45	2.75	2.94
COMPBIM8	Company marketing	3.03	3.00	3.19	3.28
COMPBIM9	Training and education	3.65	3.90	4.06	4.33

COMPBIM10	Organisational culture and structure	3.77	3.55	3.88	3.78
COMPBIM11	Company business strategy and alliances	3.26	3.20	3.31	3.78
COMPBIM12	Research and development	3.29	3.20	3.25	3.44
COMPBIM13	Company profitability	3.90	4.00	3.94	4.11
COMPBIM14	Company productivity	4.55	4.85	4.69	4.72
COMPBIM15	Performance efficiency through predictability	4.77	4.90	4.88	4.89
COMPBIM16	The market Share	3.61	3.60	3.25	3.89
COMPBIM17	Customer loyalty	3.90	3.95	4.00	4.11
COMPBIM18	Differentiation/ uniqueness	3.74	3.80	3.38	3.89
COMPBIM19	Cost reduction	4.23	4.30	4.31	4.56
COMPBIM20	Speed and quality of delivery	4.71	4.90	4.94	4.83
COMPBIM21	The ability to add value to the society	3.97	4.15	3.88	4.39
Average of Means		*3.73*	*3.71*	*3.71*	*3.94*

Similar to the exploitation of BIM, Table 44 indicates that the synergistic use of strategic tools offers a higher level of enhancement in some competitive advantages; not only for construction but also for the three other sectors. For example, Training and education (COMP9) are more enhanced when BIM, BDA, and IoT are exploited together. The situation is not always the same as for some competitive advantages it shows a higher level of enhancement when paired exploitation is in place. For example, in Retail, exploiting BDA alone enhances employee satisfaction (COMP1) more than exploiting both BDA and IoT together.

As presented in Table 44, the synergistic use of strategic tools offers a higher level of enhancement in competitive advantages for construction. Meaning- the use of BDA alone gives the least competitive advantage enhancement while the synergistic exploitation of BBI gives the highest competitive enhancement. In the ascending order of lowest degree of enhancement to the highest degree of enhancement in competitive advantages by exploiting BDA, it can be presented as below.

BDA only < BIM+BDA = BDA+IoT < BIM+BDA+IoT

Table 44- Mean values for the level of enhancement of competitive advantages by exploiting BDA

Variable	Level of competitive advantage enhancement by exploiting BIM, BDA, and IoT with different combinations- Mean values									
	Construction Sector				Retail Sector		Finance Sector		Manufacturing Sector	
	BDA only	BIM+BDA	BDA+IoT	BIM+BDA+IoT	BDA only	BDA+IoT	BDA only	BDA+IoT	BDA only	BDA+IoT
COMPBDA1	3.33	3.35	3.56	3.33	4.00	3.67	4.00	3.79	4.00	3.64
COMPBDA2	3.33	3.55	3.78	3.56	4.00	3.50	4.00	3.00	3.67	3.14
COMPBDA3	3.67	4.00	3.56	4.17	3.50	4.08	4.33	3.21	4.00	3.93
COMPBDA4	3.83	3.70	3.67	4.06	4.00	3.42	4.67	3.71	4.50	3.64
COMPBDA5	3.75	3.60	4.89	4.11	5.00	4.75	4.33	4.00	4.50	4.00
COMPBDA6	2.67	2.80	3.22	3.39	4.00	3.33	3.67	2.79	3.17	3.29
COMPBDA7	2.67	2.70	3.22	3.28	4.00	3.58	3.67	3.43	3.33	3.43
COMPBDA8	3.17	3.75	3.89	4.06	4.00	4.50	4.67	3.71	4.17	3.86
COMPBDA9	3.50	3.55	4.00	4.17	4.00	3.50	4.33	3.43	3.67	3.57
COMPBDA10	3.33	3.40	3.56	3.72	4.50	3.67	3.67	3.79	3.67	3.36
COMPBDA11	3.08	3.40	3.44	3.83	4.50	4.25	4.33	3.29	3.50	3.86
COMPBDA12	3.17	3.40	3.22	3.89	4.50	3.58	3.33	3.64	3.17	3.71
COMPBDA13	3.58	3.80	3.22	4.11	5.00	3.75	4.33	3.93	4.00	3.71
COMPBDA14	4.50	4.85	4.78	4.78	5.00	4.75	4.33	4.64	5.00	4.71
COMPBDA15	4.58	4.90	4.67	4.89	5.00	4.75	4.67	4.29	5.00	4.64
COMPBDA16	3.33	3.70	3.00	3.94	4.50	3.17	4.67	4.07	4.67	3.86
COMPBDA17	3.50	3.90	3.56	4.22	5.00	3.58	4.67	3.86	4.67	3.79
COMPBDA18	4.50	4.45	3.89	4.67	4.50	3.92	4.67	4.57	4.50	4.50
COMPBDA19	4.00	4.20	4.11	4.44	5.00	3.92	4.00	4.14	4.33	4.07
COMPBDA20	4.58	4.90	4.78	4.78	5.00	4.83	4.33	4.64	5.00	4.79
COMPBDA21	3.50	3.85	3.89	4.33	5.00	4.75	5.00	4.57	4.83	4.71
Avg of Means	***3.60***	***3.80***	***3.81***	***4.08***	***4.48***	***3.96***	***4.27***	***3.83***	***4.16***	***3.91***

BIM, BDA and IoT exploitation and their leads to competitive advantage

Similar investigations were carried out for the level of competitive advantage enhancements made by exploiting IoT. Table 45 represents these findings. According to the findings, the use of IoT alone gives the least competitive advantage enhancement while the synergistic exploitation of BBI gives the highest competitive enhancement. In the ascending order of lowest degree of enhancement to the highest degree of enhancement in competitive advantages by exploiting IoT, it can be presented as below.

IoT only < BDA+IoT = BIM+IoT < BIM+BDA+IoT

Table 45- Mean values for the level of enhancement of competitive advantages by exploiting IoT

Variable	Level of competitive advantage enhancement by exploiting IoT- Mean values						
	Construction Sector				Retail Sector	Finance Sector	Manufacturing Sector
	IoT only	BIM+IoT	BDA+IoT	BIM+BDA+IoT	BDA+IoT	BDA+IoT	BDA+IoT
COMPIOT1	3.00	3.31	3.78	3.44	3.58	3.64	3.71
COMPIOT2	3.56	3.44	3.78	3.56	3.58	3.29	3.79
COMPIOT3	4.00	4.31	3.78	4.06	3.75	3.57	3.64
COMPIOT4	3.67	3.81	3.89	4.06	4.42	3.36	3.71
COMPIOT5	3.78	3.94	4.56	3.89	4.17	3.86	3.57
COMPIOT6	2.89	2.94	3.00	3.33	2.75	2.93	3.21
COMPIOT7	2.67	2.94	2.56	3.17	3.08	3.57	3.36
COMPIOT8	3.44	3.56	3.22	4.00	3.67	3.50	3.29
COMPIOT9	3.00	4.00	3.67	4.06	4.00	3.00	3.64
COMPIOT10	3.11	3.88	3.67	3.83	3.83	3.43	3.64
COMPIOT11	3.33	3.25	3.33	3.61	3.08	3.64	3.93
COMPIOT12	3.44	3.50	3.22	4.06	3.50	2.79	3.64
COMPIOT13	3.78	3.63	3.33	3.94	3.92	4.07	3.86
COMPIOT14	4.22	4.69	4.67	4.72	4.67	4.21	4.79
COMPIOT15	4.33	4.81	4.67	4.83	4.50	4.21	4.79
COMPIOT16	3.56	3.19	3.22	3.78	3.67	4.00	3.79
COMPIOT17	3.89	3.94	3.33	4.11	3.92	3.64	3.64
COMPIOT18	4.22	4.63	4.56	4.72	4.58	4.43	4.57
COMPIOT19	3.67	4.13	4.11	4.06	3.58	3.57	3.21
COMPIOT20	4.33	4.88	4.89	4.83	4.83	4.21	4.71
COMPIOT21	3.78	3.88	4.33	4.22	4.83	4.36	4.79
Avg. of means	***3.60***	***3.84***	***3.79***	***4.01***	***3.90***	***3.68***	***3.87***

4.4.2 Qualitative analysis to the level of enhancement in competitive advantages in four sectors

As a course of action aimed at cross checking the quantitative findings and to provide more insight to quantitative data, the same area of inquiry was investigated qualitatively. Once the level of exploitation and the strategic influence is investigated qualitatively, the same population of construction was questioned with the competitive advantage achieved through the exploitation of BIM/ BDA/ IoT (*Question 3- See section 4.2.3.2)*.

As *mentioned in Section 4.2.3.2, the third question related to this chapter is as follows:*

Does employing BIM/BDA/IoT provide a competitive advantage to your company over your peer competitors?

- *(If yes), how has it given your company a competitive advantage? Can I ask you to kindly explain that with a few examples please if any?*
- *(if no), If not for competitive advantage, are there any other reasons for your company to use BIM/BDA/IoT?*

Table 46 below presents a summary of these qualitative findings via open coding and selective coding.

Table 46- Selective coding for enhancement of competitive advantage

Open and selective coding	**Themes emerging**
'how BIM/BDA/IoT enhance competitive advantage'	
“Being ahead of new standards. Because that’s when clients know we are working according to updated industry standards. Clients are requesting BIM”	Client Demand
“BIM-related costs are still high, but rising project costs due to rework and waste are making BIM products more competitive because BIM has the potential to address those issues. BIM helps in gaining efficiencies, increased productivity, and increasing our bottom line. It is not a competitive advantage as most of the competitors use them”	A more efficient and effective way of working
“Using BIM gives everybody involved in a project ‘one version of the truth’ that can be shared and perfected before construction work starts, resulting in a smoother, quicker, construction process with less scope for mistakes, disagreements, or delays”	Full integration and collaboration
“Assessing suppliers and assessing our performance against client requirements”	Performance evaluation
“Enabling a firm to bid to extract the maximum possible from the model, to drive us to the lowest cost, in the shortest possible time, produce drawings and illustrations to a very high quality”	Increased competitiveness

"BIM is crucial for winning a work advantage. Without BIM capability it is difficult to win work. The better you can demonstrate the capabilities and Spirits in them, the higher the tender responses and bids started to carry"	
"The existence of heavier weighting for BIM requirements in tendering"	Imposed mandates and standards
"Helps to improve our margins and provide better outcomes for our clients. Profitability is an outcome of gaining a competitive advantage"	Profitability
"Risk mitigating nature"	Risk mitigation
"Because construction is under-invested in terms of technology, the companies who have already started to embrace digital technologies are winning more work"	Win more work
"Greater predictability"	Foreseeability
"The risk of having outdated documents that could result in delays is eliminated by using BIM/ BDA“	Minimised shortcomings
"BIM works as a strong advertising proposition for the firm as it harps on the experience and skills of the firm rather than the size"	Advertising aspect
"It is not a competitive advantage as it is the default way of working"	Survival in the market

A striking point revealed form the interview was, a considerable number of respondents believe that BIM is <u>not</u> a competitive advantage for them because it has now been business as usual for many of their competitors. Similar answers were received for the use of BDA and IoT as well. But the way these technologies are applied seems to have played a big role in it.

> *"I don't think BIM is a competitive advantage if I'm honest. I do not think it gives us a competitive advantage against anybody else. I cannot exactly say that the use of BIM gives us a competitive edge because most of the developers nowadays use BIM. It may do for the occupational element. It may help when we look in to selling the property- bring it through the BIM model. But I think it is correct to say out modular concept has given us this competitive edge. So, in that sense, BIM owns part of the credit" (I-6).*

> *"Most of our competitors are already using BIM or Big Data. It is no longer a differentiator.*

> *In the ever-demanding commercial world we live in, most of us are looking for an edge over the competition and ways to innovate, to save money and time. As the field is almost level at the moment BIM may not be a substantial differentiator yet but some will rise to the*

surface by continuing to adopt the right tools and processes to offer more for less, better and quicker solutions with clients recognising they are buying a better service and selecting those who can demonstrate they are offering real value. (And there may even be those asset managers who do want the data too. So, using BIM is not a competitive edge anymore. How we use it is what matters. It is a more efficient way of working. So, if we demand not to, we would be left behind our competitors for not doing it" (I-7).

"Probably not anymore. I think it is just kind of expected. It is kind of more becoming the default way of working. I think it is particularly a competitive advantage in my opinion. Just because it is a better way of working, a more efficient way of working. Perhaps more importantly managing assets throughout the lifecycle" (I-9).

Some respondents see BIM as a necessity for their survival rather a competitive advantage, imposing the idea that realising the benefits is not necessarily a competitive advantage.

"It doesn't provide a competitive advantage. However, if we do not do it, then we will not survive. It's not advantageous, it is more survival" (I-11)

On the other hand, many of the respondents still believe that BIM/ BDA/ IoT has the potential to offer a competitive advantage because the clients are requesting it more than ever.

"Clients are asking for BIM now more than ever. And it is massively increasing, particularly on larger government schemes, defence, and education frameworks, mainly due to the Level 2 BIM mandate. If our clients are asking for BIM, we have due diligence to ensure that everyone in the supply chain can deliver what is required. Our BIM managers spend a lot of time with clients and their partners looking at client Employer's Information Requirements to ensure their needs are being reflected on projects. When we tender for projects, we compile different weightings based on client responses and BIM is generally receiving heavier weightings. And we can deliver it according to client requirements; our clients are confident that we can procure what they ask for; I think that's where competitive advantage is" (I-3).

Most of the participants appreciate the value-adding nature of BIM, BDA, and IoT. At the same time, some participants consider the use of BIM, BDA and IOT as a competitive advantage simply because it has been mandated and hence a heavier weighting is given in tenders.

"BIM has given a proper weighting in tenders. So, we get all our work through frameworks. And for us to get work for a framework, we need to be able to meet the requirements. Such a recent requirement is Level- 2 BIM. As an example, 2 years ago, there was only one BIM

project potential within the region, and now we got like 7 within the same region. So, that's quite good enough" (I-12).

"BIM works as a strong advertising proposition for the firm as it harps on the experience and skills of the firm rather than the size. BIM can save your company money in the long run; its greatest strength is productivity. Using BIM can increase your firm's efficiency by up to 30%. BIM also helps mitigate design failures during construction, saving your company time and resources" (I-13).

"The most important aspect of big data that adds as a competitive advantage is Greater predictability. Digital technologies improve collaboration, allowing everyone to access the same data in real-time, to test approaches and catch errors earlier (I-1)".

4.5 The relationship between exploitation and organisational competitive advantage

4.5.1 Quantitative data analysis to investigate the relationship between exploitation and organisational competitive advantage

As stated in section 1.4 of Chapter One, in the effort to improve the level of exploitation for BIM, BDA, and IoT aimed at enhancing organisational competitiveness, the relationship between exploitation and competitive advantage must be first established. Section 2.2.3 of Chapter Two denoted how this relationship has been captured in the extant literature. This research endorses the existing literature by quantitatively investigating this relationship. The following paragraphs discuss the procedure for identifying an association between BBI exploitation and competitive advantage. The more objective scientific research method is always to assume that there is no significant association between BBI exploitation and organisation competitive advantage and to express the null hypotheses as:

$H_1 0$= there is no significant relationship between the BIM exploitation and competitive advantages.
$H_2 0$= there is no significant relationship between BDA exploitation and competitive advantages.
$H_3 0$= there is no significant relationship between IoT exploitation and competitive advantages

Appendix D1 presents the correlations exploitation has with competitive advantages in construction. Because the data collected in this section are all ordinal- they show non-parametric characteristics. First, in the interest of determining the direction and strength of the relationship between variables, Spearman rank correlation analysis was conducted. The results show (Appendix D1) that there are many significant correlations. Some correlations appear to have negative directions (i.e. COMPBDA5- EXPBDA5). As suggested by Cohen (1988) if rho value is between 0.10 – 0.29, the relationship is considered to be a small correlation. Supplementary, the rho value of a medium correlation ranges between 0.30 – 0.49 while large correlation rho ranges between 0.50 – 1.00. Grounding upon the latter guidance, the following variables show large correlations. The following correlations are also statistically significant at p=0.05.

- EXPBIM3 – COMPBIM18 (rho- 506, positive)
- EXPBIM7 – COMPBIM14 (rho- 534, positive)
- EXPBIM10 – COMPBIM21 (rho- 592, positive)
- EXPBIM10 – COMPBIM19 (rho- 528, positive)
- EXPBIM10 – COMPBIM18 (rho- 524, positive)
- EXPBIM10 – COMPBIM17 (rho- 518, positive)

Describing the largest correlation, embracing new routines and processes (EXPBIM10) significantly enhance the value-added ability to the overall sustainability of the society (COMPBIM21). As a part of the development of sustainable business models, firms are often pushed to embrace new routines that simplify the complexity of information flows (Oyedele, 2016). This explains the large correlation between the two aforesaid variables. Further, answers to the following question asked in the interviews provided more insight into this proposition.

Does employing BIM provide a competitive advantage to your company over your peer competitors?
- (If yes), how has it given your company a competitive advantage? Can I ask you to kindly explain that with a few examples please if any?
- (if no), Why are you using BIM?
A fact that was mentioned by many of the interviewees to the above question was, by using BIM and extracting the embedded data from within, it can streamline the management processes of construction towards the final output. There were also beliefs postulated that BIM encourages lean routes. Therefore, the adoption of Lean management together with BIM can reduce the gap between designs and construction and therefore enhance the value-added ability.

It appears (Appendix D1) that correlations are all positive with BIM exploitation. After calculating the group means, it can be concluded that overall BIM exploitation and corresponding competitive advantages have an association (Mean rho= +.141), overall BDA exploitation and competitive advantages have an association (Mean rho= +.106) and overall IOT exploitation and competitive advantages have an association (Mean rho= +.123) while some variables association appears to be significant at 0.05 level. Hence, for the ones with significant correlations, the null hypothesis (H_10, H_20, and H_30) is rejected. As illustrated in Figure 20, BIM, BDA, and IoT exploitation generally has a positive correlation with a competitive advantage.

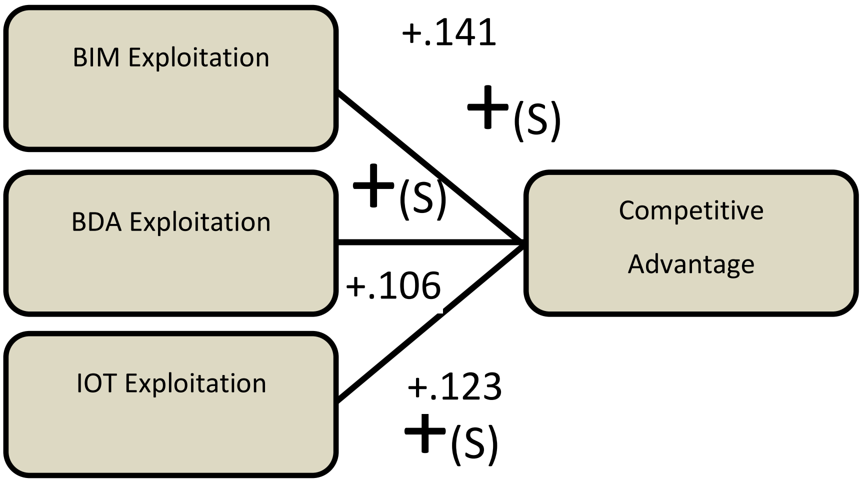


Figure 20- Correlation between BBI exploitation and competitive advantage

Correlation however does not indicate that one variable causes others (Pallant, 2011). The correlations could be a result that one causes another or an additional variable causes both variables. Hence it is important to further investigate which variable causes which. On the contrary, it is also important to mention that some authors have scientifically proven that the stronger the association between two variables, especially control and predictive, the more likely the relationship is to be causal (Hill, 2015). To satisfy the causation, partial correlation Multiple regressions analysis were performed between every EXP and COMP variable. More information on partial correlation and regression can be found in section 5.2.2. The analyses confirmed BBI exploitation influences the behaviours of competitive advantage enhancements. Hence, it can be concluded that the exploitation of BIM, BDA, and IoT cause the enhancement of organisational competitive advantage, in different strengths. The conditions under which exploitation enhances competitive advantage are discussed in Chapter Five as ‘impact factors’. Thus, the findings lead to form a part of the strategic framework.

4.6 The relationship benefits and challenges have with BBI exploitation and then with competitive advantages

4.6.1 The correlation between BIM Benefits/ challenges and BIM exploitation

Section 2.3 explained how benefits and challenges impact the exploitation of each strategic tool as documented in the literature. Moreover, section 1.3 unveiled the importance of this research emphasising how benefits may enable exploitation and thereby enhance competitive advantage. This section of the chapter empirically investigates the correlation between benefits/challenges, exploitation, and competitive advantage to corroborate the existing body of literature as well as to create a narrative towards the strategic framework.

A canonical correlation analysis was conducted using the eight benefits-challenges variables as predictors of the 10 exploitation variables to evaluate the multivariate shared relationship between the two variable sets (i.e. BIM benefits and BIM exploitation). It is important to mention that the two-correlation analysis performed in this chapter has used the construction database only. The analysis yielded eight functions with squared canonical correlations (Appendix D2) of .736, .594, .422, .248, .229, .182 and .035 for each successive function. Collectively, the full model across BIM benefit functions was statistically significant at Wilks's λ = .439 criterion F (36, 245.79) = 0.870, p < .001. while BIM challenges functions was statistically significant at Wilks's λ = .656 criterion F (28, 304.03) = 1.250, p < .001. Appendix D2 presents the summary of the canonical correlation between benefits-challenges and exploitation for BIM. Looking at the canonical correlation summary, it appears that out of the 8 overall correlations, only the first one is statistically significant at the .05 level. It is important to distinguish the difference between this summary and the pair-wise correlations as the latter gives an understanding of every individual correlation and the former gives an overall picture.

Looking at the pairwise correlation table (Table 47), it can be deduced that all BENBIM variables have positive correlations with EXPBIM variables while some of the CHBIM variables have negative correlations with EXPBIM variables. Quite a considerable number of significant correlations can be seen at less than 0.05 of p-value. This is denoting that the more benefits are accrued, the more exploitation has resulted for BIM.

According to the guidelines suggested by Cohen (1988) (see section 4.5.1) few large correlations exist as follows. They are also statistically significant at p=0.05.

- BENBIM2 – EXPBIM10 (rho- 502, positive)
- BENBIM3 – EXPBIM10 (rho- 502, positive)
- BENBIM3 – EXPBIM7 (rho- 548, positive)

Examining the largest correlation, reduction in the overall time (BENBIM3) positively impact performing daily tasks more effectively (EXPBIM10) is the largest strength. This was evident in the literature as well as in the qualitative interviews suggesting that BIM improves communication among project team members, and other relevant parties involved in the project. Consequently, making it easier to visualise problems in advance, so that the waste of time is minimised.

Interestingly the correlations between challenges and exploitation are all 'small', mostly negative, and they do not show a statistical significance. This denotes that the more challenges faced the less exploitation can be achieved for BIM.

Table 47- Canonical correlations between BENBIM-CHBIM and EXPBIM variables

Correlations[a]											
		EXPBIM1	**EXPBIM2**	**EXPBIM3**	**EXPBIM4**	**EXPBIM5**	**EXPBIM6**	**EXPBIM7**	**EXPBIM8**	**EXPBIM9**	**EXPBIM10**
BENBIM1	Correlation	0.370	0.313	0.461	0.417	0.437	0.447	0.461	0.357	0.473	0.441
	Sig. (2-tailed)	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
BENBIM2	Correlation	0.371	0.429	0.464	0.370	0.347	0.323	0.325	0.327	0.460	0.502
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.001	0.003	0.002	0.002	0.000	0.000
BENBIM3	Correlation	0.369	0.459	0.484	0.490	0.384	0.399	0.548	0.369	0.425	0.502
	Sig. (2-tailed)	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
BENBIM4	Correlation	0.336	0.367	0.388	0.302	0.237	0.189	0.280	0.235	0.317	0.336
	Sig. (2-tailed)	0.002	0.001	0.000	0.005	0.029	0.084	0.009	0.031	0.003	0.002
CHBIM1	Correlation	-0.204	-0.334	-0.188	-0.109	-0.102	0.003	-0.048	-0.080	0.032	-0.075
	Sig. (2-tailed)	0.061	0.002	0.084	0.321	0.352	0.977	0.660	0.469	0.769	0.494
CHBIM2	Correlation	-0.190	-0.076	-0.001	-0.060	0.100	0.068	0.053	0.018	-0.006	-0.079
	Sig. (2-tailed)	0.082	0.487	0.992	0.587	0.363	0.537	0.628	0.868	0.955	0.473
CHBIM3	Correlation	-0.071	-0.084	-0.079	-0.102	-0.048	0.007	-0.105	0.075	-0.035	-0.018
	Sig. (2-tailed)	0.516	0.447	0.472	0.352	0.659	0.949	0.337	0.494	0.750	0.870
CHBIM4	Correlation	-0.163	-0.058	-0.041	-0.075	-0.114	-0.085	-0.054	0.069	-0.133	-0.095
	Sig. (2-tailed)	0.135	0.596	0.709	0.495	0.300	0.437	0.623	0.528	0.225	0.385

4.6.2 The correlation between BIM Benefits/ challenges and Competitive advantage

Looking at the pairwise correlations between BIM Benefits/ challenges and Competitive advantage (Table 48), it can be deduced that all BENBIM variables have positive correlations with COMPBIM variables while some of the CHBIM variables have negative correlations with COMPBIM variables. Quite a considerable number of significant correlations show a statistical significance in the correlations between BIM benefits/challenges and competitive advantage. However, there was only one large correlation which was between BENBIM3 – COMPBIM18 (rho- 556, positive). This indicates that reduction in the overall time (BENBIM3) helped to enhance the organisational differentiation/ uniqueness in services (COMPBIM18). According to Porter (1985) differentiation is a competitive advantage when the value for the customer is offered either by lowering prices or by providing greater benefits and services that justify higher prices. In this case, it can be presumed that greater benefits are received when overall design and construction time is reduced by employing BIM. This time saving is passed on to the client as a benefit/ greater service and hence it is an enhancement for differentiation.

Table 48- Canonical correlations between BENBIM-CHBIM and COMPBIM variables

		BENBIM1	BENBIM2	BENBIM3	BENBIM4	CHBIM1	CHBIM2	CHBIM3	CHBIM4
COMPBIM 1	Correlation	.237*	0.163	0.161	0.043	-0.072	0.164	0.035	0.002
	Sig. (2-tailed)	0.029	0.137	0.140	0.699	0.511	0.133	0.750	0.983
COMPBIM 2	Correlation	0.159	0.106	0.152	0.100	-0.105	-0.026	0.007	-0.056
	Sig. (2-tailed)	0.147	0.336	0.164	0.360	0.337	0.812	0.947	0.610
COMPBIM 3	Correlation	0.207	.258*	.263*	0.141	-0.014	0.210	0.049	0.107
	Sig. (2-tailed)	0.057	0.017	0.015	0.198	0.902	0.054	0.659	0.331
COMPBIM 4	Correlation	.271*	.244*	.303**	0.114	-0.123	0.150	-0.027	0.076
	Sig. (2-tailed)	0.012	0.025	0.005	0.299	0.263	0.169	0.806	0.489
COMPBIM 5	Correlation	0.184	.364**	.244*	.321**	0.025	-0.002	-0.032	-0.164
	Sig. (2-tailed)	0.092	0.001	0.025	0.003	0.822	0.985	0.774	0.134
COMPBIM 6	Correlation	.284**	.291**	.268*	0.061	-0.016	-0.031	-0.093	-0.036
	Sig. (2-tailed)	0.008	0.007	0.013	0.579	0.887	0.776	0.396	0.744
COMPBIM 7	Correlation	.234*	.297**	.335**	0.068	-0.034	0.107	0.007	0.051
	Sig. (2-tailed)	0.031	0.006	0.002	0.536	0.755	0.328	0.953	0.642
COMPBIM 8	Correlation	.305**	.281**	.310**	-0.050	-0.124	0.015	-0.055	0.027
	Sig. (2-tailed)	0.004	0.009	0.004	0.651	0.258	0.893	0.620	0.807
COMPBIM 9	Correlation	.345**	.237*	.407**	0.145	-0.021	0.057	0.084	0.003
	Sig. (2-tailed)	0.001	0.029	0.000	0.186	0.851	0.603	0.445	0.975
COMPBIM 10	Correlation	.238*	0.202	.334**	.227*	-0.168	-0.034	-0.104	-0.181
	Sig. (2-tailed)	0.028	0.064	0.002	0.037	0.125	0.754	0.342	0.097

COMPBIM 11	Correlation	.261*	.224*	.448**	.258*	-0.111	-0.055	-.218*	-0.127
	Sig. (2-tailed)	0.016	0.040	0.000	0.017	0.310	0.619	0.045	0.245
COMPBIM 12	Correlation	0.107	0.001	0.151	-0.058	-0.052	0.128	0.116	0.119
	Sig. (2-tailed)	0.330	0.991	0.167	0.599	0.636	0.241	0.290	0.279
COMPBIM 13	Correlation	.322**	.248*	.394**	0.195	-0.067	0.039	-0.058	-0.165
	Sig. (2-tailed)	0.003	0.022	0.000	0.074	0.544	0.722	0.600	0.131
COMPBIM 14	Correlation	.323**	.306**	.377**	.219*	-0.059	0.023	-0.050	-0.068
	Sig. (2-tailed)	0.003	0.004	0.000	0.044	0.593	0.834	0.650	0.537
COMPBIM 15	Correlation	.296**	.275*	.273*	.319**	-0.135	-0.192	-0.177	-0.189
	Sig. (2-tailed)	0.006	0.011	0.011	0.003	0.219	0.078	0.105	0.083
COMPBIM 16	Correlation	.263*	0.185	.307**	0.149	-0.168	0.092	0.075	0.016
	Sig. (2-tailed)	0.015	0.090	0.004	0.173	0.123	0.400	0.498	0.885
COMPBIM 17	Correlation	.305**	.364**	.380**	0.201	-0.070	0.106	0.105	0.049
	Sig. (2-tailed)	0.005	0.001	0.000	0.065	0.524	0.333	0.337	0.654
COMPBIM 18	Correlation	.366**	.312**	.556**	.331**	-0.189	0.035	0.004	0.020
	Sig. (2-tailed)	0.001	0.004	0.000	0.002	0.084	0.751	0.969	0.859
COMPBIM 19	Correlation	.450**	.290**	.487**	.278**	-.250*	-0.084	-0.056	-0.121
	Sig. (2-tailed)	0.000	0.007	0.000	0.010	0.021	0.443	0.608	0.269
COMPBIM 20	Correlation	0.173	0.190	.286**	.388**	-0.176	-0.153	-0.202	-.306**
	Sig. (2-tailed)	0.114	0.082	0.008	0.000	0.108	0.161	0.063	0.004
COMPBIM 21	Correlation	.409**	.233*	.401**	0.155	-0.189	0.044	-0.003	-0.011
	Sig. (2-tailed)	0.000	0.032	0.000	0.157	0.083	0.688	0.978	0.917

In summary, the set of predictor variables for BIM benefits secures a positive correlation with both BIM exploitation and competitive advantage being statistically significant at 0.01. The set of predictor variables for BIM challenges in-general were negatively related to overall BIM exploitation and overall competitive advantage. However, when pair-wise correlations are observed, the correlations were not all ‘negative’. Positive correlations can also be seen between BIM challenges and BIM exploitation (Table 47), The abstract idea of this analysis has been put into diagram form as presented in Figure 21.

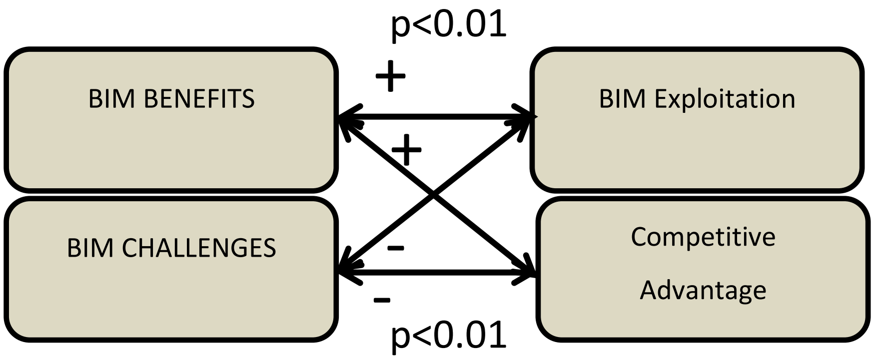


Figure 21- Correlation between group variables BIM benefits-challenges, BIM exploitation and competitive advantage

4.6.3 Canonical correlation between BDA Benefits/ challenges and BDA exploitation

Similar canonical correlation analysis was employed for BDA. Collectively, the full model across BDA benefit functions was statistically significant when the Wilks's λ = .639 criterion F (49, 451.29) = 1.236, p < .001. while BDA challenges functions was statistically significant when the Wilks's λ = .704 criterion F (46, 404.80) = 1.105, p < .001.

As shown in Appendix D3, a considerable amount of large positive correlations can be seen between BDA benefits and BDA exploitation. Examining the largest positive correlation between BENBDA1 and EXPBDA1 (rho= 0.672), time, and cost reduction (BENBDA1) largely helps strategic leadership given for BIM exploitation (EXPBDA1). This can be attributed to several causes. First as mentioned by some of the strategic managers, the efficient ways of storing, managing and analysing information provide strategic managers with more knowledge that can be used to improve strategic planning. Better planning means accurate estimates and a better understanding of timelines and costs. These benefits have triggered most of the strategic managers to try-out some features of BDA and hence they initiate the adoption process towards exploitation. On the other hand, time reduction helps in improving construction productivity.

4.6.4 Canonical correlation between BDA Benefits/ challenges and Competitive Advantage

Looking at the pairwise correlations as shown in Appendix D4, between BDA benefits-challenges and competitive advantages, it can be deduced that most of the BDA benefits have positive correlations with competitive advantages. Some of the CHBDA variables however have negative correlations with COMPBDA variables. Examining the large correlations, only one large correlation can be seen between BENBDA4 and COMBDA7 remarking a rho value of 520. This is significant at p=0.01. This suggests that new product/ service innovation (BENBDA4) largely aids enhancing company governance (COMPBDA7). Angel (2006) affirms that while product innovation improves functionality the service innovation improves attractiveness or performance. The enhancement in company governance hence can be attributed to this improved performance.

All-in-all, BDA benefits, secure a positive correlation with both BDA exploitation and competitive advantage being statistically significant at 0.01. A set of predictor variables for BDA challenges were negatively related to overall BDA exploitation and overall competitive advantage. The abstract idea of this analysis has been taken into the diagram as presented in Figure 22.

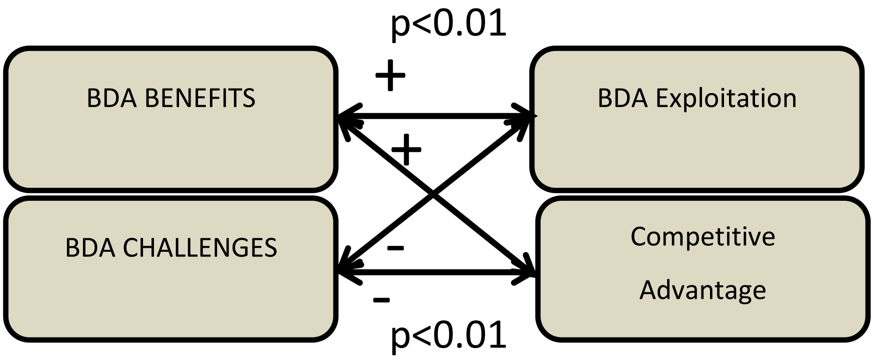


Figure 22- Correlation between group variables BDA benefits/ challenges, BDA exploitation and competitive advantage

4.6.5 Canonical correlation between IoT Benefits/ challenges and IoT Exploitation

A similar canonical correlation analysis was conducted for IoT variables as well. Appendix D5 presents the correlations between IoT benefits-challenges and IoT exploitation. Quite a few large positive correlations can be seen between the following variables:

- BENIOT1-EXPIOT1 (0.569, Positive)
- BENIOT1-EXPIOT2 (0.609, Positive)
- BENIOT2-EXPIOT1 (0.552, Positive)
- BENIOT3-EXPIOT9 (0.576, Positive)
- BENIOT3-EXPIOT10 (0.587, Positive)
- BENIOT4-EXPIOT3 (0.564, Positive)
- BENIOT4-EXPIOT10 (0.512, Positive)
- CHIOT1-EXPIOT2 (0.501, Negative)

Inspecting the largest correlation, real-time data sharing (BENIOT1) greatly assists in deploying IoT tools and applications that enable IoT performance (EXPIOT2). As explained in section 1.2.1, the construction sector currently shows low productivity. One of the reasons for this productivity hinderance includes relying on paper-based processes. Because these processes are not digitised, the time it takes for information to be shared is longer and perhaps it may not be shared with the correct party. Working based on different versions of the truth has been a part of the fragmentation problem. Further, not being able to capture and analyse data from paper-based processes is another drawback. Therefore, timely access to the data has been of concern to many construction workers. This would reduce procurement costs and execution times. The sensors allow generating a range of information about construction location, surrounding environment, and user activities. Sharing this sensor information with team members in real-time allows the information to be analysed instantaneously (Heiskanen, 2017). This rationalises the above correlation as real-time data sharing facilitates fully utilising the IoT tools. There is also a large negative correlation between the lack of standardised guidelines and deploying IoT tools and applications. This is another striking fact that emerged from the interviews- that the limitations of current IoT standards are hindering IoT exploitation. Many of the interviewees brought up the fact that the current IoT standards set for construction neither fit the nature of construction activity nor are they aligned with a construction method or format for an application. In this regard, there is a great need for a holistic view of the standards and guidelines.

4.6.6 Canonical correlation between IoT Benefits/ challenges and Competitive Advantage

The canonical correlations between IoT benefits-challenges and competitive advantage revealed that all 'BENIOT' variables have positive correlations with COMPIOT variables while some of the CHIOT variables are having negative correlations with COMPIOT variables. Although there were no large correlations seen as shown in Appendix D6, there were some statistically significant correlations. Highest among the significant correlations can be seen between COMPIOT15 and BENIOT3. This means that remote/ automated operation and usage monitoring offered by IoT help to increase performance efficiency and predictability. Many of the interviewees mentioned that monitoring the key points of a process to identify poor performance is a competitive advantage as it will allow taking predictive precautions with regards to safety, security, or productivity breaches. Although there were some negative correlations between IoT challenge and competitive advantages, none of them were statistically significant.

Drawing from the above inferences it appears that IoT benefits, secures a positive correlation with both IoT exploitation and competitive advantage, but they did not show a statistically significance. The predictor variable set-IoT challenges were negatively related to overall IoT exploitation and overall competitive advantage. The abstract idea of this analysis has been taken into a diagram as presented in Figure 23.

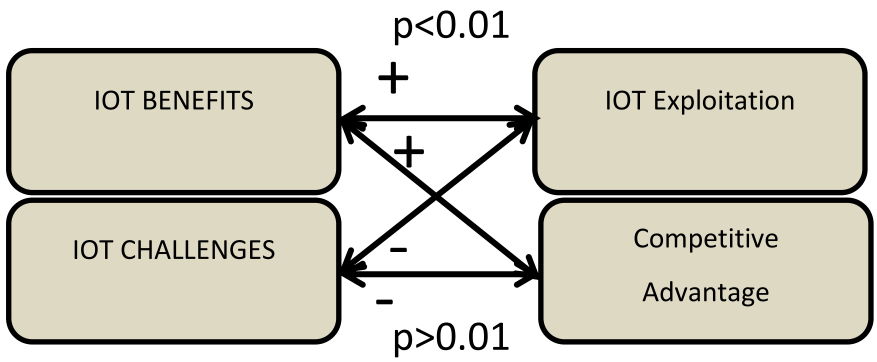


Figure 23-Correlation between group variables IoT benefits/ challenges, IoT exploitation and competitive advantage

Given the correlation data, the overall direction of benefits remarks a positive correlation while challenges remark a negative correlation. All findings were carried forward to the development of the Framework. Considering the findings, it is conspicuous that the extent to which BDA and IoT have been implemented and exploited complexly varies between different aspects of implementation and exploitation. Taking the level of exploitation, benefit accrual, and competitive advantage enhancement into consideration, the RFM sectors are mostly ahead of the construction sector. Hence it is worthwhile seeking the lessons learned from the RFM sectors to explore what can be adopted into the construction industry.

4.7 Chapter 4 contribution to the strategic framework

4.7.1 Development of first order proposed Strategic framework

Section 2.7.1 explained the need for the development of strategic framework along with the intended end-users of the framework. The purpose of a framework is to make recommendations of 'what to do' and 'what should be done' (Hamzah *et al.*, 2011). Frameworks are developed to reinforce the understanding of an issue or area of study, provide structured direction, communicate relationships within a system for a defined purpose, and support decision making and action (Phaal, 2004). In addition, a 'strategic' framework acts as a benchmark, providing a frame of reference to handle both quantitative and qualitative objectives (Day and Wensley, 1988). Strategic frameworks have been widely applied in construction management research (Sonmez *et al.*, 2002). There are several frameworks that have already been developed aiming at implementing BIM, BDA, and IoT (Coates, 2013; Lam *et al.*, 2017; Lin *et al.*, 2017b; Pasini *et al.*, 2016) in construction management literature. For example, Lam *et al.* (2017) propose a framework to make decisions on BIM implementation by evaluating the economic, social, and environmental aspects of the BIM implementation process. Although there have been several such frameworks, it appears that the current construction practices are lacking a tool or a framework that informs how the technologies lead to competitive advantage. Thus, the development of such a framework would not only help the development of technologies but also help to provide some investment advice to its users.

The strategic framework that has been proposed in this study links concepts from literature with empirical evidence to support the improved level of BBI exploitation for competitive advantage. The qualitative (semi-structured interviews) and quantitative (web-based questionnaire surveys) data collection procedures that helped devise these links are discussed in Chapter-3, 4, 5, and 6. The empirical investigations described in those chapters provide the basis for the development of the framework.

BBI exploitation in an organisation or in a project management practice is a process of decision making in a complex integrated environment, which involves both quantitative and qualitative information. The strategic framework relies upon the constructivist knowledge, where the interaction between the object (research problem: BBI exploitation) and the subject (strategic decision-maker) is clearly defined (Sonmez *et al.*, 2002). A framework is also a tool that assists in organising a vast knowledge domain in both explicit and tacit approaches and facilitates the creation of new knowledge (Minsky, 1992). A frame is born when a new trend that differs from commonly agreed perception is encountered and it is structured into memorable information. This frame should have the ability to customise and adapt to be able to fit into different circumstances. A framework also takes the appearance of a data-structure that epitomises a stereotyped situation that one or a group of people encountered as a research question. Framework often guides the reader with a set of structured information indicating; what will happen next and how to react to that, what happens if it didn't work, etc. which is very similar to network nodes and relations (Minsky, 1992).

In fact, 'framework' is a common and frequently used term in B, B, I ontology, which enables the readers to share the knowledge established by key players in the subject domain. Thus, this study intends to develop a framework to help improve the level of exploitation for BIM, BDA, and IoT by visualising the associated knowledge required to understand how BBI collaborations affect the competitiveness enhancing process.

The Figure 24 below is a high-level (First-order) framework that describes the four main cycles of strategy in improving the current exploitation levels to achieve competitive advantage. Each Cycle includes four strategic states, separated by varied activities involved when executing the strategic apex. The strategic apex is divided into three for BIM, BDA, and IoT. The clockwise movement of the cycle indicates the increase (from high to low) of the level of exploitation, benefit accrual, challenges faced, and competitiveness enhancement.

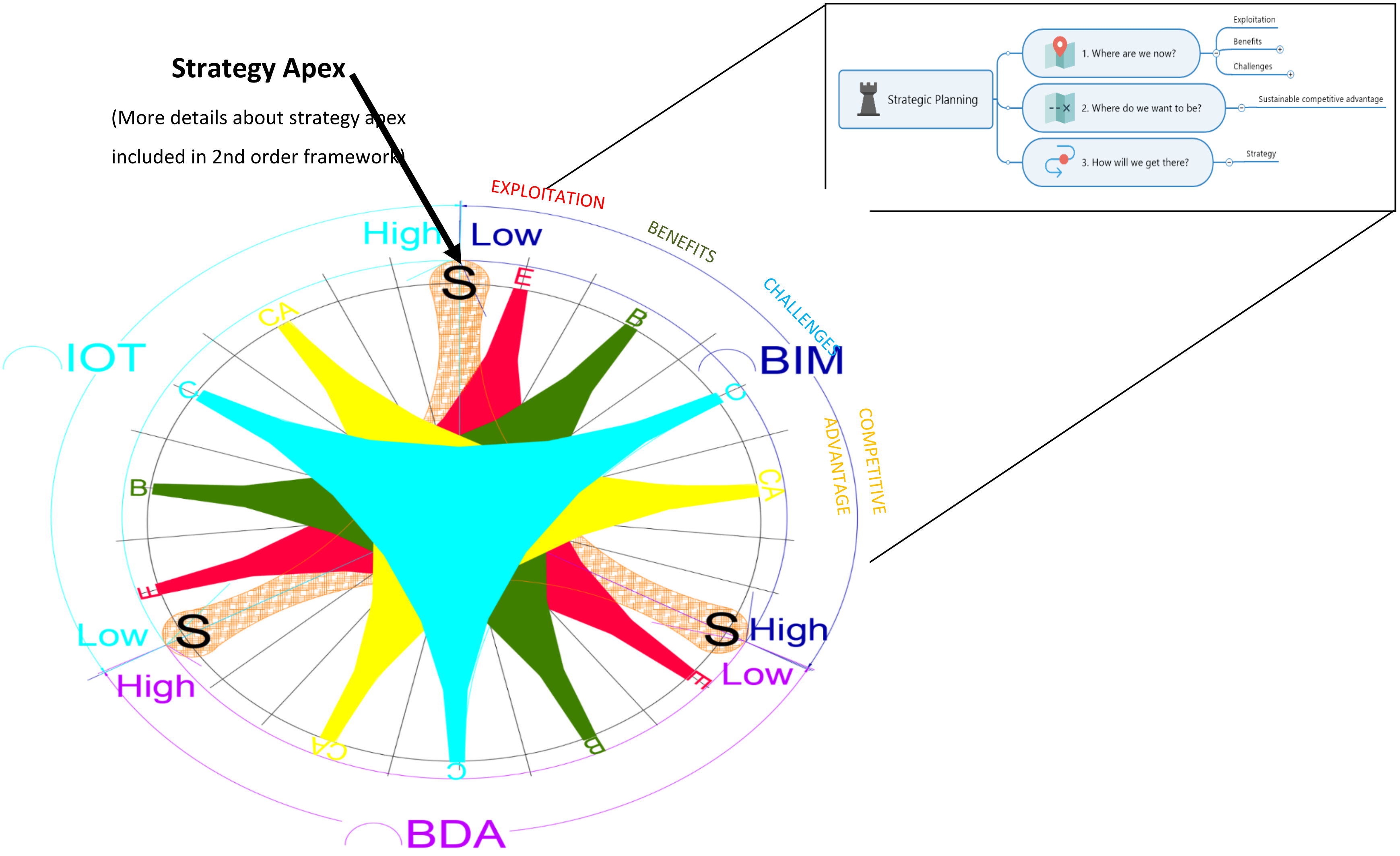


Figure 24- First-order strategic framework

STRATEGY [S]

According to Mintzberg's view on strategy, this study considers strategy as a general direction set for an organisation and its various components to achieve a desired state (i.e. maximising competitive advantage) in the future. To this end, a well-defined roadmap needs to be established for an organisation. This roadmap requires setting a direction of an organisation outlining where they are now (the current status), where do they want to be in the future (the future status) and how will they get there (the process of transforming current status to future status). Although the three technologies require equal strategic influence, the strategic apex differentiates the use of three strategic tools inter alia: BIM, BDA, and IoT. The Strategic apex for all three strategic tools consists of the following perspectives. Each tier (simple fraction of strategic tool) must go through four statuses as a part of the strategic apex. How the strategic apex must be executed is as follows:

PLAN: According to the strategic point of view defined by Henry Mintzberg, any given entity (i.e. an organisation) should first evaluate the current position (Where are we now in terms of exploitation) of exploitation before we go about the improving it. Once the status is identified, then the entity should understand the desired status (where do we want to be?). Once the current and desired status is distinguished, the strategy that takes the entity from the current status to the desired status must be identified. This can be called the PLAN. 'Plan' looks at the current level of exploitation [E].

[E] EXPLOITATION: First, the level of exploitation must be constantly evaluated and re-evaluated to see which position the current level of exploitation is at(where are we now) and to which position this needs to be improved (where do we want to be). This would range from lower levels of exploitation to higher levels of exploitation.

PLOY- A ploy seeks to put an organisation in a favourable competition with other potential providers of the same service(s) by outperforming them. To outperform the competitors, an organisation must establish a mechanism that enables them to enhance their competitive edge by providing a superior/ unique service. Ploy therefore focuses on Competitive Advantages [CA].

[CA] COMPETITIVE ADVANTAGE: The level of enhancement in competitive advantages must be evaluated from the current status to the desired status for more improvements. According to the operational definition for CA used in this thesis, several competitive advantages are evaluated to see how best they can be enhanced by exploiting BBI.

POSITION- Positioning the three strategic tools in such a way that they either individually or collectively maximise competitive advantage is a choice that organisations must make at the outset.

BIM, BDA and IoT exploitation and their leads to competitive advantage

The positioning looks at benefits accrued [B] and the challenges [C] faced like a cost-benefit analysis.

[B] BENEFITS: The extent to which benefits are accrued now, and to what extent this needs to be improved to meet the desired status must be evaluated. This would range from lower levels of benefit accrual to higher levels of benefit accrual.

[C] CHALLENGES: The extent to which challenges could be overcome must be evaluated to see the current capability to overcome challenges and how it helps or impedes reaching the desired future status. This would range from lower levels of exposure to challenges to higher levels of exposure to challenges

PERSPECTIVE- A vision towards the future and extracting the best practice lessons learned from three other sectors is important. The ways an organisation will be able to or will choose to operate largely depends on its perspective towards organisation culture. The perspective therefore looks at the cultural factors of an organisation that put themselves in a favourable business position. The impact of 'organisation culture' is well covered in second-order framework.

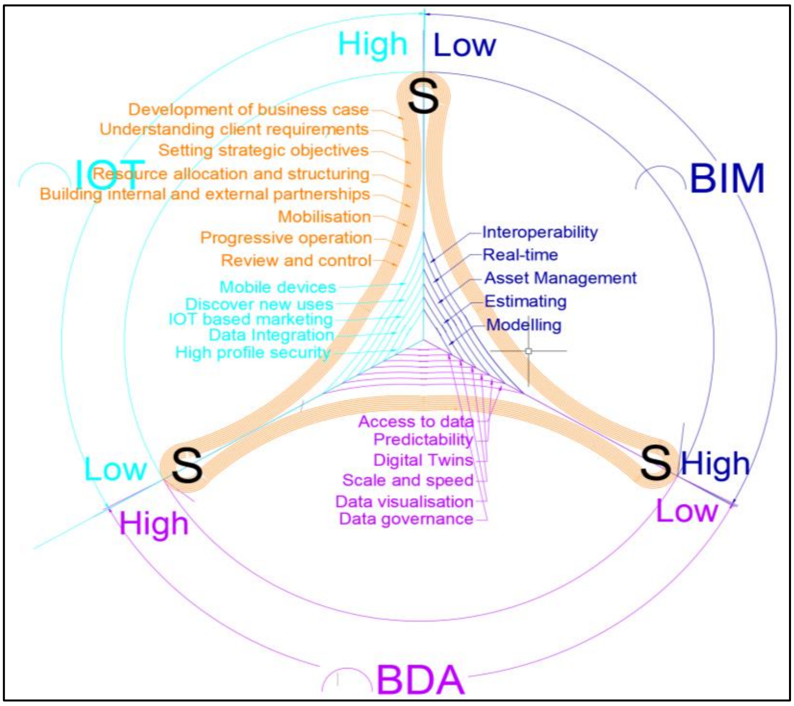
PATTERN- Identify the factors that impact on exploitation and enhance competitive advantages and the type of impact they have towards enhancing competitive advantage. These factors include Structure, and Size. The impact of organisation structure and size on maximising organisational competitive advantage is evaluated in second-order framework.

The subsequent paragraphs describe each part of the strategic framework in more detail. The level of detail drills down to two levels as second order and third order.

4.7.2 Development of second order (Magnify X 1) proposed Strategic framework

[S] STRATEGY

The STRATEGIC APEX helps to determine the strategic requirements to exploit BIM, BDA, and IoT. Qualitative data was primarily employed in establishing strategic requirements. As explained in Section 4.2.3.3, the lessons learned (qualitative data) from Retail, Finance, and Manufacturing sectors were combined with BIM strategy development qualitative data (from construction) to develop the criteria for strategy. The figure below shows part of the second-order strategic framework for STRATEGY.



[E] **Figure 25- Magnify x 1 Strategy Apex** **EXPLOITATION**

As stated in section 4.2.3, the levels of exploitation in BIM, BDA, and IoT vary depending on several factors. Figure 26 shows a snapshot of how well construction is currently exploiting BIM, BDA, and IoT.

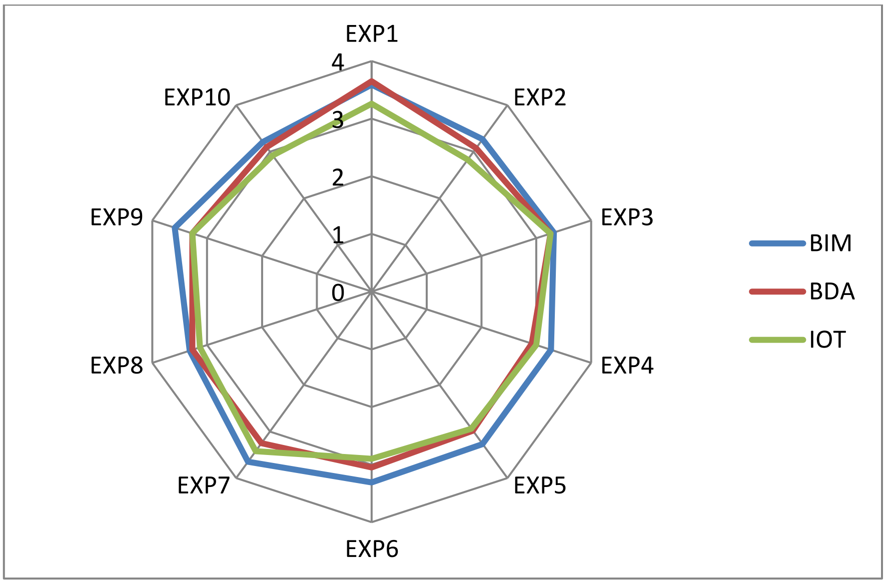


Figure 26- Radar diagram for B, B, I exploitation in the construction

Considering the average of the sums of mean values the overall exploitation levels for BIM, BDA, and IoT can be presented in Table 49. The most exploited strategic tool in construction is reported to be BIM.

BIM, BDA and IoT exploitation and their leads to competitive advantage

Table 49- Average of the sums of mean values for three strategic tools in terms of exploitation

BIM		BDA		IoT	
Out of 4	Out of 5	Out of 4	Out of 5	Out of 4	Out of 5
3.38	4.23	3.18	3.98	3.09	3.86

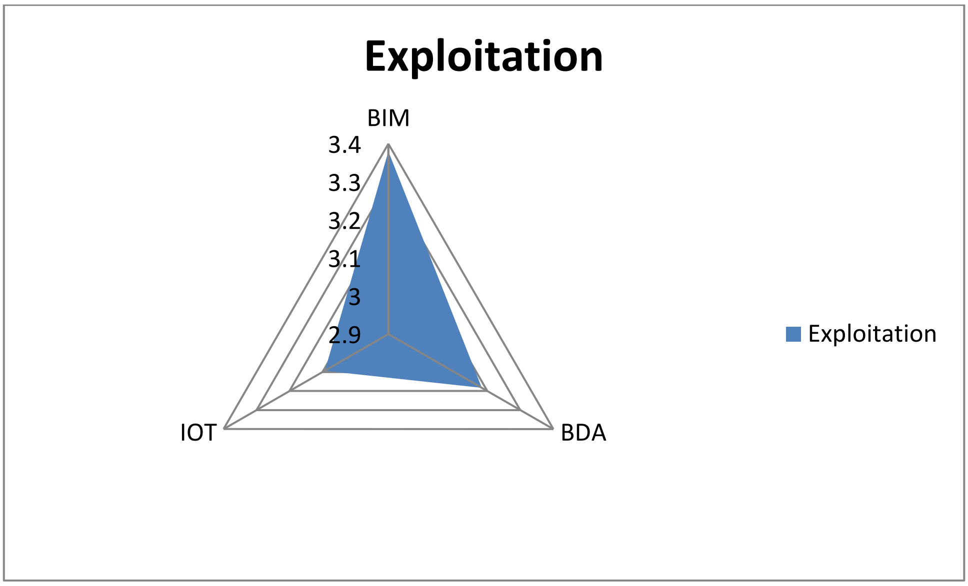


Figure 27- Radar diagram for B, B, I exploitation on averages

From the qualitative data, it was discovered that the level of exploitations is often interpreted based on the following:

- Adoption rate (number of projects, departments, disciplines)
- Age of adoption
- Accreditation
- Input-related
- Operational Process-related
- Output-related

These indicators were also incorporated with the second-order framework below. These are placed in the order of their importance. Another striking point that emerged from the qualitative data is that **individual years of experience** in the use of each strategic tool and the **individual extent of use** also influence the level of exploitation. Hence, these two were also added into the second-order framework.

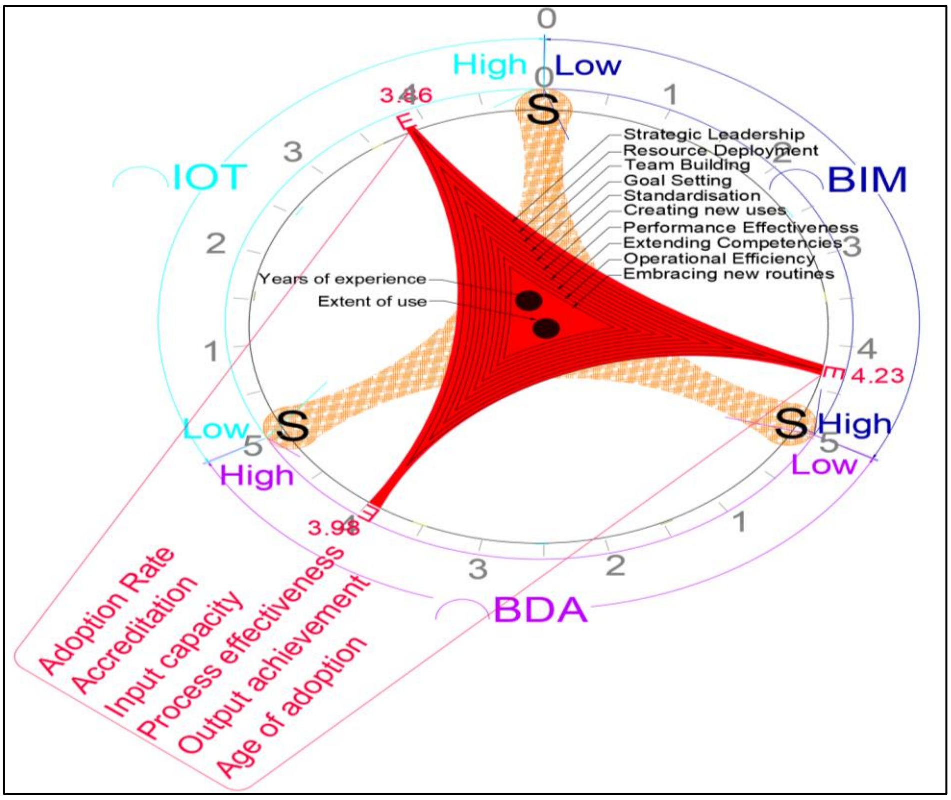


Figure 28- Magnify X 1 Exploitation (E)

[B] BENEFITS

Analysing the benefits one-by-one, the highly accrued benefit from BIM was BENBIM4 (Enable faster and better decisions through greater collaboration). The highly accrued benefit for BDA in construction was BENBDA2 (Identification of important information (through advanced analytics) improves the quality of decision making) while BENIOT3 (Remote/ automated operation) was the area that IOT benefits the most.

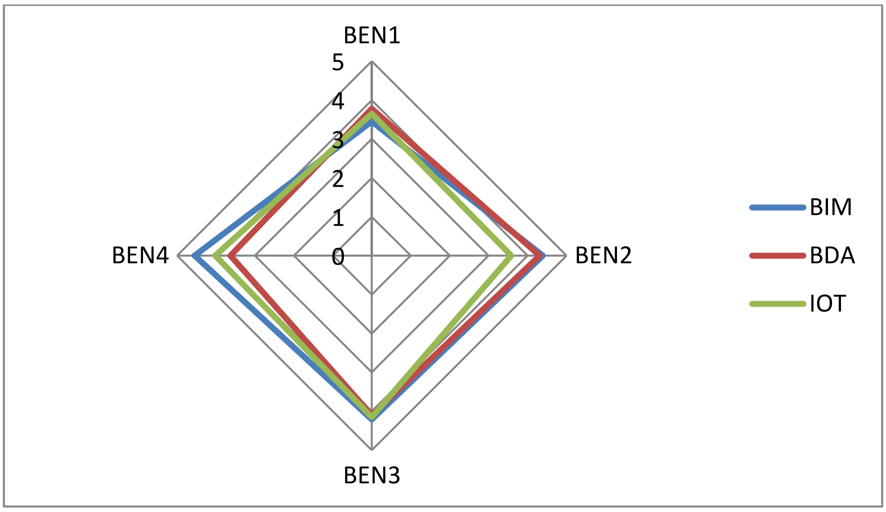


Figure 29- Radar diagram for B, B, I benefits in construction

BENBIM3 (Reduction in the overall time, from inception to completion of construction with less need for rework and early risk/ clash detection), BENBIM4 (Enable faster and better decisions through greater collaboration) were critical benefits concerning BIM alone. Combining both quantitative and qualitative data analysed in section 4.3.1, following magnified (x1) second-order partial framework can be developed.

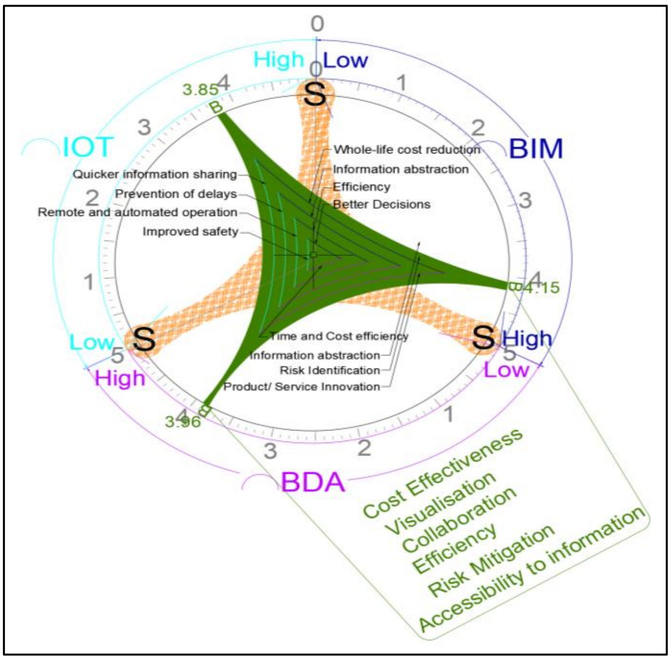


Figure 30- Magnify X 1 Benefits (B)

[C] CHALLENGES

CHBIM1 (Lack of in-house expertise and therefore salary premium of employing personnel trained in BIM) has been reported as the most challenging area for BIM exploitation. For BDA exploitation, CHBDA3 (legal issues regarding data ownership, copyright, and data protection) has been the most challenging area while CHIOT2 (Privacy and security of transferred data) has also been quite challenging compared to the other challenges for IoT exploitation.

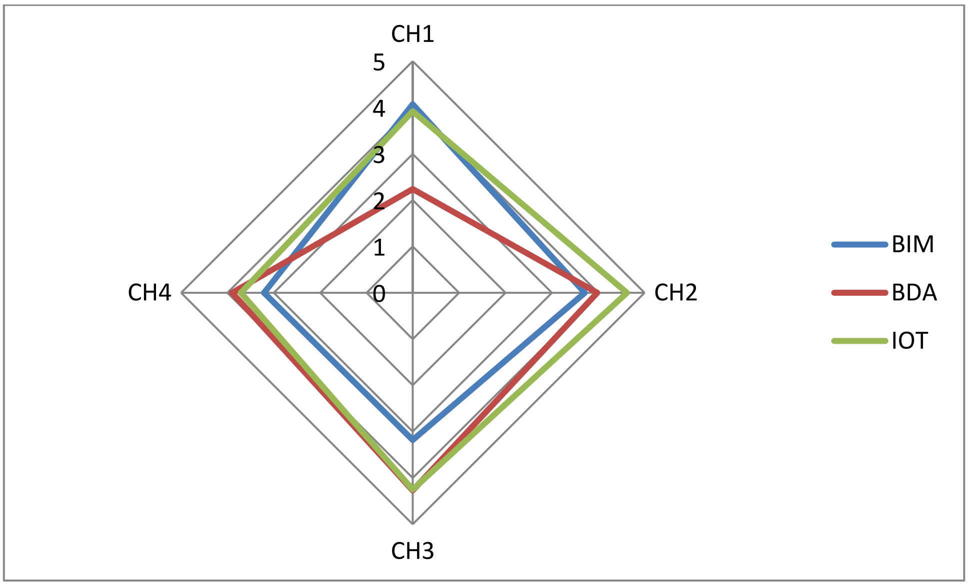


Figure 31- Radar diagram for B, B, I challenges in construction

Considering the overall benefit accrual, BIM is in the lead. Considering the challenges on the other hand, IoT faces more challenges compared to the other two strategic tools. With the rapid growth of technology and its advancement, the growth of cyber-attacks that damage the privacy, protection and security has been a great challenge. This has also changed consumers' perception-IoT to be 'less reliable'. Moreover, lacking a logging system has urged the need for a proper and more reliable logging and observing system. As emerged from the qualitative data, these might be the possible reasons for IoT being more challenging.

Table 50- Average of the sums of mean values for three strategic tools in terms of benefits and challenges

	BIM	**BDA**	**IoT**
Benefits	4.15	3.96	3.85
Challenges	3.54	3.60	4.13

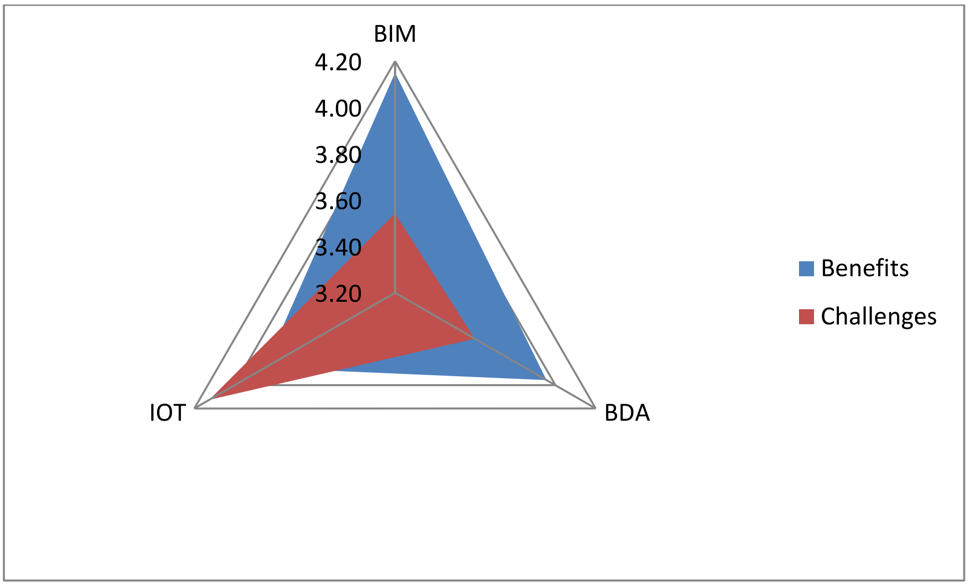


Figure 32- Comparison radar diagram for B, B, I benefits and challenges in construction

Combining both quantitative and qualitative data analysed in section 4.3.1, the following magnified (x 1) second- order partial framework was developed.

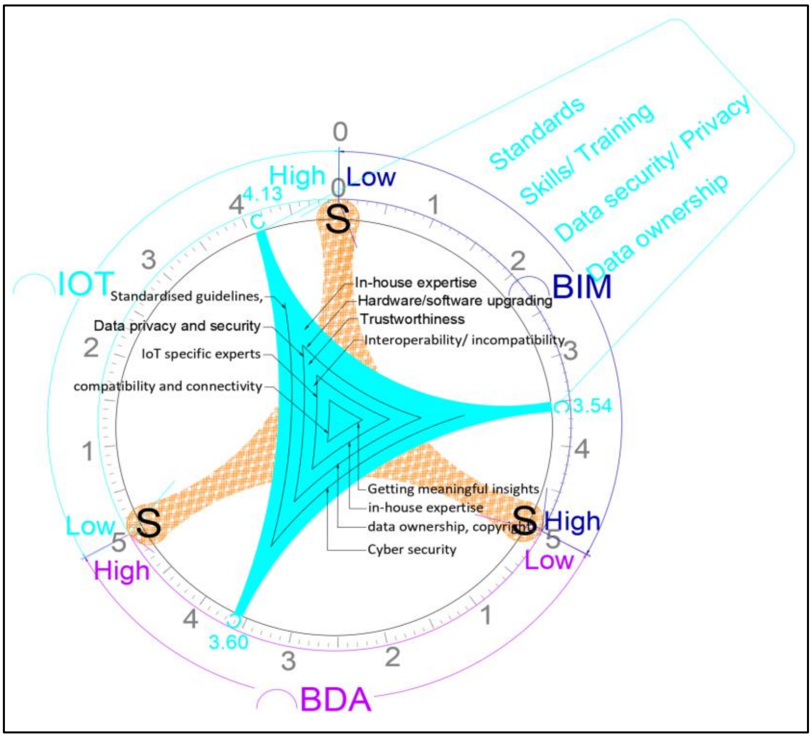


Figure 33- Magnify X 1 Challenges (C)

[CA] COMPETITIVE ADVANTAGE

The figure below shows how BIM, BDA, and IoT individually help to enhance competitive advantages.

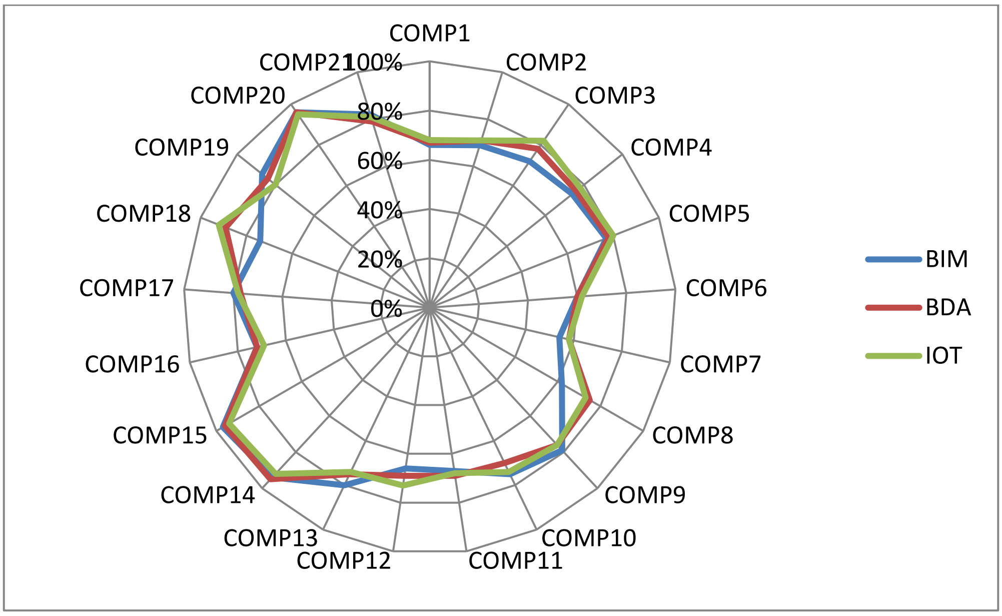


Figure 34- Radar diagram for competitive advantages in construction

Many of the competitive advantages that were identified as critical in the quantitative study were also acknowledged in the qualitative study by all sectors. I-32 from the Retail sector mentioned during the interview that enhanced data analytics solutions enable the retailers to make smart business decisions, improving customer satisfaction and the customer experience, and thereby increasing *customer retention*. The same interviewee mentioned that *Cost reduction* is one of the most important advantages they have received from Big Data analytics-

> *"The more data you have, the easier it is to identify the ways to make business operations more efficient. By analysing data on energy usage, suppliers, time-to-market, etc. businesses can pinpoint where to make the most effective cost-savings" (I-32).*

Employee satisfaction was also mentioned by many interviewees as a competitive advantage that they have received or expect to receive by using BIM, BDA, and IoT.

> *"I can see our employees have a positive attitude towards these new technologies that we are piloting. We have given the shares of our gain that we already piloted. Employees want financial security from their organisation and if an organisation fails to provide this, then it can lose its human resource. Most of the business corporations these days are giving employee's a part in the shares. This is just one way of increasing job satisfaction and job security" (I-32).*

> *"Our people are happy because they know that we are not an out-dated company. We constantly change our way of working according to market demand" (I-28).*

BIM, BDA and IoT exploitation and their leads to competitive advantage

Considering the overall mean scores, BDA and IoT enhance competitive advantage in approximately equal highest scores (77%) while BIM enhances competitive advantage in 75%. This would resembles 3.75 of mean score for BIM and 3.85 for BDA and IoT out of 5.

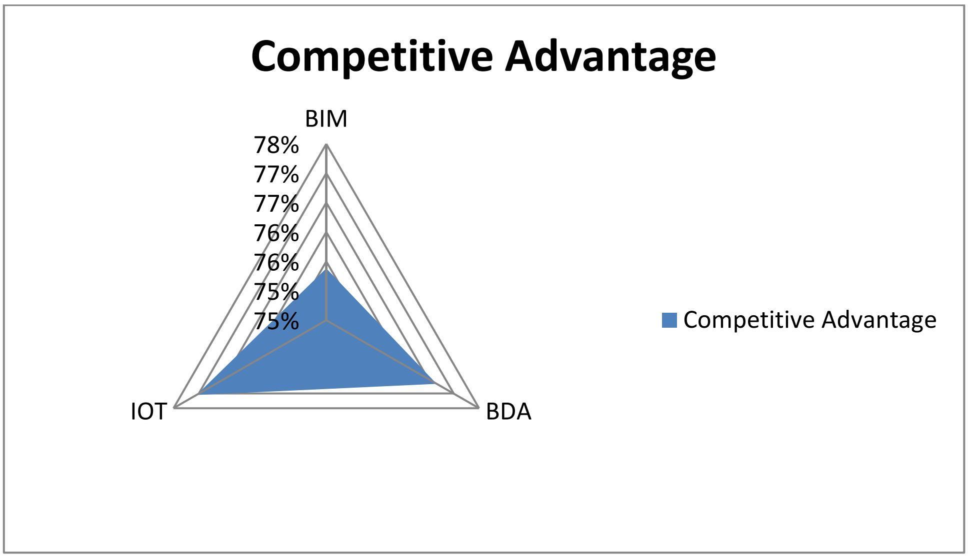


Figure 35- Radar diagram for average BBI competitive advantage in the construction

Considering both quantitative and qualitative data on competitive advantage analysed in section 4.4, the following second-order partial second framework for competitive advantage was developed.

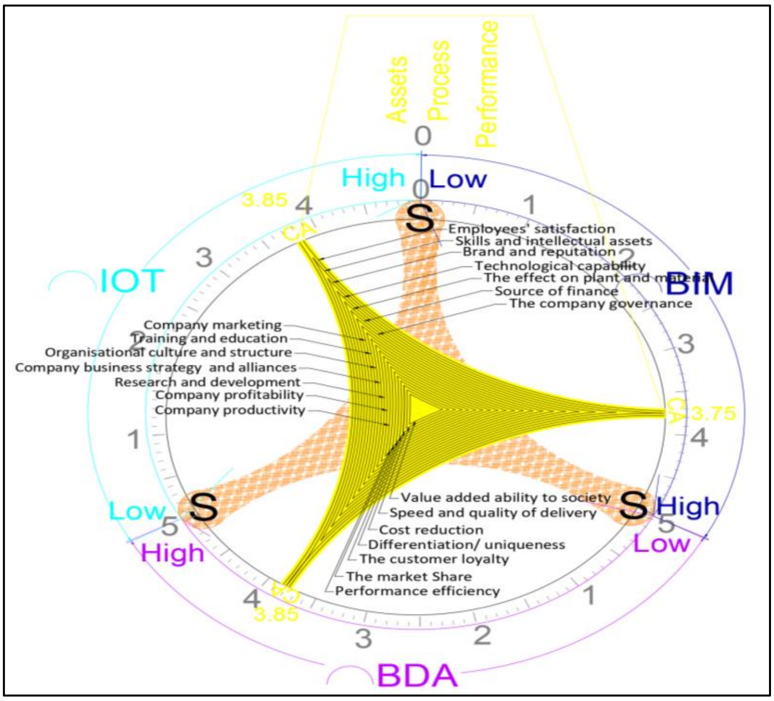


Figure 36- Magnify X 1 Second order partial framework for Competitive Advantage (CA)

Drawing from the findings so far, following Magnify X 1- Second-order framework was developed. This remarks on fulfilling a part of the strategic framework development as outlined in Objective-6.

To complete the strategic framework, supportive information (Magnify X 2- third order) regarding the impact of organisational culture, structure, and size on BBI exploitation is required. This is comprehensively investigated in Chapter Five.

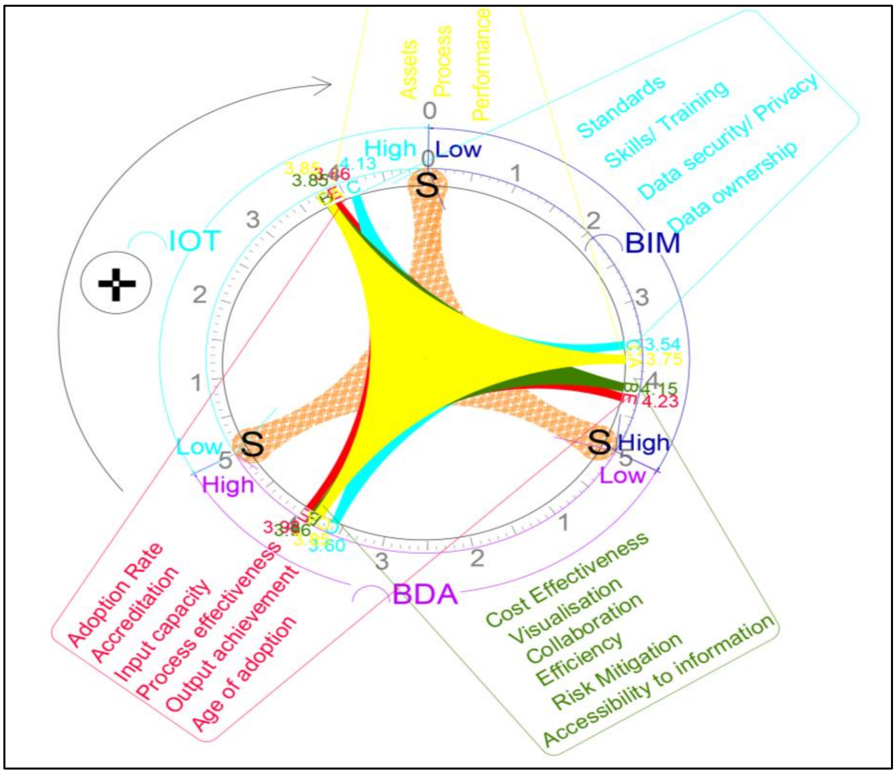


Figure 37- Magnify X 1- Second-order framework

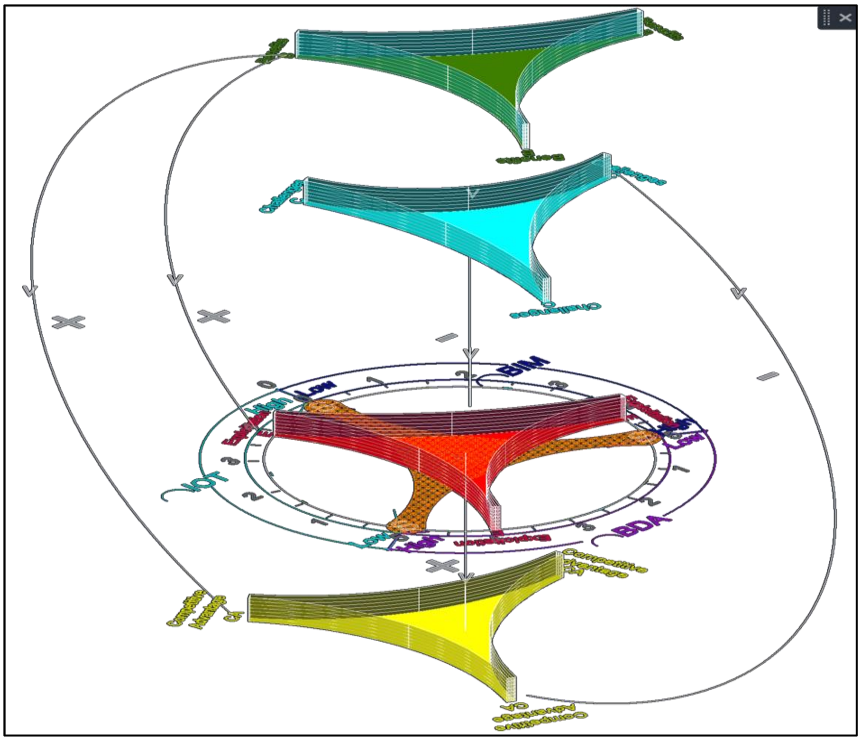


Figure 38- Magnify X 1- Second-order framework with relationships

4.8 Discussion for Chapter Four

Even though the existing body of knowledge has given insights to the BIM/ BDA/ IoT adoption and implementation, this has caused complexity on setting a fine separation line between adoption and implementation. Further, no particular literature has been published to date on the direction of BIM/ BDA/ IoT exploitation (Porwal and Hewage, 2013). The need to adopt a strategic approach for technology implementations has long been a focus for many global economic forums (Kumar, 2016). This study is predominantly underpinned by Mintzberg's 5Ps approach for strategic management. That being the case, this Ph.D. study first makes efforts to analyse the current situation of BIM, BDA and IoT exploitation levels, because 'plan' is the first view of strategic management (See Table 2). The data reveals (as shown in Table 21) that the exploitation levels for BDA and IoT in construction are relatively lower than BIM exploitation. Even though the UK government's ambition is to take on "a global leadership role in BIM exploitation", it appears to have faced challenges to develop and maintain its international construction competitiveness. This has fundamentally influenced the increase in the use of BIM (Bryde et al., 2013). When exploitation was scrutinised, it was convincing that areas such as training, upskilling, making new uses, and process effectiveness are yet to be improved.

As defined in the 'position' view of strategic management (See Table 2), a full analysis of the challenges and the opportunities for BIM,BDA and IOT exploitation was performed. The insights gained by Big data and predictive analytics appear to becoming the newest competitive edge for many of the industries (HM Government, 2017). The findings reveal that certain benefits have accrued at higher levels than the others. For example, concerning construction practices, the benefit received from the identification of important information (through advanced analytics) to improve the quality of decision making is larger than the benefit received from time and cost reduction. This difference has not been adequately captured in the literature. The analytics are also helping to determine the best way to approach clients, the alternative ways to do the transactions, and finally, work out what potential future bids/ sales are.

Next, the extent to which competitive advantages are enhanced by BBI exploitation was investigated using the determinants of competitive advantage. This was guided by the 'Ploy' trajectory as defined by Mintzberg's 5Ps approach (See Table 2). The strategic use of BIM, BDA, and IoT has been widely acknowledged in the literature for their potential of adding value to the final product and thereby improving competitive advantage. The discussions in literature were predominantly focused on five main themes inter alia: Lifecycle and sustainability, design and construction, technologies, and professions (Whyte, 2012). Quantitative analysis of the level of enhancement in competitive advantages across four sectors revealed that performance efficiency through predictability (COMP15), and speed and quality of delivery (COMP20) were the two competitive advantages that were highly affected by exploiting BIM for positive enhancement. The results provide some guidance and a direction for the strategic managers in identifying these competitive advantages and structure their company strategies. The qualitative study in this study develops a part of the strategic framework (the strategy apex) detailing the strategic influences of exploiting BIM, BDA, and IoT. Further, to develop a strategy to exploit either BIM, BDA, or IoT, firms must first develop a business case clearly understanding the client requirements. Then, the strategic objectives must be established by allocating the most feasible amount of resources into each objective achievement. Establishing internal and external partnerships has also been highlighted in the findings as a strategic requirement. Thereafter, mobilising the strategic intent followed by progressive operation, review, and control is recommended.

The last two trajectories look at the ‘pattern’ and the ‘perspective’ (See Table 2). The choices an organisation makes about its strategy rely heavily on its structure, scale, and the culture. This part of the study looked at the relationship organisation structure, culture, and size have on BBI exploitation and thereby enhancing competitive advantage. The way an organisation will be able to or will choose to operate is crucial in strategic exploitation of technologies. Concerning the relationships between exploitation, benefits-challenges, and competitive advantage the findings show different types of correlations between each other. BBI exploitation in general has a positive relationship with competitive advantages. Moreover, BBI exploitation influences the behaviours of competitive advantage enhancements. Some culture aspects like ‘low power distance’ happened to show significant positive correlations with strategic leadership received from senior management and the ability to deploy tools and workflows. Further reasoning for these correlations is discussed in section 7.2.3. The detailed interactive framework (e-version of the framework) shows how differently and complexly BBI exploitation influences different determinants of competitive advantage. The findings of this chapter helped developing first order (Section 4.7.1) and second order (Section 4.7.2) strategic framework.

4.9 Summary of Chapter Four

This chapter first investigated the extent to which BIM, BDA, and IoT are being exploited in four sectors. While construction was leading in the exploitation of BIM, the retail sector was taking the lead in the exploitation of both BDA and IoT. Second, in the investigation of the extent to which the benefits were accrued, the benefit that has been accrued to the highest extent was ‘making faster and better decisions through greater collaboration’. Challenges for BIM on the other hand was prejudiced towards lack of in-house BIM expertise. These findings suggested the need for training and possible advantages of investment decisions in BIM. In terms of BDA, the legal issues regarding data ownership, copyright, and data protection has been the greatest challenge that hampers the ability to exploit BDA in construction. Thereafter, the chapter investigated the relationship between exploitation and competitive advantage. It was found that BBI exploitation not only positively correlated with competitive advantages, but also caused competitive advantage. Further, the findings of this chapter recommend the synergistic exploitation of BIM, BDA, and IoT (BBI exploitation) as it gives a higher level of competitive advantage enhancement than when they are exploited individually. The collective findings lead to the development of the first order and second order strategic framework. Having established that exploitation causes and correlates with a competitive advantage, the next step is to explore the impact of organisational culture, structure, and size towards exploitation, as doing so gives further insights into 'how best' firms could enhance their competitive edge by exploiting these three technologies.

Chapter Five

5 Factors that impact BBI exploitation and competitive advantage

5.1 Introduction to Chapter Five

The purpose of this chapter is two-fold. First to establish the factors that impact construction organisations ability to exploit BIM, BDA, IOT for competitive advantage. Thereafter, the different and complex ways construction organisations can maximise their competitive advantage by exploiting BIM, BDA, and IoT are investigated. The most critical factors that impact BBI exploitation and competitive advantage have been explored and established in the review of the literature (see section 2.6 of Chapter Two). Thus, this chapter focuses on the achievement of Objective-3 (as stated in section 1.4) while answering the two research questions (as stated in section 1.5). Figure 39 shows the position of this chapter in the thesis and how this chapter contributes to the framework development. In the fulfilment of objective 3, the following are the expectations that are met in this chapter.

I. Ascertain the impact of organisational culture on the exploitation of BBI
II. Ascertain the impact of organisational structure on the exploitation of BBI
III. Ascertain the impact of organisational size on the exploitation of BBI

In the attempt of investigating the factors and their impact on the exploitation of BIM, BDA, and IoT for competitive advantage, data collected from the questionnaire survey was first employed. Ordinary correlation analysis was employed in the investigation of the relationship between various variables.

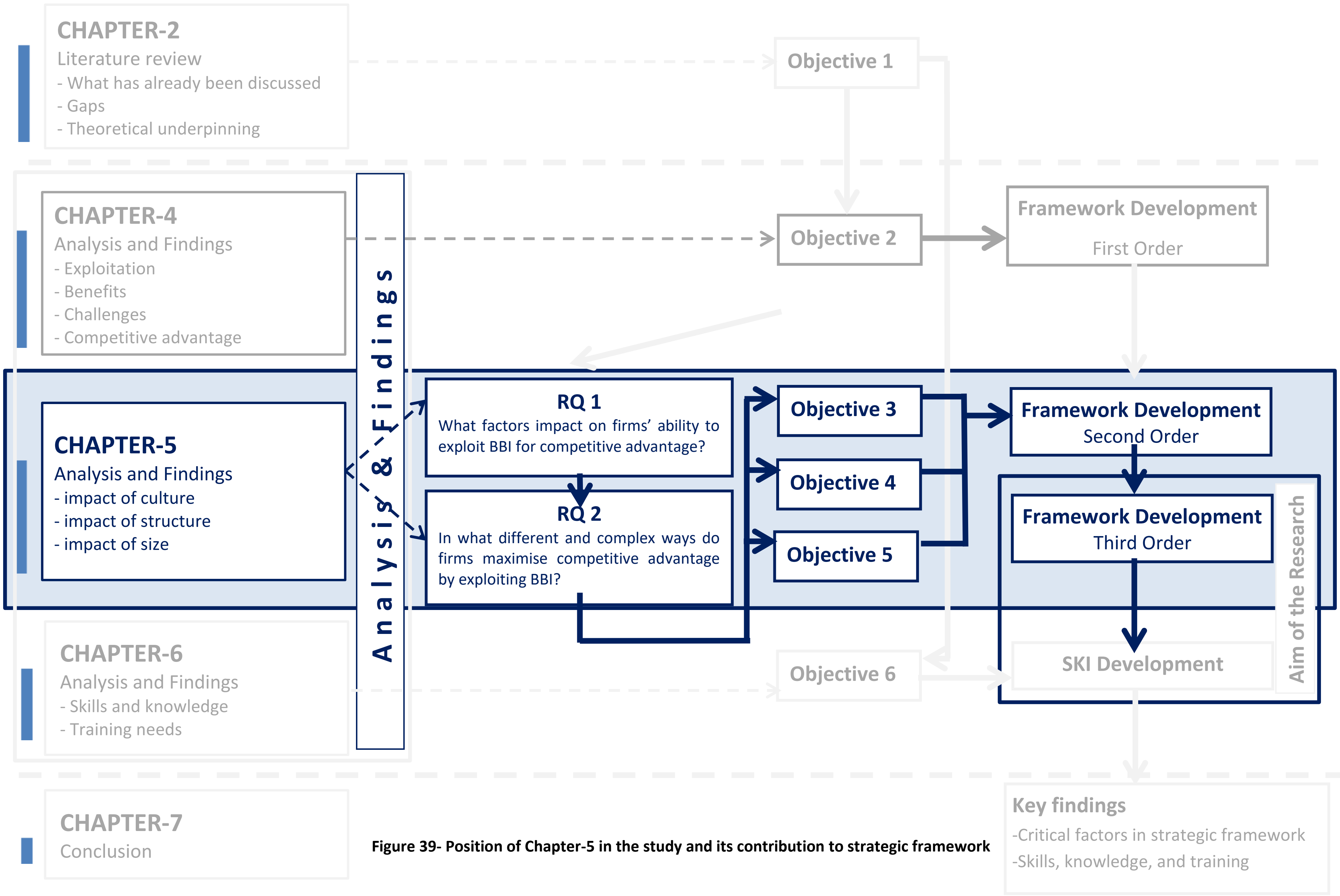


Figure 39- Position of Chapter-5 in the study and its contribution to strategic framework

5.2 Ascertain the impact of organisational culture on the exploitation of BBI

5.2.1 Establishing the culture variables

The construct variables for the exploitation of BIM, BDA, and IoT are listed and comprehensively described in Chapter Four (Please see 4.2.3.1). The basis on which these factors were selected are discussed in section 2.5.1 of Chapter Two. Table 51 shows the selected construct variables for organisation culture brought forward from section 2.6.2 of Chapter Two. while Figure 40 illustrates the types of correlations studied between each variable, it is worthwhile to note that the phraseology used in the questions on organisation culture implicit the impact it has on BBI exploitation (Table 51). For example, ‘the impact of empowering employees and including them in decision-making on achieving the best possible use of BIM’ is one such phrase. Further, for the ease of data analysing, culture factors that represent three strategic tools were distinguished by separate variables. A full list of questions and variables can be found in Appendix C.

Table 51- Construct variables for organisation culture

Organisation Culture Factors	Code	Dimension
The impact of empowering employees, and including them in decision-making on achieving the best possible use	CULT1	Power distance
The impact of having clear job responsibilities and job security on achieving the best possible use	CULT2	Uncertainty Avoidance
The impact of group/ teamwork on achieving the best possible use	CULT3	Individualism/ collectivism
The impact of competitive, result-focused, and risk-taking work environment on achieving the best possible use	CULT4	Masculinity/ Femininity

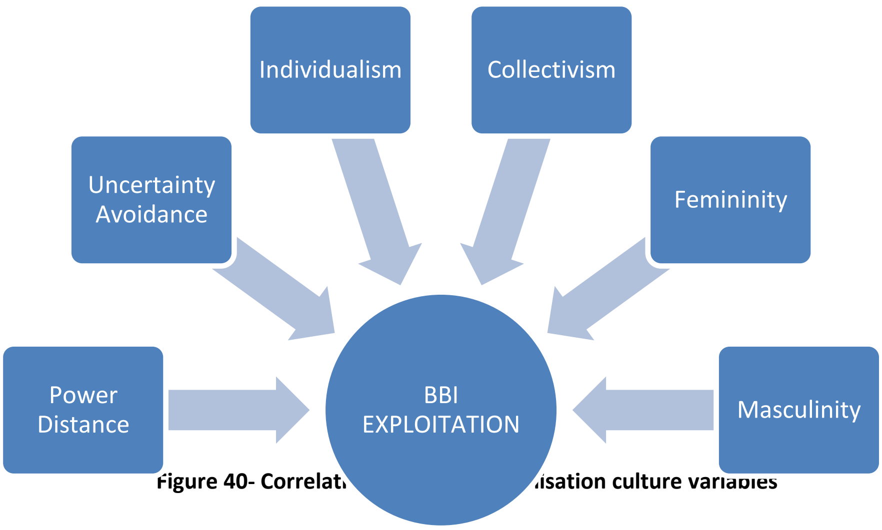


Figure 40- Correlat… …isation culture variables

5.2.2 Quantitative data analysis for organisation culture and BBI exploitation

Preliminary analysis- Assessing reliability

Before looking into the correlations between culture factors, a reliability test was carried out to check whether the required consistency between measuring variables exists. The reliability test for exploitation variables has already been done in Chapter-4. Hence in this section, reliability is checked for the culture factors only. Cronbach's alpha cut-off criterion for this test was 0.70. Table 52 shows a run of the Cronbach's alpha on the items of the questionnaire that measures group variables- culture. The Cronbach's alpha value for CULTURE variables was 0.929- which is a considerably high value and therefore indicates a good internal consistency of the items in the scale. In the exploration of 'Cronbach alpha- if item deleted', the deletion of one variable- CULTBIM2 increases the overall Cronbach-alpha value up to 0.931. But considering the value of retaining that variable and comparing the corrected item-total correlation with other related values, the item was not deleted.

Table 52- Reliability test for all CULT variables

Reliability Statistics	
Cronbach's Alpha	**N of Items**
.929	12

5.2.2.1 Descriptive statistics for the impact of cultural factors on BIM, BDA and IOT exploitation

The questionnaire contained questions that directly indicate the impact of organisation cultural factors on the exploitation of BIM, BDA, and IoT. First and foremost, the descriptive statistics for these impacts were investigated. Due to the limitations of the questionnaire survey (i.e. time it takes to complete the questionnaire, lengthiness of the questionnaire, etc), only four construct variables related to culture were used in the questionnaire. The values of the 5-point Likert scale used in these questions were: 1-Very negative impact, 2- Somewhat Negative impact, 3- Neither negative nor positive impact, 4-Somewhat Positive impact, 5-Very Positive impact. Considering the wording of these values, the higher the mean score, the more positive the impact is.

A similar scoring system as employed in Chapter- 4 which was influenced by Jaafar *et al.* (2018) was employed for the selection criteria. The values were adjusted to fit with the wording of the questions and they are presented in Table 53.

Table 53- Overall suitability scale for cultural factors

Mean interval scale	Mean value scale
1.00–1.80	Very negative impact
1.81–2.60	Somewhat Negative impact
2.61–3.40	Neither negative nor positive impact
3.41–4.20	Somewhat Positive impact
4.21–5.00	Very Positive impact

Table 54 shows the mean values related to the impact that organisation culture variables have on BBI exploitation. The phraseology of the questions was not biased in any direction and hence the respondents were given the opportunity to decide the direction of the impact. However, it is important to mention that the positive/ negative impact (causation) mentioned here is not equal to the positive/ negative correlation between independent and dependent factors obtained via inferential statistics which is presented later in this chapter. As shown in Table 54, all culture variables possess some sort of a positive correlation with BBI exploitation. This means that culture (based on the way it was defined) helps in exploiting BBI. Collectivism especially shows the highest positive impact with BIM exploitation (CULTBIM3). Collectivists are motivated by group goals and hence highly facilitate BIM exploitation. In this question, the researcher pre-establishes that the organisation culture impacts on BBI exploitation from literature (See Chapter-2), and hence only the positivity/ negativity/ neutrality of this impact (causation) is investigated. The inferential statistics presented in section 5.2.2.2 provide more insights into these impacts.

Table 54- Descriptive statistics for Culture variables towards BIM, BDA, and IoT

Variable	Mean	Std. Deviation	Rank	Impact
CULTBIM3	4.68	0.517	1	Very Positive
CULTIOT2	4.63	0.687	2	Very Positive
CULTBIM2	4.61	0.558	3	Very Positive
CULTBDA2	4.61	0.558	4	Very Positive
CULTBDA3	4.42	0.792	5	Very Positive
CULTIOT3	4.37	0.817	6	Very Positive
CULTBDA1	4.36	0.804	7	Very Positive
CULTBIM1	4.32	0.711	8	Very Positive
CULTIOT1	4.06	0.826	9	Somewhat Positive impact

CULTBDA4	4.05	0.705	10	Somewhat Positive impact
CULTBIM4	3.93	0.720	11	Somewhat Positive impact
CULTIOT4	3.88	0.808	12	Somewhat Positive impact

Because it is necessary to ascertain the impact of group variables on BBI exploitation, the group means were also calculated, and thus the impact of group variables is presented in Table 55; Table 56 and Table 57. Commencing with the highest mean score as presented in Table 55, the impact of group/ teamwork on achieving the best possible use of BIM (CULTBIM3) is very positive. Explaining the latter finding, increased productivity and performance resulted from groups that work well together and can achieve much more than individuals working on their own. Section 5.2.3 unveils some possible reasons for this view. However, teamwork intrinsically possesses some negative influences as well, these are explained in section 5.2.4. Masculinity shows a relatively less positive impact compared other cultural factors. Descriptive statistics for the impact of culture on BIM exploitation shows a very positive impact.

Table 55- Impact of organisation culture on BIM exploitation

BIM				
Variable	**Mean**	**Impact**	**Total Mean**	**Total Impact**
CULTBIM1	4.32	Very Positive impact	4.39	Very Positive impact
CULTBIM2	4.61	Very Positive impact		
CULTBIM3	4.68	Very Positive impact		
CULTBIM4	3.93	Somewhat Positive impact		

Table 56 illustrates the group mean values that each Impact of organisation culture has on BDA exploitation. From the descriptive statistics, it was identifiable that culture has a 'very positive impact' towards BDA exploitation. However, it is advisable to check this with inferential statistics where the relationships and causations are derived between cultural impact and BDA exploitation

For BDA exploitation, uncertainty avoidance (CULTBDA2) appears to have the highest positive impact (see Table 56). People in cultures with high uncertainty avoidance often tend to minimise the occurrence of unknown and unusual circumstances and often proceed with pre-tested approaches. This also appeared in the interview data (see section 5.2.3). The main disadvantage of this cultural behaviour is that doing so would hamper ones' ability to trial and error r new routines and processes and thus it hampers the ability to innovate. However, the cultures that make careful and step-by-step changes by attentive planning tend to be more pragmatic and more tolerant to change- which indeed is an enabler for technology exploitation. This could be a reason why high uncertainty avoidance appears to positively impact BDA exploitation to the highest extent of all.

Factors that impact BBI exploitation and competitive advantage

Table 56- Impact of organisation culture on BDA exploitation

BDA				
Variable	**Mean**	**Impact**	**Total mean**	**Total Impact**
CULTBDA1	4.36	Very Positive impact	4.36	Very Positive impact
CULTBDA2	4.61	Very Positive impact		
CULTBDA3	4.42	Very Positive impact		
CULTBDA4	4.05	Somewhat Positive impact		

As with BIM and BDA exploitation, the questionnaire contained questions that directly indicate the impact of organisation cultural factors on the exploitation of IoT, and the descriptive statistics of these impacts were first investigated. Table 54 shows all these descriptive statistics related to the impact CULTURE has on IoT exploitation. Table 57 illustrates the mean value each Impact of organisation culture has on IoT exploitation and as a group. From the descriptive statistics, it is convincing that culture has a 'very positive impact' towards IoT exploitation. However, as with BIM and BDA, investigating inferential statistics to discover relationships and causations is vital.

Given the results for IoT, similar to the situation explained for BDA, uncertainty avoidance (CULTIOT2) seems to positively impact on IoT exploitation more than others. Masculinity (CULTIOT4) is the culture factor that least positively impacts on IoT exploitation. With regards to the newness in IoT provisions in construction, overly risk-taking and a high degree of competition may result in uncalculated losses. A similar view emerged from the interviews which was introduced as 'toxic masculinity' or 'destructive masculinity'. Although risk-taking can progressively lead to success, at certain times overly risk-taking may result in unmanaged losses. Taking unmanageable risks especially in IoT provisions may initially leave a company with ambiguity and difficulties in implementing IoT, and thereby inhibit IoT exploitation as well.

Table 57- Impact of organisation culture on IoT exploitation

IoT				
Variable	**Mean**	**Impact**	**Total mean**	**Total Impact**
CULTIOT1	4.06	Somewhat Positive impact	4.24	Very Positive impact
CULTIOT2	4.63	Very Positive impact		
CULTIOT3	4.37	Very Positive impact		
CULTIOT4	3.88	Somewhat Positive impact		

5.2.2.2 Inferential statistics for culture-BIM exploitation correlation analysis

Appreciating the impact of organisation culture variables on exploitation via descriptive statistics, brings with it an obligation to investigate the relationship between cultural impact and BBI exploitation via inferential statistics. The Spearman rank-order correlation coefficient (Spearman's correlation, for short- denoted by the symbol r_s or pronounced rho) and Kendall's tau are nonparametric measures of the strength and direction of association that exists between two variables measured on at least one ordinal scale (Pallant, 2011). According to the principle assumptions, the two variables used in Spearman's correlation are required to be measured on an ordinal scale.

The Chi-square test has also been widely used in testing for association between responses, especially between two categorical variables. Spearman rank correlation and Kendall's tau are often used for measuring and testing the association between two continuous or ordered categorical responses. Garland, (1991) and Gong (2018) in their studies based on the level of agreement of respondents through ordinal Likert scale data have treated 'level of agreement' data as continuous or ordered categorical responses. This has also been acknowledged by Gaito (1980) and Townsend and Ashby (1984) on their reviews on Measurement scales and statistics. Since the variables in the inquiry of this research are all on an ordinal scale, plus all the dependent and independent data are based on an interval scale (where the interval is equal between two scales) the data in this research are treated as *ordinal continuous* data. Hence, the Spearman rank-order correlation coefficient was appropriate to measure the correlation instead of the Chi-square test. Further, this test informs a monotonic relationship between two variables. A Spearman's rank-order correlation was carried out to determine the strength and the direction of the relationship between the impact of organisation culture variables and exploitation variables. It is noteworthy to mention that only the first analysis is detailed described (with concept models) while all other analyses are presented succinctly, focusing more on the result as they follow a similar procedure as the first one. The large number of variables and large number of pair-wise correlations involved caused this complexity.

The more objective scientific research method is always to assume that no such organisation culture- BBI exploitation relationship exists and to express the null hypothesis. As illustrated in Table 51, culture is defined in four constituents. Since the existing body of knowledge shows ambivalent features about the impact these four culture constituents have on organisational performance caused by technology exploitation, the following hypotheses are suggested:

HC_10= there is no significant relationship between low Power Distance and exploitation of BBI for competitive advantage

HC_20= there is no significant relationship between low uncertainty avoidance and exploitation of BBI for competitive advantage

HC_30= there is no significant relationship between Collectivism and exploitation of BBI for competitive advantage

HC_40= there is no significant relationship between Masculinity and exploitation of BBI for competitive advantage.

As suggested by Cohen (1988), the following guidelines were used to interpret correlation data.

- Small correlation (r= 0.10 – 0.29)
- Medium correlation (r= 0.30 – 0.49)
- Large correlation (r= 0.50 – 1.00)

First, in the interest of determining the direction and strength of the relationship between variables, Spearman rank correlation analysis was employed. This indicated that there were no negative values for any of the Correlation Coefficients (Table 58). This means that there is a positive correlation between the two group variables (BIM exploitation and organisation culture). Second, concerning the strength of the relationship, Correlation Coefficient of '0' indicates a non-significant relationship. Correlation Coefficient of '1.0' indicates a perfect positive correlation, and value of -1.0 indicates a perfect negative correlation (Pallant, 2011). From Table 58 it is apparent, that the significance varies between variables.

The Kendall's Tau statistics were also computed for the same set of variables, as it offers an alternative to Spearman's rank correlation. Kendall's Tau usually gives smaller values than Spearman's rho correlation as Kendall's calculations are based on concordant and discordant pairs (Gray, 2012). However, it is generally accepted that p-values are more accurate with smaller sample sizes (Gong, 2018). On the other hand, Spearman's rho usually has larger values than Kendall's Tau as Spearman's Calculations are based on deviations. Because Spearman's rho is much more sensitive to error and discrepancies in data while the distribution of Kendall's tau has better statistical properties, both were investigated. The correlation Tau-b was selected among three different versions where the denominator of Tau-b consider either variable and the pairs that are tied (Gray, 2012). Because there are many ties expected in ordinal data, Tau-b is the most appropriate. In most of the cases, the interpretations of Kendall's tau and Spearman's rank correlation coefficient are very similar and invariably lead to the same inferences. Hence, only the latter is presented in this section of the chapter.

Table 58- Spearman's correlation analysis for organisation culture and BIM exploitation

		EXPBIM1	EXPBIM2	EXPBIM3	EXPBIM4	EXPBIM5	EXPBIM6	EXPBIM7	EXPBIM8	EXPBIM9	EXPBIM10
CULTBIM1	**Correlation**	.438**	.418**	.469**	.280**	.299**	0.201	.325**	.312**	.425**	.466**
	Sig. (2-tailed)	0.000	0.000	0.000	0.010	0.006	0.065	0.002	0.004	0.000	0.000

	N	85	85	85	85	85	85	85	85	85	85
CULTBIM2	**Correlation**	0.129	.308**	0.205	.267*	.216*	0.136	0.108	0.142	0.125	0.192
	Sig. (2-tailed)	0.238	0.004	0.060	0.013	0.047	0.215	0.324	0.194	0.253	0.078
	N	85	85	85	85	85	85	85	85	85	85
CULTBIM3	**Correlation**	.244*	.336**	.344**	.342**	.355**	.230*	.239*	.263*	.387**	.416**
	Sig. (2-tailed)	0.024	0.002	0.001	0.001	0.001	0.035	0.028	0.015	0.000	0.000
	N	85	85	85	85	85	85	85	85	85	85
CULTBIM4	**Correlation**	.305**	.357**	.364**	.471**	.336**	.221*	.264*	.311**	.275*	.505**
	Sig. (2-tailed)	0.005	0.001	0.001	0.000	0.002	0.042	0.015	0.004	0.011	0.000
	N	85	85	85	85	85	85	85	85	85	85
**. Correlation is significant at the 0.01 level (2-tailed).											
*. Correlation is significant at the 0.05 level (2-tailed).											

These guidelines are applicable regardless of having a negative sign in front of the r-value. Based on the above guidelines, the correlation between BIM exploitation and organisation culture variables shows all positive relationships in a variety of strengths (Table 58). For example, the relationship between CULTBIM4 and EXPBIM10 shows the largest positive correlation between each other (r = 0.505, N= 85, p <0.01). This means that the higher the competitiveness or the risk-taking nature of a work environment, the higher the rate of embracing new routines and processes. Further, to get an idea of how much variance these two variables share with each other, coefficient determination could be calculated by squaring the r-value. For the same above example, $r^2 = 0.255$. This equals 25.5% when converted to a percentage. Meaning, CULTBIM4, and EXPBIM10 share 25.5% of the variance between each other. There is a considerable variance overlapping between the variables. In the attempt to assess the significance level, Sig. (2-tailed) indicates how much confidence it is possible to have in the results obtained. Statistical significance does not indicate how strongly the two variables are associated (Pallant, 2011). Since this value is strongly influenced by the sample size (N), in large samples (N = 100+), a very small correlation may reach statistical significance (p <0.05). Since the sample size of this survey is also closer to 100, a quite decent level of confidence can be reached as the results are statistically significant for quite a few variables. The null hypothesis related to low power distance ($HC_{1}0$= there is no significant relationship between the low power distance and BIM exploitation) is rejected for all EXP variables except EXPBIM6.

Because only the CULTBIM1-EXPBIM6 correlation possesses a correlation which is not significant at r=0.05 (Table 58). All other exploitation variables have positive correlations which are significant at r=0.01.This means that the lower the power distance the higher the exploitation of BIM. This entails that lower levels of inequality and more inclusivity for all levels of employees encourage the exploitation levels for BIM. Further, compared to low power distance, uncertainty avoidance has less significance in the correlation with BIM exploitation. Only CULTBIM2-EXPBIM2 shows a correlation which is significant at r=0.01 and therefore rejects the null hypothesis for uncertainty avoidance concerning EXPBIM-2. This hints that the higher the uncertainty avoidance the higher the deployment of appropriate BIM tools, applications, and workflows. There are statistically significant correlations between CULTBIM3-EXPBIM variables and CULTBIM4- EXPBIM variables. Therefore, null hypothesis is rejected for CULTBIM3 and CULTBIM4 as well. This entails that collectivism and masculinity significantly encourages BIM exploitation.

Finally, to find out the mean r-value between two group variables, the mean of all positive/ negative r-values were calculated (regardless of the sign) and resulted with M= 0.300, meaning there's a Medium (M) correlation (r= 0.30 – 0.49) between BIM exploitation and organisation culture. To obtain the direction of the group correlation, the net mean-value was calculated. Thus, the first finding with respect to correlations for objective-3 is illustrated in Figure 41.

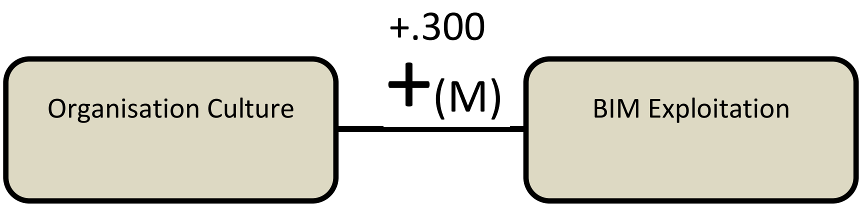


Figure 41- Correlation between group variables culture and BIM exploitation

Partial Correlation Analysis

Correlation is merely an indication of the direction and the strength of a relationship; however, it does not indicate which variable impacts (or causes) what (Pallant, 2011). The existence of correlations could be attributed to the fact that one causes another, or an additional variable causes both variables. Hence it is important to further investigate which variable causes which. It is also important to mention that some authors have scientifically proven that the stronger the association between two variables is, especially control and predictive, the more likely the relationship is to be causal (Hill, 2015). For identifying causal relationships or impacts, partial correlation analysis is therefore employed (See Table 59). As a successive step, multiple regression was also calculated.

The three tests are comprehensively explained for the first correlation only. For all other correlations, only a summary is presented.

According to Gray (2012), the existence of a positive correlation between two variables (organisation culture and BIM exploitation) however is equally compatible with two views. The first view is that the extent to which cultural impact exists reflects the extent to which they have exploited BIM. On the other hand, the extent to which BIM is being exploited reflects the extent to which their culture behaves. This leads to the creation of two contradictory models, each able to live quite happily with the correlations yielded by two variables (r= 0.30, see Table 59). The essence of this section is to see which model is correct to confirm which variable causes which. To this end, the correlation between dependent variables is studied first. As mentioned above, the association between two variables provides two contradictory causal relationships. Gray (2012) purports that there is, however, still another possibility that there can be another variable that influences the original correlation (a third variable). The r-value between this third and two original variables can be higher than the original r-value. Such a pattern of correlation is consistent and indeed suggestive of a third hypothesis, namely that CULTBIM1 has a strong causal influence on both EXPBIM1 and EXPBIM2 as shown in Figure 42.

Table 59- Original zero correlation and the partial correlation between EXPBIM1, EXPBIM2 setting CULTBIM1 as the control variable

Correlations					
Control Variables			EXPBIM1	EXPBIM2	CULTBIM1
-none-[a]	EXPBIM1	Correlation	1.000	.688	.511
		Significance (2-tailed)	.	.000	.000
		df	0	83	83
	EXPBIM2	Correlation	.688	1.000	.442
		Significance (2-tailed)	.000	.	.000
		df	83	0	83
	CULTBIM1	Correlation	.511	.442	1.000
		Significance (2-tailed)	.000	.000	.
		df	83	83	0
CULTBIM1	EXPBIM1	Correlation	1.000	.600	
		Significance (2-tailed)	.	.000	
		df	0	82	
	EXPBIM2	Correlation	.600	1.000	
		Significance (2-tailed)	.000	.	
		df	82	0	
a. Cells contain zero-order (Pearson) correlations.					

The results of the partial correlation show that there was a high, positive partial correlation between the two dependent variables, "EXPBIM1" and "EXPBIM2", whilst controlling for "CULTBIM1", which was statistically significant [r(82) = +.600, n = 115, p = .000]. However, when referred to original spearman's correlation- also known as the zero-order correlation- between "EXPBIM1" and "EXPBIM2", without controlling for "CULTBIM1", it is apparent that there was also a statistically significant, moderate, positive correlation between "EXPBIM1" and "EXPBIM2" (r(82) = +.688, n = 115, p = .000). Controlling CULTBIM1, the correlation between EXPBIM1 and EXPBIM2 (+.688) was reduced to +.600. Although the reduced value of the partial coefficient suggests that part of the EXPBIM1-EXPBIM2 relationship is shared with another variable, it remains large and statistically significant. The comparable partial for EXPBIM1-EXPBIM2 is .600 showing that the linear relationship remains strong even after the effect of another variable in the model are eliminated. This suggests that "CULTBIM1" has the potential to make a large- medium influence in controlling the relationship between "EXPBIM1" and "EXPBIM2" (+.511 and +.442 respectively).

As per the descriptive statistics (Table 55) and partial correlation results (Table 59), it can be concluded that organisation culture causes EXPBIM1 and EXPBIM2 for their level of exploitation. This relationship together with causation is illustrated in Figure 42 (the arrow is the addition which indicates this causation).

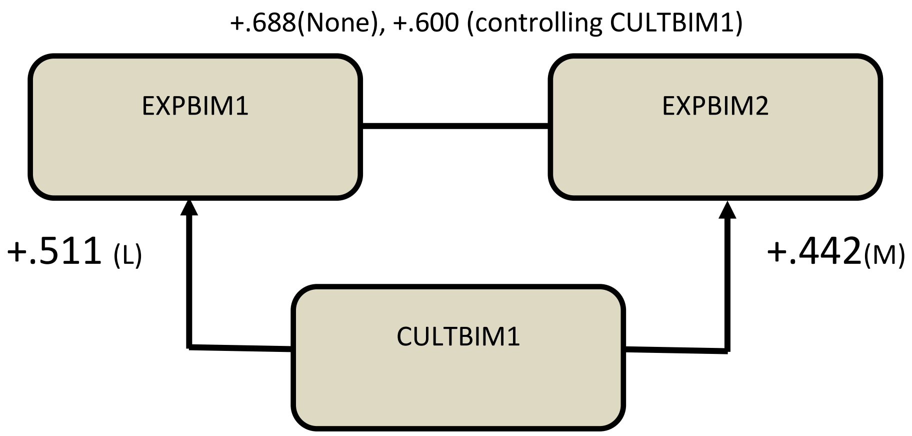


Figure 42- Causation/ impact CULTBIM1 has on EXPBIM1 and EXPBIM2

Notwithstanding the above inference, the investigation can be further extended using another statistical technique to strengthen the finding. This technique is discussed in the next section.

Multiple regression analysis

Multiple regression can tell how well a set of variables can predict an outcome (Pallant, 2011). Each independent variable is evaluated in terms of its predictive power, over and above that offered by all the other independent variables. For example, the research question could read as: "how well do the measures of organisation culture predict the level of exploitation for BIM?" This will eventually confirm whether culture impacts on BIM exploitation or not. To perform Multiple regression analysis, one continuous dependent variable, and two or more continuous independent variables are required (Pallant, 2011). Multiple regression tells how much of the variance in the dependent variable (DV) (EXPBIM1) can be explained by the independent variables (IV) (CULTBIM1, CULTBIM2- for this test, two independent variables were used) while indicating the relative contribution of each independent variable (Pallant, 2013).

According to Table 60, the independent variables (CULTBIM1 and CULTBIM2) show some relationship with dependent variable EXPBIM1 (+.511, +.110 respectively). The correlation between each of the two independent variables mustn't be too high (because it is faulty to include two variables with a bivariate correlation of 0.7 or more in the same analysis) (Pallant, 2013).

Table 60- Correlation between CULTBIM1, CULTBIM (IV) and EXPBIM1 (DV) in multiple regression

Correlations					
		N	**EXPBIM1**	**CULTBIM1**	**CULTBIM2**
Correlation	**EXPBIM1**	85	1.000	.511	.110
	CULTBIM1	85	.511	1.000	.224
	CULTBIM2	85	.110	.224	1.000
Sig. (1-tailed)	**EXPBIM1**	85	.	.000	.158
	CULTBIM1	85	.000	.	.019
	CULTBIM2	85	.158	.019	.

Next, the ‘collinearity diagnostics’ on the variables are presented in Table 61. Tolerance is an indicator of how much of the variability of the specified independent is not explained by the other independent variables in the model. If the Tolerance value is too small (< 0.1) it indicates that the multiple correlations with other variables is high, suggesting the possibility of multi-collinearity (Pallant, 2013). VIF (Variance inflation factor) is the inverse of the Tolerance value. The problem arises only if the VF value is above 10 indicating multicollinearity (Pallant, 2013). Having a closer look at Table 61, it is convincing that there’s no multi-collinearity in this analysis- hence the data is safe-enough for regression analysis.

Table 61- Collinearity Diagnostics for Multiple regressions

Coefficients[a]							
Model	**Unstandardised Coefficients**	**Standardised Coefficients**	**t**	**Sig.**	**95.0% Confidence Interval for B**	**Correlations**	**Collinearity Statistics**

		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	**(Constant)**	1.562	.588		2.657	.009	.393	2.731					
	CULTBIM1	.475	.090	.512	5.251	.000	.295	.655	.511	.502	.499	.950	1.053
	CULTBIM2	-.005	.115	-.005	-.048	.962	-.235	.224	.110	-.005	-.005	.950	1.053
a. Dependent Variable: EXPBIM1													

The ‘R Square’-value in Table 62 tells how much of the variance in the dependent variable (EXPBIM1) is explained by CULTBIM1 and CULTBIM2- this is simply the coefficient of determination (CD) whereas the adjusted R square is calculated by using the degrees of freedom to reduce the estimate and to allow for shrinkage with resampling (Gray, 2012). When the variability of the residual values around the regression line relative to the overall variability is small, the predictions from the regression equation are good. If there is no relationship between the two variables (IV and DV), then the ratio of the residual variability of the one variable to the original variance is equal to 1.0. Then R-square would be 0. If both variables are perfectly related then there is no residual variance and the ratio of the variance would be 0.0, making R-square = 1. In this case, ‘R Square’ value is 0.261 (26.1% expressed as a percentage). R can be one measure of the quality of the prediction of the dependent variable. As outlined by Cohen (1988), the regression and correlation coefficients are closely related and the strength of the influence could be determined by the relative variance of the partial correlations (among dependent variables). The extent to which this variance is explained by the independent variables could also be determined by this. As suggested by Cohen (1988) the following guidelines could be used to interpret regression coefficient data to determine the strength of the effect/ impact.

- Small size of effect ($0.1 \le r < 0.3$)
- Medium size of effect ($0.3 \le r < 0.5$)
- Large size of effect ($r \ge 0.5$)

Building upon this notion, the strength of the influence/ impact is calculated. The output is presented in Table 62. Because the all-in-one partial correlation was carried out by controlling all independent variables together, the strength of the impact received for all independent variables was repeated among all CULT factors.

To find out whether it is statistically acceptable to use four variables to control, widely acceptable critical values for evaluating Mahalanobis distance values were considered. According to Tabachnick and Fidell (2012), the critical value for four independent items is 18.27. The maximum value in this data set is 18.369, which slightly exceeds the critical value. However, it is also possible to run the analysis by controlling each independent factor one by one which are supposed to have a Mahal-distance of 13.82. Hence, confirming the suitability to use four variables to control.

Table 62- Model summary for multiple regression analysis

Model Summary[b]				
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
1	.511[a]	.261	.243	.574
a. Predictors: (Constant), CULTBIM2, CULTBIM1				
b. Dependent Variable: EXPBIM1				

To assess the statistical significance of the result, it is necessary to check the ANOVA (Table 63). This tests the null hypothesis that multiple Regression in the population equals 0. The model in this case reaches statistical significance (Sig. = .000; this means $p<.0005$). The table shows that the independent variables statistically significantly predict the dependent variable ($p < .0005$) (i.e., the regression model is a good fit for the data). Upon examination of all tests related to Multiple-regression analysis, inferences can be drawn that the measures of organisation culture (CULTBIM1 and CULTBIM2) predict measures of the level of exploitation for BIM (EXPBIM1). However, it is possible to expect unusual cases that have standardised residual values above 3.00 and below -3.00 in large samples (Pallant, 2013). Among the sample tested in this section, only two cases were found through case-wise diagnostics where the model could not predict that value.

Table 63- ANOVA for multiple regression analysis

ANOVA[a]						
Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	Regression	9.541	2	4.770	14.462	.000[b]
	Residual	27.048	82	.330		
	Total	36.588	84			
a. Dependent Variable: EXPBIM1						
b. Predictors: (Constant), CULTBIM2, CULTBIM1						

The presence of outliers can be detected from the normal P-P plot (Figure 43). Outliers are the cases that have a standardised residual of more than 3.3 or less than -3.3 (Tabachnick and Fidell, 2007).

With large samples, it is not uncommon to find several outlying residuals. Hence, if a few were found in the scatterplot, it is not necessary to take any action (Pallant, 2013).

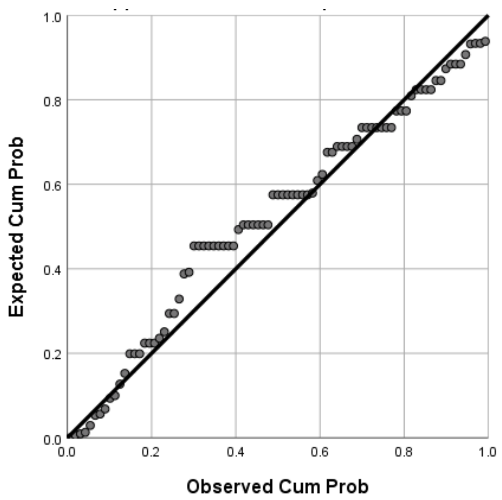


Figure 43- Normal P-P Plot Regression standardised residual for EXPBIM1

Thus, considering the following three analyses:

- Spearman's Correlation analysis.
- Partial Correlation analysis and.
- Multiple Regression analysis.

It can be concluded that CULTBIM1 has a positive correlation with EXPBIM1; which is statistically significant and further, CULTBIM1 has an influence on the relationship between EXPBIM1 and EXPBIM2 while, CULTBIM1 can predict the measures of EXPBIM1. This means that low power distance has a positive correlation with leadership received from senior managers. Where power distance is low in an organisation, employees enjoy a greater degree of autonomy and independence. Consequently, when the leadership and support offered by strategic managers is higher, then the tendency of lower-level managers to engage more on the decision making also becomes higher. The pros and cons of low power distance are extensively discussed in section 5.2.3. Figure 44 shows the initial model drawn from all the above inferences.

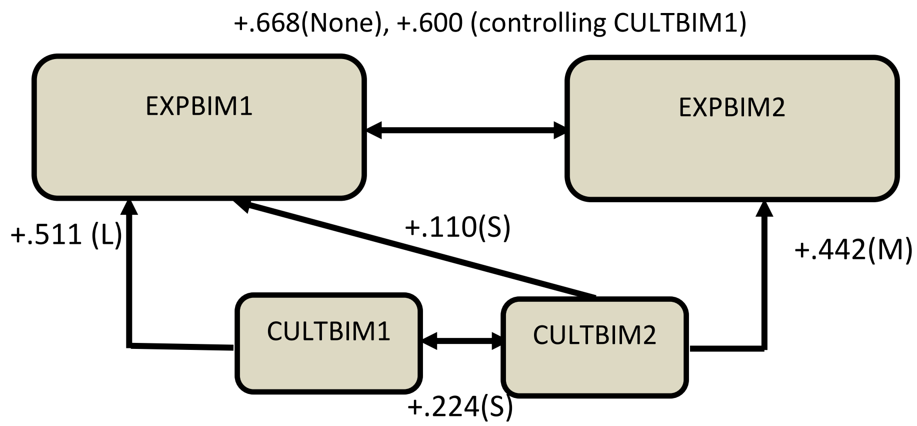


Figure 44- Initial correlation model fed in to strategic framework

This indicates a causal relationship which constitutes the following propositions:

1. The higher the impact of empowering employees, and including them in decision-making (CULTBIM1), the higher the strategic leadership and support from senior management for BIM (EXPBIM1).
2. The impact of empowering employees, and including them in decision-making (CULTBIM1) has an influence/ impact on strategic leadership and support from senior management for BIM (EXPBIM1)

Likewise, similar steps were undertaken to see the direction and correlation between all culture variables and BIM exploitation variables. A full explanation for all three tests is not presented for other variables, but a summary of findings is presented.

From the descriptive statistics, the nature of the impact that the cultural factors have on BIM exploitation variables can be seen. Subsequently, the relationship and causation between cultural impact and BIM exploitation were investigated through inferential statistics. Drawing from the correlation inferences, the impact of culture on BIM exploitation are summarised in Appendix E1: Hypothesised relationships of inter-organisational culture and BIM exploitation. This leads to constitute several propositions. Based on the definition used for culture in this research, the quantitative study shows an overall positive relationship between culture as a group and BIM exploitation as a group. Moreover, cultural constituents impact/ influence BIM exploitation in varying degrees of strength and significance. Thus, the following simplified model was developed forming a part of the Strategic Framework. A more detailed correlation and causation list can be found in Appendix E1.

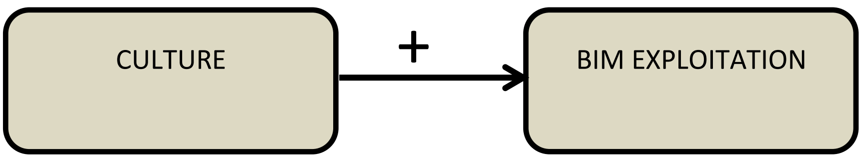


Figure 45- Correlation and causation between Culture as a whole and BIM exploitation

5.2.2.3 Inferential statistics for culture-BDA exploitation correlation analysis

A Spearman's rank-order correlation was carried out to determine the strength and direction of the relationship between the impact of organisation culture and BDA exploitation. The analysis resulted in the data presented in Table 64.

According to Cohen's (1988) guidelines, the correlation between BDA exploitation and organisation culture impact variables shows all positive relationships in a variety of strengths. The largest positive correlation can be seen between EXPBDA1 and CULTBDA1 ($r = 0.452$, $N = 59$, $p < 0.01$). This means that the lower the power distance, the higher the strategic leadership for BDA exploitation. The manager's potential to motivate and persuade others to accomplish company goals is higher when the power distance is low. Thus, low power distance is in favour of BDA exploitation. To get an idea of how much variance the two latter variables share with each other, coefficient determination was calculated by squaring the r-value. For EXPBDA1-CULTBDA1, $r2 = 0.204$. This equals to 20.4% converted to a percentage. Meaning, CULTBDA1, and EXPBDA1 share 20.4% of the variance between them. In summary, the null hypothesis related to low power distance (HC_10= there is no significant relationship between low Power Distance and exploitation of BDA for competitive advantage) was rejected and the alternative hypothesis for EXPBDA1, EXPBDA3 and EXPBDA10 was supported. Teasing out the highest r-value for CULTBDA1, low power distance correlates (medium correlation) with the leadership received from strategic managers on the exploitation of BDA. There were no significant correlations between uncertainty avoidance and BDA exploitation. This entails that NULL hypothesis- HC_20 is not rejected. Null hypothesis- HC_30 and HC_40 were also rejected as Collectivism (CULTBDA3) and Masculinity (CULTBDA4) show quite a few significant correlations with BDA exploitation.

Table 64- Spearman's correlation analysis for organisation culture and BDA exploitation

		EXPBDA1	EXPBDA2	EXPBDA3	EXPBDA4	EXPBDA5	EXPBDA6	EXPBDA7	EXPBDA8	EXPBDA9	EXPBDA10
CULTBDA1	Correlation Coefficient	.452**	0.105	.290*	0.217	0.164	0.250	0.155	0.255	0.060	.298*
	Sig. (2-tailed)	0.000	0.428	0.026	0.099	0.214	0.056	0.241	0.051	0.650	0.022
	N	59	59	59	59	59	59	59	59	59	59
CULTBDA2	Correlation Coefficient	0.220	0.080	0.239	0.249	0.127	0.175	0.134	0.202	0.072	0.176
	Sig. (2-tailed)	0.093	0.546	0.068	0.057	0.339	0.186	0.312	0.125	0.590	0.181
	N	59	59	59	59	59	59	59	59	59	59
CULTBDA3	Correlation Coefficient	.317*	0.238	.313*	.370**	.279*	0.230	0.152	.317*	0.133	.310*
	Sig. (2-tailed)	0.015	0.069	0.016	0.004	0.032	0.079	0.252	0.015	0.314	0.017
	N	59	59	59	59	59	59	59	59	59	59
CULTBDA4	Correlation Coefficient	.396**	0.170	.329*	.308*	0.237	0.169	.311*	.326*	.259*	.367**

	Sig. (2-tailed)	0.002	0.197	0.011	0.018	0.071	0.201	0.017	0.012	0.047	0.004
	N	59	59	59	59	59	59	59	59	59	59
**. Correlation is significant at the 0.01 level (2-tailed).											
*. Correlation is significant at the 0.05 level (2-tailed).											

In the attempt of obtaining the mean r-value between two group variables, the mean of all positive/ negative r-values were calculated (regardless of the sign) and resulted with M= 0.174, meaning there's a Small (S) correlation between BDA exploitation and organisation culture. To obtain the direction of the group correlation, the net mean-value was calculated. Thus, the finding with respect to correlations that satisfied objective-3 is illustrated in Figure 46.

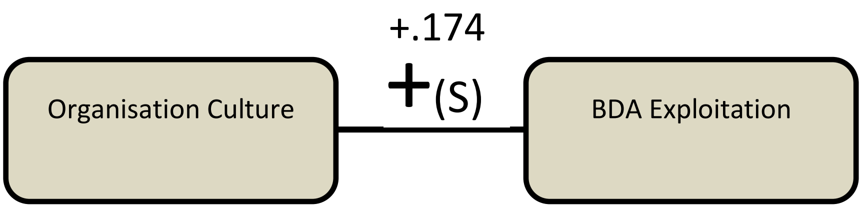


Figure 46- Correlation between group variables culture and BDA exploitation

Partial correlation and multiple regression analysis were also carried out to determine the causation between CULT and BDA EXPLOITATION variables. The results of the partial correlation show that there were statistically significant positive partial correlations between all dependent variables (paired-wise)- "EXPBDA1 to EXPBDA10", whilst controlling for "CULTBDA1, CULTBDA2, CULTBDA3 and CULTBDA4". However, the strength of these positive correlations varies. Moreover, considerable differences can be seen between 'original zero-order' and 'controlled partial' correlation coefficients. It was also noticeable that when CULT factors were controlled, some correlation coefficients were increased while some were reduced. These results suggest that CULT variables influence the relationship between the dependent variables.

According to the 'R Square', value CULTBDA1, CULTBDA2, CULTBDA3, and CULTBDA4 have the ability [r^2=0.300 (30% expressed as a percentage)] to explain the variance in the dependent variable (EXPBDA1). Moreover, the model, in this case, reaches statistical significance (Sig. = .001; this means p<.0005). After examination of all tests related to Multiple- regression analysis, inferences can be drawn that the measures of organisation culture (CULTBDA1, CULTBDA2, CULTBDA3, and CULTBDA4) have a statistically significant ability to predict the measures of the BDA level of exploitation. The points in the normal P-P plot (Figure 47) mostly remain in a reasonably straight diagonal line from the bottom left to top right. This would suggest that no major deviations from normality and not many outlying residuals in the data set exist. In determining the strength of influence/ impact, a similar procedure as with BIM was carried out.

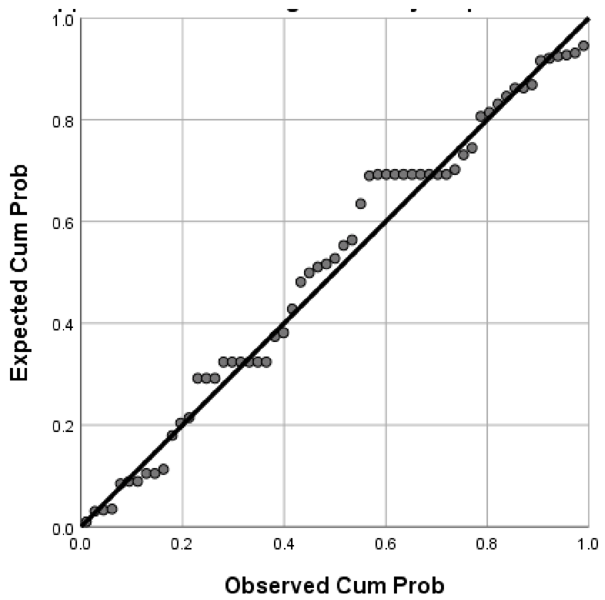


Figure 47- Normal P-P Plot Regression standardised residual for EXPBDA1

A reasonable interpretation is that the bivariate associations between EXPBDA1, EXPBDA2, EXPBDA3, EXPBDA4, EXPBDA5, EXPBDA6, EXPBDA7, EXPBDA8, EXPBDA9, and EXPBDA10 are largely dependent upon the existence of CULTBDA1, CULTBDA2, CULTBDA3, and CULTBDA4, whereas the CULTBDA1 is at the least (M=.083) influence/impact for them. Drawing from the inferences, the results of the correlations and the impact of culture on BDA exploitation are summarised in Appendix E2.

Findings lead to constitute several propositions. Based on the definition employed for culture in this research, the quantitative study shows an overall positive relationship between culture as a group and BDA exploitation as a group. Moreover, cultural constituents impact/ influence BDA exploitation in varying degrees of strengths and significances. Thus, the following simplified-model (Figure 48) was developed forming a part of the Strategic Framework.

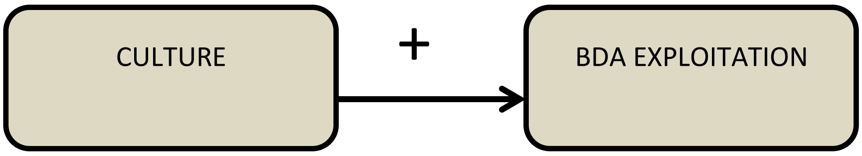


Figure 48- Correlation and causation between Culture as a whole and BDA exploitation

5.2.2.4 Inferential statistics for culture-IoT exploitation correlation analysis

A Spearman's rank-order correlation analysis was carried out to determine the strength and direction of the relationship between the impact of organisation culture and IoT exploitation. The results of the analysis consisting of both positive and negative correlations are presented in Table 65.

Compared with culture-BIM exploitation correlations, organisation culture generally has smaller and less significant correlations with IOT exploitation (see Table 65). Low power distance shows statistically significant correlation only with EXPIOT3; r= 0.356 (appropriately selected IOT team with right skills and training). This means that the lower the power distance, the easier to select the right team with right skills. Null hypothesis is accepted for CULTIOT2 as there are no significant correlations reported for uncertainty avoidance with IOT exploitation. Null hypothesis is rejected for most of the CULTIOT3 and CULTIOT4 variables, meaning collectivism and masculinity greatly help IOT exploitation. However, the higher the masculinity of the organisation culture, the lower the individuals create new uses for them. Similarly, the higher the collectivism the lower the effectiveness in performance (EXPIOT7). The latter two correlations are two negative correlations reported for IOT exploitation.

Table 65- Spearman's correlation analysis for organisation culture and IoT exploitation

		EXPIOT1	EXPIOT2	EXPIOT3	EXPIOT4	EXPIOT5	EXPIOT6	EXPIOT7	EXPIOT8	EXPIOT9	EXPIOT10
CULTIOT1	Correlation Coefficient	0.115	0.181	.356**	0.189	0.273	0.048	-0.049	0.138	0.140	0.220
	Sig. (2-tailed)	0.416	0.198	0.010	0.179	0.051	0.738	0.733	0.329	0.323	0.118
	N	52	52	52	52	52	52	52	52	52	52
CULTIOT2	Correlation Coefficient	0.175	0.113	0.150	0.238	0.121	0.105	-0.023	-0.160	0.102	0.164
	Sig. (2-tailed)	0.214	0.424	0.288	0.089	0.391	0.459	0.871	0.258	0.472	0.246
	N	52	52	52	52	52	52	52	52	52	52
CULTIOT3	Correlation Coefficient	.310*	0.246	.365**	0.245	.322*	0.075	-0.027	0.085	0.209	.295*
	Sig. (2-tailed)	0.025	0.079	0.008	0.080	0.020	0.600	0.852	0.547	0.138	0.034
	N	52	52	52	52	52	52	52	52	52	52
CULTIOT4	Correlation Coefficient	.378**	.300*	.337*	0.172	.326*	-0.012	0.233	0.235	.472**	.435**

	Sig. (2-tailed)	0.006	0.031	0.015	0.223	0.019	0.932	0.097	0.093	0.000	0.001
	N	52	52	52	52	52	52	52	52	52	52
**. Correlation is significant at the 0.01 level (2-tailed).											
*. Correlation is significant at the 0.05 level (2-tailed).											

In favour of obtaining the mean r-value between two group variables, the mean of all positive/ negative r-values were calculated (regardless of the sign) and resulted with M= 0.146, meaning there's a Small (S) correlation between IoT exploitation and organisation culture. To obtain the direction of the group correlation, the net mean-value was calculated. Thus, the finding with respect to correlations for objective-3 is illustrated in Figure 49.

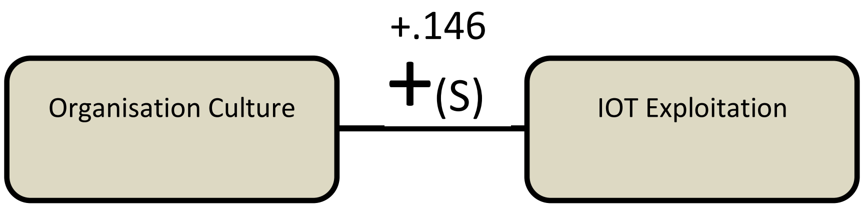


Figure 49- Correlation between group variables culture and IoT exploitation

Partial correlation and multiple regression analysis were also carried out to determine the causation between CULT and IoT EXPLOITATION variables. The results of the partial correlation show that there were, both positive and negative partial correlations between all dependent variables (paired-wise)- "EXPIOT1 to EXPIOT10", whilst controlling for "CULTIOT1, CULTIOT2, CULTIOT3 and CULTIOT4", which were statistically significant. An examination into partial correlations between EXPIOT variables (EXPIOT1 to EXPIOT10) and each of the other variables shows that when controls were applied for all CULT variables, all relationships between EXPIOT1 to EXPIOT10 and other variables were reduced. However, the same could not be seen when controls were applied to each CULT variable relationship with other variables. Although the latter correlations were reduced in magnitude, five of the coefficients remain statistically significant, including that with CULTIOT4.

Running a multiple regression analysis further confirms the influence CULTURAL impact has on IoT exploitation. According to ANOVA tables produced in regression analysis, significant values for each control variable are less than 0.05, which indicates the significance of the regression. Together, all these results suggest that CULT variables influence the relationship between dependent variables for IoT exploitation. A reasonable interpretation is that the bivariate associations between EXPIOT1 to EXPIOT10 are dependent upon CULT variables. Drawing from the inferences, the results of the correlation and impact of culture on IoT exploitation are summarised in Appendix E3.

Based on the definition used for culture in this research, the quantitative study shows both positive and negative relationships between culture as a group and IoT exploitation as a group. Moreover, cultural constituents impact/ influence IoT exploitation in varying degrees of strengths and significances. Thus, the following simplified-model (Figure 50) was developed forming another part of the Strategic Framework.

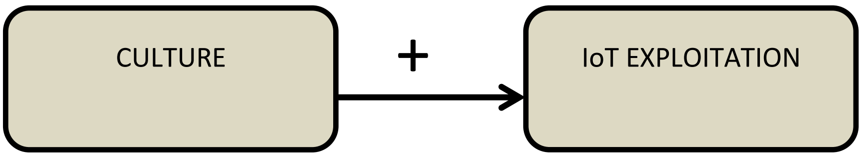


Figure 50- Correlation and causation between Culture as a whole and BIM exploitation

Following the investigation of the correlations and causations between culture and exploitation, the objective is then to select the critical impact variables for BBI exploitation. Critical factors are factors that are crucial in the strategic decision-making process. These factors play a pivotal role in determining the success or failure of a decision (Pinto and Slevin, 1987). In the interest of determining the level of criticality, considering the mean score of a given Likert scale is not suitable. Therefore, results obtained from partial correlation were used. Controlling one independent variable at a time followed by taking the amount-correlation coefficient decreased/ increased into account was a best practice. For example, controlling CULTBIM1, the change of correlation between EXPBIM1-EXPBIM2 was investigated. The investigation continued for all EXP variables corresponded to all three strategic tools (BIM, BDA, and IoT) and the Group Mean change in correlations are listed in Table 66 and ranked according to descending order. The highest two ranks are 'critical' to the BBI exploitation.

Table 66- Summary of culture-exploitation impact

Code	Mean change in correlations	Group Mean	Rank
CULTBIM1	0.136	0.117	4
CULTBDA1	0.102		
CULTIOT1	0.114		
CULTBIM2	0.102	0.121	3
CULTBDA2	0.138		
CULTIOT2	0.123		

CULTBIM3	0.224	0.298	1
CULTBDA3	0.368		
CULTIOT3	0.302		
CULTBIM4	0.232	0.171	2
CULTBDA4	0.107		
CULTIOT4	0.173		

5.2.3 Qualitative data analysis for organisation culture and BBI exploitation

The relationships identified between organisation culture and BIM exploitation through NVivo concept mapping are illustrated in Figure 51. The coded opinions were categorised into relationships and then the directions of the relationships were established after studying the content of each respondent's opinion. Interestingly, the qualitative data give a similar picture to what quantitative data gave on the relationship organisation culture has with BIM exploitation. When specifying down to the variables of organisational culture and BIM exploitation, the situation remains the same. For example, as illustrated in Figure 51, competitive, result-focused and risk-taking environment has a positive relationship with strategic leadership. This was also confirmed by quantitative data analysis.

Out of the 25 interviewees, almost all interviewees were of the same viewpoint that the given culture constituents positively impact BBI exploitation. Equal power distribution supports innovation and diversified idea generation which is essential to technology exploitation (I-4). When workers have well-defined responsibilities, it is easier for the management of human resources to determine whether there is a need for creating new roles or recruiting more employees. This helps in keeping the costs down by avoiding redundant recruitments while also making it easier to recruit qualified workers for necessary positions. (I-11, I-14, I-17). Furthermore, all interviewees were in agreement that works performed collectively do improve the communication of the team, performing things far more quickly and efficiently, helps teams to be confident that every single document has the same annotation in the same place, and it explicates the same thing.

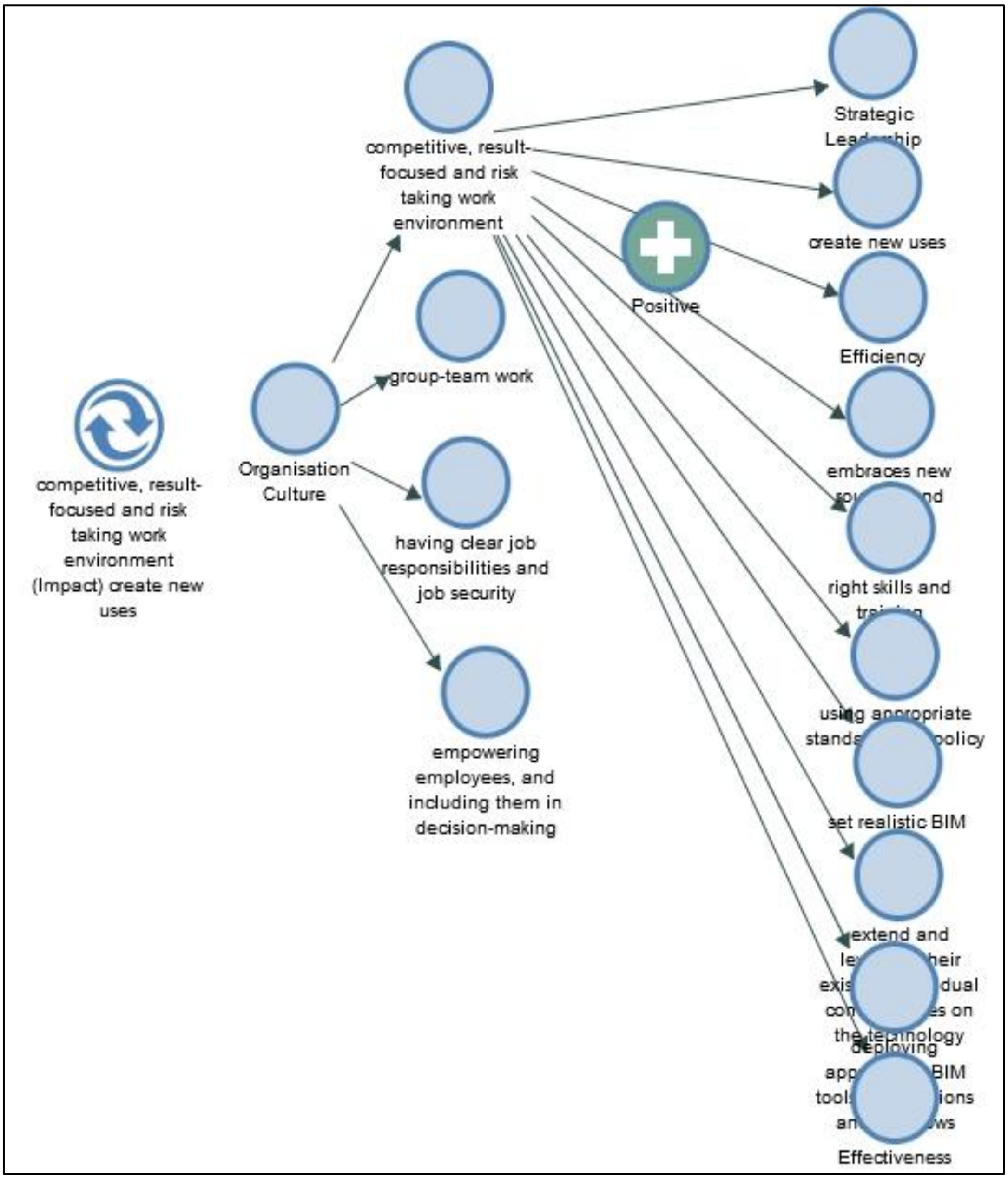


Figure 51- Concept map produced through NVivo for the relationship between org. culture and BIM exploitation

The respondents were asked about the characteristics of their organisational culture to gauge the extent to which the organisation culture helps or hinders exploiting BIM/ BDA/ IoT for competitive advantage. The questions outlined below inquire about these characteristics related to organisation culture.

- Could you please tell me how the power and authority are distributed in your company? Do you think it is distributed equally where subordinates have the freedom to express disagreement with their superiors?
- Do you think this power distribution and individuals' right of disagreement has an impact on BIM <u>implementation</u> and then its <u>exploitation for competitive advantage?</u> If yes how?

- If it affects differently, please can you kindly share your thoughts in the same way for Big Data Analytics and the Internet of Things? Or do you think it affects in the same way as for BIM?

The same structure of the question was employed for all cultural constituents. The themes that emerged from thematic analyses were categorised into two main categories : Whether each culture constituent helps or hinders B/B/I exploitation; and how the culture constituent helps/ hinders exploiting BIM/ BDA/ IoT for competitive advantage.

Content analysis was carried out with the questions continually raised including: "How?"; "Why?"; "Under which conditions?"; "With which consequences?" "How do people construct beliefs?"; "How do they manage the claimed circumstances?"; "Why do they think, feel, and act the way that they do?"; "Under which conditions do they think, feel, and act that way?"; and "What are the consequences of their beliefs, feelings, and actions?" (Charmaz, 1990). The first step- 'open coding' was conducted in such a way that the codes and categories reflect emerging ideas rather than a mere description of the topics. Second, 'focused (or selective) coding' was carried out to summarise the pre-identified open coded themes into categories. 'Axial coding' is the third step followed to develop themes of higher abstraction level. Finally, core categories are developed by studying the content of underlying categories and codes emerging from axial coding. If recurrent themes/issues were found, then they were followed up on which can, and often, lead to grounded theorists' approach in an unanticipated direction. This was reinforced when the analysis and data collection moved along simultaneously allowing the researcher to follow up on ideas at the same time they are created. The subsequent chapters explain the ideas that emerged from the data (broken down into a constantly refining series of questions) when proceeding with content analysis.

Interviewees presented different views about the impact culture has on exploitation in general. For example, I-5 emphasised the equal importance of both individualism and collectivism. According to the latter interviewee, being independent and holding responsibilities is crucial for technology exploitation. However, he further explained the importance of getting together and having regular meetings with the team to communicate the common goals and how it ultimately prevents employees 'going off track'.

> *" Everything we do is aimed at building a common goal. We are all doing different jobs, so you need to make sure that every job complements each other and that we work together and that we're not holding each other back. Making our steps together is a very social role" (I-5).*

Factors that impact BBI exploitation and competitive advantage

Table 67 below shows a summary of the themes that emerged from the answers to the semi-structured questions around culture.

Table 67- Selective coding for organisation culture impact on the exploitation

Culture constituent-helps or hinders exploitation?	**How/ why that helps/ hinders**
Low Power distance-empowering employees and including them in decision making	
Helps	-Harnessing the skills and wisdom of a wider group of employees -Creating a transparent working environment -Creating creative clusters -Increased creativity in work practices/ decisions -Promotes democratic culture -Decisions are based on different perspectives and hence minimised potential hazards -Lateral problem solving - Building effective work relationships with shared purposes
hinders	-Loses control over the work -Less authoritative in target achievement, review, and follow-up
High Power Distance-Maintaining the power distance between higher and lower levels	
helps	-Standardise the workflows -Making sure that the company missions and visions are met -Spreading consistence working ethics -Having responsible professionals for high-risk strategic decisions
Hinders	-Discourage employees to raise their voice with disagreements -Development of the sense of 'not-valued'
Low Uncertainty Avoidance- clear job responsibilities and job security	
helps	-Easy to solve disputes -Avoids duplication of tasks - Attracting highly motivated, high performing people and teams -Creating core capabilities among employees
Hinders	-Low chance to learn new things and knowledge expansion -Creating rigidity in core capabilities -Making employees unready for unprecedented events
High Uncertainty Avoidance- nested job responsibilities, low job security	
Helps	-Encourages integrated working practices

hinders	-confusion about one's scope of work leads to lower performance -Lack of accountability
No impact	-The job market contains a lot of dynamics where job-security is not expected -The current structure of tasks require input from diversified disciplines hence cannot be defined
Collectivism- collective work	
Helps	- Bring together many ideas/ solutions to diverse disciplines -Better co-ordination for the complexities related to technology -Better integration -Improved collaborative practices -Straightforward inter-relationship -Early engagement of the supply chain -Promotes innovation -Increased productivity -Knowledge sharing -Development of inclusive relationships based on mutual trust, respect, and understanding. -Assuming collective responsibility
hinders	-Creating unhealthy competition -Conflict of individual interests
Individualism- self-reliance	
helps	-Improve employee confidence levels in their intuition - Being independent -Embracing individuality -Striving towards one's own goals and personal development - Helping one to push outside of comfort zone to try new things and broaden experience -Training to take responsibilities
Hinders	-Prevents the knowledge sharing opportunities
Masculinity - risk-taking competitive nature	
Helps	-Risk-taking gives either a benefit or a lesson for future -Competitive environments encourage efficient target achievement -Healthy competition improves work enthusiasm

	-Risk-taking introduces new opportunities and collaborative partnerships
Hinders	-Internal competitiveness increases pressure and stress -Can lead to potential losses
Femininity- friendly working environment	
helps	-Encourages motivation to use technologies -Retaining talents for a longer time - Boosted individual productivity through improved mental health among employees and work satisfaction - Having equal access to opportunities -Promotes inclusivity -Diversity appreciated -Building the feeling of 'valued-member'. -Recognising and celebrating success with awards encourages employees for more progressive work -Improved mutual trust, respect, and understanding among employees. - Ensure the safety and wellbeing of employees - sufficient priority for our personal and family importance as well. - Sufficient priority for employee family importance
hinders	-Taking formal rules and procedures for granted -Negligence in performing the job role up to the satisfactory standard

5.2.4 Discussion on findings of the culture-exploitation relationship

This section discusses the empirics discovered in this research as an extension to the existing body of knowledge. The discussion is folded around the impact of four culture variables.

Power Distance

The academic dilemma caused by the paralytic nature of opinions and arguments around the impact of organisational power distance and exploitation gave rise to hypotheses that there is no significant relationship between Low Power Distance and exploitation of BBI for competitive advantage. Based on the findings shown in Appendix E1, empowering employees and including them in decision making positively impact BIM, BDA, and IoT exploitation. This means that when the power distance is low, firms tend to successfully exploit the technologies more. Further, this employee empowerment and inclusion in decision making influences the extent to which firms exploit BM. The strength of this influence is higher for certain exploitation measures. For example, employee empowerment influences the effectiveness of daily tasks more than it does for setting realistic BIM goals. The higher the extent to which the less powerful members expect and accept that power is distributed unequally, the higher the extent that it hinders digital technology exploitation. Relationships between subordinates and superiors in a high-power distance cultural setting are frequently loaded with unhealthy emotions and employee inter-relations. In a low-power distance environment where limited numbers of supervisors are allocated, superiors are more accessible for subordinates, and the superiors act as more resourceful democrats. Under these circumstances, more respect is guaranteed between superiors and subordinates. This has been identified as a major impacting factor for BIM, BDA, and IoT exploitation.

Uncertainty Avoidance

Even though the review of literature has shown that uncertainty makes a difference among organisations and their output of digital technology, the literature does not show a consensus of agreement that it causes better performance or otherwise. The qualitative and quantitative findings of this study have provided more clarity into this confusion. The management of an organisation culture could be strategically used towards enhancing organisational competitive advantage especially by making the employees more stabilised with more job security and clearly documented job responsibilities. It was emphasised that, having clear job scope and job security helps to solve disputes, avoid duplication of tasks, and attract high performing employees to the team. However, views can also be seen in favour of the opposite; that a high level of uncertainty helps digital technology exploitation as it encourages creativity and lateral thinking. Moreover, because the scope of any given job role is not fixed (and often subjected to change due to unprecedented events), employees often learn each other's tasks envisaging them to be all-rounded skilled and knowledgeable.

Collectivism/ Individualism

The contradictory views retrieved from the literature on the impact of collectivism on organisational performance lead to explore the context-specific relationship between collectivism/ individualism and technology exploitation. As shown in Appendix E1, E2 and E3, a small-medium correlation was observed between collectivism (teamwork) and BIM/ BDA/ IoT exploitation. Further, partial correlations suggest that collectivism causes technology exploitation to some extent. A few of the prominent reasons that emerged from the qualitative study for this causation include straightforward inter-relationship, early engagement of the supply chain, promoting innovation, increased productivity, and knowledge sharing. However, most interviewees emphasised the importance of having both independent and collective working characteristics.

Masculinity/ Femininity

Considering the obscureness caused by the absence of a consensus on which one masculinity or femininity, helps technology exploitation, this Ph.D. study explored the technology-specific data via qualitative and quantitative research. In general, the study revealed that both masculinity and femininity help exploitation at different levels. For example, while risk-taking (a characteristic of Masculine culture) gives either a benefit or a lesson for the future it also encourages healthy competition among employees. Femininity promotes inclusivity and diversity which would help to retain skilled employees for a longer time. Thus, the equal importance of both Masculinity and Femininity is emphasised.

5.3 Ascertain the impact of organisational structure on the exploitation of BBI

5.3.1 Establishing the structure variables

The construct variables for exploitation factors concerning BIM, BDA, and IoT are listed and comprehensively described in Chapter -4 (Please see 4.2.3.1). Table 68 shows the construct variables for organisation structure brought forward from Chapter-2 literature review while Figure 52 illustrates the types of correlations studied between each variable. It is worthwhile noting that the questions around organisation structure were phrased to indicate the impact itself. For example, one such question includes 'the impact of centralised decision making, authority, and flow of communication at the top management without employees' participation in achieving the best possible use of BIM'. Further, the STRUC factors have separate variables for all three strategic tools. A full list of questions and variables can be found in Appendix C.

Table 68- Construct variables for organisation structure

Organisation Structure Factors	Code	Dimension
The impact of centralised decision making, authority and flow of communication at the top management without employees' participation on achieving the best possible use	STRUC1	Centralisation

The impact of having highly formal rules and procedures on achieving the best possible use	STRUC2	Formalisation
The impact of having a substantial number of status, layers, levels of professional roles on achieving the best possible use	STRUC3	Stratification

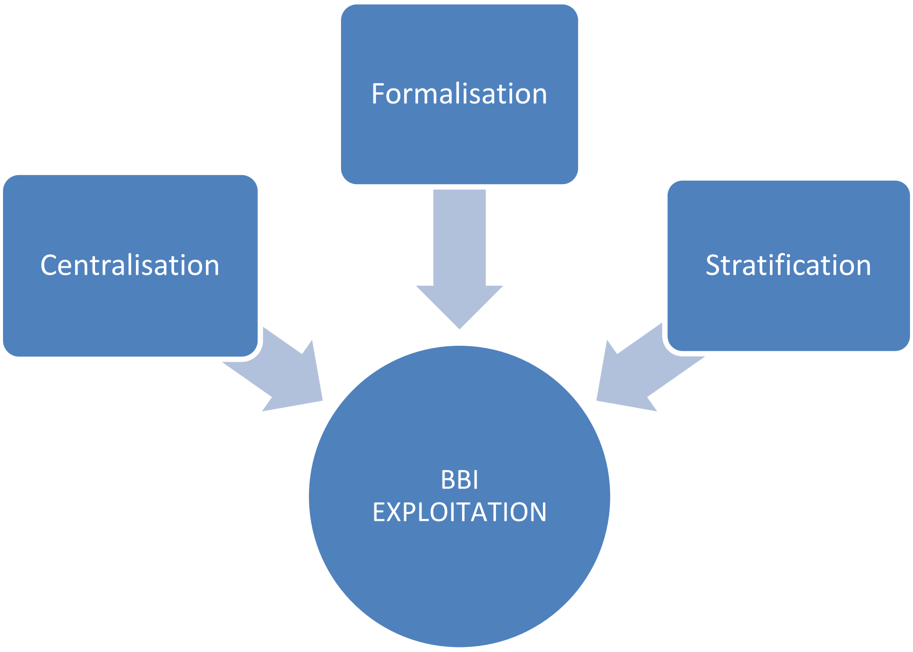


Figure 52- Correlations between organisation structure variables

5.3.2 Quantitative data analysis for organisation structure and BBI exploitation

5.3.2.1 Descriptive statistics for the impact of structure on BBI exploitation

Before looking into the correlation between organisation structure and exploitation, a reliability test was carried out to check whether the required consistency in measuring the variables exists. Cronbach's alpha cut-off criterion for this test is 0.70. Table 69 shows a run of the Cronbach's alpha on the items of the questionnaire that measures group variables- STRUCTURE. The Cronbach's alpha value for STRUCTURE variables is 0.772- which is a considerably high value. A high value of Cronbach alpha indicates a good internal consistency of the items in the scale. The deletion of three variables- STRUCBIM3, STRUCBDA3, STRUCIOT3 increases the overall Cronbach-alpha value up to a maximum of 0.796. But considering the value of retaining those variables and corrected item-total correlation with other related values, it seems that the amount decreased or increased in corrected item correlation is insignificant (i.e. 0.14). Therefore, no item was deleted.

Table 69- Reliability test for all STRUC variables

Reliability Statistics	
Cronbach's Alpha	N of Items
.772	9

Table 70 shows some important descriptive statistics related to the impact that organisation structure variables have on BBI exploitation variables. The wording of the question was not biased in any direction and hence the respondents were given the opportunity to decide the direction of the impact. However, it is important to mention that the positive/ negative impact (causation) mentioned here does not equal to the positive/ negative correlation between independent and dependent factors obtained via inferential statistics which is later presented in this chapter. This analysis looks at the impact between culture and BBI exploitation at the descriptive statistics level. In this question, the researcher establishes that the organisation structure impacts BBI exploitation based on the information received from literature (See Chapter-2), and hence only the positivity/ negativity/ neutrality of this impact is investigated. The mean values presented in Table 70 specify the impact organisation structure variables have on BIM, BDA, and IoT exploitation variables. According to the criteria presented in Table 53, the level of impact for each variable was determined and ranked accordingly. 'Neither negative nor positive' impact that the organisation structure in general has on exploitation indicates that organisation structure (based on the way is has been defined in this research) does not relate with BBI exploitation in general. The way an organisational structure is set up and administered can have a direct effect on a company's ability to exploit technologies. However, given the agile nature of technologies, chances are there that the structure could also be independent of the level of exploitation.

Table 70- Descriptive statistics for Structure variables towards BIM, BDA, and IoT

Variable	Mean	Std. Deviation	Rank	Impact
STRUCBIM1	3.28	1.065	1	Neither negative nor positive impact
STRUCIOT1	3.15	.978	2	Neither negative nor positive impact
STRUCBIM3	3.13	.813	3	Neither negative nor positive impact
STRUCBDA3	3.12	.672	4	Neither negative nor positive impact
STRUCIOT3	3.06	.777	5	Neither negative nor positive impact
STRUCBDA1	2.97	1.159	6	Neither negative nor positive impact
STRUCBIM2	2.89	1.000	7	Neither negative nor positive impact

STRUCIOT2	2.81	.908	8	Neither negative nor positive impact
STRUCBDA2	2.75	1.010	9	Neither negative nor positive impact

Because it is necessary to ascertain the impact of culture as a group on BBI exploitation, the group means were calculated and thus the group impact is presented in Table 71; Table 72; and Table 73. The tables indicate that structure in general does not show a negative or a positive correlation towards BBI exploitation. The flaws in an organisational structure can be independent of the technology exploitation as most of the breakdowns in communication or lapses in responsibility need to be repaired within the technology platforms to support efficiency.

Table 71- Impact of organisation culture on BIM exploitation

BIM				
Variable	**Mean**	**Impact**	**Total Mean**	**Total Impact**
STRUCBIM1	3.28	NNNP	3.10	Neither negative nor positive impact (NNNP)
STRUCBIM2	2.89	NNNP		
STRUCBIM3	3.13	NNNP		

Table 72- Impact of organisation culture on BDA exploitation

BDA				
Variable	**Mean**	**Impact**	**Total mean**	**Total Impact**
STRUCBDA1	2.97	NNNP	2.95	Neither negative nor positive impact (NNNP)
STRUCBDA2	2.75	NNNP		
STRUCBDA3	3.12	NNNP		

Table 73- Impact of organisation culture on IoT exploitation

IoT				
Variable	**Mean**	**Impact**	**Total mean**	**Total Impact**
STRUCIOT1	3.15	NNNP	3.01	

STRUCIOT2	2.81	NNNP		Neither negative nor positive impact (NNNP)
STRUCIOT3	3.06	NNNP		

5.3.2.2 Inferential statistics for structure-exploitation correlation analysis

After appreciating the impact of organisation structure on BBI exploitation via descriptive statistics, it is then required to investigate the relationship between structure and BBI exploitation via inferential statistics. The Spearman rank-order correlation coefficient and Kendall's tau-b nonparametric statistical analyses were executed as they measure the strength and direction of the association that exists between the structure variables and exploitation variables.

The ambivalence effect in the evolvement of literature around the impact of organisation structure on organisational performance in general and in specific to digital exploitations influenced the proposal of the following hypothesis. To start with an impartial standpoint is taken. It is assumed that there is no organisation structure- BBI exploitation relationship exists and to express the null hypotheses as:

HS_10= there is no significant relationship between Centralised decision making and exploitation of BBI for competitive advantage

HS_20= there is no significant relationship between highly formalised rules and exploitation of BBI for competitive advantage

HS_30= there is no significant relationship between higher stratification in the structure and exploitation of BBI for competitive advantage

STRUCTURE and BBI EXPLOITATION

As shown in Table 74, there are no significant correlations between the impact of organisation structure and BIM exploitation, except for STRUCBIM3-EXPBIM9. The computed values for Spearman rank-order correlation coefficient (r.) ranges from + values to - values. For example, EXPBIM5 has a negative correlation with STRUCBIM1. Although a negative correlation exists between the latter two variables, this is not significant at the 0.05 level. This means that there is no sufficient evidence to suggest that more use of standards and policy initiatives lowers the impact of centralised decision making, authority and flow of communication at the top management without employees' participation on achieving the best possible use of BIM. Perhaps, this is an indication that the current standards and policy initiatives do not necessarily help to control the workflows under a single authority. But EXPBIM9, and STRUCBIM3 have a negative correlation which is significant at 0.05 level (Sig= 0.045). This means that the level of stratification in structure significantly correlates with the ability to operate more efficiently. The HS_10 null hypothesis is therefore rejected for latter correlation (EXPBIM9-STRUCBIM3). This could be an indication that if an organisational structure is not set up properly, information will not be able to travel efficiently where it is needed. The null hypotheses: HS_20 and HS_30 are not rejected for all other correlations.

Table 74- Spearman's correlation analysis for organisation structure and BIM exploitation

		EXPBIM1	EXPBIM2	EXPBIM3	EXPBIM4	EXPBIM5	EXPBIM6	EXPBIM7	EXPBIM8	EXPBIM9	EXPBIM10
STRUCBIM1	**Correlation Co**	0.089	0.012	0.083	0.025	-0.090	0.028	0.055	0.061	-0.108	0.021
	Sig. (2-tailed)	0.418	0.916	0.450	0.821	0.413	0.802	0.620	0.582	0.325	0.849
	N	85	85	85	85	85	85	85	85	85	85
STRUCBIM2	**Correlation Co.**	0.097	0.197	0.075	0.010	0.000	0.121	0.132	0.120	-0.127	0.158
	Sig. (2-tailed)	0.378	0.071	0.496	0.929	0.997	0.270	0.227	0.273	0.247	0.148
	N	85	85	85	85	85	85	85	85	85	85
STRUCBIM3	**Correlation Co**	-0.052	-0.071	-0.055	-0.062	-0.061	-0.051	0.091	-0.011	-.218*	-0.027
	Sig. (2-tailed)	0.635	0.519	0.617	0.574	0.581	0.644	0.410	0.922	0.045	0.804
	N	85	85	85	85	85	85	85	85	85	85

In pursuance of finding the mean r-value between two group variables, the mean of all positive/ negative r-values were calculated (regardless of the sign) and resulted with M= 0.105, meaning there's a Small (S) correlation (r= 0.10 – 0.29) between BIM exploitation and organisation structure. To obtain the direction of the group correlation, the net mean-value was calculated. Thus, the finding with respect to correlations for objective-3 is illustrated in Figure 53.

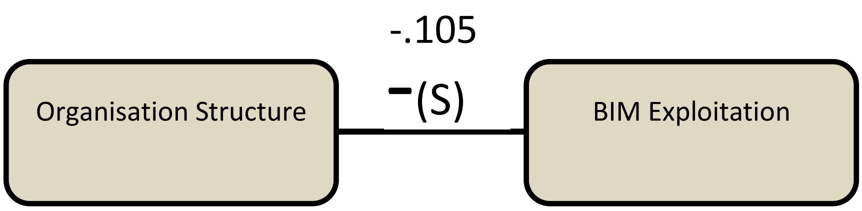


Figure 53- Correlation between group variables structure and BIM exploitation

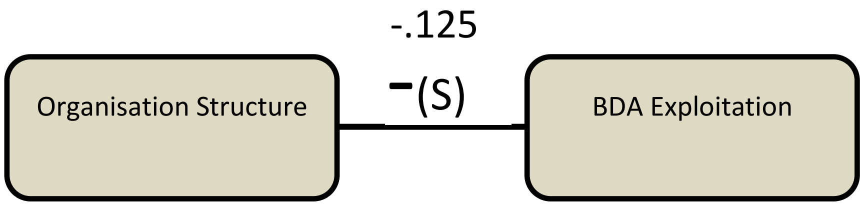
In testing the null hypothesis for BDA (Table 75), it was found that there are no significant correlations between the impact of organisation structure and BDA exploitation except for the correlations: STRUCBDA1-EXPBDA1, STRUCBDA1-EXPBDA4, SRUCBDA1-EXPBDA7, and STRUCBDA3-EXPBDA5. The largest among them was STRUCBDA3- EXPBDA5 although this was reported to be a medium correlation (R= -.317, Sig.2-tailed= 0.014). The null hypothesis is therefore rejected for these significant correlations only. Apart from these highlights, the computed values of Spearman rank-order correlation coefficient (r.) ranges from + values to - values. In summary, null hypothesis HS_20 was completely accepted as there were no significant correlations related to STRUCBDA2 (high formalisation) at all. It might be the case that there's not enough evidence to suggest that highly formal rules help or inhibit BDA exploitation. For STRUCBDA3, HS_30 was rejected only for the correlation between STRUCBDA3- EXPBDA5. The latter largest and significant correlation could be an indication that macro-level differentiations between levels within an organisation facilitate the appropriate use and allocation of standards and policy initiatives for Big Data. HS_10 was rejected in relation to three significant correlations.

Table 75- Spearman's correlation analysis for organisation structure and BDA exploitation

		EXPBDA1	EXPBDA2	EXPBDA3	EXPBDA4	EXPBDA5	EXPBDA6	EXPBDA7	EXPBDA8	EXPBDA9	EXPBDA10
STRUCBDA1	**Correlation Coefficient**	-.310*	-0.135	-0.213	-.286*	-0.198	-0.250	-.290*	-0.223	-0.167	-0.239
	Sig. (2-tailed)	0.017	0.308	0.105	0.028	0.132	0.057	0.026	0.089	0.206	0.069
	N	59	59	59	59	59	59	59	59	59	59
STRUCBDA2	**Correlation Coefficient**	-0.167	0.031	0.020	-0.178	-0.172	-0.093	-0.093	-0.139	-0.035	-0.087
	Sig. (2-tailed)	0.205	0.818	0.878	0.177	0.194	0.485	0.482	0.292	0.792	0.514
	N	59	59	59	59	59	59	59	59	59	59
STRUCBDA3	**Correlation Coefficient**	-0.214	-0.124	0.069	-0.118	-.317*	-0.009	-0.041	-0.105	0.084	-0.086
	Sig. (2-tailed)	0.104	0.349	0.605	0.374	0.014	0.947	0.760	0.430	0.528	0.516
	N	59	59	59	59	59	59	59	59	59	59
**. Correlation is significant at the 0.01 level (2-tailed).											
*. Correlation is significant at the 0.05 level (2-tailed).											

Similar to what was done with BIM, the mean r-value between two group variables were calculated (regardless of the sign) and resulted in M= 0.125, meaning there's a Small (S) correlation (r= 0.10 –

0.29) between BDA exploitation and organisation structure. To obtain the direction of the group correlation, the net mean-value was calculated. Thus, the finding with respect to correlations for objective-3 is illustrated in Figure 54.



The computed values of Spearman rank-order correlation coefficient (r.) ranges from + values to – values. In testing the null hypothesis for IoT (Table 76), the only significant correlation that appears to happen is between STRUCIOT1- EXPIOT5 (r= -.289, p= 0.038). The null hypothesis (HS_10) is therefore rejected for this significant correlation only. The null hypotheses: HS_20 and HS_30 are not rejected as there were no significant correlations reported along STRUCIOT2 and STRUCIOT3. Not having significant correlations between formalisation and IOT exploitation can be a reflection of the unpredictable nature involved with IOT exploitation. Because, when the structure is highly formalised, employees know where to turn to get some procedure guideline. This has led employees to respond to problems in a similar way across the organisation and therefore promotes consistency of behaviour. This has led to the understanding that organisational behaviour is predictable. When the structural formalisation does not relate with behaviours concerning IOT exploitation, employees tend to make more creative solutions and hence they are encouraged to adopt a new line of thinking and possibly lateral thinking. The unrelatedness between stratification and IoT exploitation could be a manifestation of how rewards and opportunities assimilate for different functional levels of an organisation. This would also suggest that the criteria used to match employees with job roles around IOT exploitation also follows a consistent path for employees at any level.

Table 76- Spearman's correlation analysis for organisation structure and IoT exploitation

		EXPIOT1	**EXPIOT2**	**EXPIOT3**	**EXPIOT4**	**EXPIOT5**	**EXPIOT6**	**EXPIOT7**	**EXPIOT8**	**EXPIOT9**	**EXPIOT10**
STRUCIOT1	**Correlation Coefficient**	-0.180	-0.058	-0.210	-0.204	-.289*	-0.234	-0.207	-0.161	0.064	0.018
	Sig. (2-tailed)	0.202	0.684	0.135	0.146	0.038	0.095	0.140	0.253	0.650	0.901
	N	52	52	52	52	52	52	52	52	52	52

STRUCIOT2	**Correlation Coefficient**	0.047	0.098	-0.033	0.037	-0.134	-0.044	0.018	0.132	0.120	0.149
	Sig. (2-tailed)	0.738	0.488	0.818	0.795	0.343	0.758	0.897	0.352	0.397	0.291
	N	52	52	52	52	52	52	52	52	52	52
STRUCIOT3	**Correlation Coefficient**	-0.122	0.065	0.072	-0.069	-0.061	-0.115	-0.168	-0.042	0.109	-0.069
	Sig. (2-tailed)	0.388	0.649	0.613	0.625	0.666	0.416	0.234	0.768	0.440	0.627
	N	52	52	52	52	52	52	52	52	52	52
**. Correlation is significant at the 0.01 level (2-tailed).											
*. Correlation is significant at the 0.05 level (2-tailed).											

With a view to finding the mean r-value between two group variables, the mean of all positive/ negative r-values were calculated (regardless of the sign) and resulted with M= 0.105, meaning there's a Small (S) correlation (r= 0.10 – 0.29) between IoT exploitation and organisation structure. To obtain the direction of the group correlation, the net mean-value was calculated. Thus, the finding with respect to correlations for objective-3 is illustrated in Figure 55.

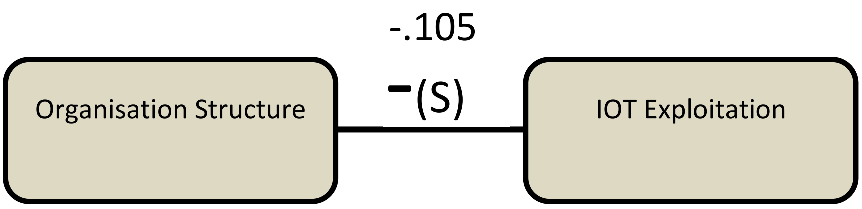


Figure 55- Correlation between group variables structure and IoT exploitation

Partial Correlation Analysis

Partial correlation analysis was performed to see whether there is a significant change in the relationships between all exploitation variables when STRUC variables are controlled. This helped to discover the influence organisation structure has on BBI exploitation.

The results of the partial correlation show that almost all the correlations between exploitation variables have been subjected to some degree of change when control was applied to STRUC variables. For example, the correlation between EXPBIM1 and EXPBIM2 which was +.688 (in zero-order) has increased to +.696 as a result of controlling all STRUCBIM variables at once. This means, under the same circumstances, STRUC variables influence/ impact the correlations between BIM, BDA, and IoT exploitation variables.

Multiple regression analysis

Multiple regressions could confirm how well the measures of organisation structure predict the level of exploitation for BIM/ BDA/ IoT. This will eventually confirm whether structure impacts on BBI exploitation or not. Multiple regression analysis was carried by setting related STRUC variables as independent (or predictive) variables and one exploitation variable, as a dependent variable, at a time.

The relationship and causation between structural impact and BBI exploitation were investigated through inferential statistics and led to constitute several propositions. Based on the definition used for an organisation structure in this research, the quantitative study shows an overall negative relationship between structure as a group and BBI exploitation as a group. Moreover, structural constituents impact/ influence BBI exploitation in varying degrees of strength and significance. Thus, the following simplified-model (Figure 56) was developed forming a part of the Strategic Framework.

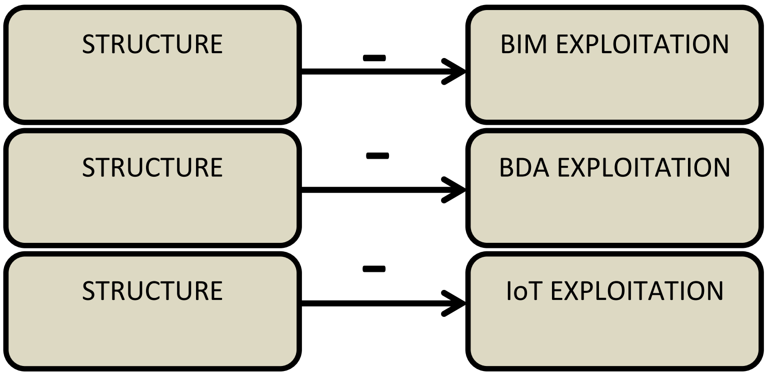


Figure 56- Correlation and causation between structure as a whole and B, B, I exploitation

The same p le at a time followed by taking the amount-correlation coefficient decreased/ increased into account. For example, controlling STRUCBIM1, the change of correlation between EXPBIM-EXPBIM2 was investigated. The investigation continued for all EXP variables corresponded to all three strategic tools (BIM, BDA, and IoT) and the Group Mean change in correlations are listed in Table 77 and ranked according to descending order. In pursuance of identifying the critical structure factors, the highest two ranks were considered as ‘critical’.

Table 77- Summary of structure-exploitation impact

Code	Mean change in correlations	Group Mean	Rank
STRUCBIM1	0.112	0.105	3
STRUCBDA1	0.102		
STRUCIOT1	0.102		
STRUCBIM2	0.220	0.165	2
STRUCBDA2	0.168		
STRUCIOT2	0.108		
STRUCBIM3	0.322	0.287	1
STRUCBDA3	0.286		
STRUCIOT3	0.254		

5.3.3 Qualitative data analysis for organisation structure and BBI exploitation

Many previous studies indicated the critical role that organisational structure plays in innovation and technology. These include different constituents such as centralisation (Bezweek and Egbu, 2012), formalisation (Rahmat and Ali, 2010), and cross-functional integration (Tang *et al.*, 2013) in influencing organisational innovative technology implementation.

Content analysis was carried out with the questions continually raised including: “How?“; “Why?“; “Under which conditions?“; “With which consequences?” “How do people construct beliefs?”; “How do they manage the claimed circumstances?”; “Why do they think, feel, and act the way that they do?”; “Under which conditions do they think, feel, and act that way?”; “What are the consequences of their beliefs, feelings, and actions?” (Charmaz, 1990). These questions were raised when analysing the data in the first step- open coding. The first step- ‘open coding’ was conducted in such a way that the codes and categories reflect the essence of emerging ideas rather than simply a narration of the theme. Second, ‘focused (or selective) coding’ was carried out to summarise the pre-identified open coded themes into categories. ‘Axial coding’ was the third step followed to develop themes of higher abstraction level. Finally, core categories were developed by scrutinising the content of underlying categories and the codes which emerged from axial coding. The subsequent chapters explain the ideas that emerged from the data (broken down into a constantly refining series of questions) when proceeding with content analysis.

33% strongly affirmed that their organisations follow a centralised decision-making process while 30% strongly believed that they possess a decentralised structure. 36% of participants were of the opinion that their organisation structure holds the characteristics of both. 1% did not answer this question.

A clear inspection of qualitative interviews reveals that the impact of given structure constituents on exploitation show a mix of directions and strengths. For example, interviewees hold mixed opinions for the centralised decision making, authority, and flow of communication at the top management. 50% mentioned that the involvement of lower-tier workers in decision making through decentralisation increases organisational complexity. They have seen a possibility of conflicts arising when work is carried over to the functional management during the project. Further, interviewees who were in favour of centralisation urged the importance of cooperation between functional and project management. On the other hand, the rest believes the good side of decentralisation.

Many of the participants explained the reasons for this classification (centralisation or decentralisation) in their organisations in line with technology implementation. Fragmentation in the supply chain was one such cause for companies to have a centralised decision-making procedure. Their perception is that having a central control immensely helps to manage fragmentation and hence facilitates technology implementation. Another cause for deciding to have a central control is the gap in task interdependencies. When the connection between preceding and succeeding tasks are lost, time laps and floating times are created. This would eventually contribute to delays. Having a central control prevents these loopholes by seeing the bigger picture. Respondents based on their experiences reveal interconnected issues addressed by centralisation as supply chain fragmentation, difficulties in overseeing entire organisation activities for continuous improvement, difficulties in planning, and controlling project delivery.

5.3.4 Discussion on the findings of structure exploitation relationship

Centralisation

The ones who claimed to have a centralised structure were of the opinion that having central control over the departments in an organisation enables technology implementation. Armandi and Mills (1982) in their study tested the renowned 'Blau-Hage Model' to see the correlation between organisational Size, structure, and efficiency. In this study, efficiency was employed as a generic factor related to organisational performance while efficiency was considered as an enabler for innovative technology adoption (Nayir *et al.*, 2014). Hage's (Hage, 1965) axiomatic theory, based upon the Weberian model of bureaucracy draws the proposition: 'the higher the centralisation, the higher the organisational efficiency'. However, Armandi and Mills (1982), disagree with the latter proposition and conclude, that centralisation and efficiency are not associated with each other. While few were in total disagreement of the fact that it helps, their opinion was justified with some evidence to support how centralisation hampers the ability to exploit technologies. The latter participants' perception was that delegating decision making power to lower-level managers is far more effective than making them centralised and limited to the higher-level managers. The remaining participants were in the middle-ground manifesting a diplomatic stance- 'Sometimes it helps, and sometimes it inhibits'. After initial open coding, focused (selective) coding was carried out to identify the subcategories of higher abstraction level codes. Table 78 presents the coding process for the impact centralisation has with technology exploitation.

Table 78- Coding for the impact of centralisation has on technology exploitation

Open code	**Focused/ selective code**	**Axial Code**	**Core category**
'what is the impact.'	**'On what Basis.'**	**'Why it is such.' (Higher order)**	**'what emerges from that.'**
it inhibits	Poor collaboration with front-line employees	Collaboration between employers from all levels	Lack of employee empowerment (Hinders)
it inhibits	Poor collaboration with front-line employees	Collaboration between employees from all levels	Staff demotivated from lack of their input (Hinders)
it inhibits	Slow response to rapid changes in the market as well as internal changes	Slow to adapt	Slow to adapt (Hinders)
it inhibits	Poor collaboration with front-line employees	Collaboration between employees from all levels	Less interdepartmental communication and knowledge circulation/ sharing (Hinders)
it inhibits	Most departmental decisions require approval from superiors	Slow to adapt	Employees feeling unvalued (Hinders)
It helps	Deliver projects within agreed tolerances of quality, time, and cost	Project tolerances	Being within the agreed project tolerances (Helps)
It helps	Reliable	Decisions made by the most experienced people	Reliable decision making (Helps)

It helps	Predictable	Decision Making	Predictable decision making (Helps)
It helps	Repeatable	Decision Making	Repeatable decision making (Helps)
It helps	Allows setting performance indicators to inform firm performance	Performance monitoring	Setting KPIs (Helps)
It helps	The tough decisions must be made from the top management	Risk-taking	Risk transfer to the top management (Helps)
It helps	Need for cost control as it is easy to spend money so quickly in digital space.	Strategic Cost control	Being prudent (Helps)
It helps	Helps to make decisions, and to follow up when policy setting is handled strictly at the top level.	Centralised policymaking	Initiating a central policy to ensure the rest of the company follows the direction of the executive (Helps)
It helps	Coping with complexities	Organisation size	Coping with large (Helps)
It helps	The basis of decisions is mostly similar	Decision made with mutual business goals	Uniformity in principles where the decisions are made (Helps)
It helps	Everyone follows company missions and visions	Employees are encouraged to work towards mutual company goals	Achieve the highest standards of business conduct, ethics, and integrity (Helps)

Findings demonstrated the ways in which centralisation harms digital technology adoption with its impeding nature. In other words, when superiors choose not to involve their subordinates in decision-making processes, employees tend to become less motivated and feel excluded from the team. This may result in developing a reluctance to generate creative ideas within employees. From the employees' perspective, this perception serves as a 'barrier' to the generation of novel ideas and thereby inhibits novel technology implementation (Dedahanov *et al.*, 2017). In a similar vein, Polansky and Hughes (1986) also discovered a negative link between centralisation and employee innovativeness. Building upon this argument, it can be deduced that the higher the centralisation in an organisation, the lower the innovative capacity. This would lead to impeded technology implementation. Further, choosing not to seek subordinate input gives employees the perception that their opinions were not valued and that the act of information-sharing to seek more input is futile. This would ultimately lead to employee dissatisfaction which would not add any progressive value towards technology implementation. Centralisation may further hinder interdepartmental communication, knowledge sharing and knowledge circulation (Souitaris, 2001) due to the existence of time-consuming centralised communication channels. Being slow to adapt to changes is another barrier identified by centralised structures. Similarly, Drucker (1992) affirms that a lower degree of centralisation enables quick decision-making and rapid change management for continuous new knowledge creation.

On the contrary, findings also suggest that centralisation enables project delivery within agreed tolerances of quality; time, and cost, for experienced people are involved in decision making. Previous studies have investigated the impact of the degree of centralisation on the operational efficiency of technology especially with regards to time, cost, and quality tolerances. This has also been acknowledged in the literature emphasising the importance of input from experienced people with a broader strategic view into technology implementation (Henderson and Ruikar, 2010).

Decentralisation

Among the eight participants who claimed to follow a decentralised structure in their day-to-day work, seven mentioned the positive influence it makes on their technology implementation process. Only one participant saw that it hinders more than it helps. Less hierarchical decision-making that can be seen in a decentralised structure helps more informed decision making. It encourages concurrent engineering and facilitates engagement from various firms for their dynamic and frequent interactions. The empirical studies found strong support towards the use of decentralised structures especially in automotive and high-tech solutions aiming at improving operational efficiency. Table 79 summarises the themes that emerged from qualitative analysis regarding the impact of decentralised structures on BBI exploitation. This summary provides an evaluation of how these 'emerging categories' enable or impede technology exploitation. According to the nature of themes emerged, they are categorised as to whether it 'helps' or 'hinders' exploitation.

Table 79- Coding for the impact of decentralisation has on technology exploitation

Open code	Focused/ selective code	Axial Code	Core category
'what is the impact.'	**'On what Basis.'**	**'Why it is such.' (Higher order)**	**'what emerges from that.'**
It helps	Less hierarchical	Shared input	Interaction between employees (Helps)

It helps	Encourages concurrent engineering	different stages of decision-making run simultaneously	Overlapping decision-making activities (Helps)
It helps	Allows being more Interactive	Decomposition of inputs	Aggregation of inputs from different team members (Helps)
It helps	Having a choice for many	Choice/ preferences	Freedom of choice (Helps)
It helps	Risk exposure on technical or scope.	Risk-taking	Risk-sharing (Helps)
It helps	If all involved in decision making, they all must be controlled.	Quality control gateways	A higher number of quality control gateways (Helps)
It hinders more than it helps	Becomes more subjective rather than a decision that is based on group consensus	The degree to which subjective-objective decision making is concerned	Subjective nature of decisions (Hinders)
It hinders more than it helps	Need for steering the group to make big decisions	Being led or leading	Not being able to control the course of action and momentum of process activities (Hinders)
Sometimes it does not help	In a way, it increases organizational complexity.	Organisation complexity	Increased organisational complexity in decision making (Hinders)
It helps	Retention of expert teams	Behaviour of project teams	Retention and rapid dispersion of expert teams into new projects after existing project completion (Helps)
It helps	Team building	The cooperation between managers from different levels	The cooperation between functional and project management (Helps)
It helps	Team building	The cooperation between managers from different levels	Training lower-level managers to take the lead (Helps)
It helps	Team building	The cooperation between managers from different levels	Team spirit (Helps)

It helps	Team building	The cooperation between managers from different levels	High morale (Helps)
Sometimes it does not help	Team building	The cooperation between managers from different levels	conflicts arising during the project carrying over to functional management (Hinders)
Sometimes it does not help	Erroneous decisions	Lack of experience about the broader view	Decisions made by less experienced people on the organisation broader view (Hinders)
Sometimes it does not help	Leads to discrepancies	Clashes with organisation strategy	Decisions being inconsistent with the overall strategy (Hinders)
It helps	Shared knowledge	Shared knowledge	Representation and contribution to the core knowledge of group intelligence and crowd wisdom (Helps)
It helps	Shared knowledge	Shared knowledge	collective consciousness (Helps)
It helps	it encourages motivation and creativity,	Collaborative team behaviour	Employee motivation by the opportunity to make decisions and be creative (Helps)
It helps	allows many minds to work simultaneously on the same problem	Collaborative team behaviour	Synchronised team working (Helps)
It helps	Distribution of authority	Shared input	Flexibility (Helps)
It helps	Distribution of authority	Authentication	Individualization (Helps)
It helps	Distribution of authority	Providing a better level of service to the client	Competition between different departments out of which best practice may emerge (Helps)
It helps	Distribution of authority	Distribution of authority	Building independence in employees (Helps)
It helps	Front line employees feel like a part of the team	Sense of inclusivity	Sense of inclusivity (Helps)
It helps	Front line employees feel more empowered	Build confidence	Confidence building (Helps)

It helps	Subject-specific knowledge utilisation	Speed of problem reaction	Quick response to internal and external changes (Helps)

The organisations with decentralised characteristics show a hierarchical line of communication and decision making while the control was centralised, the decision-making was not strictly hierarchical. This flexibility was an enabler for technology exploitation.

Formalisation

The impact of having highly formal rules and procedures also reported mixed opinions as 30% of interviewees see the benefits of highly formal rules while the rest see the drawbacks of it. I-20 believes that too rigid structures (with highly formal rules) are not good for an organisation generally and technology exploitation particularly. Many were of the opinion that rather than encouraging structural rigidity, letting people play their part in their preferred way of working is much more productive. I-21 takes a similar standpoint highlighting that a loosened structure makes it easier to move and adapt much quicker while formalisation requires passing through more gate keepers and hence takes more time. On the contrary, I-5 sees the need for establishing such rules and regulations as they streamline the information movement and hence more efficiently and effectively support innovation.

> *"When you say formalised, it does not mean it is unrelenting, like an old-school curriculum. It needs to be formalised, so that you have a process and you follow procedure, but that procedure should allow for independent experimentation and innovation in a controlled manner" (I-5)*

When comparing qualitative and quantitative data, qualitative data helps to explain the inferences obtained from quantitative data. Table 80 presents the coding emerged from answers received on formalisation.

Table 80- Selective coding for the impact of formalisation on exploitation

Formalisation	**How/ why that helps/ hinders**
***Low* Formalisation**	
Helps	-Timesaving in approvals, decision points - Flexibility to adapt and change the systems to suit compliance needs -Encourages creativity and innovation

hinders	-Difficulty to transform traditional work practices into modern practices
***High* Formalisation**	
helps	-consistence between the innovative technology and the organisations' existing experiences and structures -Digitisation requires some form of formalised structured way of working -Setting mandates/ compulsions help changing/ transforming traditional cultural settings -Sets out rules and procedures for managing large and complex work packages - Setting formalised standards avoids the delays that occurred from trial and error conflicts
Hinders	-Restricted creativity and innovation

Stratification

In terms of stratification, I-17 holds the point of view that having a substantial number of statuses, or layers, or levels of professional roles is an enabler for technology adoption. Because buildings often consist of a complex social and material manifestation, the construction process often relies on shared frames of references such as standards of practice, legal arrangements, and industry norms which require a collaborated approach from every stratum, layer and professional role involved in a construction project. This level of stratification helps to easily navigate through the changes to legal risks associated with standards of practice. Moreover, a higher number of tiers in a structure is an indication of the existence of a higher number of specialised employees. They are regarded as the experts/ champions for a given area. This is an enabler for technology exploitation. Just as with the advantageous side of stratification, there was also an equal amount of opinion in favour of the negative side of stratification. Table 81 summarises the themes which emerged from the narratives around the positive and negative impact of stratification towards technology exploitation. Drawing from the findings of qualitative data, an extension to the second-order strategic framework was developed.

Table 81- Selective coding for the impact of stratification on exploitation

Stratification	How/ why that helps/ hinders
***Low* Stratification**	

helps	-Easy communication lines -Knowing who dealt with the daily activity schedule makes it easier to work
Hinders	-Creates conflicts about the scope of work
***High* Stratification**	
helps	- Awareness of who is responsible for what with a clear reporting line -Prevent task duplication and rework -Ease of employee deployment -Fair and reasonable pay-structure -Procedural decision making -Existence of gate-keepers for certain company particulars - The healthy difference in risk and responsibility sharing -Ease of dispute track and trace -Creating manageable chunks of larger tasks -Appointment of dedicated professionals for tasks
hinders	- Delays in decision making -Sophistication adds more complexity into the process -Imbalance in workloads for employees

5.4 Ascertain the impact of organisation size on the exploitation of BBI

5.4.1 Establishing the size variables

Table 82 shows the construct variables used for organisation size which were brought forward from Chapter-2 literature review. Figure 57 illustrates the types of correlations studied between size variables. As with culture and structure, it is worthwhile noting that the questions around organisation size were phrased considering the impact itself. For example, the impact of the number of full-time employees on achieving the best possible use of IoT was directly questioned in the questionnaire. Further, just as with culture and structure the 'size' factors contained separate variables for all three strategic tools. A full list of questions and variables can be found in Appendix C.

Table 82- Construct variables for organisation size

Organisation Size Factors	Code	Dimension
The impact of the number of full-time employees on achieving the best possible use	SIZ1	Number of employees
The impact of annual turnover on achieving the best possible use	SIZ2	Annual Turnover

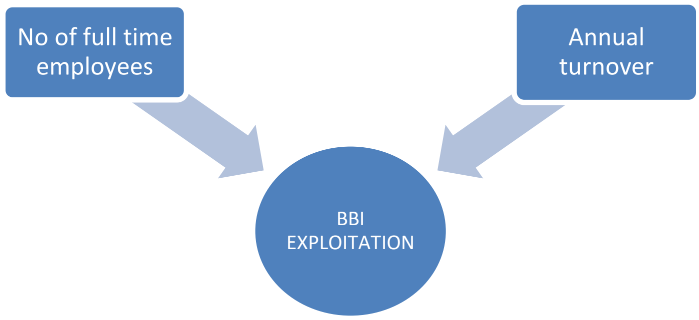


Figure 57- Correlations between organisation size variables

5.4.2 Quantitative data analysis for organisation size and BBI exploitation

5.4.2.1 Descriptive statistics for the impact of organisation size on BBI exploitation

The questionnaire contained questions that directly indicate the impact of organisation size on the exploitation of BIM, BDA, and IoT. Fundamentally, the descriptive statistics for these impacts were investigated. Values of the 5-point Likert scale in these questions were: 1-Very negative impact, 2-Somewhat Negative impact, 3- Neither negative nor positive impact, 4-Somewhat Positive impact, and 5-Very Positive impact. Considering the phrasing of these values, the higher the mean score, the more positive the impact is. Table 83 specifies the impact organisation size variables have on BIM, BDA, and IoT exploitation variables. The results show that organisation size has a 'somewhat positive' impact on the exploitation of BIM, BDA, and IoT generally. The impact of annual turnover toward IOT exploitation is the highest of all. IoT as it is filled with opportunism is challenging, especially given the costs associated with the tools and technology. Further, given the time it takes to build an IoT system and the complexity involved, the cost of development could get higher. This urges the requirement of a substantial amount of funding and thus explains the importance of company turnover especially for IoT exploitation.

Table 83- Descriptive statistics for organisation size variables towards BIM, BDA, and IoT

Descriptive Statistics				
	Minimum	Maximum	Mean	Std. Deviation
SIZIOT2	2	5	3.96	0.713
SIZBIM2	3	5	3.91	0.684
SIZBDA2	2	5	3.86	0.730
SIZBIM1	2	5	3.68	0.676
SIZIOT1	2	5	3.44	0.698
SIZBDA1	2	5	3.41	0.673
Valid N (listwise)				

Because it is necessary to ascertain the impact of size constructs as a group on BBI exploitation, the group means were calculated and thus the impact of group variables are presented in Table 84; Table 85 and Table 86. Organisation size all in all shows a somewhat positive impact towards BIM, BDA and IOT exploitation.

Table 84- Impact of organisation size on BIM exploitation

BIM				
Variable	**Mean**	**Impact**	**Total Mean**	**Total Impact**
SIZBIM1	3.68	Somewhat Positive impact	3.80	Somewhat Positive impact
SIZBIM2	3.91	Somewhat Positive impact		

Table 85- Impact of organisation size on BDA exploitation

BDA				
Variable	**Mean**	**Impact**	**Total mean**	**Total Impact**
SIZBDA1	3.41	Somewhat Positive impact	3.64	Somewhat Positive impact
SIZBDA2	3.86	Somewhat Positive impact		

Table 86- Impact of organisation size on IoT exploitation

IoT				
Variable	**Mean**	**Impact**	**Total mean**	**Total Impact**
SIZIOT1	3.44	Somewhat Positive impact	3.70	Somewhat Positive impact
SIZIOT2	3.96	Somewhat Positive impact		

5.4.2.2 Inferential statistics for the size-exploitation correlation analysis

The realisation of the impact of organisation size on BBI exploitation via descriptive statistics was succeeded by inferential statistics. Inferential statistics were employed to make statistical inferences. Frequencies and mean values for exploitation factors which were split into each organisation size group were initially observed in Table 87. Highlighting the most noticeable findings, the small organisations reported operating more efficiently than the rest of the organisations after they started using BIM (EXPBIM9). Interestingly, micro organisations are the ones that were mostly deploying big data sets for both tangible and intangible assets to enable big data analytics (EXPBDA2).

Table 87- Frequencies for BIM, BDA and IoT exploitation variables

BIM			BDA			IOT		
	ORGSIZ	**Mean Rank**		**ORGSIZ**	**Mean Rank**		**ORGSIZ**	**Mean Rank**
EXPBIM1	Micro	30.83	EXPBDA1	Micro	38.00	EXPIOT1	Micro	33.38
	Small	56.50		Small	38.00		Small	23.00
	Medium	33.88		Medium	28.75		Medium	29.72
	Large	43.43		Large	29.50		Large	25.16
	Total			Total			Total	
EXPBIM2	Micro	35.33	EXPBDA2	Micro	44.25	EXPIOT2	Micro	35.00
	Small	54.83		Small	33.50		Small	30.50
	Medium	43.13		Medium	16.83		Medium	24.94
	Large	42.83		Large	30.89		Large	25.74
	Total			Total			Total	
EXPBIM3	Micro	41.17	EXPBDA3	Micro	20.75	EXPIOT3	Micro	35.25
	Small	41.17		Small	32.50		Small	26.00
	Medium	47.25		Medium	28.17		Medium	22.44
	Large	42.92		Large	30.50		Large	26.57

	Total			Total			Total	
EXPBI M4	Micro	47.33	EXPBDA 4	Micro	41.75	EXPIO T4	Micro	36.25
	Small	55.33		Small	41.75		Small	36.25
	Medium	49.25		Medium	22.33		Medium	25.72
	Large	42.00		Large	29.98		Large	25.11
	Total			Total			Total	
EXPBI M5	Micro	35.17	EXPBDA 5	Micro	39.75	EXPIO T5	Micro	27.25
	Small	54.33		Small	39.75		Small	27.25
	Medium	48.50		Medium	28.75		Medium	24.28
	Large	42.57		Large	29.36		Large	26.92
	Total			Total			Total	
EXPBI M6	Micro	34.33	EXPBDA 6	Micro	30.00	EXPIO T6	Micro	28.13
	Small	46.33		Small	30.00		Small	27.75
	Medium	39.00		Medium	21.83		Medium	23.89
	Large	43.43		Large	31.00		Large	26.89
	Total			Total			Total	
EXPBI M7	Micro	42.83	EXPBDA 7	Micro	26.00	EXPIO T7	Micro	34.25
	Small	38.33		Small	35.00		Small	40.50
	Medium	36.00		Medium	23.33		Medium	18.28
	Large	43.57		Large	30.78		Large	26.91
	Total			Total			Total	
EXPBI M8	Micro	46.33	EXPBDA 8	Micro	37.25	EXPIO T8	Micro	32.75
	Small	41.83		Small	37.25		Small	32.75
	Medium	38.75		Medium	25.50		Medium	18.94
	Large	43.14		Large	29.96		Large	27.32
	Total			Total			Total	
EXPBI M9	Micro	44.00	EXPBDA 9	Micro	48.00	EXPIO T9	Micro	35.63
	Small	57.00		Small	35.50		Small	19.50
	Medium	37.50		Medium	25.33		Medium	23.44
	Large	42.69		Large	29.61		Large	26.64
	Total			Total			Total	
EXPBI M10	Micro	44.50	EXPBDA 10	Micro	50.50	EXPIO T10	Micro	36.75
	Small	44.50		Small	41.00		Small	27.50
	Medium	33.75		Medium	27.58		Medium	22.56
	Large	43.37		Large	29.01		Large	26.30
	Total			Total			Total	

Univariate analysis was carried out to show the association between size and exploitation. Non-parametric Kruskal Wallis test was utilised to examine the effect of organisation size on the exploitation of BIM (see Table 88). Table 88 showed that there were no statistically significant differences in Exploitation variables between four different organisation sizes. For example, for

Factors that impact BBI exploitation and competitive advantage

EXPBIM1 [$\chi2(2) = 3.276$, $p = 0.351$ (which is above 0.05), with a mean rank Exploitation of 30.83 for micro, 56.50 for small, 33.88 for medium and 43.43 for Large] there were no statistically significant differences across four organisation sizes. All p values were above 0.05, and therefore, the results indicate that organisation size has not influenced the way they have exploited BIM, BDA and IOT.

Table 88- Kruskal-Wallis test for organisation size and exploitation

Test Statistics[a,b]			
BIM			
	Kruskal-Wallis H	df	Asymp. Sig.
EXPBIM1	3.276	3	.351
EXPBIM2	1.154	3	.764
EXPBIM3	0.183	3	.980
EXPBIM4	1.455	3	.693
EXPBIM5	1.360	3	.715
EXPBIM6	0.656	3	.883
EXPBIM7	0.710	3	.871
EXPBIM8	0.219	3	.974
EXPBIM9	1.728	3	.631
EXPBIM10	0.698	3	.874
a. Kruskal Wallis Test			
b. Grouping Variable: ORGSIZ			
BDA			
	Kruskal-Wallis H	df	Asymp. Sig.
EXPBDA1	1.063	3	.786
EXPBDA2	6.515	3	.089
EXPBDA3	0.876	3	.831
EXPBIM4	3.950	3	.267
EXPBDA5	1.623	3	.654
EXPBDA6	2.170	3	.538
EXPBDA7	1.562	3	.668
EXPBDA8	1.301	3	.729
EXPBDA9	3.410	3	.333
EXPBDA10	4.450	3	.217
a. Kruskal Wallis Test			
b. Grouping Variable: ORGSIZ			
IoT			
	Kruskal-Wallis H	df	Asymp. Sig.

EXPIOT1	1.847	3	.605
EXPIOT2	1.941	3	.585
EXPIOT3	2.236	3	.525
EXPIOT4	3.492	3	.322
EXPIOT5	0.265	3	.966
EXPIOT6	0.415	3	.937
EXPIOT7	6.987	3	.072
EXPIOT8	3.876	3	.275
EXPIOT9	2.637	3	.451
EXPIOT10	2.819	3	.420
a. Kruskal Wallis Test			
b. Grouping Variable: ORGSIZ			

Once the statistical non-significance for the difference in exploitation for different organisation sizes was perceived from data, the relationship between organisation size and BBI exploitation was investigated via the Spearman rank-order correlation coefficient.

Considering the duality impact of organisation size on the exploitation of BBI for competitive advantage as discovered from the literature, this research proposes some hypotheses for further investigation. Beginning with an unbiased standpoint, it was assumed that there no significant relationship exists between organisation size and BBI exploitation. Thus, the null hypotheses are expressed as:

HSi$_1$0= there is no significant relationship between the number of employees in an organisation and exploitation of BBI for competitive advantage

HSi$_2$0= there is no significant relationship between the annual turnover of an organisation and exploitation of BBI for competitive advantage

In testing the null hypothesis for BIM (Table 89), it appears that the computed value of the Spearman rank-order correlation coefficient (r.) ranges from + values to - values. For instance, EXPBIM1 has a positive correlation with SIZBIM1 (r_s=0.082, p>.05). Although it reports a positive correlation, it is not significant at the 0.05 level. On the other hand, EXPBIM10 and SIZBIM1 have a positive correlation which is significant at 0.05 level (r_s=0.228, Sig= 0.036). This is also the only correlation that shows a statistical significance. The null hypothesis is therefore rejected only for the correlation between EXPBIM10-SIZBIM1. This means that there is an ample amount of evidence to suggest that the higher the number of full-time employees on achieving the best possible use of BIM, the higher the adoption and diffusion of BIM within the organisation. This also leads to embracing new routines and processes. This could be an indication that the amount of human resources has been prominent as an indication of technological exploitation capacity. Few negative correlations can also be seen in the analysis (i.e. EXPBIM2- SIZBIM2). Further detail about SIZEBIM-EXPBIM correlation and causation can be found on Appendix E7.

For BDA, the only correlation that reports a significant p-value below 0.05 was between SIXBDA1-EXPBDA8. Further detail about SIZEBDA-EXPBDA correlation and causation can be found on Appendix E8. The extent to which employees can leverage their individual competencies on technology depends on the number of full-time employees in a company. This can be partially due to legislation in place. When the numbers in terms of employees are high, certain regulations can be enforceable in favour of the employees (i.e. health insurance). These legislations might encourage employees to strengthen their existing competencies as well as to develop new ones.

The correlation between SIZIOT1 and EXPIOT4 appears to be the one and only statistically significant correlation for IOT exploitation. The latter correlation not only shows statistical significance, but also negative in terms of direction. This indicates that there is a strong negative relatedness between the number of full-time employees and setting realistic IOT goals (i.e. short term/ medium term/ long term).The lower the number of employees, the easier the goal setting is. Organisations with a smaller number of employees could offer more flexibility in the work/life balance. Moreover, such companies are aware that they cannot provide the same benefits that a large company can. Therefore, they will often make exceptional efforts to ensure that the business runs smoothly. This may lead to effective goal setting. Further detail about SIZE-IOT exploitation correlation and causation can be found on Appendix E9.

Table 89- Spearman's correlation analysis for organisation size and BIM, BDA and IoT exploitation

BIM											
		EXPBIM1	**EXPBIM2**	**EXPBIM3**	**EXPBIM4**	**EXPBIM5**	**EXPBIM6**	**EXPBIM7**	**EXPBIM8**	**EXPBIM9**	**EXPBIM10**
SIZBIM1	Correlation	0.082	0.028	0.111	0	0.144	0.039	0.207	0.072	0.178	.228*
	Sig.	0.453	0.8	0.313	1	0.189	0.724	0.057	0.512	0.104	0.036
SIZBIM2	Correlation	0.092	-0.083	-0.044	-0.044	-0.028	0.063	0.068	-0.087	0.009	0.03
	Sig.	0.402	0.448	0.691	0.69	0.798	0.564	0.536	0.43	0.936	0.787
BDA											
		EXPBDA1	**EXPBDA2**	**EXPBDA3**	**EXPBDA4**	**EXPBDA5**	**EXPBDA6**	**EXPBDA7**	**EXPBDA8**	**EXPBDA9**	**EXPBDA10**
SIZBDA1	Correlation	0.091	0.233	0.119	-0.005	0.145	0.135	0.156	.284*	0.028	0.063
	Sig.	0.495	0.075	0.371	0.972	0.273	0.307	0.239	0.029	0.831	0.636
SIZBDA2	Correlation	-0.19	-0.145	-0.045	-0.028	-0.089	0.055	0.066	0.141	-0.098	-0.189

	Sig.	0.15	0.273	0.736	0.835	0.503	0.679	0.619	0.287	0.461	0.152
IoT											
		EXPIOT5	**EXPIOT2**	**EXPIOT3**	**EXPIOT4**	**EXPIOT5**	**EXPIOT6**	**EXPIOT7**	**EXPIOT8**	**EXPIOT9**	**EXPIOT10**
SIZIOT1	Correlation	-0.029	-0.024	-0.13	-.281*	-0.02	-0.113	0.071	0.078	0.178	0.122
	Sig.	0.839	0.866	0.36	0.044	0.889	0.425	0.615	0.584	0.207	0.391
SIZIOT2	Correlation	-0.058	-0.232	0.01	-0.158	0.016	-0.005	0.07	0.077	0.058	-0.1
	Sig.	0.681	0.098	0.945	0.263	0.911	0.97	0.622	0.589	0.685	0.479
**. Correlation is significant at the 0.01 level (2-tailed).											
*. Correlation is significant at the 0.05 level (2-tailed).											

In the interest of finding the mean r-value between-group variables, the mean of all positive/ negative r-values were calculated (regardless of the direction). To obtain the direction of the group correlation, the net mean-value was calculated and resulted in values as stated in Table 90. Because the measures of the independent variable (organisation size) contain two distinct measures (number of full-time employees and annual turnover), unlike with other independent variables, the correlations here were investigated separately for these two measures

Table 90- Correlation Mean values of all exploitation variables

BIM EXPLOITATION		
Independent Variable	**Mean**	**Direction and strength of Correlation**
SIZBIM1	0.096	Positive (Small)
SIZBIM2	0.055	Negative (Small)
BDA EXPLOITATION		
Independent Variable	**Mean**	**Direction and strength of Correlation**
SIZBDA1	0.117	Positive (Small)
SIZBDA2	0.101	Negative (Small)
IoT EXPLOITATION		
Independent Variable	**Mean**	**Direction and strength of Correlation**
SIZIOT1	0.085	Positive (Small)
SIZIOT2	0.078	Negative (Small)

Examining the data provided in Table 90, and the supportive data presented in Appendix E7,E8 and E9, the following simple models were produced. Figure 58, Figure 59, Figure 60 show the correlation organisation size measures have on BIM, BDA, and IoT exploitation. To summarise the findings in relation to the impact organisation size shows with BBI exploitation, annual turnover shows a small negative correlation while number of full-time employees shows a small positive correlation.

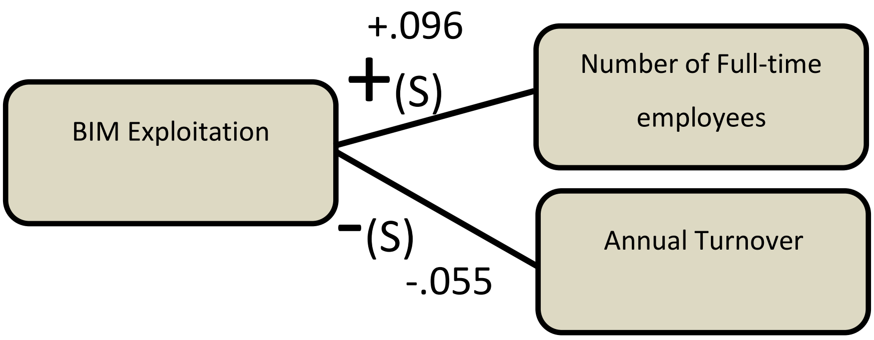


Figure 58- Correlation between organisation size measures and BIM exploitation

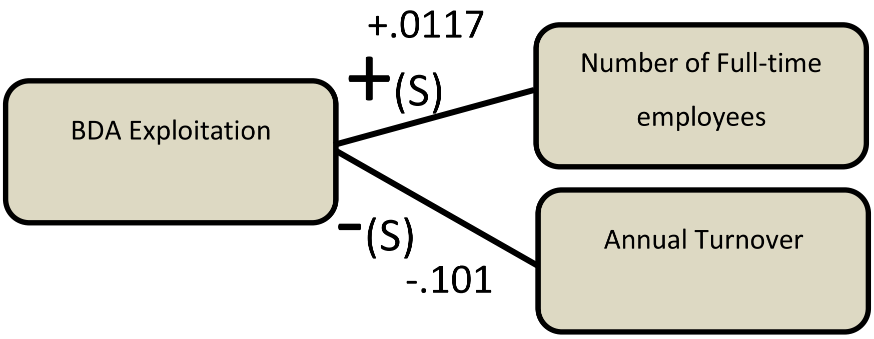


Figure 59- Correlation between organisation size measures and BDA exploitation

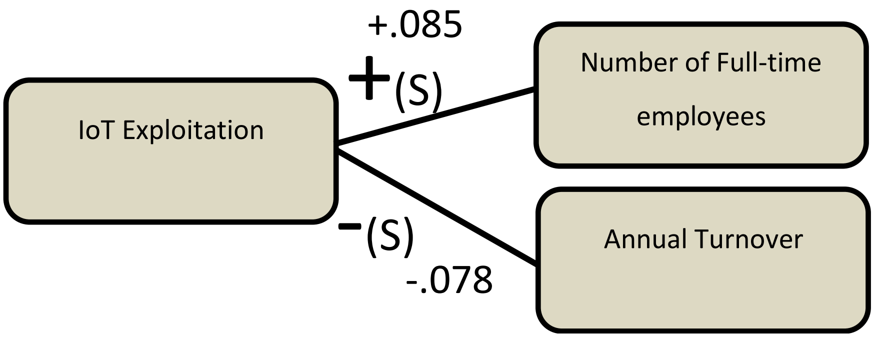


Figure 60- Correlation between organisation size measures and IOT exploitation

Partial Correlation Analysis and Multiple regression analysis

Partial correlation analysis was performed to see whether there is a significant change in the relationships between all exploitation variables when SIZE variables are controlled. This helps to discover the influence SIZE variables have on BBI exploitation. The results of the partial correlation show that almost all the correlations between exploitation variables have been subjected to some degree of change when control was applied to SIZE variables. For example, the correlation between EXPIOT1 and EXPIOT2 which was +.517 (in zero-order) has increased to +.527as a result of controlling SIZIOT1 and SIZIOT2 variables at once. This means the two measures of organisation size have some influence on all exploitation variables related to BIM, BDA, and IoT.

Multiple regressions analysis was also performed to see if the measures of organisation size predict the level of exploitation for BIM/ BDA/ IoT. This eventually confirmed whether organisation size impacts on BBI exploitation or not. The r-value was considered when determining the strength. It tells how much of the variance in the dependent variable (EXPBIM1) is explained by SIZBIM1 and SIZBIM2. The guidelines suggested by Cohen (1988) were used to determine the strength of the influence/ impact. The results of the multiple regression analysis show that there is a higher impact from annual turnover than from the number of full-time employees. However, none of the impacts were significant at the 0.05 level. All information drawn from the aforementioned inferences are shown in Appendix E7, Appendix E8, and Appendix E9. Concerning the causation, the influence organisation size can have on BBI exploitation in general is insignificant. Hence, only the correlation is indicated in the models below. Having less or more employees or having less or more turnover does not necessarily make a significant influence/causation for the ability to exploit BBI for an organisation.

In the attempt to check the level of criticality in these two organisation size measures, the same partial correlation was conducted, but controlling one independent variable at a time followed by taking the amount-correlation coefficient decreased/ increased into account. For example, controlling SIZBIM1, the change of correlation between EXPBIM-EXPBIM2 was investigated. The investigation continued for all EXP variables corresponded to all three strategic tools (BIM, BDA, and IoT) and the Group Mean change in correlations are listed in Table 91. The group means were then ranked according to descending order. From the results received from regression analysis, it is convincing that annual turnover is more critical compared to the number of full-time employees when it comes to the impact of organisation size on BBI exploitation.

Table 91- Summary of size-exploitation impact

Code	Mean change in correlations	Group Mean	Rank
SIZBIM1	0.134	0.117	2
SIZBDA1	0.115		
SIZIOT1	0.101		
SIZBIM2	0.152	0.213	1
SIZBDA2	0.271		
SIZIOT2	0.216		

5.4.3 Qualitative data analysis for organisation size and BBI exploitation

The respondents were asked about the size of their organisation and the impact that size has on BBI exploitation to determine the dynamics of organisation size and how that helps or hinders the exploitation process. The following are the two questions related to organisation size.

1. What benefits does size (in terms of the number of employees) give you in BIM implementation and then its exploitation for competitive advantage? Or do you think it inhibits?
- If it affects differently, please can you kindly share your thoughts in the same way for Big Data Analytics?
- If it affects differently, please can you kindly share your thoughts in the same way for the Internet of Things?

2. What benefits do size in terms of annual turnover gives in BIM implementation and then its exploitation for competitive advantage? Or do you think it inhibits?
- If it affects differently, please can you kindly share your thoughts in the same way for Big Data Analytics?
- If it affects differently, please can you kindly share your thoughts in the same way for the Internet of Things?

In comparison between qualitative and quantitative data, it is substantiating that constituents of organisation size hold mixed results in the investigation of the impact of size on BBI exploitation. Some see the advantage of having a large turnover/ number of employees while the rest see it as a disadvantage. Among the 25 interviews conducted for construction, 16 interviewees mentioned the advantages of being large in terms of organisation size. These include economies of scale, carving good deals out with potential suppliers, collaboration, and more skills/ knowledge from a range of employees. Some do not see that the number of employees has an impact on BIM or Big data.

> *"Let us say everybody uses it and so we have more staff, we have more projects, but still if we don't know how to deal with it properly, then you are out. Especially the staff related to the number of projects we have; the use of BIM is strategy forward anyway which is not affected by the number of employees. It does not help to improve it, because you have more staff" (I-3)*

However, they see the importance of making greater turnover as higher turnover in harnessing data, tools, and equipment. Being small, on the other hand, in terms of less hierarchies and less overheads is considered to be an enabler for being flexible and easy to adapt.

> *"The bigger the turnover you have, the more money to spend over that. You need to have the basic capital to spend on these digital tools. That is the most important thing. However, I do not think turnover matters too. But the way a company invests matters. I think making a profit has something to do with it. Sometimes smaller architectural companies do better than large ones. So, I do not think size matters. And also, I would say, the smaller, the easier to adopt, train staff and manage BIM" (I-3)*

Some see the disadvantages of large organisations attributed to less flexibility and rigidity. Few had a completely different opinion to this inquiry believing that both small and large organisations find it easy to exploit technologies, but the medium-sized organisations are the ones that are finding it exceptionally difficult because they have less capacity to take risks (I-22). Armandi and Mills (1982) in their study tested the renowned 'Blau-Hage Model' to see the causal relationship which constitutes the proposition: Large size organisations promote structural differentiation (or complexity). The study then concluded with the preposition: the higher the complexity, the lower the efficiency. This is directly linked to technology exploitation because when the efficiency, in general, is low, it does not provide adequate technology or the required flourishing environment to run effectively (Marsh and Mannari, 1981). The qualitative data, therefore, complements the quantitative findings by elaborating the mean rank findings as an expansion to the already discovered knowledge. The advantage of rich content analysis is that it allows a certain phenomenon to expand into different emerging core categories (Charmaz, 1990). For example, in the investigation of the impact of organisational size on BBI exploitation, qualitative data not only provide the nature of impact but also 'explain' on what basis size impacts exploitation and as such, 'why' and 'how'.

Drawing from the qualitative findings on organisation size, the following key themes were identified.

Org Size constituent-helps or hinders exploitation?	**How/ why that helps/ hinders**
Low Number of employees	
Helps	-Ease of re-shaping and smaller structures for technology exploitation -Improved flexibility in change management

	- Easier to manage, maintain, and learn when it is condensed as opposed to very diluted. -Higher adaptability
hinders	-Less tendency to embrace risks considering the resource consumption involved
High Number of employees	
helps	- Having scale and breadth of skills -Grooming employees to become experts or specialists -High potential to bid for and win large projects considering the workforce capacity
hinders	-Getting into politics -Dividing into collective groups and unions -Rigid systems make it difficult to adapt
Low Annual turnover	
helps	-The cost of mistakes is lower -Easy to trial adoption at a smaller scale - Higher adaptability
Hinders	-Discouraged exploitation considering the high resource-consuming and expensive process -Less tending to embrace risks considering the costs involved
High Annual turnover	
helps	*-Increased ability to take financial risks* *-Economies of scale* *-Ability to bear the high costs associated with technology exploitation (software and hardware purchasing, training and development)* *-Profits in cash cycles are re-invested* *-Making the cultural transition easier with available funds* -High potential to bid and win for large projects considering the workforce capacity -Improved capabilities to work with clients across disciplines -Easy to find hidden disaggregated losses
Hinders	-Inclined to keep original production rather than innovate - Rigid systems make it difficult to adapt

Factors that impact BBI exploitation and competitive advantage

No impact	- A business at any size can get value from technologies. What it needs is the right data and skills to manage the data -Managing processes and stakeholders does not require high workforces/ higher revenues -The know-how of managing the process is independent of turnover or number of employees - Exploitation is driven by senior management and the client regardless of the size of the company - Construction companies generally have very low-profit-margins and it does not prevent adopting BIM/BDA/IoT

5.4.4 Discussion on the findings of the size-exploitation relationship

There are certain characteristics of firms that impact their ability to exploit BIM, BDA, and IoT. Firstly, this is related to the firm's capacity for technology uptake. This capacity ranges from technological competencies, skills, expertise and the availability of physical and monetary assets. The ability to develop and maintain a strategic management process is another important factor that differentiates a firm's ability to exploit technologies. To this end, both full-time employees and annual turnover impacts. The inability to fund long-term technological systems is a major barrier for small firms that are turning-over in lower values. Literature also captures the perceived advantages of being small in organisation size. These advantages mostly include, lack of experience in complex technology-based management and funding difficulties (Freel, 2005). Large organisations on the other hand lack the flexibility and agility to change systems to meet exploitation edges. The findings also conclude that small size organisations possess organisational strengths, which would help them to exploit technologies. These strengths include less formality, flexibility, agility, and ease of communication which lead to faster decision making and hence helping technology exploitation.

This remarks on the achievement of the objective- 3 (as stated in section 1.4). As explained in Chapter-2.3, studying the past patterns triggered by behaviours within an organisation is important to execute the strategic approach. Addressing this need, the impact of organisational culture, structure, and size on the exploitation of BBI is established. At the same time, this also remarks addressing two research questions as outlined in section 1.5 of Chapter One.

5.5 Chapter 5 contribution to the strategic framework

5.5.1 Development of the third order proposed Strategic framework

The importance and the need for developing a strategic framework are explained in section 2.7. The development of first order and second order strategic frameworks are also explained in section 4.7.1 and 4.7.2 respectively.

Drawing from the conclusions of semi-structured interviews and web-based questionnaire surveys the third-order strategic framework (Magnify x 2) was developed. This part of the framework focuses on the relationships between impact factors, exploitation, and competitive advantage.

Initially, the direction and strength of correlations between variables were derived from quantitative analysis as presented in sections 5.1 - 5.4. Please see the coding list attached in Appendix C along with the third-order strategic framework to be able to identify each code. The factors that impact the exploitation process were derived from the quantitative study. The correlations, directions, and impact were then tested using SPSS. These are detailed and explained in Chapter-4 and Chapter-5.

Considering the relationships and criticality of impact factors, the third-order strategic framework was developed as shown in Figure 61. Taking into account the complex linkage between factors and their impact on the exploitation of three different strategic tools, an interactive strategic framework was developed. Please see the attached interactive strategic framework developed in Ms. Excel for more information. This remarks on the achievement of objective- 5 (as stated in section 1.4- Research aim and objectives). In summary, drawing form the findings described in section 2.7.1, the predominant need for developing the strategic framework was established. This also satisfies the research aim (see section 1.4) of developing a framework for improved exploitation of BIM, Big Data Analytics, and the Internet of Things as strategic tools for competitive advantage in construction. By perusing the interactive strategic framework, one can understand what impact/cause the exploitation of BIM, BDA, and IoT is able to contribute to making the organisations ready to withstand impact factors and respond to the potential internal and external dynamics. Further how each aspect must be strategically controlled and paired could also be identified. Such identification offers an opportunity to strengthen current and future investment decisions on BIM, BDA, and IoT to enhance organisational competitive advantage. Section 4.7.1 presents the first-order strategic framework providing the positioning of higher abstraction level strategy, exploitation, benefits, and challenges. Section 4.7.2 thereafter delineates these first-order aspects with more attributes. This resembles magnifying x1 of the previous level. This section (5.5.1) completes the strategic framework by illustrating an array of correlations between each aspect. Figure 61 provides a brief sighting of the full version. Thus, remarking the achievement of the fifth

(5th) objective (as outlined in 1.4): the development of a strategic framework for improved exploitation levels of BBI for competitive advantage in construction is completed.

***The e-version of this interactive Strategic Framework can be found on the below link:**

https://bit.ly/366mZlc

Alternatively, the excel file is attached herewith.

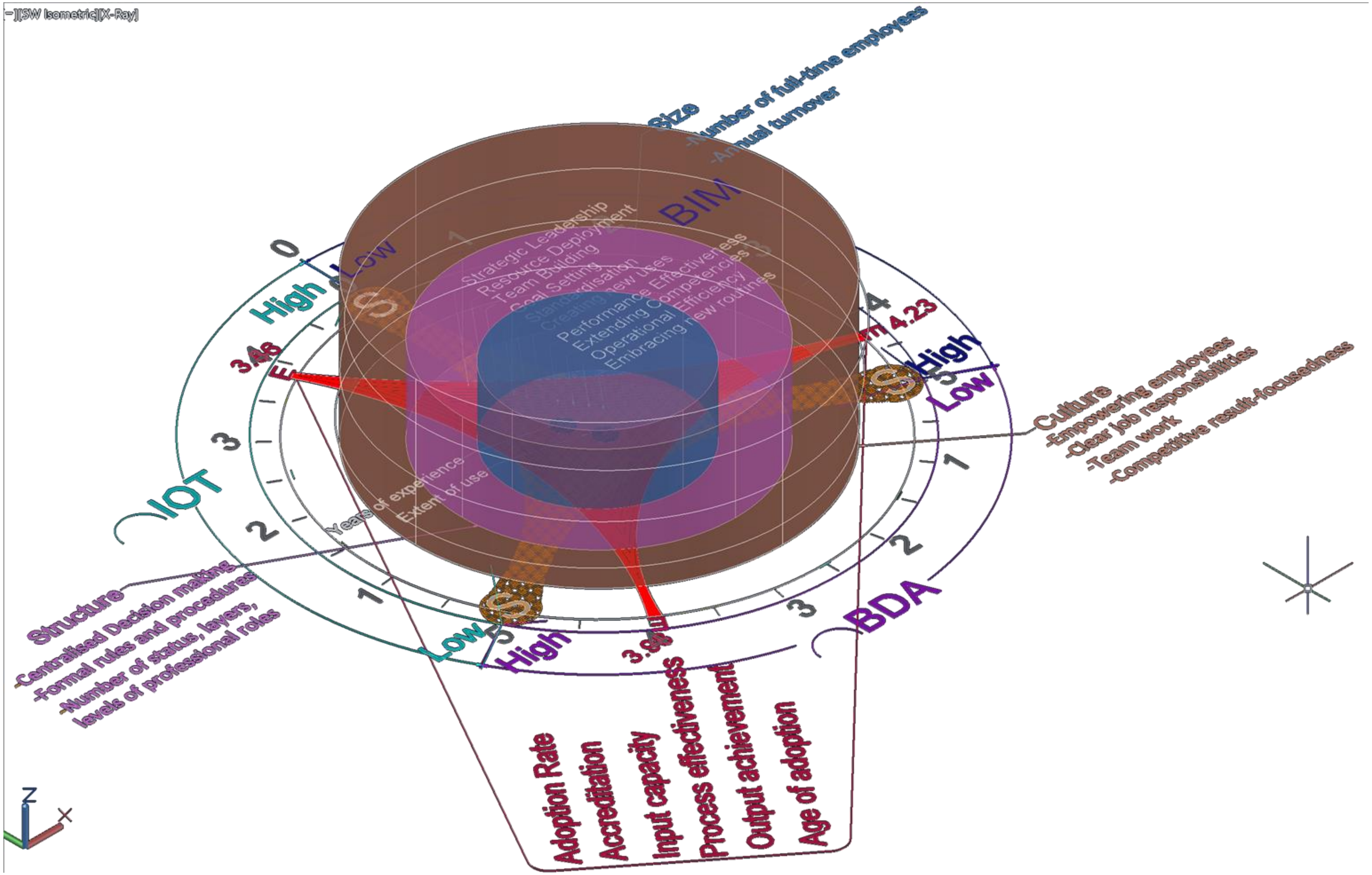


Figure 61- Proposed Strategic Framework for improved BBI exploitation levels for competitive advantage

5.6 Discussion for the proposed strategic framework

As rationalised in Chapter 2.2, the 5Ps strategic approach (in strategic management literature) suggested by Henry Mintzberg was employed as the main theoretical underpinning on which all sub-concepts were laid. This approach suggests that a firm should continuously evaluate the current state, the desired future state, and things that need to be done to continuously improve and reach the desired future state. In the attempt of doing so, firms must set a strategy that serves as a plan, position, perspective, ploy, and pattern. Given these 5Ps of the strategic approach, exploitation, benefits, challenges, and competitive advantage were aligned as a strategic framework; positioning BIM, BDA, and IoT as strategic tools. A strategic framework should briefly discuss how each stakeholder group, or an organisation will benefit from improving the exploitation levels for BIM, BDA, and IoT. The strategic framework is not a repetition of a project plan or a business case. A project plan is a detailed document that discusses the resource requirements, allocation, and timeframes for accomplishing a series of tasks over a defined period. A business case is a formalised justification for a significant expenditure, which includes a discussion of risks, alternatives, and methodologies. The strategic framework complements both the project plan and the business case and shows how an organisation could enhance competitive advantage by exploiting the strategic tools. For ease of communication, the strategic framework has been developed as an e-version with more detail.

For a construction organisation to maximise competitive advantages, this research suggests, that the organisation must evaluate the current exploitation, benefits, and challenges first. Understanding the desired state of these constituents is the next step. Once the current and desired future state is identified, then the 'know-how' involves identification of the strategic influence, factors that impact the exploitation process, and the extent to which competitive advantages could be enhanced. In this section, these are briefly discussed both to highlight how the strategic framework could help improve exploitation levels of BIM, BDA, and IoT in construction organisations and how the framework appreciates the inherent complexity involved.

Chapter-4 shows that the exploitation of BIM in construction is higher than the exploitation of BDA and IoT in construction. The 'exploitation' involves a series of aspects from strategic leadership to resource deployment, team building, goal setting, standardisation, creating new uses, operational efficiency, and so on. The research offers a 'blanket' view of exploitation consisting of key categories that any exploitation factor would fall in to. These include adoption rate, accreditation, resource input capacity, process effectiveness, outcome achievement, and rate of adoption. For example, level of exploitation is often interpreted as the successful dispersion among different disciplines (i.e. departments, business units, projects, branches, etc). On the other hand, it is also interpreted as the extent to which each organisation has received relevant accreditation (i.e. ISO for BIM). Some professionals gauge the level of exploitation by evaluating the achievement of outcomes (i.e. increasing productivity). It is also convincing that different sectors exploit the strategic tools at different levels. An interesting point that emerged from the study is that the level of exploitation is dependent on the individual years of experience and extent of use. This means that the higher the years of experience in a domain, the higher the level of exploitation of that domain.

Chapter-5 shows the impact of organisation culture, structure, and size on the exploitation of BIM, BDA, and IoT. First, it was explored that low power distance (more employee engagement and empowerment), low uncertainty avoidance (more clarity in job responsibilities and more job security), collectivism (more group work) and Masculinity (competitive result focus practice) very positively impact on BIM, BDA, and IoT exploitation. This positive impact does not resemble the inferential aspect of data, but the essence of positivity in enabling/ helping exploitation is shown. Drilling down to the inferential statistics, correlations in different sizes were identified. Highlighting the important points, having a result-focused and a competitive organisation culture highly influence the tendency to embrace new routines and processes caused by BIM. This can be attributed to the risk-taking involved in competitive culture as it opens-up new opportunities and collaborative partnerships. Many researchers point out that due to the noticeable inequality between managers and subordinates, most people do not speak up about their progressive suggestions that might help to gain success in the use of technology (Fikret Pasa, 2000). Further, within this sort of setting, subordinates do not even expect their managers to have a democratic style and this hinders innovative behaviour (Engelen *et al.*, 2014). Moving on with another constituent- Masculinity: early research on the relationship between risk-taking competitiveness and technology exploitation suggested that such a healthy competitive environment promotes productive working. Furthermore, they implied that risk-taking increases the chance of getting progressive and profitable outcomes onboard (Cheung *et al.*, 2011). The relation between collective organisational working and technological innovation recognised that performing collective work packages (or teamwork) is important as a source of competitive advantage(Sanz-Valle *et al.*, 2011). The proposed strategic framework shows a medium- large influence of impact factors towards all exploitation constructs. The detailed strategic framework provides more explanation as to why certain correlations are higher than the rest. Offering a more elaborated picture about the dynamism related to the impact, the framework was developed as an e-based version.

Factors that impact BBI exploitation and competitive advantage

In the investigation of the role of organisational structure in exploitation, none of the structure constituents show a significant positive influence on exploitation. Instead, all the structure constituents show neither a negative nor a positive influence. When inferential statistics were scrutinised, a mix of both positive and negative correlations could be seen, where the majority were small correlations. This means that even though the organisation structure does not have a strong influence nor significant correlation with exploitation, it does show small influences. The important findings include low levels of formalisation help BIM and IoT exploitation while high levels of formalisation particularly help BDA exploitation. Low levels of centralisation help BIM exploitation while high levels of centralisation help BDA, and IoT exploitation. The reasons behind some of these correlations as emerged from qualitative data can be described as follows. High centralisation helps exploitation because it helps to maintain consistency in workflows and meeting mutual project goals. When the decision making is decentralised, there is a potential that employees may work according to their own agendas. While the centralisation helps exploitation in such a manner, decentralisation also helps exploitation by increased employee engagement and facilitating innovation. This is true particularly in ICT adoption and implementation where knowledge is often shared (Egbu, 2000). There has been a long standing argument that strategies within an organisation influence structure and vice-versa. A seminal work developed by Chandler's (1962) famous postulation that "structure follows strategy" can be considered as a good foundation.

A similar proposition can be seen between organisation size and B, B, I exploitation. Considering the capacity to deploy a workforce, hiring a higher number of employees helps technology exploitation more than hiring a lower number of employees. At the same time, having a low number of employees indicates less rigidity in core structure which makes it easier to change, re-shape, and adapt. Such flexibility helps technology exploitation. While organisation size in general shows a somewhat positive impact, there is information in favour of its neutral impact as well. For example, some professionals see organisation size as an entirely independent feature to technology exploitation because what matters is getting value from data regardless of the annual turnover or number of heads involved in the process.

As illustrated in Figure 61, an organisation must pay more attention to their adoption rate, accreditation, resource input capacity, the effectiveness of the process, and the level of achievement in the outputs to be able to exploit BIM, BDA, and IoT for competitive advantage. A controversial argument has been made that the age of adoption could sometimes be in favour of exploitation as with age, more experience is gained while more lessons are learned. However, despite having more years of experience in the adoption, there is a possibility that start-up companies could also make the most out of the strategic tools if they succeed in the exploitation constituents. The factors are 'critical' because for example, without strategic leadership and effective training to build the required skill set, BIM, or BDA or IoT exploitation is not possible and hence the best beneficial use could not be achieved. One of the most time-consuming portions of an exploitation strategy is likely to be the training of staff. The exploitation of these strategic tools changes how everyone in an organisation will operate and to that end, a shift in organisation 'culture' and 'structure; is a must. The next is to devise a well-thought out strategy, which will enable the exploitation process to be cost and time efficient. It is very important to identify the challenges at the outset because every time a new strategy is implemented, knowing how to react to those challenges saves resources. When it comes to the benefits, most of the step-backs that a company decides to make are results of not knowing the real value that the technologies can add to the company. Taking the time to identify, understand, and map these benefits as early as possible assists the decision-makers in an organisation to create a smooth implementation process. With the benefits identification, it is then worth considering how the 'strategic tools' exploitation will impact the business outputs or the results. Looking at competitors to get an idea of how other companies are using it could help.

However, there are some limitations in the strategic framework. The framework only provides formative guidance for an 'organisation' in the construction industry (not a 'project'). Therefore, the framework does not reflect the stages of a project. Because the unit of analysis was set to be 'organisation' every step that was taken as the research progressed was built upon the concept of an organisation.

The proposed strategic framework is beneficial for clients, contractors, designers, architects, facility managers, engineers, and cost consultants in the industry because it helps to understand the critical aspects of consideration for BBI exploitation. Knowing these would help in recognising the key capabilities an organisation possesses and help in improving readiness for initiating the BBI exploitation process. The specific benefits include:

- Understanding of strategic requirements that need to be in place in developing the BBI exploitation strategy.
- Understanding the areas to consider when improving BBI exploitation levels assists an organisation to perform a self-maturity study of the current and desired future status. This would ultimately help an organisation to continuously improve to reach the desired state.
- Understanding the key benefits and how they influence organisational competitive edge helps to foresee the return on investment.
- Identifying the challenges that greatly hinder organisational competitive advantage helps early risk identification and making a contingency plan.

Factors that impact BBI exploitation and competitive advantage

- Identifying the cultural/ structural and organisation size aspects that greatly support BBI exploitation helps developing a strategy to enhance competitive edge.
- Understanding the critical impact factors will help them to plan and prepare the enablers and infrastructure for BBI exploitation.
- Understanding the competitive advantages offered by BBI exploitation helps to make business/ investment decisions along the line of value proposition of BBI adoption.

The strategic framework is beneficial for educators as it provides a formative guidance for training developers and academic institutions to identify the present and future knowledge-skill demands and adapt the education systems accordingly. Policymakers may improve their awareness of the need for forming new regulations/ policies around BBI adoptions. Finally, funders/Investors may also benefit from knowing the BBI exploitation levels in sectors for more informed business/ investment decisions. This would help to pitch the right market for investment and improve awareness of the marketability of BBI enabled projects and organisations. The framework also carries indirect societal implications as it encourages corporate social responsibility and sustained competitive advantage.

5.7 Summary of Chapter Five

This chapter discussed the association that organisation culture, structure, and size have with BBI exploitation. The questionnaire surveys together with semi-structured interviews were used in this regard. At some points, qualitative data elaborated on the arguments presented in quantitative data analysis while at other points qualitative data expanded the quantitative findings. Highlighting a few of the key findings, it was suggested that the lower the power distance the higher the strategic leadership received from senior management. Correspondingly, it was suggested that the lower the power distance the higher the ability to deploy tools and workflows. Likewise, conclusions were made for culture, structure, and size. The collective findings lead to the development of a third-order framework and thus completes the full interactive strategic framework. The framework identifies the critical factors pertinent to the exploitation of BIM, BDA, and IoT for competitive advantage along with the associations between them. The application of this framework informs firms on 'how best' to exploit the technologies to enhance their competitive edge. Not only that but it also encourages stakeholders in an organisation to exploit BIM, BDA, and IoT for organisational competitive advantage. Once the critical factors that need to be considered when exploiting technologies are known, it is then required to explore the skills and training needs for the exploitation process. The next chapter, therefore, looks at the skills and training needs that managers at varying levels are required to possess to exploit BIM, BDA, and IoT.

Chapter Six

6 The Skills and Knowledge required for BBI implementation and exploitation

6.1 Introduction to Chapter Six

It has been established that the skills and training are crucial aspects for BBI exploitation. Section 2.5.1 and 4.2.3.1 identify 'skills and need for training' as a construct constituent for the operational definition for BBI exploitation. This chapter therefore explores the importance of skills and knowledge requirements for BIM, BDA, and IoT implementation and exploitation. Moreover, the extent to which these skills-knowledge dimensions require training is another strand explored in this chapter. The relative importance and the need for training, are investigated in respect of two cross-sectional timings: current (now) and future (in the next five years). In the achievement of the sixth objective, this chapter aims at meeting the following expectations.

i. Explore the skills and training needs for effective implementation, exploitation of BBI for competitive advantage along with their need for training

ii. Develop a skills and knowledge inventory (SKI)

Although the SKI does not intend to position within the strategic framework, it is expected that the SKI stands side-by-side with the framework complementing each other. Figure 62 shows the Position of Chapter-6 in the study and its contribution to research output

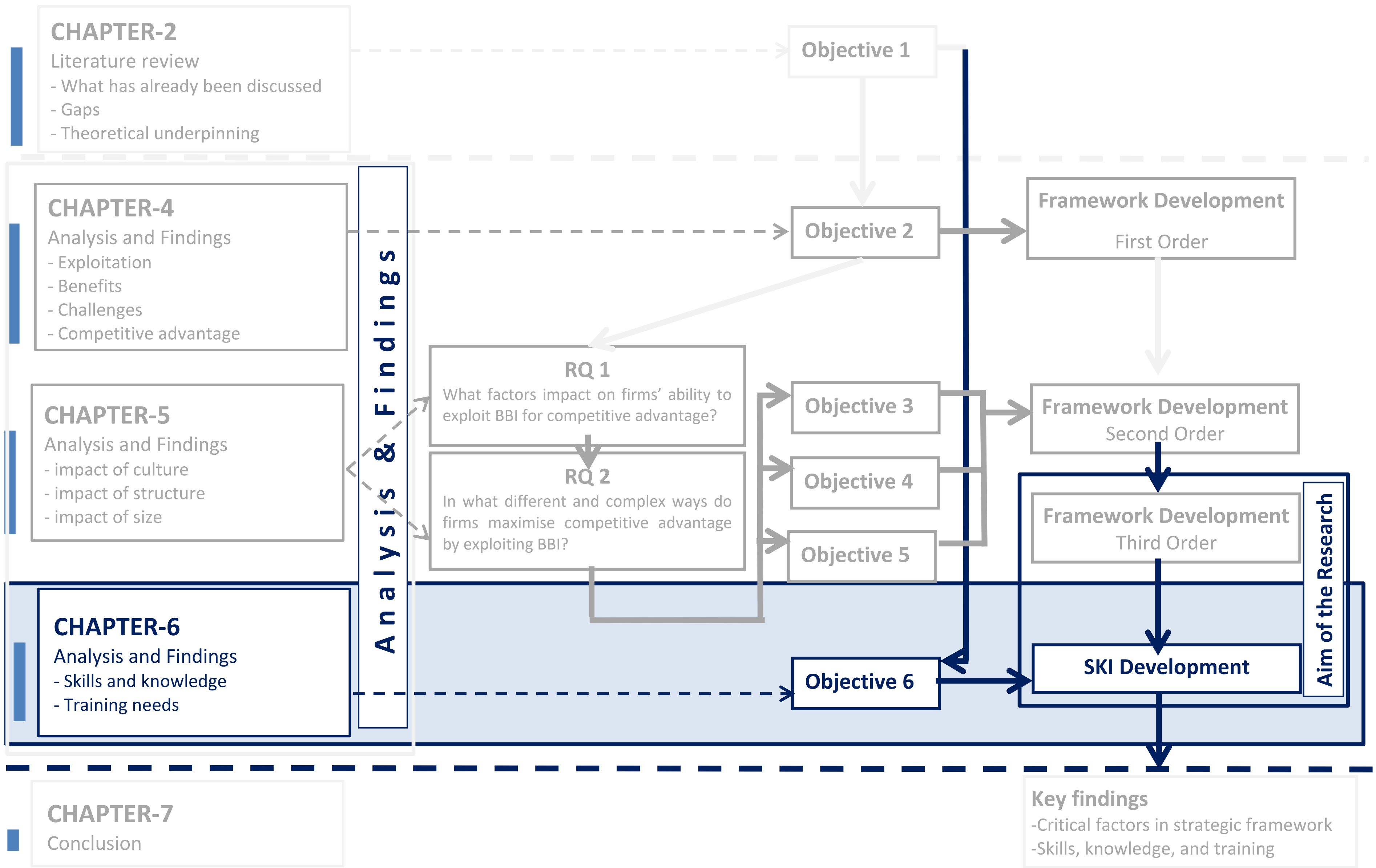


Figure 62- Position of Chapter-6 in the study and its contribution to strategic framework

6.2 Explore the skills and training needs for effective implementation and exploitation of BBI for competitive advantage

6.2.1 Establishing the variables for skills/ knowledge dimensions and training needs (SKT) for successful BBI exploitation

In addition to the strategic approach suggested by Mintzberg (1987, 2008) described in section 2.8 of Chapter Two, the theory of the firm as defined by Mintzberg (1973) also affirms that a firm must have an organisational structure, that clearly breaks down the management roles and responsibilities to reflect the skills and knowledge requirements. The strategic apex (includes senior management), Middle line (links the strategic apex to the operating core) and Operating core are the three hierarchical levels of an organisation that break down management roles and responsibilities. Considering this composition, the skills and knowledge introduced in this chapter were given with adequate attention to detail to be able to reflect the differentiation of skills-knowledge requirements for three hierarchical levels.

According to Henry Mintzberg, the skills of individual managers do not always contribute to the success of an organisation (Lundberg and Mintzberg, 1991). Effective managers use their transferable and switchable skills (i.e. leadership roles) independently for the right situation to develop themselves based on protocols for action. Henry Mintzberg distinguishes ten key managerial roles that managers and executives must fulfil. Because managers at every level constantly switch their tasks according to situations and unexpected changes, there are ten primary roles or behaviours that can be used to categorise these different functions. The ten roles include Figurehead, Leader, Liaison, Monitor, Disseminator, Spokesperson, Entrepreneur, Disturbance Handler, Resource Allocator, Negotiator. These managerial Roles are subsequently divided into three categories: the interpersonal category, the informational category, and the decisional category. By reflecting on these managerial behaviours, it is possible to find out the areas in which managers can improve themselves and how they can develop the right skills- knowledge at different times. Please see Appendix C (From 31.1.a to 33.20.f) for the skills/ knowledge dimensions required for BIM, BDA, and IoT that were used in the questionnaires for further investigations.

6.2.2 Quantitative data analysis for skills and knowledge dimensions related to BBI Implementation, exploitation and need for training

6.2.2.1 Analysing and refining the quantitative data

It is generally accepted that the first step in any skills-knowledge management programme is the identification of the most important skills-knowledge areas and then the identification of the need for training (Briscoe *et al.*, 2001; Mumford *et al.*, 2000). Through a web-based questionnaire, managers were asked the current and future relative importance of skills-knowledge dimensions. Further, the need for training for these dimensions was also questioned.

The quantitative analysis of skills-knowledge and training needs for BBI exploitation commences with the data collected on managers' perceptions of the degree of importance and the degree of need for training in their present job. Data is firstly presented at an aggregate level and then followed by an evaluation for education and training needs at disaggregated levels: strategic, tactical, and operational.

First, in the investigation of the reliability of the data sets, Cronbach's alpha value was calculated and resulted as shown in Table 92. Skills/knowledge (SK) dimension variables related to BIM, BDA, and IoT show Cronbach alpha values of greatly higher than 0.7. This indicates a good level of internal consistency between the SK variables.

Table 92- Cronbach's alpha values for BIM, BDA and IoT skill/ knowledge dimension variables

Cronbach's alpha values for skill/ knowledge dimension variables		
SK_BIM	**SK_BDA**	**SK_IoT**
0.928	0.940	0.937

From a list of 20 skills/knowledge dimensions (from each strategic tool), managers who participated in the web-based questionnaire were asked to indicate the degree of importance and the degree of need for training in each of the skill-knowledge dimensions (see all variables related to the questionnaire in Appendix C). The values of the Likert scale include 'Not at all important', 'Fairly Important', 'important', and 'very important'. These were coded 1, 2, 3, and 4, respectively. Mean scores were computed from the ordinal coding of these data. Because the results obtained from both the mean score method and the level of enhancement index were equal, only the mean score method is presented in this section. The increase of mean score signifies an increasing relative importance as well as an increasing need for training.

6.2.2.2 Skills and knowledge dimensions required for BIM

Table 93 presents data on the 'current' importance of these skills-knowledge dimensions in the implementation, exploitation, and the need for training for managers at an aggregate level. The most mentioned skill-knowledge dimension which managers believe to be important for BIM implementation was Strategic Planning (SKBIMIMPNOW7). Strategic planning helps in outlining how different people will interact with the collaborated model throughout the lifecycle and how they meet the strategic goals of the project in advance. This would also help to identify the tasks associated with the BIM execution plan. As the majority of the companies are currently in the process of BIM execution, a strategic guide provides more insight as to how BIM can be implemented as a part of a comprehensive system consisting of design, construction, management, operation, maintenance, and use of buildings. This explains the current importance of the strategic management for practices. However, in terms of the need for training, this dimension is ranked 4th. Meaning, even though the managers believe strategic planning is important for BIM implementation, its training requirement is less than for innovation management, information management, and teamwork. The main reasons why strategic management is important for current BIM implementation is because it facilitates setting priorities, allocating energy and resources, creating operational flows, and ensuring that employees and other stakeholders are working toward common goals. These are also reported to be important aspects of BIM implementation (Abanda *et al.*, 2015). The qualitative data analysis presented in section 6.2.3 provides more justification for the importance of strategic management. For current BIM exploitation, the most important skill/ knowledge was information management. This is mainly due to the need of establishing a cyclic mechanism consisting of acquiring information from one or more sources, the governorship of information, and the distribution of that information to those who need it. Further, having a mechanism for information management helps to reach intended outcomes/results. Information Management (SKBIMEXPNOW20) seems to be the most important skill/ knowledge dimension for BIM exploitation. To exploit BIM, BIM-related job roles must be reinforced with information management skills starting from acquisition of information to the storing, processing and distribution of them. This may particularly involve managing the Common Data Environment and information exchange between project members. However, in terms of training requirements, information management ranks second to innovation management (SKBIMNFTNOW18) as it requires the most training. This indicates that the support and facilitation for experimental work needs more attention and hence employees must be trained for dealing with the changes associated with innovation for continuous improvement.

Table 93- Current Skill-knowledge dimensions for BIM

BUILDING INFORMATION MODELLING (BIM)- NOW								
IMPLEMENTATION			EXPLOITATION			NEED FOR TRAINING		
Variable	Mean	Rank	Variable	Mean	Rank	Variable	Mean	Rank
SKBIMIMPNOW7	3.55	1	SKBIMEXPNOW20	3.49	1	SKBIMNFTNOW18	3.31	1
SKBIMIMPNOW18	3.53	2	SKBIMEXPNOW5	3.45	2	SKBIMNFTNOW20	3.31	2
SKBIMIMPNOW5	3.51	3	SKBIMEXPNOW4	3.20	3	SKBIMNFTNOW5	2.75	3

SKBIMIMPNOW20	3.48	4	SKBIMEXPNOW18	3.15	4	SKBIMNFTNOW7	2.74	4
SKBIMIMPNOW1	3.39	5	SKBIMEXPNOW1	3.12	5	SKBIMNFTNOW1	2.73	5
SKBIMIMPNOW4	3.29	6	SKBIMEXPNOW14	3.05	6	SKBIMNFTNOW2	2.67	6
SKBIMIMPNOW16	3.15	7	SKBIMEXPNOW2	3.01	7	SKBIMNFTNOW15	2.66	7
SKBIMIMPNOW2	3.15	8	SKBIMEXPNOW6	2.95	8	SKBIMNFTNOW12	2.65	8
SKBIMIMPNOW8	3.06	9	SKBIMEXPNOW15	2.88	9	SKBIMNFTNOW6	2.65	9
SKBIMIMPNOW3	3.01	10	SKBIMEXPNOW13	2.85	10	SKBIMNFTNOW3	2.60	10
SKBIMIMPNOW17	2.95	11	SKBIMEXPNOW12	2.78	11	SKBIMNFTNOW16	2.59	11
SKBIMEXPNOW6	2.95	12	SKBIMEXPNOW3	2.75	12	SKBIMNFTNOW8	2.58	12
SKBIMIMPNOW11	2.94	13	SKBIMEXPNOW7	2.62	13	SKBIMNFTNOW4	2.56	13
SKBIMIMPNOW12	2.87	14	SKBIMEXPNOW10	2.56	14	SKBIMNFTNOW14	2.54	14
SKBIMIMPNOW9	2.85	15	SKBIMEXPNOW8	2.55	15	SKBIMNFTNOW13	2.54	15
SKBIMIMPNOW10	2.85	16	SKBIMEXPNOW19	2.55	16	SKBIMNFTNOW17	2.53	16
SKBIMIMPNOW19	2.85	17	SKBIMEXPNOW9	2.48	17	SKBIMNFTNOW9	2.52	17
SKBIMIMPNOW13	2.73	18	SKBIMEXPNOW11	2.46	18	SKBIMNFTNOW19	2.46	18
SKBIMIMPNOW15	2.59	19	SKBIMEXPNOW17	2.46	19	SKBIMNFTNOW11	2.45	19
SKBIMIMPNOW14	2.52	20	SKBIMEXPNOW16	2.46	20	SKBIMNFTNOW10	2.35	20

The present study strives to investigate if there is a relationship between the skills/knowledge dimensions which managers perceive as important for technology implementation and exploitation, and their degree of need for training. Nonparametric Canonical Correlation Analysis was employed in this regard. The canonical correlation investigates the correlation between a variable from one dataset against the entire other dataset. Further it also investigates the correlations of individual variables within one dataset. By testing the null hypothesis, it can be confirmed that there is no significant correlation between the degree of importance of skill/knowledge dimensions in BIM exploitation and their degree of need for training. The Spearman's coefficient of correlation (r.) for BIM exploitation and need for training was 0.637. This value was significant at the 0.05 level (Wills statistics = 0.001, Sig= 0.011). The null hypothesis related to BIM was therefore rejected. This means that what managers perceive to be important for BIM exploitation significantly relates to their training requirements. By testing the null hypothesis, it could also be confirmed that there is no significant correlation between the degree of importance of skill/knowledge dimensions in BIM implementation and their degree of need for training. Spearman's coefficient of correlation (r.) for BIM implementation and need for training was 0.246. This value was not significant at the 0.05 level (Wills statistics = 0.002, Sig= 0.201). The null hypothesis was therefore not rejected. This means that there is no significant relationship between the importance of skills-knowledge dimensions for BIM implementation and the need for their training.

Table 94 shows mean scores for the level of importance in BIM implementation, exploitation, and need for training in the next five years (future). The results show that in the next five years, the most important skill-knowledge dimension for BIM implementation would be, Innovation Management (SKBIMIMPFUT18). But, when it comes to BIM exploitation, the most important skill-knowledge dimensions in the future would be Information Management (SKBIMEXPFUT20). The reason for this could be the BIM mandates imposed by the government. The Construction Industry Council (CIC) BIM Protocol has emphasised the importance of Information Management to the Level 2 BIM process and this is particularly mandated to the Information Manager role. As a part of the BIM Level 2 process, roles, responsibilities, tasks, and services related to information management are clearly defined in the EIR. To be able to demonstrate Level-2 BIM, information management services must show a relatively higher importance. At the same time, the respondents have also identified that Information management (SKBIMEXPFUT20) is the skill-knowledge dimension that BIM needs the most training for in the future.

Further investigation into the results of this study showed that respondents with fewer years of experience in BIM have the most need for training in Information Management, compared to the respondents who have more experience in BIM. Similarly, managers who have been involved with BIM for a relatively short period need to learn and train about BIM more than their counterparts who have spent many years in the use of BIM.

Table 94- Future Skill-knowledge dimensions for BIM

BUILDING INFORMATION MODELLING (BIM)- FUTURE								
IMPLEMENTATION			EXPLOITATION			NEED FOR TRAINING		
Variable	Mean	Rank	Variable	Mean	Rank	Variable	Mean	Rank
SKBIMIMPFUT18	3.67	1	SKBIMEXPFUT20	3.68	1	SKBIMNFTFUT20	3.22	1

SKBIMIMPFUT20	3.60	2	SKBIMEXPFUT18	3.47	2	SKBIMNFTFUT18	3.14	2
SKBIMIMPFUT7	3.54	3	SKBIMEXPFUT5	3.45	3	SKBIMNFTFUT7	2.78	3
SKBIMIMPFUT5	3.36	4	SKBIMEXPFUT4	3.15	4	SKBIMNFTFUT6	2.74	4
SKBIMIMPFUT1	3.22	5	SKBIMEXPFUT14	3.14	5	SKBIMNFTFUT5	2.67	5
SKBIMIMPFUT16	3.13	6	SKBIMEXPFUT15	3.00	6	SKBIMNFTFUT1	2.56	6
SKBIMIMPFUT4	3.07	7	SKBIMEXPFUT13	2.98	7	SKBIMNFTFUT12	2.46	7
SKBIMIMPFUT6	3.00	8	SKBIMEXPFUT6	2.94	8	SKBIMNFTFUT3	2.39	8
SKBIMIMPFUT2	2.91	9	SKBIMEXPFUT1	2.91	9	SKBIMNFTFUT13	2.35	9
SKBIMIMPFUT8	2.89	10	SKBIMEXPFUT2	2.76	10	SKBIMNFTFUT4	2.34	10
SKBIMIMPFUT17	2.85	11	SKBIMEXPFUT12	2.71	11	SKBIMNFTFUT8	2.27	11
SKBIMIMPFUT3	2.78	12	SKBIMEXPFUT3	2.64	12	SKBIMNFTFUT15	2.25	12
SKBIMIMPFUT12	2.67	13	SKBIMEXPFUT8	2.41	13	SKBIMNFTFUT14	2.18	13
SKBIMIMPFUT10	2.62	14	SKBIMEXPFUT7	2.41	14	SKBIMNFTFUT2	2.18	14
SKBIMIMPFUT11	2.61	15	SKBIMEXPFUT17	2.31	15	SKBIMNFTFUT9	2.07	15
SKBIMIMPFUT19	2.55	16	SKBIMEXPFUT19	2.29	16	SKBIMNFTFUT16	2.01	16
SKBIMIMPFUT9	2.52	17	SKBIMEXPFUT9	2.26	17	SKBIMNFTFUT17	2.00	17
SKBIMIMPFUT13	2.49	18	SKBIMEXPFUT10	2.24	18	SKBIMNFTFUT19	1.96	18
SKBIMIMPFUT15	2.44	19	SKBIMEXPFUT11	2.13	19	SKBIMNFTFUT10	1.94	19
SKBIMIMPFUT14	2.33	20	SKBIMEXPFUT16	2.06	20	SKBIMNFTFUT11	1.76	20

6.2.2.3 Skills and knowledge dimensions required for BDA

As with BIM, the mean scores were observed to find out whether there is a pattern in the importance of skills and knowledge dimensions between BIM and BDA. According to the results presented in Table 95, the most important skill-knowledge dimension for BDA implementation was Strategic Planning (SKBDAIMPNOW7). The case might be that the strategy is not only about what data is readily or potentially available, it is also about what organisations want to achieve, and how data can help them to achieve it. The respondents believe that Strategic planning is equally important for both BIM and BDA. The most important skill-knowledge area for BDA exploitation was reported to be Teamwork (SKBDAEXPNOW5) while the least important was Tendering and Procurement (SKBDAEXPNOW11). This difference in BDA implementation and exploitation can be an indication of the different requirements of turning strategies and plans into actions and continued benefits. It is convincing that coordination with other team members is crucial for BDA exploitation more than for its implementation. This is especially because it helps to ensure nothing is missed and makes sure that there are no unnecessary duplications. Teams can often fail in the process of exploiting BDA because of the lack of communication or information sharing. In a similar fashion to BIM, the respondents believe that Information management (SKBDANFTNOW20) is the skill-knowledge dimension that has the greatest need for training now.

In the interest of investigating if there is a relationship between the skills/knowledge dimensions which managers perceive as important in BDA implementation, BDA exploitation, and their degree of need for training, nonparametric Canonical Correlation Analysis was employed. The null hypothesis that claims to have no significant correlation between the degree of importance of skill/knowledge dimensions in BDA Implementation, BDA exploitation, and their degree of need for training was tested. Spearman's coefficient of correlation (r.) for implementation and exploitation was 0.802. This value was significant at the 0.05 level (Wills statistics = 0.000, Sig= 0.042). The null hypothesis is therefore rejected. This means that what is perceived to be important for BDA implementation is important for BDA exploitation as well. The situation was very much similar to the BDA need for training as well.

Table 95- Current Skill-knowledge dimensions for BDA

BIG DATA ANALYTICS (BDA)- NOW								
IMPLEMENTATION			EXPLOITATION			NEED FOR TRAINING		
Variable	Mean	Rank	Variable	Mean	Rank	Variable	Mean	Rank
SKBDAIMPNOW7	3.58	1	SKBDAEXPNOW5	3.42	1	SKBDANFTNOW20	3.32	1
SKBDAIMPNOW1	3.51	2	SKBDAEXPNOW20	3.39	2	SKBDANFTNOW18	3.19	2
SKBDAIMPNOW5	3.51	3	SKBDAEXPNOW1	3.24	3	SKBDANFTNOW16	2.86	3
SKBDAIMPNOW18	3.49	4	SKBDAEXPNOW4	3.22	4	SKBDANFTNOW12	2.78	4
SKBDAIMPNOW20	3.39	5	SKBDAEXPNOW14	3.12	5	SKBDANFTNOW7	2.76	5
SKBDAIMPNOW4	3.37	6	SKBDAEXPNOW6	3.12	6	SKBDANFTNOW17	2.76	6
SKBDAIMPNOW6	3.24	7	SKBDAEXPNOW15	3.08	7	SKBDANFTNOW6	2.69	7
SKBDAIMPNOW2	3.22	8	SKBDAEXPNOW2	3.05	8	SKBDANFTNOW5	2.69	8
SKBDAIMPNOW16	3.22	9	SKBDAEXPNOW18	2.97	9	SKBDANFTNOW1	2.64	9
SKBDAIMPNOW3	3.07	10	SKBDAEXPNOW13	2.88	10	SKBDANFTNOW14	2.64	10
SKBDAIMPNOW12	3.00	11	SKBDAEXPNOW12	2.78	11	SKBDANFTNOW15	2.61	11
SKBDAIMPNOW11	3.00	12	SKBDAEXPNOW7	2.71	12	SKBDANFTNOW3	2.58	12
SKBDAIMPNOW17	2.97	13	SKBDAEXPNOW3	2.68	13	SKBDANFTNOW2	2.58	13
SKBDAIMPNOW8	2.95	14	SKBDAEXPNOW19	2.64	14	SKBDANFTNOW13	2.56	14

SKBDAIMPNOW9	2.93	15	SKBDAEXPNOW17	2.63	15	SKBDANFTNOW4	2.53	15
SKBDAIMPNOW19	2.90	16	SKBDAEXPNOW9	2.63	16	SKBDANFTNOW8	2.51	16
SKBDAIMPNOW10	2.90	17	SKBDAEXPNOW16	2.56	17	SKBDANFTNOW19	2.49	17
SKBDAIMPNOW13	2.76	18	SKBDAEXPNOW10	2.53	18	SKBDANFTNOW9	2.47	18
SKBDAIMPNOW14	2.71	19	SKBDAEXPNOW8	2.53	19	SKBDANFTNOW11	2.41	19
SKBDAIMPNOW15	2.59	20	SKBDAEXPNOW11	2.44	20	SKBDANFTNOW10	2.32	20

The same analysis was run for 'future' BDA implementation, BDA exploitation and the need for BDA training as presented in Table 96. The results show that in the next five years, skills, and knowledge around Strategic Planning (SKBDAIMPFUT7) will be quite important for BDA implementation while Information Management will be the most important skill-knowledge for BDA exploitation. Strategic management seems to have a similar importance for both now and future BDA implementation because the organisations are still making sense of aligning their Data Strategy with their business objectives. Depending on changing business objectives, organisations may institute strategic data management plans for now and the future. The respondents were of a similar opinion for BIM as well. Strategic planning will be an important dimension for both BIM and BDA implementation. Supply Chain Management has reported being the skill-knowledge dimension that needs the least training for BDA. The reasons could be that even though supply chains generate big data, the value in fact lies within the ability to turn that data into meaningful insights. Most companies already have adequate training and related systems for supply chain management. But they lack a structured process to explore, evaluate and capture big data opportunities in their supply chains.

Further investigation into the results of this study showed that respondents with fewer years of experience in BDA have the most need for training in Information Management, compared to the respondents who have more experience in BDA.

Table 96- Future Skill-knowledge dimensions for BDA

BIG DATA ANALYTICS (BDA)- FUTURE								
IMPLEMENTATION			**EXPLOITATION**			**NEED FOR TRAINING**		
Variable	**Mean**	**Rank**	**Variable**	**Mean**	**Rank**	**Variable**	**Mean**	**Rank**
SKBDAIMPFUT7	3.76	1	SKBDAEXPFUT20	3.78	1	SKBDANFTFUT20	3.20	1

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SKBDAIMPFUT18	3.71	2	SKBDAEXPFUT18	3.44	2	SKBDANFTFUT6	2.98	2
SKBDAIMPFUT20	3.63	3	SKBDAEXPFUT5	3.37	3	SKBDANFTFUT18	2.98	3
SKBDAIMPFUT5	3.42	4	SKBDAEXPFUT15	3.22	4	SKBDANFTFUT7	2.97	4
SKBDAIMPFUT1	3.29	5	SKBDAEXPFUT4	3.17	5	SKBDANFTFUT5	2.75	5
SKBDAIMPFUT16	3.16	6	SKBDAEXPFUT14	3.17	6	SKBDANFTFUT12	2.59	6
SKBDAIMPFUT6	3.15	7	SKBDAEXPFUT1	3.10	7	SKBDANFTFUT4	2.56	7
SKBDAIMPFUT4	3.07	8	SKBDAEXPFUT2	3.02	8	SKBDANFTFUT13	2.54	8
SKBDAIMPFUT8	3.05	9	SKBDAEXPFUT6	2.98	9	SKBDANFTFUT1	2.53	9
SKBDAIMPFUT17	2.93	10	SKBDAEXPFUT13	2.88	10	SKBDANFTFUT2	2.44	10
SKBDAIMPFUT2	2.93	11	SKBDAEXPFUT12	2.86	11	SKBDANFTFUT8	2.39	11
SKBDAIMPFUT3	2.88	12	SKBDAEXPFUT8	2.58	12	SKBDANFTFUT3	2.37	12
SKBDAIMPFUT12	2.68	13	SKBDAEXPFUT7	2.54	13	SKBDANFTFUT15	2.29	13
SKBDAIMPFUT11	2.64	14	SKBDAEXPFUT3	2.54	14	SKBDANFTFUT14	2.22	14
SKBDAIMPFUT10	2.61	15	SKBDAEXPFUT9	2.36	15	SKBDANFTFUT16	2.15	15
SKBDAIMPFUT9	2.59	16	SKBDAEXPFUT16	2.34	16	SKBDANFTFUT9	2.09	16
SKBDAIMPFUT13	2.58	17	SKBDAEXPFUT19	2.32	17	SKBDANFTFUT17	1.98	17
SKBDAIMPFUT19	2.49	18	SKBDAEXPFUT17	2.25	18	SKBDANFTFUT10	1.95	18
SKBDAIMPFUT15	2.36	19	SKBDAEXPFUT10	2.25	19	SKBDANFTFUT11	1.73	19
SKBDAIMPFUT14	2.32	20	SKBDAEXPFUT11	2.08	20	SKBDANFTFUT19	1.71	20

6.2.2.4 Skills and knowledge dimensions required for IoT

Table 97 illustrates the extent to which respondents think the IoT skills-knowledge dimensions are important for implementation, exploitation, and the extent to which they need training in those dimensions. Interestingly, the two most important skills-knowledges for IoT implementation were Leadership (SKIOTIMPNOW1) and Teamwork (SKIOTIMPNOW5). The latter is also the most important skill-knowledge for IoT exploitation. This shows a quite different behaviour from BIM and BDA implementation-exploitation. At an aggregated level, respondents believe that they need more training in Information management (SKIOTNFTNOW20) and innovation management (SKIOTNFTNOW18)-this is quite like BIM and BDA training.

To check the null hypothesis that there is no significant correlation between the degree of importance of skill/knowledge dimensions in IoT Implementation and IoT exploitation, Nonparametric Canonical Correlation Analysis was employed. Spearman's coefficient of correlation (r.) for implementation and exploitation was 0.651. This value is not significant at the 0.05 level (Wills statistics = 0.116, Sig= 1.000). The null hypothesis was therefore accepted. This means that there is no statistically significant correlation between skills-knowledge required for implementation and IoT exploitation. Same Nonparametric Canonical Correlation Analysis was employed to see if there is a difference between IoT exploitation and the need for training. The Spearman's coefficient of correlation (r.) for exploitation and need for training was 0.712. This value also showed a non-significance at the 0.05 level (Wills statistics = 0.063, Sig= 0.997). The null hypothesis was therefore accepted. This means that there is no statistically significant correlation between skills-knowledge required for IoT exploitation and the need for IoT training.

Table 97- Current Skill-knowledge dimensions for IoT

INTERNET OF THINGS (IoT)- NOW								
IMPLEMENTATION			EXPLOITATION			NEED FOR TRAINING		
Variable	Mean	Rank	Variable	Mean	Rank	Variable	Mean	Rank
SKIOTIMPNOW1	3.58	1	SKIOTEXPNOW5	3.40	1	SKIOTNFTNOW20	3.33	1
SKIOTIMPNOW5	3.54	2	SKIOTEXPNOW20	3.33	2	SKIOTNFTNOW18	3.23	2
SKIOTIMPNOW7	3.52	3	SKIOTEXPNOW1	3.23	3	SKIOTNFTNOW4	2.85	3
SKIOTIMPNOW6	3.44	4	SKIOTEXPNOW18	3.15	4	SKIOTNFTNOW5	2.85	4
SKIOTIMPNOW18	3.42	5	SKIOTEXPNOW4	3.13	5	SKIOTNFTNOW7	2.83	5
SKIOTIMPNOW20	3.31	6	SKIOTEXPNOW14	3.10	6	SKIOTNFTNOW6	2.81	6
SKIOTIMPNOW2	3.25	7	SKIOTEXPNOW15	3.06	7	SKIOTNFTNOW3	2.77	7

SKIOTIMPNOW16	3.23	8	SKIOTEXPNOW2	3.02	8	SKIOTNFTNOW1	2.75	8
SKIOTIMPNOW4	3.17	9	SKIOTEXPNOW13	2.96	9	SKIOTNFTNOW15	2.71	9
SKIOTIMPNOW11	3.13	10	SKIOTEXPNOW6	2.92	10	SKIOTNFTNOW14	2.71	10
SKIOTIMPNOW3	3.12	11	SKIOTEXPNOW3	2.90	11	SKIOTNFTNOW13	2.71	11
SKIOTIMPNOW17	3.00	12	SKIOTEXPNOW12	2.73	12	SKIOTNFTNOW17	2.65	12
SKIOTIMPNOW12	2.96	13	SKIOTEXPNOW19	2.65	13	SKIOTNFTNOW2	2.65	13
SKIOTIMPNOW19	2.92	14	SKIOTEXPNOW10	2.63	14	SKIOTNFTNOW16	2.63	14
SKIOTIMPNOW10	2.90	15	SKIOTEXPNOW17	2.60	15	SKIOTNFTNOW12	2.62	15
SKIOTIMPNOW9	2.83	16	SKIOTEXPNOW16	2.56	16	SKIOTNFTNOW19	2.56	16
SKIOTIMPNOW8	2.81	17	SKIOTEXPNOW7	2.56	17	SKIOTNFTNOW9	2.54	17
SKIOTIMPNOW13	2.77	18	SKIOTEXPNOW9	2.54	18	SKIOTNFTNOW8	2.54	18
SKIOTIMPNOW14	2.73	19	SKIOTEXPNOW8	2.54	19	SKIOTNFTNOW11	2.50	19
SKIOTIMPNOW15	2.62	20	SKIOTEXPNOW11	2.44	20	SKIOTNFTNOW10	2.44	20

The investigations were continued for ‘future’ IoT implementation, IoT exploitation, and need for IoT training as presented in Table 98. Interestingly, Innovation Management (SKIOTIMPFUT18) has ranked the highest for a skill-knowledge dimension required for IoT implementation in the next five years. Just as for BDA exploitation, the most important skill for IoT exploitation was Information Management. This indicates similar patterns between BDA and IoT exploitation in the next five years. Although strategic planning is considered as an important skill for future IoT implementation (holding the second rank), the importance of it for future IoT exploitation was comparatively low (rank 11). Further, the need for training in strategic management was also quite high but low in order compared with information management and innovation management. Providing more insight into data reveals that respondents with fewer years of experience in IoT have the most need for training in Information Management, compared to the respondents who have more experience in IoT. This also showed a similar trend with BIM and BDA.

Table 98- Future Skill-knowledge dimensions for IoT

INTERNET OF THINGS (IoT)- FUTURE								
IMPLEMENTATION			EXPLOITATION			NEED FOR TRAINING		
Variable	Mean	Rank	Variable	Mean	Rank	Variable	Mean	Rank
SKIOTIMPFUT18	3.73	1	SKIOTEXPFUT20	3.71	1	SKIOTNFTFUT 20	3.15	1
SKIOTIMPFUT7	3.62	2	SKIOTEXPFUT18	3.52	2	SKIOTNFTFUT 18	3.02	2
SKIOTIMPFUT20	3.58	3	SKIOTEXPFUT15	3.38	3	SKIOTNFTFUT 7	2.83	3
SKIOTIMPFUT1	3.42	4	SKIOTEXPFUT5	3.35	4	SKIOTNFTFUT 6	2.83	4
SKIOTIMPFUT16	3.33	5	SKIOTEXPFUT14	3.19	5	SKIOTNFTFUT 5	2.79	5
SKIOTIMPFUT5	3.29	6	SKIOTEXPFUT13	3.02	6	SKIOTNFTFUT 12	2.63	6
SKIOTIMPFUT4	3.15	7	SKIOTEXPFUT4	2.96	7	SKIOTNFTFUT 1	2.60	7
SKIOTIMPFUT6	3.08	8	SKIOTEXPFUT6	2.92	8	SKIOTNFTFUT 4	2.37	8
SKIOTIMPFUT3	3.06	9	SKIOTEXPFUT1	2.87	9	SKIOTNFTFUT 15	2.31	9
SKIOTIMPFUT2	2.88	10	SKIOTEXPFUT12	2.73	10	SKIOTNFTFUT 13	2.31	10
SKIOTIMPFUT17	2.75	11	SKIOTEXPFUT7	2.65	11	SKIOTNFTFUT 2	2.27	11
SKIOTIMPFUT11	2.75	12	SKIOTEXPFUT2	2.62	12	SKIOTNFTFUT 8	2.23	12
SKIOTIMPFUT8	2.69	13	SKIOTEXPFUT3	2.54	13	SKIOTNFTFUT 3	2.21	13
SKIOTIMPFUT10	2.67	14	SKIOTEXPFUT10	2.37	14	SKIOTNFTFUT 16	2.19	14
SKIOTIMPFUT12	2.65	15	SKIOTEXPFUT9	2.31	15	SKIOTNFTFUT 14	2.12	15
SKIOTIMPFUT19	2.62	16	SKIOTEXPFUT17	2.25	16	SKIOTNFTFUT 10	2.08	16
SKIOTIMPFUT13	2.56	17	SKIOTEXPFUT8	2.23	17	SKIOTNFTFUT 17	2.02	17
SKIOTIMPFUT9	2.44	18	SKIOTEXPFUT19	2.21	18	SKIOTNFTFUT 9	1.98	18
SKIOTIMPFUT15	2.35	19	SKIOTEXPFUT16	2.15	19	SKIOTNFTFUT 19	1.83	19

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SKIOTIMPFUT14	2.25	20	SKIOTEXPFUT11	2.08	20	SKIOTNFTFUT 11	1.63	20

6.2.2.5 Skills and Knowledge dimensions required to be possessed by different levels of managers to implement and exploit BIM

This section of the chapter analyses the importance of skills/knowledge and training needs for each level of management; strategic, tactical, and operational at a disaggregated level. Section 4.2.2 in Chapter Four presented the distribution of survey respondents based on the level of their job role. In construction, the highest proportion of 68% was strategic managers.

A scoring system influenced by Jaafar et al. (2018) was employed for the selection criteria of SKI. The values were adjusted according to the number of points in the scale and presented in Table 99. According to the results, most of the skill-knowledge dimensions can be categorised as ‘important’ or ‘very important’ because most of the mean scores report to exceed 2.51.

Table 99- Overall suitability scale for SKI

Mean interval scale	Mean value scale
1.00–1.75	Not at all important
1.76–2.50	Fairly Important
2.51–3.24	Important
3.25–4.00	Very Important

The skill/knowledge dimensions which managers believe to be most important and which need most training are discussed. The categories 'Very important' and ‘important’ (mean score 2.51-4.00) are combined to form the 'Most important' skill-knowledge areas.

An inspection into Table 100 reveals that managers at the senior level believe Innovation Management (SKBIMIMPNOW18) is the most important skill-knowledge dimension for current BIM implementation. Managers from the rest of the levels (middle-level and lower level) see the importance of Innovation management in fourth-order importance. Lower-level managers acknowledge the importance of Information Management (SKBIMIMPNOW20) as a higher-order importance. The author sought to establish if there is any significant need for training for Innovation management and discovered that senior managers still believe innovation management is the area that needs most training (See Table 102). Innovation management by simplest definition refers to the handling of all the activities needed to “introduce something new” (Barrett and Sexton, 2006), which in practice means more for strategic managers as they belong to the strata that bring up new ideas, develop, prioritise, implement them, and put them into practice. For example, to introduce IoT into a construction practice the prioritisation must be transpired from the strategic managers by launching new IoT products, or by introducing new internal processes related to IoT.

Table 100 - Skill-knowledge Dimensions required for current BIM implementation, ordered according to the degree of importance as responded by three levels of managers

BIM Implementation-NOW					
Senior Management		**Middle-level Management**		**Lower level Management**	
Skill/knowledge	Mean	Skill/knowledge	Mean	Skill/knowledge	Mean
SKBIMIMPNOW18	3.66	SKBIMIMPNOW5	3.58	SKBIMIMPNOW20	3.38
SKBIMIMPNOW7	3.66	SKBIMIMPNOW7	3.53	SKBIMIMPNOW4	3.38
SKBIMIMPNOW20	3.64	SKBIMIMPNOW1	3.42	SKBIMIMPNOW1	3.25
SKBIMIMPNOW5	3.53	SKBIMIMPNOW18	3.26	SKBIMIMPNOW18	3.25
SKBIMIMPNOW6	3.43	SKBIMIMPNOW4	3.26	SKBIMIMPNOW16	3.13
SKBIMIMPNOW1	3.40	SKBIMIMPNOW6	3.26	SKBIMIMPNOW5	3.13
SKBIMIMPNOW4	3.29	SKBIMIMPNOW3	3.11	SKBIMIMPNOW2	3.13
SKBIMIMPNOW16	3.24	SKBIMIMPNOW20	3.05	SKBIMIMPNOW17	3.00
SKBIMIMPNOW2	3.22	SKBIMIMPNOW2	2.95	SKBIMIMPNOW6	3.00
SKBIMIMPNOW8	3.16	SKBIMIMPNOW16	2.89	SKBIMIMPNOW3	3.00
SKBIMIMPNOW11	3.03	SKBIMIMPNOW13	2.89	SKBIMIMPNOW12	2.88
SKBIMIMPNOW3	2.98	SKBIMIMPNOW9	2.89	SKBIMIMPNOW10	2.88
SKBIMIMPNOW17	2.98	SKBIMIMPNOW8	2.89	SKBIMIMPNOW7	2.88
SKBIMIMPNOW19	2.90	SKBIMIMPNOW17	2.84	SKBIMIMPNOW19	2.75
SKBIMIMPNOW12	2.90	SKBIMIMPNOW10	2.84	SKBIMIMPNOW13	2.75
SKBIMIMPNOW9	2.84	SKBIMIMPNOW12	2.79	SKBIMIMPNOW9	2.75
SKBIMIMPNOW10	2.84	SKBIMIMPNOW11	2.79	SKBIMIMPNOW8	2.75
SKBIMIMPNOW13	2.67	SKBIMIMPNOW19	2.74	SKBIMIMPNOW11	2.63
SKBIMIMPNOW15	2.59	SKBIMIMPNOW15	2.63	SKBIMIMPNOW15	2.50
SKBIMIMPNOW14	2.55	SKBIMIMPNOW14	2.53	SKBIMIMPNOW14	2.25

A similar exploration was done for BIM exploitation as presented in Table 101 and it revealed that managers at senior management level believe Information Management (SKBIMEXPNOW20) to be the most important skill-knowledge dimension for BIM Exploitation. Unlike for BIM implementation (as shown in Table 100) the reason for Innovation Management being prominent for implementation while Information Management is prominent for exploitation might be due to the requirement difference for implementation and exploitation. Because exploitation by definition (see section 2.5.1) leans more towards refining, extending, and leveraging existing competencies rather than creating new ones that indeed require incorporation of acquired and transformed information into its operations. The latter is an important step in information management.

'Teamwork' (SKBIMEXPNOW5) is reported to be the most important skill-knowledge dimension for Middle-level managers while 'Motivation' (SKBIMEXPNOW4) was reported to be the most important skill-knowledge dimension for Lower-level management.

Table 101- Skill-knowledge Dimensions required for current BIM exploitation, ordered according to the degree of importance as responded by three levels of managers

BIM Exploitation-NOW								
Senior Management			Middle-level Management			Lower level Management		
Skill/knowledge	N	Mean	Skill/knowledge	N	Mean	Skill/knowledge	N	Mean
SKBIMEXPNOW20	58	3.60	SKBIMEXPNOW5	19	3.47	SKBIMEXPNOW4	8	3.50
SKBIMEXPNOW5	58	3.50	SKBIMEXPNOW4	19	3.47	SKBIMEXPNOW20	8	3.38
SKBIMEXPNOW18	58	3.34	SKBIMEXPNOW1	19	3.26	SKBIMEXPNOW1	8	3.12
SKBIMEXPNOW14	58	3.09	SKBIMEXPNOW20	19	3.21	SKBIMEXPNOW14	8	3.00
SKBIMEXPNOW1	58	3.07	SKBIMEXPNOW14	19	2.95	SKBIMEXPNOW5	8	3.00
SKBIMEXPNOW4	58	3.07	SKBIMEXPNOW2	19	2.95	SKBIMEXPNOW3	8	3.00
SKBIMEXPNOW6	58	3.05	SKBIMEXPNOW6	19	2.84	SKBIMEXPNOW2	8	3.00
SKBIMEXPNOW2	58	3.03	SKBIMEXPNOW15	19	2.84	SKBIMEXPNOW18	8	2.87
SKBIMEXPNOW13	58	2.98	SKBIMEXPNOW12	19	2.79	SKBIMEXPNOW19	8	2.75
SKBIMEXPNOW15	58	2.97	SKBIMEXPNOW7	19	2.74	SKBIMEXPNOW11	8	2.63
SKBIMEXPNOW12	58	2.83	SKBIMEXPNOW3	19	2.74	SKBIMEXPNOW10	8	2.62
SKBIMEXPNOW3	58	2.72	SKBIMEXPNOW18	19	2.68	SKBIMEXPNOW13	8	2.50
SKBIMEXPNOW8	58	2.62	SKBIMEXPNOW10	19	2.68	SKBIMEXPNOW7	8	2.50
SKBIMEXPNOW7	58	2.60	SKBIMEXPNOW16	19	2.63	SKBIMEXPNOW6	8	2.50
SKBIMEXPNOW19	58	2.55	SKBIMEXPNOW17	19	2.63	SKBIMEXPNOW12	8	2.38
SKBIMEXPNOW10	58	2.52	SKBIMEXPNOW13	19	2.58	SKBIMEXPNOW17	8	2.38
SKBIMEXPNOW9	58	2.50	SKBIMEXPNOW9	19	2.53	SKBIMEXPNOW16	8	2.38
SKBIMEXPNOW16	58	2.41	SKBIMEXPNOW11	19	2.53	SKBIMEXPNOW15	8	2.38
SKBIMEXPNOW11	58	2.41	SKBIMEXPNOW19	19	2.47	SKBIMEXPNOW9	8	2.25
SKBIMEXPNOW17	58	2.41	SKBIMEXPNOW8	19	2.47	SKBIMEXPNOW8	8	2.25

In the investigation of the need for training, senior managers and lower-level managers were of the same opinion that the skill-knowledge dimension that needs most training was 'Innovation Management (Table 102). Middle managers were of a different opinion, ranking information management (SKBIMNFTNOW20) as the skill that needs most training. The reason for this difference between different job roles can be attributed to the existent low power distance between senior managers and operational managers and hence allowing operational managers to contribute to the innovation management process more than middle-level managers.

Table 102- Skill-knowledge Dimensions require training for current BIM use, ordered according to the degree of training requirement as responded by three levels of managers

BIM Need for Training-NOW

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Senior Management			Middle-level Management			Lower level Management		
Skill/knowledge	N	Mean	Skill/knowledge	N	Mean	Skill/knowledge	N	Mean
SKBIMNFTNOW18	58	3.40	SKBIMNFTNOW20	19	3.05	SKBIMNFTNOW18	8	3.38
SKBIMNFTNOW20	58	3.40	SKBIMNFTNOW18	19	3.00	SKBIMNFTNOW20	8	3.25
SKBIMNFTNOW7	58	2.86	SKBIMNFTNOW9	19	2.89	SKBIMNFTNOW19	8	2.75
SKBIMNFTNOW5	58	2.81	SKBIMNFTNOW2	19	2.79	SKBIMNFTNOW17	8	2.63
SKBIMNFTNOW1	58	2.76	SKBIMNFTNOW1	19	2.74	SKBIMNFTNOW15	8	2.63
SKBIMNFTNOW6	58	2.76	SKBIMNFTNOW12	19	2.68	SKBIMNFTNOW13	8	2.63
SKBIMNFTNOW12	58	2.72	SKBIMNFTNOW5	19	2.68	SKBIMNFTNOW14	8	2.50
SKBIMNFTNOW2	58	2.71	SKBIMNFTNOW15	19	2.68	SKBIMNFTNOW10	8	2.50
SKBIMNFTNOW15	58	2.66	SKBIMNFTNOW17	19	2.63	SKBIMNFTNOW6	8	2.50
SKBIMNFTNOW16	58	2.62	SKBIMNFTNOW16	19	2.63	SKBIMNFTNOW5	8	2.50
SKBIMNFTNOW3	58	2.62	SKBIMNFTNOW11	19	2.63	SKBIMNFTNOW3	8	2.50
SKBIMNFTNOW8	58	2.60	SKBIMNFTNOW3	19	2.58	SKBIMNFTNOW1	8	2.50
SKBIMNFTNOW4	58	2.60	SKBIMNFTNOW10	19	2.58	SKBIMNFTNOW9	8	2.38
SKBIMNFTNOW14	58	2.55	SKBIMNFTNOW8	19	2.58	SKBIMNFTNOW8	8	2.38
SKBIMNFTNOW13	58	2.52	SKBIMNFTNOW13	19	2.58	SKBIMNFTNOW7	8	2.38
SKBIMNFTNOW17	58	2.48	SKBIMNFTNOW14	19	2.53	SKBIMNFTNOW4	8	2.38
SKBIMNFTNOW11	58	2.45	SKBIMNFTNOW7	19	2.53	SKBIMNFTNOW16	8	2.25
SKBIMNFTNOW19	58	2.43	SKBIMNFTNOW4	19	2.53	SKBIMNFTNOW2	8	2.13
SKBIMNFTNOW9	58	2.41	SKBIMNFTNOW19	19	2.42	SKBIMNFTNOW11	8	2.00
SKBIMNFTNOW10	58	2.26	SKBIMNFTNOW6	19	2.37	SKBIMNFTNOW12	8	2.00

Similar to previously explained data, Table 103, Table 104, and Table 105 present data on skills and knowledge dimensions which senior, middle, and lower-level managers most believe to be important and most need training for in their future job. Considering the future perspective, the first rank skill/knowledge dimension for three job levels does not show much of a difference from the current perspective as innovation management and information management were still considered to be the most important skills. However, middle-level managers trust that having teamwork skills is very important for future BIM implementation. It is compelling that middle- level managers show an indistinguishable point of view towards both current and future dimensions.

Table 103- Skill-knowledge Dimensions required for future BIM implementation, ordered according to the degree of importance as responded by three levels of managers

BIM Implementation-FUTURE								
Senior Management			Middle-level Management			Lower level Management		
Skill/knowledge	N	Mean	Skill/knowledge	N	Mean	Skill/knowledge	N	Mean
SKBIMIMPFUT20	58	3.74	SKBIMIMPFUT5	19	3.58	SKBIMIMPFUT18	8	3.63
SKBIMIMPFUT18	58	3.72	SKBIMIMPFUT18	19	3.53	SKBIMIMPFUT16	8	3.25
SKBIMIMPFUT7	58	3.64	SKBIMIMPFUT20	19	3.47	SKBIMIMPFUT7	8	3.25

SKBIMIMPFUT5	58	3.41	SKBIMIMPFUT7	19	3.37	SKBIMIMPFUT20	8	2.88
SKBIMIMPFUT1	58	3.31	SKBIMIMPFUT4	19	3.21	SKBIMIMPFUT19	8	2.88
SKBIMIMPFUT16	58	3.26	SKBIMIMPFUT1	19	3.11	SKBIMIMPFUT1	8	2.88
SKBIMIMPFUT6	58	3.16	SKBIMIMPFUT3	19	3.05	SKBIMIMPFUT17	8	2.75
SKBIMIMPFUT4	58	3.07	SKBIMIMPFUT17	19	2.95	SKBIMIMPFUT4	8	2.75
SKBIMIMPFUT2	58	3.02	SKBIMIMPFUT8	19	2.95	SKBIMIMPFUT10	8	2.75
SKBIMIMPFUT8	58	2.95	SKBIMIMPFUT6	19	2.84	SKBIMIMPFUT11	8	2.62
SKBIMIMPFUT17	58	2.83	SKBIMIMPFUT2	19	2.84	SKBIMIMPFUT5	8	2.50
SKBIMIMPFUT12	58	2.74	SKBIMIMPFUT9	19	2.79	SKBIMIMPFUT14	8	2.50
SKBIMIMPFUT3	58	2.72	SKBIMIMPFUT16	19	2.68	SKBIMIMPFUT13	8	2.50
SKBIMIMPFUT11	58	2.67	SKBIMIMPFUT19	19	2.68	SKBIMIMPFUT3	8	2.50
SKBIMIMPFUT10	58	2.60	SKBIMIMPFUT10	19	2.63	SKBIMIMPFUT12	8	2.38
SKBIMIMPFUT13	58	2.50	SKBIMIMPFUT15	19	2.58	SKBIMIMPFUT8	8	2.38
SKBIMIMPFUT19	58	2.47	SKBIMIMPFUT12	19	2.58	SKBIMIMPFUT2	8	2.25
SKBIMIMPFUT9	58	2.47	SKBIMIMPFUT13	19	2.47	SKBIMIMPFUT15	8	2.25
SKBIMIMPFUT15	58	2.41	SKBIMIMPFUT14	19	2.42	SKBIMIMPFUT9	8	2.25
SKBIMIMPFUT14	58	2.28	SKBIMIMPFUT11	19	2.42	SKBIMIMPFUT6	8	2.25

An inspection of Table 104 and Table 105 interestingly reveals that managers at all levels consider ‘information management’ as the most important skill/ knowledge dimension for future BIM exploitation and it also carries a greater need for training in the future. The main reason for this trend can be the serious consequences resulting from not understanding the information demands put on employees and the practical ethical challenges that may arise associated with information management in the future. Improving the skills around information management allows organisations of all sizes find new and more efficient ways to utilise this information to build business strategies.

Table 104- Skill-knowledge Dimensions required for future BIM exploitation, ordered according to the degree of importance as responded by three levels of managers

BIM Exploitation-FUTURE								
Senior Management			Middle-level Management			Lower level Management		
Skill/knowledge	N	Mean	Skill/knowledge	N	Mean	Skill/knowledge	N	Mean
SKBIMEXPFUT20	58	3.72	SKBIMEXPFUT20	19	3.63	SKBIMEXPFUT20	8	3.50
SKBIMEXPFUT18	58	3.57	SKBIMEXPFUT5	19	3.53	SKBIMEXPFUT5	8	3.25
SKBIMEXPFUT5	58	3.45	SKBIMEXPFUT18	19	3.42	SKBIMEXPFUT17	8	3.00
SKBIMEXPFUT14	58	3.24	SKBIMEXPFUT4	19	3.37	SKBIMEXPFUT13	8	3.00
SKBIMEXPFUT6	57	3.12	SKBIMEXPFUT1	19	3.11	SKBIMEXPFUT18	8	2.88
SKBIMEXPFUT4	58	3.12	SKBIMEXPFUT14	19	3.00	SKBIMEXPFUT4	8	2.88
SKBIMEXPFUT15	58	3.09	SKBIMEXPFUT13	19	2.89	SKBIMEXPFUT3	8	2.88
SKBIMEXPFUT13	58	3.00	SKBIMEXPFUT15	19	2.84	SKBIMEXPFUT14	8	2.75

SKBIMEXPFUT1	58	2.91	SKBIMEXPFUT3	19	2.74	SKBIMEXPFUT2	8	2.75
SKBIMEXPFUT12	58	2.86	SKBIMEXPFUT2	19	2.74	SKBIMEXPFUT15	8	2.75
SKBIMEXPFUT2	58	2.78	SKBIMEXPFUT7	19	2.68	SKBIMEXPFUT12	8	2.63
SKBIMEXPFUT3	58	2.57	SKBIMEXPFUT6	19	2.68	SKBIMEXPFUT10	8	2.38
SKBIMEXPFUT8	58	2.50	SKBIMEXPFUT19	19	2.53	SKBIMEXPFUT8	8	2.38
SKBIMEXPFUT7	58	2.34	SKBIMEXPFUT9	19	2.42	SKBIMEXPFUT1	8	2.38
SKBIMEXPFUT19	58	2.26	SKBIMEXPFUT10	19	2.37	SKBIMEXPFUT7	8	2.25
SKBIMEXPFUT17	58	2.26	SKBIMEXPFUT12	19	2.26	SKBIMEXPFUT9	8	2.25
SKBIMEXPFUT9	58	2.21	SKBIMEXPFUT16	19	2.21	SKBIMEXPFUT6	8	2.25
SKBIMEXPFUT10	58	2.17	SKBIMEXPFUT17	19	2.16	SKBIMEXPFUT19	8	2.00
SKBIMEXPFUT11	58	2.16	SKBIMEXPFUT8	19	2.16	SKBIMEXPFUT11	8	2.00
SKBIMEXPFUT16	58	2.03	SKBIMEXPFUT11	19	2.11	SKBIMEXPFUT16	8	1.87

In addition to the point featured in the previous paragraph, Table 105 further spotlights that Tendering and Procurement is perceived by both strategic and operational managers to be the least important skill/knowledge dimension. One reason for this situation can be the high availability of training and education for tendering and procurement. Moreover, how tendering and procurement align with the organisation strategy is a basic learning requirement in many of the employee start-up courses in companies. Strategic planning, teamwork, and decision-making have also marked as high order needs and the most important skill-knowledge dimensions. These were marginally higher for senior and middle managers than lower managers. While the skill-knowledge dimension of 'Negotiation' was ranked 10th by senior managers, the same skill-knowledge dimension was ranked 7th and 4th respectively by middle-level and lower-level managers. This result is not surprising as managers from all levels engage with negotiating to a certain extent. Further, it is also compelling that when citing negotiating as an important part of the tendering/ bidding process people buy into the view that negotiating is a skill/ knowledge which is more important than tendering.

Table 105- Skill-knowledge Dimensions require training for future BIM use, ordered according to the degree of training requirement as responded by three levels of managers

BIM need for Training- FUTURE								
Senior Management			**Middle-level Management**			**Lower level Management**		
Skill/knowledge	N	Mean	Skill/knowledge	N	Mean	Skill/knowledge	N	Mean
SKBIMNFTFUT20	58	3.22	SKBIMNFTFUT20	19	3.32	SKBIMNFTFUT20	8	3.00
SKBIMNFTFUT18	58	3.14	SKBIMNFTFUT18	19	3.26	SKBIMNFTFUT18	8	2.88
SKBIMNFTFUT7	58	2.88	SKBIMNFTFUT6	19	2.89	SKBIMNFTFUT1	8	2.87
SKBIMNFTFUT6	58	2.71	SKBIMNFTFUT7	19	2.84	SKBIMNFTFUT3	8	2.75
SKBIMNFTFUT5	58	2.69	SKBIMNFTFUT5	19	2.68	SKBIMNFTFUT8	8	2.63

SKBIMNFTFUT1	58	2.59	SKBIMNFTFUT13	19	2.58	SKBIMNFTFUT6	8	2.63
SKBIMNFTFUT12	58	2.48	SKBIMNFTFUT3	19	2.53	SKBIMNFTFUT14	8	2.50
SKBIMNFTFUT8	58	2.34	SKBIMNFTFUT4	19	2.47	SKBIMNFTFUT13	8	2.50
SKBIMNFTFUT4	58	2.29	SKBIMNFTFUT12	19	2.47	SKBIMNFTFUT5	8	2.50
SKBIMNFTFUT3	58	2.29	SKBIMNFTFUT1	19	2.37	SKBIMNFTFUT2	8	2.50
SKBIMNFTFUT15	58	2.26	SKBIMNFTFUT15	19	2.37	SKBIMNFTFUT17	8	2.38
SKBIMNFTFUT13	58	2.26	SKBIMNFTFUT2	19	2.32	SKBIMNFTFUT4	8	2.38
SKBIMNFTFUT14	58	2.14	SKBIMNFTFUT10	19	2.21	SKBIMNFTFUT12	8	2.25
SKBIMNFTFUT2	58	2.09	SKBIMNFTFUT9	19	2.21	SKBIMNFTFUT9	8	2.25
SKBIMNFTFUT16	58	2.00	SKBIMNFTFUT16	19	2.16	SKBIMNFTFUT10	8	2.13
SKBIMNFTFUT9	58	2.00	SKBIMNFTFUT14	19	2.16	SKBIMNFTFUT7	8	1.88
SKBIMNFTFUT19	58	1.93	SKBIMNFTFUT19	19	2.16	SKBIMNFTFUT15	8	1.87
SKBIMNFTFUT17	58	1.91	SKBIMNFTFUT17	19	2.11	SKBIMNFTFUT19	8	1.75
SKBIMNFTFUT10	58	1.83	SKBIMNFTFUT11	19	2.00	SKBIMNFTFUT16	8	1.75
SKBIMNFTFUT11	58	1.69	SKBIMNFTFUT8	19	1.89	SKBIMNFTFUT11	8	1.75

Similar analyses were carried-out for BDA and IoT to see whether any patterns could be discovered for BDA and IoT concerning the most important and most training needed skills-knowledge dimensions between different levels of managers. Although the data tables are not presented within the main body of text, these data (for BDA and IoT) are incorporated in the interactive SKI.

The skills-knowledges that require most training in the future include information management, innovation management, strategic planning, leadership, risk management, and operational management. Generally, all three levels believe that tendering and procurement is the skill-knowledge that requires the least amount of training. This means that in the future, tendering and procurement will not be a prominent area that needs to be prioritised for training. However, the structure of the training programme would need to consider the job roles of managers due to their positions in the organisation. For example, leadership skill was ranked 6th by senior managers, while it was ranked 8^{th} and 17th by middle- level and lower-level managers respectively for BDA use in the next five years. Therefore, the training organised for strategic managers specifically needs more focus on leadership skills.

To summarise the discussions in this section of the chapter, there are skill-knowledge dimensions for which managers at all levels need most training now and in the future for the implementation and exploitation of all three strategic tools (BIM, BDA, and IoT). The four main areas of training are:

I. Information Management
II. Innovation Management
III. Decision making
IV. Strategic Planning

On the other hand, in light of the degree of importance, there are skill-knowledge dimensions which managers at all levels believe to be most important for now and in the future in terms of implementation and exploitation of all three strategic tools (BIM, BDA, and IoT). With the type of Likert scale data (values that are gradually increasing) collected in this study, the mean value was used to measure the central tendency. By assigning numbers to the categories, it was able to get the mean value of each skill/ knowledge dimension separately for each domain (B, B, I) and then to take the final mean values of Skill/ knowledge dimensions for all three domains. For example, 'Strategic Planning (SK7)' has scored mean values of 3.55, 3.58 and 3.52 for BIM, BDA and IoT implementation (NOW) respectively. These values are comparatively higher than the rest skill/ knowledge dimensions. The six areas of importance are:

I. Leadership
II. Teamwork
III. Motivation
IV. Strategic Planning
V. Information Management
VI. Innovation Management

As presented in the interactive SKI, a comparison of the relative importance of skills/knowledge for BDA implementation and exploitation skills shows that the skills/knowledge associated with leadership and teamwork are higher than the rest for current BDA exploitation for strategic managers; reflecting the need for better strategic leadership and the relatively higher levels of isolated working practices.

6.2.2.6 Development of interactive e-based Knowledge Skill inventory (e-SKI)

Based on the above quantitative data, an interactive e-based inventory was produced. According to Barker Caza and Creary (2016), a skills knowledge inventory is a comprehensive detailed list that showcases a specific skill set that is needed to apply for a specific job. In line with this definition, an interactive database that would help to sort customised skills-knowledge set to match each professional was developed. The subsequent paragraphs explain how the findings of the quantitative study were utilised towards the development of the interactive knowledge skill Inventory (SKI). All data analysed with regards to current and future skills/knowledge and training needs were categorised into four categories as follows:

- Very High
- High
- Low

- Very Low

The four categories indicate a measure for ‘level of importance’ as well as for ‘need for training’. Once all data were categorised as above, the next step was to develop a ‘what-if analysis’ in Ms. Excel. What-If Analysis is the process of changing the values in cells to see how those changes will affect the outcome of formulas on the worksheet. What-If Analysis tools in Excel were used in different sets of values retrieved from the skills/knowledge data (for BIM, BDA, and IoT). One or more formulae to explore all the various results were employed in this regard. It is important to mention that the interactive SKI consists of three separate forms for BIM, BDA, and IoT placed in three separate tabs.

For the data entry section criteria, three questions were asked as follows.

- Please select your job level
- Implementation/ Exploitation/ Need for Training
- Current/ Future

All three questions offer the opportunity to select from a drop-down list as shown in Figure 63, Figure 64, and Figure 65. For the job level, there are three options to select from the drop-down menu: Strategic, Tactical, and Operational (Figure 63,). This way, the most relevant information could be retrieved for any professional depending on their job level in an organisation.

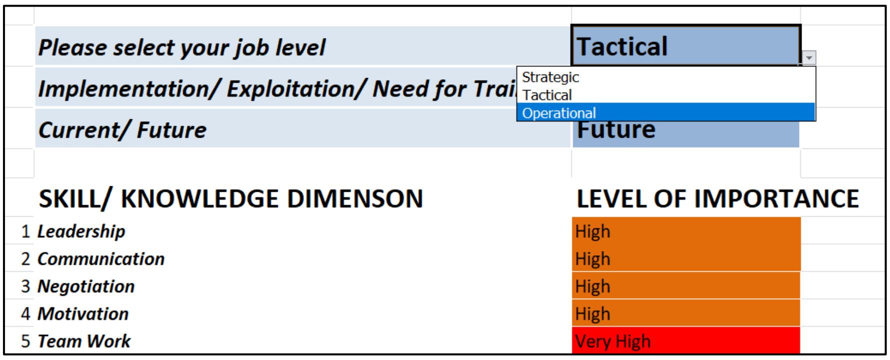

Figure 63- Selection for the job level

Next, the interactive SKI prompts to select whether the skill set is related to implementation, exploitation, or need for training. This can also be selected via a drop-down menu as shown in Figure 64.

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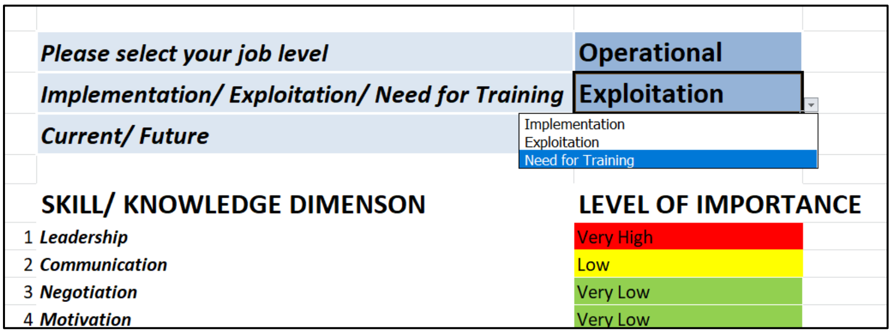

Figure 64- Selection for implementation/ exploitation/ need for training

Finally, the time frame must be selected to view the results. Another drop-down menu was created to select whether the user is looking for current skills- knowledge or future skills-knowledges. Figure 65 shows how this selection can be made from the drop-down menu.

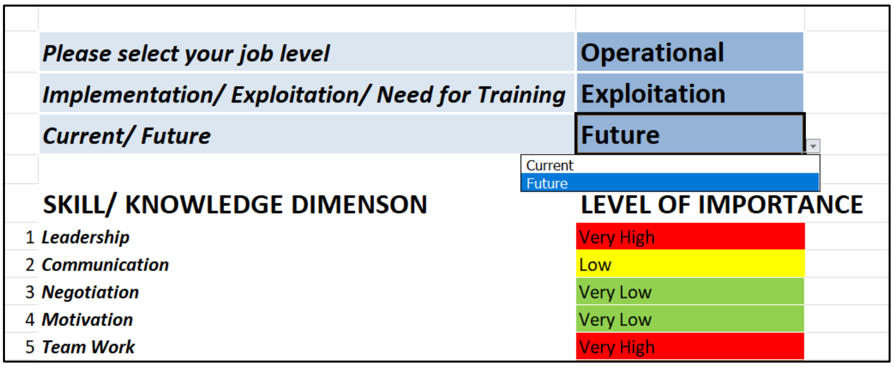

Figure 65- Selection for time frame-Current/ Future

As soon as these three selections are made, the inventory automatically gives the user the level of importance of each skill/knowledge dimension specific to the selections made. For example, as shown in Figure 66, the user searches for the <u>current</u> <u>need for training</u> of the <u>skills/knowledge</u> related to <u>operational level</u>. The interactive SKI results with the level of training required for 20 skill/ knowledge. As seen in Figure 66, it is informing that skill 18 (Innovation Management) and 20 (Information Management) are going to be the areas that require training in the highest extents in the future (in the next five years).

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INTERACTIVE SKILLS/ KNOWLEDGE INVENTORY FOR BUILDING INFORMATION MODELLING (BIM)

Please select your job level	Operational
Implementation/ Exploitation/ Need for Tr	Need for Training
Current/ Future	Current

	SKILL/ KNOWLEDGE DIMENSON	LEVEL OF IMPORTANCE
1	*Leadership*	Low
2	*Communication*	Low
3	*Negotiation*	Low
4	*Motivation*	Low
5	*Team Work*	Low
6	*Decision Making*	Low
7	*Strategic Planning*	Low
8	*Partnership and Alliancing*	Low
9	*Finance Accounting and Budgeting*	Low
10	*Marketing*	Low
11	*Tendering and Procurement*	Low
12	*Risk Management*	Low
13	*Quality Management*	High
14	*Performance Management*	Low
15	*Operational Management*	High
16	*Technological infrastructure Management*	Low
17	*Legislation Management*	High
18	*Innovation Management*	Very High
19	*Supply Chain Management*	High
20	*Information Management*	Very High

Figure 66- Interactive BIM Skills/ Knowledge Inventory

In exactly the same manner, the interactive SKIs were also developed for BDA and IoT. Figure 67 presents the Interactive SKI for Big Data Analytics while Figure 68 presents the interactive SKI for the Internet of Things.

INTERACTIVE SKILLS/ KNOWLEDGE INVENTORY FOR BIG DATA ANALYTICS (BDA)

Please select your job level	Strategic
Implementation/ Exploitation/ Need for	Implementation
Current/ Future	Current

	SKILL/ KNOWLEDGE DIMENSON	LEVEL OF IMPORTANCE
1	*Leadership*	Very High
2	*Communication*	Very High
3	*Negotiation*	High
4	*Motivation*	Very High
5	*Team Work*	Very High
6	*Decision Making*	Very High
7	*Strategic Planning*	Very High
8	*Partnership and Alliancing*	High
9	*Finance Accounting and Budgeting*	High
10	*Marketing*	High
11	*Tendering and Procurement*	High
12	*Risk Management*	High
13	*Quality Management*	High
14	*Performance Management*	High
15	*Operational Management*	High
16	*Technological infrastructure Management*	Very High
17	*Legislation Management*	High
18	*Innovation Management*	Very High
19	*Supply Chain Management*	High
20	*Information Management*	Very High

Figure 67- Interactive BDA Skills/ Knowledge Inventory

INTERACTIVE SKILLS/ KNOWLEDGE INVENTORY FOR INTERNET OF THINGS (IOT)		
	Please select your job level	Operational
	Implementation/ Exploitation/ Need for Trainin	Exploitation
	Current/ Future	Future
	SKILL/ KNOWLEDGE DIMENSON	LEVEL OF IMPORTANCE
1	*Leadership*	Very High
2	*Communication*	Low
3	*Negotiation*	Very Low
4	*Motivation*	Very Low
5	*Team Work*	Very High
6	*Decision Making*	High
7	*Strategic Planning*	High
8	*Partnership and Alliancing*	High
9	*Finance Accounting and Budgeting*	Very Low
10	*Marketing*	High
11	*Tendering and Procurement*	Low
12	*Risk Management*	High
13	*Quality Management*	High
14	*Performance Management*	High
15	*Operational Management*	Very High
16	*Technological infrastructure Management*	Very Low
17	*Legislation Management*	Low
18	*Innovation Management*	High
19	*Supply Chain Management*	Low
20	*Information Management*	Very High

Figure 68- Interactive IOT Skills/ Knowledge Inventory

****The e-version of this interactive Knowledge Skill Inventory (SKI) can be found on the link below:***

https://bit.ly/3mPg32q

Alternatively, the excel file is attached herewith.

6.2.3 Qualitative Data Analysis

As described in methodology section 3.10, NVivo version 12 was employed to analyse all qualitative data received from semi-structured interviews. All together 25 professionals were interviewed from the construction sector. This section explains data collected regarding the skills and training needs for BIM, BDA, and IoT. A complete list of interview questions can be found in Appendix B.

First, in completion of the SKI, the current BIM skills were identified from the interview data. In establishing main skill sets, researcher-derived codes which invoke conceptual and theoretical frameworks to identify implicit meanings within the data were used. These are labelled as latent codes (Bryman, 2001).There was a considerable number of knowledge-skill dimensions identified from the interviews. These were categorised into themes and mapped against the skill-knowledge dimensions used in questionnaires. Interestingly, all identified skills (Current skill-knowledge dimensions for BIM) were able to classify into at least one of the skill-knowledge dimensions identified by the questionnaire survey. The future skills and training needs were also analysed to derive themes and they were also categorised into the themes identified by the QUAN study. When identifying the sub-skills the researcher expected to present participants' views in a more realist and descriptive way. Therefore, data driven (semantic) codes were used for this purpose. The researcher started coding the transcripts with the latent codes, and in the process of coding, semantic codes were identified and reported as sub-skills. Semantic codes are emerging data to discover new knowledge (Bryman, 2001). Both these latent and semantic codes together helped generating the SKI (Appendix F1). Hence, qualitative analysis aided complementing the quantitative findings with further insight as 'expansion' to the already developed SKI. Subsequently, another column was added to the SKI explaining additional sub-dimensions (with semantic codes) pertinent to the key skill-knowledge dimensions. Then the training requirements were analysed using the content analysis- text querying function of NVivo. The words that frequently appear after training was a key observation. Building upon this observation, the discussions around training requirements were summarised into a few themes as benefits, different means of training, and level of training requirement. This information was then added into a new column. Some of the important points that emerged from the qualitative data analysis concerning SKI are summarised in subsequent paragraphs.

Appendix F1 provides a summary of findings together with the key themes identified from the qualitative study regarding skills/knowledge dimensions. The letter 'I' represents the identifier prefix followed by the reference number (ex: I-9 is the 9^{th} interviewee in the list). Cluster analysis, mind-mapping, and project mapping were used in the development of the qualitative part of SKI. Such cluster analyses produced in NVivo are illustrated in Figure 69 and Figure 70.

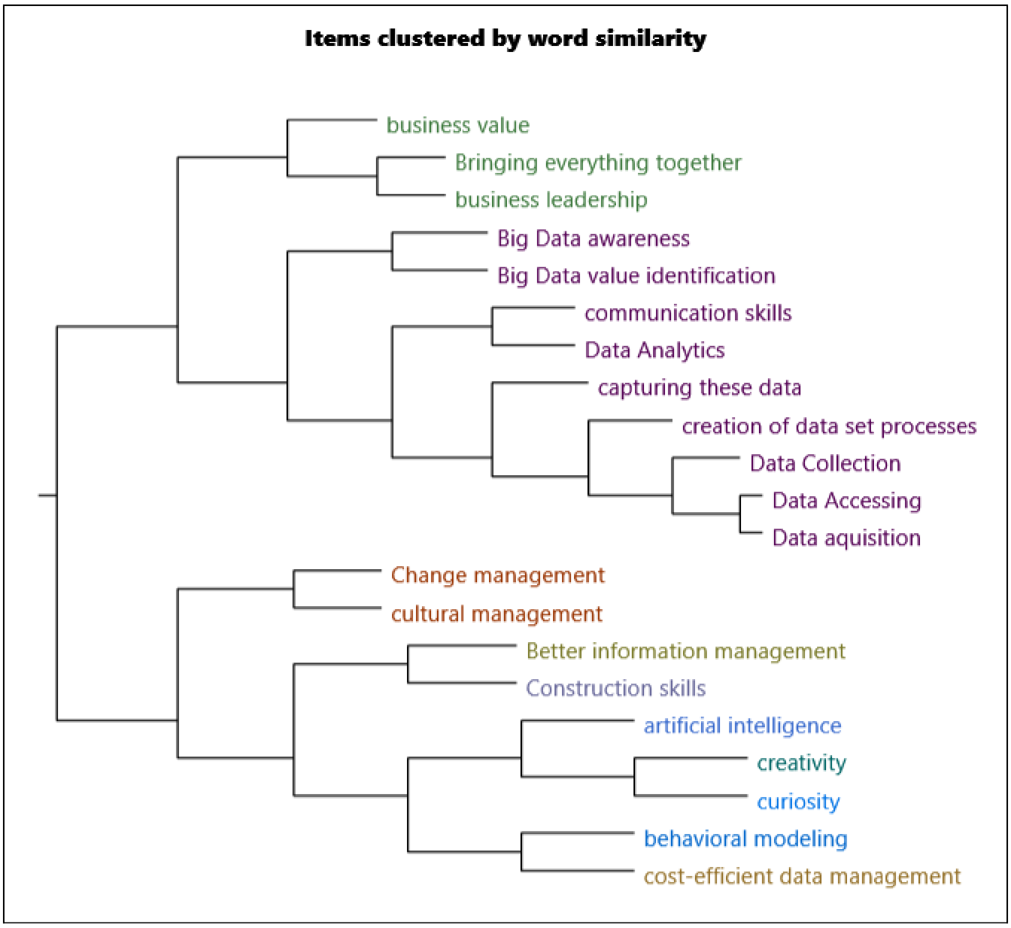

Figure 69- Cluster analysis produced in NVivo for BDA skills

Among the interviews, for the question regarding the current and future training requirements for BIM, the majority of the interviewees (84%) mentioned that their organisations require more training in the skills, knowledge dimensions for implementation and exploitation of BIM, while 6% mentioned that their organisations currently have a good training policy and are currently executing beneficial training programmes for areas including BIM technical knowledge as well as soft skills such as leadership, teamwork, project management. 10% said that even though their organisations have well-managed training programmes there's still room for improvement.

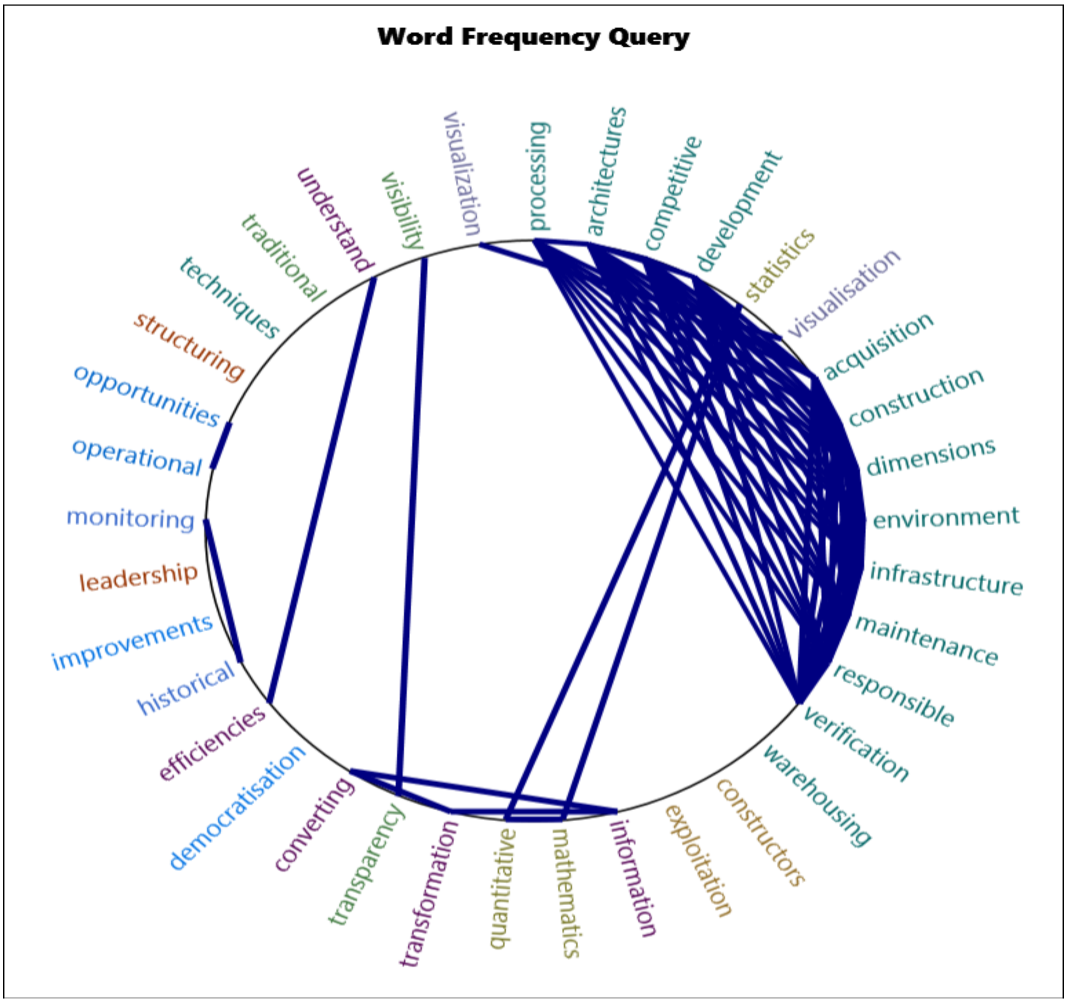

Figure 70- Cluster analysis produced in NVivo for Future BDA skills

The comments concerning the need-for-training were included as a separate column to the SKI (See Appendix F2). According to Katz (1955), technical skills are the most important set of skills for lower-level managers, i.e. for people who are working within the matter of profession. As with the case with technical skills, human skills are also regarded for a particular strata: the ability to communicate and cooperate with other people is crucial for lower and middle management, but the importance of technical skills is gradually decreasing in the higher administrative layers (Katz, 1955). As a manager gets promoted, the scope of work and the job role transforms into a more human interactive role. Therefore, the technical skills will not matter much for senior managers (Katz, 1955). Instead, there will be a need for conceptual skills, i.e. for the ability to stay away from the details and see the organisation as a whole, and then to communicate the vision in such a manner that would motivate others (Katz, 1955).

Section 6.2.2.2 described the importance of strategic management for current BIM implementation. In identifying the extent to which strategic management complements technology implementation and thereby competitiveness enhancement and which patterns are the most relevant for answering the research questions, the frequency of appearance of a certain code is important. Nevertheless, there were some codes that do not frequently appear but are meaningful for answering the research question. Therefore, the frequency and the importance of a certain code have equally taken into consideration. In establishing the sub knowledge/ skill dimensions, the researcher developed data-driven codes (semantic codes) instead of latent codes which are usually developed based on the theoretical lens of the study (Bryman, 2001). The interviews emphasised that technology plays an important role in facilitating strategic performance management and vice versa. The qualitative data revealed that strategic management is a crucial dimension that needs to be improved as a skill/knowledge because:

- It helps to build up a strategy for technology planning and forecasting,
- It provides guidance for technology transfer and acquisition,
- It defines the future direction, and makes decisions on allocating its resources as a prerequisite for innovation management,
- It extends as a control mechanism for guiding the technology implementation and issues associated with it

On the future skills and training needs, many do not expect a massive transformation of the industry in terms of BIM skills and training needs, especially because the industry is yet to fill the current skill gap (See Appendix F1). The identified skills were coded and visualised through a hierarchy chart produced in NVivo. As presented in Appendix F1, the importance of having both technical and management skills/knowledge for every employee was emphasised. The reason for this, which emerged from the interviews, was the usefulness of possessing multi-disciplinary skills in the exploitation of an innovative technology triggered by the higher demand for such skills. Innovation or innovative technology implementation is rarely a result of a solo act. Indeed, digital innovation-led organisations are increasingly employing multidisciplinary teams to address the multi-disciplinary problems associated with highly integrated technologies. On the other hand, another view which was emphasised was that ‘not everybody is required to have training in all areas’. The interviewees who were in favour of this opinion highlighted the importance of employee job-specialisation. Regarding training provisions, most of the interviewees agreed that there’s still room for improvement. As described in previous paragraph, the frequency and the importance of a certain code have equally taken into consideration. In establishing the most important sub knowledge/ skill dimensions for future BBI implementation and exploitation, data-driven codes (semantic codes) instead of latent codes were used. The areas that require most training include general management skills like strategic planning, collaboration, and communication. An attempt was made to ascertain why some of the interviewees indicated a higher need for training for BIM exploitation. BIM exploitation needs more training because:

- There is a need to unlock the full potential of the BIM technology although some sort of training exists in their companies (9)
- The AEC industry projects involve huge investments of capital, and therefore there is limited room for errors; works must be performed correctly and speedily to maximise efficiency and improve profit margins (3 responses)

A similar approach was followed to identify BDA skills-knowledge and training needs for both current and future perspectives from interviews. The themes that emerged for BDA skills/knowledge are presented in Appendix F1. For the future perspective, there were mixed opinions as some of the interviewees believe that there will be a revolutionary transformation in the industry over the next five years. At the same time, a similar proportion of managers believes that there won't be a considerable change in the next five years (See Appendix F1). Some managers see the need for training attributed to the increased number of professionals that enter the Built Environment as well as the creation of a bridge between the data science and traditional business worlds. As mentioned by one of the interviewees, the focus of big data training is not what a big data tool can do, but what the industry can do with the output from the tool. This signifies the purpose of big data training. Concerning the need for training, quite like BIM, the majority believes the need for more training opportunities. A minority was satisfied with the current organisational training in place. Some of the interviewees claimed that the current training is sufficient in some areas but inadequate in other areas. The skills around human dimensions like soft skills, including leadership, people management, and behavioural science were highly suggested training areas for current BDA implementation and exploitation. The opinions were slightly different for the future as the managers see the evolvement of big data technologies in the next five years. An attempt was also made to ascertain why some of the interviewees indicated a greater need for training for BDA exploitation. The reasons were grouped into three themes based on their responses as follows:

- Big data is a considerably new area especially for construction and therefore managers need training geared towards practical application (16 responses);
- The emphasis on technical BDA skills and knowledge are quite different from general BDA skills and knowledge. Therefore, there is a need for conducting light-touch as well as advanced types of programmes tailor-made for different job roles (13 responses);
- Having knowledge and expertise in programming languages and analytics is an added advantage for every professional for their profile. Big data has been the new normal data processing method (4 responses).

The same set of questions was asked for IoT implementation and exploitation as well. Concerning the Key IOT skills, the majority of the strategic managers mentioned the unimportance of technical

IOT skills, but the importance of spreading awareness and convincing its value (See Appendix F1). Some of the interviewees identified the importance of strong leadership, and that a strong leadership capability is vital to any organisational improvement. Those organisations seem to continually work towards building the skills of their senior executives, functional leaders, and key project delivery personnel. Seven other identified skills are important especially for strategic managers who work with IoT. These skills were mainly around 'how to implement with operational skills'; 'how to maximise the beneficial outcome in its maximum potential'; 'how to create a strategy plan'; and 'changing the mindset' of individuals to start recognising the opportunities to bring into the business. The latter was very much related to entrepreneurial skills. Among all of these, 'being able to convince the value of IoT for the rest of the employees' was an important skill especially for IoT exploitation as mentioned by the interviewees. This highlights that the awareness of the strategic value of IoT among industry professionals is quite low and hence the investments are also low compared to BIM and BDA.

Considering all these qualitative opinions and perceptions, the quantitative-based findings were expanded with further insight. Following the qualitative data analysis of RFM sectors, any new skill-, knowledge dimension, and training need that was identified was added to the existing SKI and the SKI was further enhanced. Please see Appendix F2. This information supports the SKI with further insights- i.e. sub skill/knowledge dimensions for now and future with further information for training needs. The interviewees' jobs as defined by their application of skills/knowledge are, generally, unique, with some overlaps across levels of management and types of organisations. This demystifies the view that management tasks for BBI exploitation are different across management strata. For example, the sub-skills that are required by a strategic manager could overlap with the sub-skills required by an operational manager.

Thus, remarks on the achievement of the fifth objective- to explore, skills, training needs for effective implementation, and exploitation of BBI for competitive advantage and, in this regard, develop a skill and knowledge inventory (SKI) (See section 1.4). The combination of quantitative (section 6.2.2) and qualitative (section 6.2.3) data helped in providing a comprehensive view of the knowledge and skills required by each professional in a construction organisation. This therefore addresses the need for a better understanding of the job role of three different levels of managers, and the skills and knowledge they need and bring to their work to be able to exploit BIM, BDA and IOT (see section 2.8.3). This supports the overall strategic approach for improving BBI exploitation levels for competitive advantage in construction.

6.3 Discussion for Chapter Six

6.3.1 Discussion on Skills/ knowledge Inventory

Enhancing competitive advantage requires input from different stakeholders with different backgrounds and it is in the central focus that they are required to work together with the different sets of skills and knowledge that they possess. Improving the levels of exploitation requires an understanding of the key stakeholders, how can they be purposefully integrated depending on the level of importance in certain skills/knowledge and the need for training for those skills. Authors in construction management stress the importance of collaborating and sharing knowledge, skills, and expertise, and thus purports the need for an overarching picture of skills/knowledge in particularly ICT adoption to meet the needs of the clients (Egbu, 2000). Employees within an organisation, represent one out of three hierarchical layers: strategic, tactical, and operational. The use of a knowledge skill inventory can be invaluable for meeting a firm's goals and objectives and for making better management and human resource decisions, and thus should inform the role for each employee who represents any given hierarchical layer.

Chapter-6 shows the skills and knowledge requirements for BIM, BDA, and IoT exploitation separately. The skills and knowledge dimensions represent both soft and hard skills. A striking finding from the quantitative study was that 'Innovation Management' and 'Information management' are the two skill/ knowledge dimensions that have the highest level of importance for all three hierarchical levels and all three strategic tools. The qualitative data resulted in more explanation for the identified skills with sub-dimensions associated with the main skills/knowledge. Based on the findings, an interactive e-based Skills Knowledge Inventory (SKI) was developed in Ms. Excel. The two main information strands of the SKI include the level of importance; and need for training. For example, using SKI, a strategic manager can see: 1) the level of importance and 2) the need for training for a given skill/ knowledge out of a set of twenty skills for BIM, BDA, and IoT. The user gets the opportunity to make three selections for the search and the interactive SKI offers the results suitable for the selections made. The selection involves the following aspects:

- organisation hierarchical level (strategic/ tactical/ operational)
- level of importance for Implementation/ level of importance for Exploitation/ need for training
- time frame whether Current or Future

The literature discusses few knowledge skill inventories developed around technology in construction. The one developed by the Australasian Procurement and Construction Council (APCC) shows skills and knowledge requirements for BIM implementation. This is more of a framework than an inventory and is designed to guide and assist industry stakeholders in the adoption and implementation of BIM. It does not consider the exploitation as well as the two other strategic tools: BDA and IoT. While the latter has quite a few limitations of not being interactive it was also reported to be not very user friendly. The SKI proposed in this research is interactive and more user friendly. The future-led perspective is another uniqueness of the inventory proposed in this research. Another framework developed by Bilal Succar presents a 'competency table' that can be used to organise competency Items for developing learning units and competency-based educational programmes. This framework however addresses only current BIM competencies while presenting a list of competencies without capturing its changing nature over time. A report produced as a recommendation for the Government and the Construction Industry Training Board (CITB) also serves as a form of skill inventory although it contains several limitations such as, the outputs are more of a set of isolated survey results rather than an all-in-one framework. The knowledge framework developed by Egbu (2004) presents a conceptual model of the main factors associated with knowledge management in project-based environments. Considering the aforesaid knowledge skills inventories and frameworks, it is conspicuous that no SKI has been developed to date involving the perspectives considered in the SKI proposed in this study. This remarks on the achievement of objective- 6 (as stated in section 1.4).

The information provided in the inventory can be used by managers for improved decision making in several areas including the following:

- Identify the most needed skill/ knowledge areas and act for needful training.
- Human Resources (HR) department for their decision making on recruitment to better meet the current and future needs for technology exploitation.
- Assigning the right employees to the right tasks.
- Staffing internal project teams with the best talent to ensure organisational competitive advantage.
- Targeting training and development efforts to alleviate existing skill gaps.
- Identifying key employees to develop for future business needs.
- Developing an internal talent channel to replace key employees and managers that depart from the organisation.
- Developing a workforce plan to meet the strategic needs of the business.

6.4 Summary of Chapter Six

There is an existent need to develop a skills and knowledge inventory as outlined in Section 2.8.3. The two most prominent needs include lack of understanding in the soft and hard skills/ and the lack of understanding in specific skills and knowledge associated with BIM, BDA, and IoT concerning different perspectives (i.e. job roles, time). The findings of the quantitative study resulted in the level of importance in the skills/knowledge dimensions for implementation, exploitation, and need for training. This was developed into an interactive Skill Knowledge Inventory (SKI), using advanced Excel functions. This SKI helps a professional that practices in construction to identify the importance of skills and knowledges related to BBI exploitation. The qualitative study resulted in sub-skills and knowledge related to the higher abstraction level skills and knowledge presented in the SKI. In this chapter, it was identified that there is a significant difference in the level of importance for now and the future. This chapter fulfilled the fifth objective while remarking the completion of achieving all six objectives as established in section 1.4. While this remarks on the achievement of all six objectives, the next chapter encapsulates the key conclusions and recommendations of this research endeavour remarking the conclusion of the thesis.

Chapter Seven

7 Conclusion and Recommendation

7.1 Introduction to Chapter Seven

The last chapter of this research endeavour is designed to encapsulate the conclusions and the recommendations for future research endeavours. The chapter is split into three main sections. The first section summarises the main conclusions of this thesis. This is explained in-line with the objectives that have been achieved towards the achievement of the research aim. The second section presents a reflection of the research articulating the strengths and weaknesses of the research journey from different perspectives. The third section is dedicated to recommendations for future work while reviewing the contribution to the existing body of knowledge.

7.2 Summary of main conclusions- Aim and objectives achievement

The findings concerning the six objectives were systematically assembled to provide a logical answer to the two main research questions explained in section 1.1- Introduction to Chapter One.

7.2.1 First Objective achievement

The study commenced with a review of literature suggesting that the construction industry in the United Kingdom: lacks competition between the firms, lacks digitisation, is fragmented, possesses inhomogeneous cultures, is low in productivity, is low in profit margins. Further, while the aforesaid problems hinder the industry performance, the literature suggested that construction organisations in the UK make fewer provisions for the enhancement of their competitive edge. Competitiveness however is an effective strategy for firms to survive and grow within the market by outperforming their peer competitors. To this end, exploiting digital technologies: i.e. Building Information Modelling, Big Data Analytics, and Internet of Things as 'strategic tools' were said to be a proactive way of improving the competitiveness. The first objective of this study was to critically review the state of art in the use of Building Information Modelling (BIM), Big Data Analytics (BDA), and the Internet of Things (IoT) that leads to the competitive advantage of the construction industry. The existing literature was critically reviewed to address the first objective. The findings emphasise that BIM, BDA, and IoT could be strategically exploited to enhance organisational competitive advantage. State-of-the-art in the application of BIM, BDA, and IoT in different sectors was reviewed. This included the level of BIM, BDA, and IoT adoption and the latest trends in adoption.

One of the main reasons to improve competitive advantage in construction is that firms must have a futuristic vision either for their 'survival' or 'growth'. The findings concerning the first objective show that, due to the intricate linkage of how ICT resources utilisation may impact on organisational competitive advantage, the Asset-Process-Performance (APP framework) is the most suitable and justifiable framework to understand and model the relationship between 'competitive advantage' and digital technologies in construction firms. The 5Ps of strategic perspectives suggested by Henry Mintzberg is the most suitable theoretical underpinning to be employed in technology exploitation studies, as it helps to review the 'Strategic Apex' in an organisation from five different perspectives instead of a sequential process.

One important part of the first objective was to critically review the state of the art in the use of BBI. The state-of-the-art in the use of BIM, BDA, and IoT is focused on five main themes inter alia: Lifecycle and Sustainability, Design and Construction, Technological advances, Beneficial use, professions, and policies. Section 2.3 explained the level of development BIM, BDA and IOT have both individually and synergistically reached in the current time. Circa 62% of AEC practices are currently using BIM on some of their projects while the future usage will continue to be dominated by the AEC sector because the nature of BIM shows more focus on the built environment. One of the main reasons for choosing BIM, BDA, and IoT among all other available technologies is that 'BIM, BDA, and IoT have the highest potential to be effective when used together with data-driven approaches. The application of BDA and IoT in construction is rapidly evolving. With the mandates imposed by the UK Government , BIM/BDA/ IoT implementation has widely spread across organisations creating opportunities for increased productivity and efficiencies in construction, operation, and maintenance of facilities. Although BIM/BDA/ IoT awareness and adoption have increased compared to previous years, the attitude among employees about implementation as well as exploitation do not show a considerable change- there is still a greater need to change employee attitudes towards implementation and exploitation. The awareness improvement includes a significant organisation-culture change as well. It was found out, that synergistic strategic exploitation of BIM, BDA, and IoT possesses the potential to improve productivity and enhance efficiencies in planning, design, and overall delivery of construction projects than when they are used alone. This finding was later supported in the quantitative analysis.

These findings of the first objective brought new insights to this study allowing the researcher to accurately position the research problem and the methodology to address the research questions as outlined in Section 1.5.

7.2.2 Second and Fourth Objective achievement

The second objective of this study was to investigate the extent of exploitation, benefits, and challenges associated with BBI in the construction industry, and how that impacts on the competitive advantage of the construction industry. The fourth objective on the other hand focused on investigating the extent to which BBI are employed as competitive strategic tools in other sectors. The sectors selected include retail, finance, and manufacturing (RFM). The achievement of these two objectives shows collective effort. The data from RFM sectors were merged with construction data and discussed in Chapter- 4, Chapter- 5, and Chapter-6 as a comparison across industries. Through the review of the literature (Chapter-2), the most cited and relevant construct variables for exploitation, benefits, and challenges were identified and selected. The selected construct variables were then fed into eight questionnaire surveys (BIM only, BDA only, IoT only, BIM-BDA, BIM-IoT, BDA-IoT, BIM-BDA-IoT, RFM). Questionnaire surveys were distributed among professionals from four sectors (construction, retail, finance, and manufacturing). In all, one hundred and fifteen (115) managers from construction and fifty-one (51) from RFM sectors responded positively to the questionnaires. Semi-structured interviews were also conducted parallel to the structured questionnaire surveys with 43 professionals from four industries. Details of the execution processes for these methods are discussed in section 3.10.

Analysis of data from interviews, and questionnaires, enabled several conclusions to be drawn. First, with the level of exploitation, the level of job role (strategic, tactical, and operational) does not have a significant influence on the way organisations exploit BIM/ BDA or IoT. There was a statistically significant difference in the way people have responded to the level of exploitation in BIM, BDA, and IoT within the companies depending on respondents 'level of experience' and 'individual's extent of BIM use'. This means that an individual's level of experience in the technologies and the extent to which they use the technologies could change the way that their companies exploit the technologies. When scrutinising the level of exploitation, the extent to which respondents exploit BIM as a strategic tool was highest in construction. The level of exploitation for BDA and IoT both was highest in the Retail sector. In construction, the three most exploited areas in BIM were: managing to perform an individual's daily tasks more effectively, operational efficiency, and strategic leadership. The lowest exploited area was embracing new routines and processes to use the system in a better way. The highest exploited area for BDA in construction was strategic leadership while the lowest was setting realistic technology goals. For BBI exploitation in construction, the exploitation for the provision of 'results' was higher than for the provision of 'inputs'. Managing to perform an individual's daily tasks more effectively was the highest exploited area for IoT in construction while deploying the required resources was the lowest.

The qualitative data revealed an alternative interpretation of the exploitation and came-up with a list of 6 constituents that people often refer to as technology exploitation. These include adoption rate, accreditation, input capacity, effectiveness in operational process, degree of output achievement, and age of adoption. In the exploration of possible lessons from RFM sectors for the construction industry, 'Development of an organisational strategy' to exploit the technologies for organisational competitive advantage was prominent. First, the strategy should consist of a business case, clearly understanding the client requirements. Then, the strategic objectives must be set allocating the most feasible amount of resources into each goal achievement. Establishing internal and external partnerships has also been highlighted in the findings as a strategic requirement. Thereafter, mobilising the strategic intent followed by progressive operation, review, and control is recommended. The most mentioned strategic influences as lessons learned include predictability, access to data, and data integration.

Second, in the investigation of benefits accrued and the challenges faced, the benefit most accrued by exploiting BIM in construction was enabling faster and better decisions through greater collaboration. Although there was no significant challenge faced by construction, lack of in-house expertise, and therefore high salary premium of employing personnel trained in BIM was the most challenging area for BIM exploitation in construction. Construction was the least benefit accrued sector among the four sectors while retail was benefiting most from BDA exploitation. Although construction was benefiting least from BDA compared to the other sectors, in the construction itself, Identification of important information has primarily helped to improve the quality of decision making in construction. Legal issues regarding data ownership, copyright, and data protection were the most challenging area for construction. The retail sector was facing the least challenges while manufacturing is the sector that faces challenges the most in BDA exploitation. Construction is the second-highest sector in terms of the challenges faced. The benefit most accrued by exploiting BDA in construction was the identification of important information through advanced analytics while the most challenging area was legal issues regarding data ownership, copyright, and data protection.

The sector benefiting most from IoT exploitation was Finance, while Construction was the sector benefiting the least. Concerning challenges, the construction sector was facing the challenges to the highest extent compared with RFM sectors while Finance was experiencing the least challenges. The benefit most accrued by exploiting IoT in construction was remote/ automated operation and usage monitoring for controlling purposes while maintaining privacy and security of transferred data was the most challenging area for exploitation in construction. Out of the three strategic tools (BBI), BIM was the most beneficial as well as the most challenging strategic tool for construction. Qualitative data associated with benefits and challenges emphasised six categories of common benefits and 4 categories of common challenges.

Third, in the investigation of the level of competitive advantage enhancements, it was found out that, by exploiting BIM in construction, ‘performance efficiency’ was largely enhanced. For BDA and IoT, the highest overall level of enhancement for competitive advantages was reported by the Retail sector. However, within construction itself, performance efficiency and speed and quality of delivery were the two competitive advantages most enhanced by exploiting BDA and IoT. A striking finding is that the exploitation of synergistic technologies enhances competitive advantages more than when they are exploited alone. In ascending order, the level of enhancement in competitive advantages by exploiting BIM in construction were presented as BIM+BDA = BIM+IoT < BIM only < BIM+BDA+IoT. In ascending order, the level of enhancement in competitive advantages by exploiting BDA in construction were presented as BDA only < BIM + BDA < BDA+IoT < BIM+BDA+IoT. The level of enhancement in competitive advantages by exploiting IoT in construction in ascending order were presented as IoT only < BDA + IoT < BIM+IoT < BIM+BDA+IoT. The qualitative data with regards to competitive advantage enhancement provided more insight into the above quantitative findings by reasoning.

Fourth, in the investigation of relationships between exploitations, benefits, challenges and competitive advantage, several conclusions were made. All in all, the more firms exploit the technologies, the more chance firms get to enhance their competitive edge. Not only that, but the findings also concluded that BIM exploitation causes competitive advantage, mostly for the ones with large correlations. The largest correlation was seen between embracing new routines and value-added ability to the sustainability of society. This implies that the higher the rate of embracing new organisational routines the higher the value it adds to the society in general. As was the case with BIM, BDA and IoT also show positive correlations with a competitive advantage, where the causations were reported from the largest and strongest correlations. There is an overall positive correlation between BIM benefits and BIM exploitation. An interesting discovery was also made that BIM benefits influence/ cause BIM exploitation.

As was the case with BIM, BDA and IoT benefits also show an overall positive correlation between BDA exploitation and IoT exploitation respectively. They were also reported to cause/ influence exploitation. In general, the more challenges firms encounter, the less they enhance competitive advantages. However, interestingly, certain challenges seem to enhance certain competitive advantages. For example, the higher the hardware upgrading and software licensing costs the higher the firms show compliance with BIM standards. This was attributed to the mandates-imposed by the government. There were no sufficient discoveries to suggest that BIM/BDA/IoT challenges cause lower exploitation levels. However, where significant negative correlations were seen, significant causation can be suggested as with previous patterns of correlations. The more benefits firms accrue, the more chance firms have of enhancing their competitive edge. The more challenges firms encounter, the fewer chance firms have of enhancing their competitive edge.

7.2.3 Third Objective achievement

The third objective focused on ascertaining the impact of organisational size, culture, and structure on the effective exploitation of BBI in construction. The findings concerning the third objective show that organisation culture complexly correlates with BBI exploitation. Meaning, each culture constituent is differently correlated with each exploitation variable with different directions and different strengths. So was the strength of 'impact' and direction of impact. However, observing the entire model, it was able to be deduced that organisation culture (according to the way it has been defined and worded in the questionnaire) has a positive correlation and positive impact towards BBI exploitation.

In summary, the findings suggested several conclusions. The lower the power distance the higher the strategic leadership received from senior management and higher the ability to deploy tools and workflows. With the information emerged from the interviews, it was found out that more autocratic, or authoritarian, leadership exists when power distance is high. Similarly, when power distance is low, the leaders tend more to be 'democratic'. In democratic leadership, power is shared equally, and each subordinate has a say in setting goals and making decisions. It will also make it easier to select the right skilled team and set realistic goals. A key aspect of strategic leadership is the ability to influence others to make decisions while put them into the right direction (Betts and Ofori, 1994). Moreover, it was also discovered that when the power distance is low, the influence organisations hold to use appropriate standards is high. As explained by Hofstede, when a certain cultural bubble accepts the fact that power in organisations is distributed unequally, it becomes difficult to implement appropriate standards and discourages to work more effectively and efficiently. The lower the power distance the higher the employees extend and leverage their existing individual competencies on the technology. Low power distance influence to embrace new routines. The higher the Masculinity the higher the influence for embracing new routines and processes. Further, when the Teamwork is higher, the encouragement for work effectiveness, extending and leveraging their existing individual competencies on the technology, operational efficiency and embracing new routines are also higher.

Organisation structure complexly correlates with BBI exploitation. Meaning, each structure constituent is differently correlated with each exploitation variable with different directions and different strengths. So, it was with the strength of impact/ causation and direction of impact. However, observing the entire model, it was able to be deduced that organisation structure (according to the way it has been defined and worded in the questionnaire) has a negative correlation and negative impact towards BBI exploitation.

Findings in terms of organisation structure suggested that the higher the Centralisation the lower the- strategic leadership, deploying, setting realistic goals and the effectiveness of daily tasks. This has been attributed to the amount of interaction and feedback between the subordinates and the manager. The more feedback and interaction exist, the span of control is narrower, and therefore it enables more effectiveness from the team. The higher the Formalisation the lower the operational efficiency for BIM. The higher the Stratification the lower the use of appropriate standards/ policy initiatives for IoT.

Interestingly, organisation size had a dual direction correlation and an impact on BBI exploitation. In the circumstances where a correlation was seen, the strength and significance were very low. However, few significant correlations were discovered in the quantitative study. There are some significant positive correlations between the number of full-time employees and BBI exploitation and there are some negative correlations between annual turnover and BBI exploitation.

Because the quantitative data resulted in mixed opinions and was difficult to conclude, qualitative data was refereed to gain more insight. Closely observing the direction of the interviewee’s opinion about the impact of organisation size on BBI exploitation, it was able to conclude that organisation size has no impact on the exploitation of BBI exploitation.

7.2.4 Fifth Objective achievement

The fifth objective of this research endeavour was to develop a strategic framework for improved exploitation levels of BBI for competitive advantage. Having assembled all the findings of the previously discussed objectives, the strategic framework was developed. Presenting the most critical factors at the exploitation of BBI provides a good understanding of the areas that construction professionals need to consider when making investment decisions on implementing and exploiting BBI.

In summary, this proposed strategic framework incorporates the strategic requirements, exploitation variables, impact factors, benefits, challenges, and potential competitive advantages. Each sub-element of the framework was derived through a multi-method approach (use of quantitative and qualitative data). In conclusion, this strategic framework provides formative guidance to its users (construction industry professionals regardless of the type of organisation they work for and their job role) about the critical considerations for implementing and exploiting Building Information Modelling, Big Data Analytics, and Internet of Things for the competitive advantage of construction. Further, the study concluded the framework is much more beneficial when referred to along with the SKI. With the achievement of the sixth objective, the aim of the thesis (see section 1.4) is accomplished. Further, in retrospect of the two research questions, it can also conclude the investigation efforts have addressed the research questions listed in section 1.5.

7.2.5 Sixth Objective achievement along with the overall research aim accomplishment

The last objective of this study was to explore the skills and training needs for the effective exploitation of BBI for competitive advantage and in this regard, developing a 'Skills and knowledge Inventory (SKI). A list of most cited skills-knowledges was selected from the literature first. These were then tested using questionnaire surveys for their level of importance for present implementation, present exploitation, present need for training and future implementation, future exploitation, and future need for training.

Highlighting the significant findings, managers at the senior level believe Innovation Management to be the most important skill-knowledge dimension for current BIM Implementation. For current BIM exploitation, managers at senior level believe that Information Management is the most important skill. The situation is quite similar for future BIM implementation and future exploitation as well. Interestingly, the strategic managers have expressed their opinion on the need for training and it was revealed that these two skill/ knowledge dimensions- innovation management and information management largely require training to be able to exploit BIM presently as well as in the future.

According to the quantitative data received from the construction industry, a gradient map was created to visualise the importance of each skill-knowledge. An interactive e-based Knowledge Skill Inventory (SKI) was then developed based on the quantitative findings. Using the interactive SKI, one can swiftly search, find, and grasp the highest important skills-knowledges for now and future in terms of their application in implementation, exploitation, and need for training. The SKI was further enhanced with qualitative data. Two new columns (Appendix F2) were added to reflect the sub-skills-knowledge dimensions (current and future) and need for training identified from qualitative data. With this effort, the SKI turned out to be a more-detailed skill-knowledge inventory. Thus, SKI development was fulfilled.

7.2.6 Research contribution and its implications

The overall research investigated how exploitation of BBI contributes to enhancing the competitive advantage of construction organisations. As summarised in section 1.8, this study contributes to the existing body of knowledge with its two main research outputs- the strategic framework (https://bit.ly/366mZlc) and Skills Knowledge Inventory (SKI) (https://bit.ly/3mPg32q) developed for improved exploitation of BIM, BDA, and IoT. The strategic framework and SKI are integrative mainly because the identification of most important skills/knowledge dimension is a critical part of the strategic framework itself. Section 2.5.1 and 4.2.3.1 identify 'skills and need for training' as a construct constituent for the operational definition for BBI exploitation. The strategic framework therefore merely mentions about this aspect, but cross refers to the SKI to have a much more clearer and comprehensive understanding. The target audience could only receive the full benefit of the findings of this research if both strategic framework and SKI were referred together. The design and operation of the final framework are different from the already existing frameworks (as reviewed ins section 2.7.2) because the framework developed in this study looks at the holistic view of strategy combined with culture, structure, size, and training needs. Most importantly, a gap exists in the literature on synergistic view of BBI and how these are exploited to be able to enhance organisational competitive advantage. Exploitation in such a way that it represents both implementing and beneficial use to meet both current and future needs is an under researched area.

The aforesaid research outputs benefit different organisational stakeholders in varied ways. Framework and SKI are beneficial for clients, contractors, designers, architects, facility managers, engineers, and cost consultants in the industry because it guides the understanding of the critical aspects of consideration for BBI exploitation. This knowledge would help in recognising the key capabilities an organisation possesses and help improve readiness for initiating the BBI exploitation process. Further, while the study confirms the rising trend for BBI adoption, the findings demystify some of the prevailing misconceptions in the industry (i.e. the technologies of the inquiry are only for large companies). In light of such demystifying, funders may also benefit from improved awareness of the marketability of BBI enabled projects and organisations.

The two research outputs further benefit educators by providing an improved understanding of the present and future knowledge-skill demand and adapts the education systems accordingly. Policymakers benefit from the research outputs by providing improved awareness for the need for forming new regulations/ policies around BBI adoptions.

The research conducted in this Ph.D. study also serves as a guide for up-and-coming researchers/ scholars. First, the choice of philosophical assumptions informs the readers 'what has been studied' and 'how the authors have warranted knowledge about their chosen domains'. The interpretivism/ social constructivism approach adopted in this research has helped in identifying the basic principle that reality is socially constructed and, that there is no external reality independent of human consciousness. This assumption further helped generalisation through theoretical abstractions and gathering rich data from which ideas are induced. The main theoretical underpinning of this study- strategic management was predominantly chosen considering the emic approach as explained in section 3.3.1. The research builds a theory that explains the relationship between strategic management, competitiveness, organisation culture, structure, and size by integrating human interest. The positivism on the other hand helped demonstrating the causality of constructs. Second, the critical review of literature in these exponentially growing areas of the research interest will assist in identifying the academic discussion while the research methodological approach undertaken in this research endeavour will be of benefit to adopt, repeat or extend for further research avenues. In terms of theoretical implications, this study emphasises the suitability of 5Ps model for strategic management but establishes differently complex view on how best to place an organisation culture, stricture, size, and skills/ knowledge to be able to enhance organisational competitive edge.

A part of competitive advantage addresses corporate social responsibility and sustainability measures. Improving competitive advantage resembles the goodwill of society. Hence this research has implications for society overall as well.

The next section aims at understanding the strengths, limitations and opportunities looking back at the research inquiry as reflection is a crucial cognitive practice in the research field (Creswell, 2007).

7.3 Reflections for the research

This study is strong in several aspects including the contributions to the body of knowledge in terms of exploring the critical factors that impact the exploitation of BBI that lead to competitive advantage. The nature of the research problem and the use of a mixed-method approach to finding answers is notable. The mixed methodology approach offered to explain and complement each other to further confirm the findings through triangulation. Furthermore, the richness of interview data received from both construction and RFM brought the study into a strong position. Finally, the development of the interactive strategic framework SKI is the strength of this research as it offers a range of benefits for different stakeholders. The opportunities include, marketability of research for its provision for competitiveness enhancement and the beneficial strategic Integration of three technologies. The research serves as a starting point for further investigations on other possible impact factors.

The weaknesses and the threats on the other hand include a lower response rate for WBS-RFM. It was realised that the reason for the poor response rate was the complexity, lengthiness of the questions, and the structure. However, having a higher response rate from the CONS sectors hints that the respondents' experience in these areas has also affected the response rate. Perhaps, future research populations could target people with specialist job roles. The lack of engagement of educators and trainers in the development of the SKI is also identified as a limitation of this research. Although the research secures the consistency or replication of research findings in similar conditions, the framework and the SKI developed in this thesis has not been validated, which is another limitation. However, it is worthwhile mentioning that 'construct validity', and 'internal validity' are secured in operationalisation of concepts and the trustworthiness of data.

7.4 Reliability of research findings

Establishing the 'reliability' and 'validity' of the results in a scientific investigation is vital. First, the data used for the critical review of the literature was from reliable databases like Scopus and Elsevier. The timeframe referred to in the review was 2008-2018 which implies the contemporariness of data. The selected literature (to feed questionnaire surveys) had high citation ranks and hence confirmed the reliability of the literature review conducted in this research.

Second, the structured surveys and semi-structured interviews employed focused on professionals from all disciplines and different types of organisations. The questionnaires were piloted before actual distribution. The response rate received from construction and RFM sectors was 28.4% and 25.5% respectively- which accounts for an acceptable response rate for construction management. The respondents to these surveys showed a consensus of most of the arguments and the data was not skewed for any party. Most of the questionnaire findings were complemented by interview data. This complementarity confirms the reliability of data. Moreover, their knowledge and experience on BBI use in construction is an assurance for the reliability and validity of these collected data. The triangulation method was used to validate the results of the second objective. Further, 52.9% of respondents had an average of 6-10 years of professional experience in the use of BIM, BDA, and IoT, respectively. Therefore, it was assumed that the collected data sources were reliable. Moreover, almost all purposively selected interviewees had more than 5 years' experience in the use of B/B/I. Thus, it was confirmed that the data collected from these sources were reliable and provided a good opportunity for triangulation.

7.5 Recommendations from the overall thesis

Synergistic exploitation of BIM, BDA, and IoT provides relatively higher levels of enhancement in competitive advantages compared to singular exploitation. Therefore, efforts must be made in the provision of improving the synergies between technologies rather than exploiting them in isolation.

Strong positive correlations can be seen between low power distance, teamwork, and competitive risk-taking nature and exploitation. This recommends empowering employees, and including them in decision-making, putting employees into manageable teams and encouraging competitive, result-focused, and risk-taking work environments within construction organisation cultures.

High formalisation, high centralisation, and high stratification hamper the ability to exploit the innovative technologies towards competitive advantage. Therefore, this study recommends lowering the formalisation in such a way that the employees are given some degree of freedom to bring creative ideas to the table. Further, lowering centralisation helps speedup the information flow. Therefore, lowering centralisation in such a way that tactical managers are given some degree of decision-making power would help to reach the targets easily.

It is conspicuous that organisation size does not have a significant power to control the extent to which organisations exploit the technologies or to control the competitive advantages. Therefore, this study recommends and encourages firms of any size (micro, small, medium, or large) to initiate possible synergistic strategic exploitations of BIM, BDA, and IoT to improve their organisation competitive edge.

Skills/ knowledge dimensions such as innovation management, information management, and strategic planning are extremely crucial for both future and current technology exploitations. Therefore, more training incentives must be provisioned for the latter three skill/ knowledge dimensions.

7.6 Recommendations for future research endeavours

This research has explained the capacity of BBI to be exploited as strategic tools to improve organisational competitive advantage. Thus, the importance and the urgent need for the research interest is highly emphasised. Even though the research importance and need are currently in a critical situation, a synergistic approach to BIM, BDA, and IoT is still an innovative and a nascent concept that is not covered in detail in built environment teaching, learning, and research courses at present. Thus, this study recommends academic institutions expand current teaching and research curriculum into different aspects of BBI implementation and exploitation as portrayed in the Strategic Framework.

Further research is recommended to be conducted on other factors that may impact on BBI exploitation apart from culture/ structure. Devising a method to establish measurable outcomes of synergistic exploitations is another area for future research. The challenges identified for BBI exploitation are recommended to be taken into detailed consideration to discover the means of overcoming them. The strategic exploitation of BBI must be encouraged as a means of addressing the problems as outlined in section 1.2.1.

The strategic framework suggested in this research is recommended for validation in different types and sizes of construction organisations. Considering the bipolar nature of organisations sizes' impact on BBI exploitation, it would have been rewarding if more investigations into 'organisation size' could have been conducted. For example, taking a few sample populations that include only one category of organisation size could help compare the outcomes.

Because some of the discussions around organisation culture showed a bipolar nature, this study recommends more research into these avenues as doing so would strengthen the existing body of knowledge. For example, concerning individualism and collectivism, while the majority said, that BIM, BDA, and IoT is all about collaboration, there was a considerable amount of opinions for individualism as well. For risk-taking on the other hand, while the majority highlighted the importance of the latter, some stressed the argument that being risk-averse and less competitive (internal peer-to-peer and external) is also a key control measure at some point. In summary, perhaps making more investigations into these areas may clarify the complexity involved with the cultural factors. It recommends choosing the most 'enabling' or 'supporting' organisation culture for BBI exploitation instead of seeking the 'right' or the 'best-practice' culture.

Considering some of the dual directive opinions of organisation structure towards exploitation, it is worthwhile to conduct more investigations into the reasons behind these opinions and how they could be designed to be more enabling and supportive of BBI exploitation. For example, concerning formalisation, some mentioned that free-style working enables more creativity and innovation while some emphasised the importance of having a formally structured set of rules and regulations, which clearly documents job description/ scope of the work description. Concerning stratification and complexity, some saw the value of stratifying different specialised roles while some saw collaborative working in cross-disciplines as the 'real' collaboration. More clarification could be offered along these lines if more research were conducted.

The findings of this thesis provide a strong base for future research streams considering exploring a measuring/ scoring method for improved competitive advantage as an approach for economic value in BBI exploitation. Also, some extra efforts are recommended to repeat the research for a segment of the industry to see whether there will be a difference in the results (for example, for contractors only). Testing the applicability of the developed strategic framework in a real organisational environment is also recommended.

8 References

Abanda, F. H., Vidalakis, C., Oti, A. H. and Tah, J. H. M. (2015) A critical analysis of Building Information Modelling systems used in construction projects, *Advances in Engineering Software*. DOI:10.1016/j.advengsoft.2015.08.009.

Abdul Kadir, M. R., Lee, W. P., Jaafar, M. S., Sapuan, S. M. and Ali, A. A. A. (2005) Factors affecting construction labour productivity for Malaysian residential projects, *Structural Survey*, 23 (1), pp. 42–54. DOI:10.1108/02630800510586907.

Abiad, F. and Bitter, F. (2009) Strategy and Competitive Advantage, *Group*, pp. 1–4.

af Wåhlberg, A. E. and Poom, L. (2015) An Empirical Test of Nonresponse Bias in Internet Surveys, *Basic and Applied Social Psychology*. DOI:10.1080/01973533.2015.1111212.

Agarwal, S. (1993) Influence of Formalization on Role Stress, Organizational Commitment, and Work Alienation of Salespersons: A Cross-National Comparative Study, *Journal of International Business Studies*. DOI:10.1057/palgrave.jibs.8490252.

Ahadzie, D. K. (2007) A model for predicting the performance of project managers in mass house building projects in Ghana, *Construction*.

Ahmed, V., Tezel, A., Aziz, Z. and Sibley, M. (2017) The future of Big Data in facilities management: opportunities and challenges, *Facilities*. DOI:10.1108/F-06-2016-0064.

Ahram, T., Sargolzaei, A., Sargolzaei, S., Daniels, J. and Amaba, B. (2017) Blockchain technology innovations, in: *2017 IEEE Technology and Engineering Management Society Conference, TEMSCON 2017*.

Aibinu, A. and Papadonikolaki, E. (2016) BIM implementation and project coordination in design-build procurement, in: *Proceedings of the 32nd Annual ARCOM Conference, ARCOM 2016*.

Aibinu, A. and Venkatesh, S. (2014) Status of BIM adoption and the BIM experience of cost consultants in Australia, *Journal of Professional Issues in Engineering Education and Practice*. DOI:10.1061/(ASCE)EI.1943-5541.0000193.

Aiken, M. and Hage, J. (1968) Organizational Interdependence and Intra-Organizational Structure, *American Sociological Review*. DOI:10.2307/2092683.

Ajayi, A., Oyedele, L., Davila Delgado, J. M., Akanbi, L., Bilal, M., Akinade, O. and Olawale, O. (2019) Big data platform for health and safety accident prediction, *World Journal of Science, Technology* *and Sustainable Development*. DOI:10.1108/wjstsd-05-2018-0042.

Akhavian, R. and Behzadan, A. H. (2015) Construction equipment activity recognition for simulation input modeling using mobile sensors and machine learning classifiers, *Advanced Engineering Informatics*. DOI:10.1016/j.aei.2015.03.001.

Akhavian, R. and Behzadan, A. H. (2018) Coupling human activity recognition and wearable sensors for data-driven construction simulation, *Journal of Information Technology in Construction*.

Akhavian, R., Brito, L. and Behzadan, A. (2015) Integrated Mobile Sensor-Based Activity Recognition of Construction Equipment and Human Crews, in: *Conference on Autonomous and Robotic Construction of Infrastructure*.

Akiner, I. and Tijhuis, W. (2008) Cultural variables and the link between managerial characteristics in construction industry: reflections from Turkish and Dutch examples, in: *INTERNATIONAL CONFERENCE ON MULTI-NATIONAL CONSTRUCTION PROJECTS*. Shanghai, China, pp. 4–8.

Akintoye, A. and Skitmore, M. (1991) Profitability of UK construction contractors, *Construction Management and Economics*. DOI:10.1080/01446199100000025.

Al-Mashari, M. and Zairi, M. (1999) BPR implementation process: An analysis of key success and failure factors, *Business Process Management Journal*. DOI:10.1108/14637159910249108.

Al-Mashari, M. and Zairi, M. (2000) Revisiting BPR: A holistic review of practice and development, *Business Process Management Journal*. DOI:10.1108/14637150010283045.

Alade, K. and Windapo, A. (2020) 4IR Leadership Effectiveness and Practical Implications for Construction Business Organisations, in: *The Construction Industry in the Fourth Industrial Revolution*.

Alaka, H., Oyedele, L., Bilal, M., Akinade, O., Owolabi, H. and Ajayi, S. (2015) Bankruptcy prediction of construction businesses: towards a big data analytics approach, in: *2015 IEEE First International Conference on Big Data Computing Service and Applications*.

Alexander, J. W. and Randolph, W. A. (1985) The fit between technology and structure as a predictor of performance in nursing subunits., *Academy of Management Journal. Academy of Management*. DOI:10.2307/256240.

Allcoat, J. (2020) *Construction output in Great Britain: January 2020*.

Ambastha, A. and Momaya, K. (2004) Competitiveness of Firms: Review of theory, frameworks and models, *Singapore Management Review*, 26 (1), pp. 45–61. DOI:10.1002/ccd.10430.

Ambrosini, V. (2003) *Tacit and ambiguous resources as sources of competitive advantage*. Palgrave Macmillan UK. DOI:10.1057/9781403948083.

Ammar, A., Hanna, A. S., Nordheim, E. V. and Russell, J. S. (2003) Indicator variables model of firm's size-profitability relationship of electrical contractors using financial and economic data, *Journal of Construction Engineering and Management*. DOI:10.1061/(ASCE)0733-9364(2003)129:2(192).

An, Q. (2014) The effective classification process analysis of the big data in construction project, *Applied Mechanics and Materials*, 644–650, pp. 1749–1751. DOI:10.4028/www.scientific.net/AMM.644-650.1749.

Angel, R. (2006) Putting an Innovation Culture into Practice, *Ivey Business Journal*, 4 (2), pp. 2–6.

Anumba, C. J., Baugh, C. and Khalfan, M. M. A. (2002) Organisational structures to support concurrent engineering in construction, *Industrial Management and Data Systems*. DOI:10.1108/02635570210428294.

Anumba, C. J. and Ruikar, K. (2001) Electronic commerce in construction - Trends and prospects, in: *Automation in Construction*.

Arayici, Y., Coates, P., Koskela, L., Kagioglou, M., Usher, C. and O'Reilly, K. (2011) BIM adoption and implementation for architectural practices, *Structural Survey*. DOI:10.1108/02630801111118377.

Arayici, Y., Egbu, C. and Coates, P. (2012) Building Information Modelling (BIM) Implementation And Remote Construction Projects: Issues, Challenges, And Critiques, *Journal of Information Technology in Construction (ITcon)*, 17 (1), pp. 75–84.

Arditi, D. and Mochtar, K. (2000) Trends in productivity improvement in the US construction industry, *Construction Management and Economics*, 18 (1), pp. 15–27. DOI:10.1080/014461900370915.

Arikan, A. M. and Mcgahan, A. M. (2010) The development of capabilities in new firms, *Strategic Management Journal*. DOI:10.1002/smj.797.

Armandi, B. R. and Mills, E. W. (1982) Organizational Size, Structure, and Efficiency: A Test of a Blau-Hage Model, *American Journal of Economics and Sociology*. DOI:10.1111/j.1536-7150.1982.tb01667.x.

Assaf, S. A. and Al-Hejji, S. (2006) Causes of delay in large construction projects, *International*

Journal of Project Management, 11 (5), pp. 45–50. DOI:10.1016/j.ijproman.2005.11.010.

Atzori, L., Iera, A. and Morabito, G. (2010) The Internet of Things: A survey, *Computer Networks*. DOI:10.1016/j.comnet.2010.05.010.

Auh, S. and Menguc, B. (2007) Performance implications of the direct and moderating effects of centralization and formalization on customer orientation, *Industrial Marketing Management*. DOI:10.1016/j.indmarman.2006.02.010.

Australian Construction Industry Forum and Australasian Procurement and Construction Council (2017) BIM Knowledge and Skills Framework: An Introduction, *2017 Australian Construction Industry Forum and Australasian Procurement and Construction Council*.

Azhar, S. (2011) Building information modelling (BIM): trends, benefits, risks, and challenges for the AEC industry, *Leadership and Management in Engineering*, 11 (3), pp. 241–252.

Banafa, A. (2017) Major Challenges Facing IoT, *IEEE- Internet of Things*, 2 (3), pp. 35–43.

Barison, M. B. and Santos, E. T. (2011) The competencies of BIM specialists: A comparative analysis of the literature review and job Ad descriptions, in: *Congress on Computing in Civil Engineering, Proceedings*.

Barkai, J. (2018) The ROI of IoT: Quantifying the Strategic Value of IoT, *Internet of Things-Strategy*, pp. 2–8.

Barker Caza, B. and Creary, S. (2016) The construction of professional identity, in: *Perspectives on Contemporary Professional Work*.

Barnaghi, P., Sheth, A. and Henson, C. (2013) From data to actionable knowledge: big data challenges in the web of things, *IEEE Intelligent Systems,* 28 (6), pp. 6–11.

Barney, J. (1991a) Firm Resources and Sustained Competitive Advantage, *Journal of Management*. DOI:10.1177/014920639101700108.

Barney, J. (1991b) Firm Resources and Sustained Competitive Advantage, *Journal of Management*, 17 (1), pp. 99–120. DOI:10.1177/014920639101700108.

Barrett, P. and Sexton, M. (2006) Innovation in small, project-based construction firms, *British Journal of Management*. DOI:10.1111/j.1467-8551.2005.00461.x.

Barthorpe, S., R, D. and Miller, C. (2000) The pluralistic facets of culture and its impact on construction, *Property Management*, 18 (5), pp. 330–321.

References

Baruch, Y. (1999) Response rate in academic studies - A comparative analysis, *Human Relations*. DOI:10.1177/001872679905200401.

Baskerville, R. and Dulipovici, A. (2006) The theoretical foundations of knowledge management, *Knowledge Management Research and Practice*. DOI:10.1057/palgrave.kmrp.8500090.

Bass, B. M. and Stogdill, R. (1990) *Bass & Stogdill's Handbook of Leadership: Theory, research and applications*, *The Free Press*.

Bates, J. (1920) Alternative measures of the size of firms, *Profit, Business Saving and Investment in the United Kingdom*, 1 (1920–1962), pp. 133–149.

Bean, R. and Kiron, D. (2013) Organizational alignment is key to big data success, *MIT Sloan Management Review*.

Becerik-Gerber, B. and Kensek, K. (2010) Building information modeling in architecture, engineering, and construction: Emerging research directions and trends, *Journal of Professional Issues in Engineering Education and Practice*. DOI:10.1061/(ASCE)EI.1943-5541.0000023.

Becerik-Gerber, B. and Rice, S. (2010) The perceived value of building information modeling in the U.S. building industry, *Electronic Journal of Information Technology in Construction*.

Bell, S. and Bell, K. W. (2016) Big Data and Lean Thinking: Balancing Purpose, Process, and People, *Cutter IT Journal*.

Berger, P. and Luckmann, T. (2016) The social construction of reality, in: *Social Theory Re-Wired: New Connections to Classical and Contemporary Perspectives: Second Edition*.

Betts, M. and Ofori, G. (1992) Strategic planning for competitive advantage in construction, *Construction Management and Economics*, 10 (6), pp. 511–532. DOI:10.1080/01446199200000049.

Betts, M. and Ofori, G. (1993) Competitive advantage in construction: Reply, *Construction Management and Economics*. DOI:10.1080/01446199300000067.

Betts, M. and Ofori, G. (1994) Strategic planning for competitive advantage in construction: The institutions, *Construction Management and Economics*, 12 (3), pp. 203–217. DOI:10.1080/01446199400000029.

Bezweek, S. A. and Egbu, C. O. (2009) The role of culture on communication behaviour in public/private organisation: a review of literature, in: *Proceeding International Built Human Environment Research Week, 9th International Post Graduate Research Conference,*.

References

Bezweek, S. and Egbu, C. (2012) Impact of Information Technology in Facilitating Communication and Collaboration in Libyan Public Sector Organisations, *CIB World Congress 2010*.

Bharadwaj, A. S. (2000) A Resource-Based Perspective on Information Technology Capability and Firm Performance: An Empirical Investigation, *MIS Quarterly*, 24 (1), pp. 169. DOI:10.2307/3250983.

Bi, Z. and Cochran, D. (2014) Big data analytics with applications, *Journal of Management Analytics*. DOI:10.1080/23270012.2014.992985.

Bilal, M., Oyedele, L. O., Akinade, O. O., Ajayi, S. O., Alaka, H. A., Owolabi, H. A., Qadir, J., Pasha, M. and Bello, S. A. (2016a) *Big data architecture for construction waste analytics (CWA): A conceptual framework*, *Journal of Building Engineering*. Vol. 6. DOI:10.1016/j.jobe.2016.03.002.

Bilal, M., Oyedele, L. O., Qadir, J., Munir, K., Ajayi, S. O., Akinade, O. O., Owolabi, H. A., Alaka, H. A. and Pasha, M. (2016b) Big Data in the construction industry: A review of present status, opportunities, and future trends, *Advanced Engineering Informatics*, 30 (3), pp. 500–521.

Bilal, M., Oyedele, L. O., Qadir, J., Munir, K., Akinade, O. O., Ajayi, S. O., Alaka, H. A. and Owolabi, H. A. (2015) Analysis of critical features and evaluation of BIM software: towards a plug-in for construction waste minimization using big data, *International Journal of Sustainable Building Technology and Urban Development*, 6 (4), pp. 211–228. DOI:10.1080/2093761X.2015.1116415.

BIS (2013) UK Construction: An economic analysis of the sector, *Department for Business Information & Skills*, (July), pp. 43.

Bloisi, W., Cook, C. W. and Hunsaker, P. L. (2007) *Management & organizational Behaviour*. Maidenhead: McGraw-Hill Education.

Boeykens, S., Wouters, N. and Vande Moere, A. (2016) *BIM, Big Data and Mashup in Architectural Computing, Experimenting with Digital Technologies in Teaching*. London, UK.

Boltho, a (1996) The Assessment: International Competitiveness, *Oxford Review of Economic Policy*, 12 (3), pp. 1–16. DOI:10.1093/oxrep/12.3.1.

Borgia, E. (2014) The Internet of Things vision: Key features, applications and open issues, *Computer Communications*, 54 (2), pp. 1–4.

Bosch-Sijtsema, P., Isaksson, A., Lennartsson, M. and Linderoth, H. C. J. (2017) Barriers and facilitators for BIM use among Swedish medium-sized contractors - “We wait until someone tells us to use it”, *Visualization in Engineering*. DOI:10.1186/s40327-017-0040-7.

References

Bosch-Sijtsema, P. M., Gluch, P. and Sezer, A. A. (2019) Professional development of the BIM actor role, *Automation in Construction*. DOI:10.1016/j.autcon.2018.10.024.

Boyatzis, E. and Richard (1982) The competent manager : a model for effective performance / Richard E.Boyatzis, *Review Hugh Gunz Source: Strategic Management Journal*.

Brannen, J. (2005) Mixed Methods Research: A Discussion Paper, *ESRC National Centre for Research Methods*, pp. 1–30. DOI:10.1658/1100-9233(2004)015[0085:SAAMIP]2.0.CO;2.

Briscoe, G., Dainty, A. R. J. and Millett, S. (2001) Construction supply chain partnerships: Skills, knowledge and attitudinal requirements, *European Journal of Purchasing and Supply Management*. DOI:10.1016/S0969-7012(01)00005-3.

Brown, B., Chui, M. and Manyika, J. (2012) Are you ready for the era of 'big data'?, *McKinsey Quarterly*.

Brown, S. L. and Eisenhardt, K. M. (1995) Product Development: Past Research, Present Findings, and Future Directions, *Academy of Management Review*. DOI:10.5465/amr.1995.9507312922.

Bryde, D., Broquetas, M. and Volm, J. M. (2013) The project benefits of building information modelling (BIM), *International Journal of Project Management*. DOI:10.1016/j.ijproman.2012.12.001.

Bryman, A. (1988) The Nature of Qualitative Research, *Quantity and Quality in Social Research*, pp. 45–71. DOI:10.1136/bmj.2.2973.844-d.

Bryman, A. (2001) Qualitative data analysis, *Social Research Métodos*, pp. 387–404. DOI:10.1136/ebnurs.2011.100352.

Bryman, A. (2008) *Social research methods*. 3rd ed. Oxford: Oxford University Press.

Brynjolfsson, E. and Hitt, L. (1993) Is Information Systems Spending Productive? New Evidence and New Results, *Proceedings of the Fourteenth International Conference on Information Systems*.

Brynjolfsson, E., Hitt, L. and Kim, H. (2011) Strength in numbers: How does data-driven decision-making affect firm performance?, in: *International Conference on Information Systems 2011, ICIS 2011*.

Brynjolfsson, E. and Mcafee, A. (2014) The digitization of just about everything, *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*, pp. 57–70.

BSI (2014) PAS 1192-3:2014 Specification for information management for the operational phase of assets using building information modelling, *BSI Standards Publication*. DOI:Published by the British Standard Institute. British Standard Limited. ISSN9780580781360. /BIM TASK GROUP.

BSI (2015) *BS EN 1995-1-1 :2004+A: Eurocode 5: Design of timber structures - Part 1-1: general - common rules and rules for buildings*, *Design of Structural Elements*. DOI:10.1201/b18121-15.

Buckley, P. J., Pass, C. L. and Prescott, K. (1988) Measures of international competitiveness: A critical survey, *Journal of Marketing Management*, 4 (2), pp. 175–200. DOI:10.1080/0267257X.1988.9964068.

Burger, R. (2015) How the Construction Industry is Using Big Data, *Big Data for a Big Industry*, 4 (5), pp. 3–4.

Burgoyne, J. G. (1994) Managing by Learning, *Management Learning*. DOI:10.1177/1350507694251003.

Burns, T. and Stalker, G. M. (1961) Mechanistic and organic systems, in: *The Management of Innovation*.

Burns, T. and Stalker, G. M. (2009) Chapter 8 - Burns and Stalker, The Management of Innovation, in: *Theories of Organization*.

Burrell, G. and Morgan, G. (1982) *Sociological Paradigms and Organisational Analysis*. London: Heinemann.

Cabinet Office, H. (2011) *Government Construction Strategy*, *Construction*. Vol. 96. DOI:Vol 19.

Calantone, R. J., Harmancioglu, N. and Droge, C. (2010) Inconclusive innovation 'returns' A meta-analysis of research on innovation in new product development, in: *Journal of Product Innovation Management*.

Cameron, K. and Quinn, R. (1999) *Diagnosing and Changing Organizational Culture. Based on the Competing Values Framework*. Boston, MA: Addison-Wesley.

Cameron, K. s. and Quinn, R. E. (2006) *Diagnosing and Changing Organizational Culture: Based on the Competing Values Framework*, *The Jossey-Bass Business & Management Series*. DOI:10.1111/j.1744-6570.2006.00052_5.x.

Cao, D., Li, H. and Wang, G. (2014) Impacts of isomorphic pressures on BIM adoption in construction projects, *Journal of Construction Engineering and Management*. DOI:10.1061/(ASCE)CO.1943-7862.0000903.

References

Caputo, F., Cillo, V., Candelo, E. and Liu, Y. (2019) Innovating through digital revolution: The role of soft skills and Big Data in increasing firm performance, *Management Decision*,

Caruana, A., Morris, M. H. and Vella, A. J. (1998) The effect of centralization and formalization on entrepreneurship in export firms, *Journal of Small Business Management*.

Cattell, K., Flanagan, R. and Jewell, C. A. (2004) Competitiveness and productivity in the construction industry: the importance of definitions, in: Root (ed.) *Construction Industry Development Board (CIDB) 2nd Conference*. Cape Town, South Africa, pp. 25–35.

Cazacliu, B. and Roquet, N. (2009) Concrete mixing kinetics by means of power measurement, *Cement and Concrete Research*. DOI:10.1016/j.cemconres.2008.12.005.

CEBR (2016) *The Value of Big Data and the Internet of Things to the UK Economy*.

Chandler, A. D. (1962) *Strategy and Structure*, *Chapters in the history of the industrial enterprise*. Vol. 4.

Charmaz, K. (1990) 'Discovering' chronic illness: Using grounded theory, *Social Science and Medicine*. DOI:10.1016/0277-9536(90)90256-R.

Chau, K. W., Cao, Y., Anson, M. and Zhang, J. (2003) Application of data warehouse and decision support system in construction management, *Automation in Construction*. DOI:10.1016/S0926-5805(02)00087-0.

Chau, K. W. and Walker, A. (1988) The measurement of total factor productivity of the Hong Kong construction industry, *Construction Management and Economics*, 6 (3), pp. 209–224. DOI:10.1080/01446198800000019.

Chen, C. J. and Huang, J. W. (2007) How organizational climate and structure affect knowledge management-The social interaction perspective, *International Journal of Information Management*. DOI:10.1016/j.ijinfomgt.2006.11.001.

Chen, C. J., Huang, J. W. and Hsiao, Y. C. (2010) Knowledge management and innovativeness: The role of organizational climate and structure, *International Journal of Manpower*. DOI:10.1108/01437721011088548.

Chen, H., Chiang, R. H. L. and Storey, V. C. (2012) Business intelligence and analytics: From big data to big impact, *MIS Quarterly: Management Information Systems*. DOI:10.2307/41703503.

Chen, K., Lu, W., Peng, Y., Rowlinson, S. and Huang, G. Q. (2015) Bridging BIM and building: From a literature review to an integrated conceptual framework, *International Journal of Project Management*. DOI:10.1016/j.ijproman.2015.03.006.

Chen, Y. J., Feng, C. W., Wang, Y. R. and Wu, H. M. (2011) Using bim model and genetic algorithms to optimize the crew assignment for construction project planning, *International Journal of Technology*.

Cheung, S. O., Wong, P. S. P. and Wu, A. W. Y. (2011) Towards an organizational culture framework in construction, *International Journal of Project Management*. DOI:10.1016/j.ijproman.2010.01.014.

Chiang, C. T., Chu, C. P. and Chou, C. C. (2015) BIM-enabled Power Consumption Data Management Platform for Rendering and Analysis of Energy Usage Patterns, in: *Procedia Engineering*.

Child, J. (1974) Managerial and Organisational Factors Associated with Company Performance Part I, *Journal of Management Studies*. DOI:10.1111/j.1467-6486.1974.tb00693.x.

Child, J. (1975) Managerial and Organisational Factors Associated with Company Performance- Part II. A Contingency Analysis, *Journal of Management Studies*. DOI:10.1111/j.1467-6486.1975.tb00884.x.

Child, J. and Mansfield, R. (1972) Technology, Size, and Organization Structure, *Sociology*. DOI:10.1177/003803857200600304.

Cho, D. S., Moon, H. C. and Kim, M. Y. (2008) Characterizing international competitiveness in international business research: A MASI approach to national competitiveness, *Research in International Business and Finance*. DOI:10.1016/j.ribaf.2007.04.002.

Chu, M., Matthews, J. and Love, P. E. D. (2018) Integrating mobile Building Information Modelling and Augmented Reality systems: An experimental study, *Automation in Construction*. DOI:10.1016/j.autcon.2017.10.032.

Chui, M. (2017) Taking the pulse of enterprise IoT, *McKinsey*.

CIOB (2016) *Productivity in Construction: Creating a framework for the industry to thrive*.

CITB (2013) UK construction industry facing skills ‘time bomb’, *Citb*.

Clemons, E. K. (1986) Information systems for sustainable competitive advantage, *Information and Management*. DOI:10.1016/0378-7206(86)90010-8.

Coates, P., Arayici, Y., Koskela, L., Kagioglou, M., Usher, C. and O’Reilly, K. (2019) The key performance indicators of the BIM implementation process, in: *EG-ICE 2010 - 17th International Workshop on Intelligent Computing in Engineering*.

Coates, S. P. (2013) *Bim Implementation Strategy Framework for Small Architectural Practices*. The University of Salford.

Cohen, J. (1988) Statistical power for the social sciences, *Hillsdale, NJ: Laurence Erlbaum and Associates*.

Cohen, W. M. and Klepper, S. (1996) Firm size and the nature of innovation within industries: The case of process and product R&D, *Review of Economics and Statistics*. DOI:10.2307/2109925.

Cohen, W. M. and Levinthal, D. A. (1990) Absorptive Capacity : A New Perspective on and Innovation Learning, *Administrative Science Quarterly*, 35 (1), pp. 128–152. DOI:10.2307/2393553.

Commission of the European Communities (2003) *Commission recommendation of 6 May 2003 concerning the definition of micro, small and medium-sized enterprises*.

Connor, P. E. (1992) Decision-making participation patterns: the role of organizational context., *Academy of Management Journal. Academy of Management*.

Construction Excellence (2016) *UK Industry Performance Report*.

Creswell, J. W. (2007) *Qualitative enquiry & research design, choosing among five approaches*, *Book*. DOI:10.1016/j.aenj.2008.02.005.

Creswell, J. W. (2009) *Research design: Qualitative, quantitative and mixed methods approaches*, Oaks, T. (ed.) . CA: Sage Publications Inc.

Creswell, J. W. (2014) *Research design: Qualitative, quantitative and mixed methods approaches*. 4th ed. CA: Sage Publications Inc.

Dainty, A. (2007) A call for methodological pluralism in Built Environment Research, in: Egbu, C. and Tong, M. (eds.) *Engineering Design and Technology*. Glasgow: Emerald, pp. 1–7.

Dainty, A., Leiringer, R., Fernie, S. and Harty, C. (2017) BIM and the small construction firm: a critical perspective, *Building Research and Information*. DOI:10.1080/09613218.2017.1293940.

Damanpour, F. (1991) Organizational Innovation: A Meta-Analysis Of Effects Of Determinants and Moderators, *Academy of Management Journal*. DOI:10.5465/256406.

Dave, B., Buda, A., Nurminen, A. and Främling, K. (2018) A framework for integrating BIM and IoT through open standards, *Automation in Construction*. DOI:10.1016/j.autcon.2018.07.022.

Davenport, T. H. (2014) How strategists use 'big data' to support internal business decisions, discovery and production, *Strategy and Leadership*. DOI:10.1108/SL-05-2014-0034.

Davey, C. L., Powell, J. A., Cooper, I. and Powell, J. E. (2004) Innovation, construction SMEs and action learning, *Engineering, Construction and Architectural Management*. DOI:10.1108/09699980410547586.

David, F. R. (2011) *Strategic Management: Concepts and Cases (Thirteenth Edition)*, *Prentice Hall*. DOI:10.1688/ZfP-2014-03-Rowold.

Davies, R. and Harty, C. (2012) Control, surveillance and the 'dark side' of BIM, in: Smith, S. D. (ed.) *28th Annual ARCOM Conference*. Edinburgh, UK: Association of Researchers in Construction Management, pp. 31–39.

Day, G. S. and Wensley, R. (1988) Assessing Advantage: A Framework for Diagnosing Competitive Superiority, *Journal of Marketing*, 52 (2), pp. 1. DOI:10.2307/1251261.

De Carvalho, M. M. and Rabechini Junior, R. (2015) Impact of risk management on project performance: The importance of soft skills, *International Journal of Production Research*. DOI:10.1080/00207543.2014.919423.

De Mauro, A., Greco, M., Grimaldi, M. and Nobili, G. (2016) Beyond Data Scientists: a Review of Big Data Skills and Job Families, in: *International Forum on Knowledge Asset Dynamics 2016*.

De Mauro, A., Greco, M., Grimaldi, M. and Ritala, P. (2018) Human resources for Big Data professions: A systematic classification of job roles and required skill sets, *Information Processing and Management*. DOI:10.1016/j.ipm.2017.05.004.

DeCenzo, D. A. and Robbins, S. P. (2013) *Fundamentals of Human Resource Management - Tenth edition*, *Wiley*.

Dedahanov, A. T., Rhee, C. and Yoon, J. (2017) Organizational structure and innovation performance: Is employee innovative behavior a missing link?, *Career Development International*. DOI:10.1108/CDI-12-2016-0234.

Del Giudice, M. (2016) Discovering the Internet of Things (IoT) within the business process management, *Business Process Management Journal*. DOI:10.1108/bpmj-12-2015-0173.

Demchenko, Y., Grosso, P., Laat, C. de and Membrey, P. (2013) Addressing big data issues in scientific data infrastructure, *IEEE International Conference on Collaboration Technologies and Systems (CTS)*, 5 (8), pp. 48–55.

Deng, Z., Guo, H., Zhang, W. and Wang, C. (2014) Innovation and survival of exporters: A contingency perspective, *International Business Review*. DOI:10.1016/j.ibusrev.2013.06.003.

Denyer, D. and Tranfield, D. (2009) Producing a Systematic Review, in: Buchanan, P. D. and Bryman, P. A. (eds.) *The Sage Handbook of Organizational Research Methods*. London: Sage Publications, pp. 671–677.

Department of Trade and Industry (2016) *Industrial Policy Action Plan 2017/18 - 2019/20*, *Department Trade and Industry*.

Dewan, S. and Min, C. (1997) The Substitution of Information Technology for Other Factors of Production: A Firm Level Analysis, *Management Science*, 43 (12), pp. 1660–1675. DOI:10.1287/mnsc.43.12.1660.

Dey, I. (2003) *Qualitative data analysis: A user-friendly guide for social scientists*, *Qualitative Data Analysis: A User-Friendly Guide for Social Scientists*. DOI:10.4324/9780203412497.

Dobson, P., Starkey, K. and Richards, J. (2004) *Strategic Management- Issues and Cases*. 2nd ed. Blackwell Publishing.

Donaldson, L. (2014) *The Contingency Theory of Organizations*, *The Contingency Theory of Organizations*. DOI:10.4135/9781452229249.

Drucker, P. F. (1992) The new society of organizations., *Harvard Business Review*.

Drucker, P. F. (1999) Management Challenges for the 21st Century, *Harvard Business Review*, 86 (3), pp. 74–81. DOI:10.1300/J105v24n03_22.

Dubinsky, A. J., Michaels, R. E., Kotabe, M., Lim, C. U. and Moon, H. (1992) Influence of Role Stress on Industrial Salespeople’s Work Outcomes in the United States, Japan and Korea, *Journal of International Business Studies*. DOI:10.1057/palgrave.jibs.8490260.

Duff, A. R. and Makin, P. J. (1990) Management training needs in the U.K. construction industry, in: *CIB ’90, Building Economics and Construction Management Vol. 6, (Management of the Building Firm), 14-21 March*. Sydney, pp. 140–151.

Dunaway Virginia, M., Sullivan, Y. W. and Fosso Wamba, S. (2019) Building Dynamic Capabilities with the Internet of Things, in: *Proceedings of the 52nd Hawaii International Conference on System*

Sciences.

Eadie, R., Browne, M., Odeyinka, H., Mc keown, C. and Mc niff, S. (2015) A survey of current status of and perceived changes required for BIM adoption in the UK, *Built Environment Project and Asset Management*. DOI:10.1108/BEPAM-07-2013-0023.

Eadie, R., Browne, M., Odeyinka, H., McKeown, C. and McNiff, S. (2013a) BIM implementation throughout the UK construction project lifecycle: An analysis, *Automation in Construction*. DOI:10.1016/j.autcon.2013.09.001.

Eadie, R., Browne, M., Odeyinka, H., McKeown, C. and McNiff, S. (2013b) BIM implementation throughout the UK construction project lifecycle: An analysis, *Automation in Construction*, 36, pp. 145–151. DOI:10.1016/j.autcon.2013.09.001.

Easterby-Smith, M., Thorpe, R. and Lowe, A. (2002) *Management research: An introduction*. 2nd ed. London: Sage Publications Ltd.

Eastman, C., Liston, K., Sacks, R. and Liston, K. (2008) *BIM Handbook Paul Teicholz Rafael Sacks*. DOI:2007029306.

Egan, J. (1998) *Rethinking construction*, *Structural Engineer*. London.

Egbu, C. (2000) Knowledge Management in Construction Smes: Coping With the Issues of Structure, Culture, Commitment and Motivation, *Association of Researchers in Construction Management*.

Egbu, C. O. (1999) Skills, knowledge and competencies for managing construction refurbishment works, *Construction Management and Economics*. DOI:10.1080/014461999371808.

Egbu, C. O. (2004) Managing knowledge and intellectual capital for improved organizational innovations in the construction industry: An examination of critical success factors, *Engineering, Construction and Architectural Management*. DOI:10.1108/09699980410558494.

Engelen, A., Schmidt, S., Strenger, L. and Brettel, M. (2014) Top management's transformational leader behaviors and innovation orientation: A cross-cultural perspective in eight countries, *Journal of International Management*. DOI:10.1016/j.intman.2013.04.003.

Ericsson, S., Henricsson, P. and Jewell, C. (2005) Understanding construction industry competitiveness : the introduction of the Hexagon framework, *Proceedings of the 11th Joint CIB International Symposium Combining Forces - Advancing Facilities Management and Construction through Innovation, 13-16 June , Helsinki, Finland.*

References

Eriksson, C., Cheng, I., Pitman, K., Dixon, T., Van De Wetering, J., Sexton, M., *et al.* (2017) *Smart Cities, Big Data and the Built Environment: What's Required?*

Fellows, R. F. (1993) Competitive advantage in construction: Comment, *Construction Management and Economics*. DOI:10.1080/01446199300000066.

Fetters, M. D., Curry, L. A. and Creswell, J. W. (2013) Achieving integration in mixed methods designs - Principles and practices, *Health Services Research*. DOI:10.1111/1475-6773.12117.

Fikret Pasa, S. (2000) Leadership influence in a high power distance and collectivist culture, *Leadership & Organization Development Journal*. DOI:10.1108/01437730010379258.

Fink, A. (2010) Survey research methods, in: *International Encyclopedia of Education*.

Flanagan, R., Jewell, C., Ericsson, S. and Henricsson, J. P. E. (2005) *Measuring Construction Competitiveness in Selected Countries- Final Report*.

Flanagan, R., Jewell, C. and Lu, W. (2007a) Measuring competitiveness in the construction sector - A new perspective, in: *CME 2007 Conference - Construction Management and Economics: 'Past, Present and Future'*. pp. 1093–1102.

Flanagan, R., Lu, W., Shen, L. and Jewell, C. (2007b) Competitiveness in construction: A critical review of research, *Construction Management and Economics*, 25 (9), pp. 989–1000.

Ford, J. D. and Slocum, J. W. (1977) Size, Technology, Environment and the Structure of Organizations , *Academy of Management Review*. DOI:10.5465/amr.1977.4406731.

Fosso Wamba, S., Akter, S., Edwards, A., Chopin, G. and Gnanzou, D. (2015) How 'big data' can make big impact: Findings from a systematic review and a longitudinal case study, *International Journal of Production Economics*. DOI:10.1016/j.ijpe.2014.12.031.

Franke, R. H., Hofstede, G. and Bond, M. H. (1991) Cultural roots of economic performance: A research note, *Strategic Management Journal*, 12 (Special Issue), pp. 165–173. DOI:10.1002/smj.4250120912.

Freel, M. S. (2005) Patterns of innovation and skills in small firms, *Technovation*. DOI:10.1016/S0166-4972(03)00082-8.

Fuchs, S., Kroll, K. and Nowicke, J. (2018) *A new organizational structure and talent strategy can accelerate digitization in capital projects*.

Furnham, A. and Furnham, A. (2006) Uncertainty avoidance, in: *Management Mumbo-Jumbo*.

References

Gaito, J. (1980) Measurement scales and statistics: Resurgence of an old misconception, *Psychological Bulletin*. DOI:10.1037/0033-2909.87.3.564.

Gammelgaard, B. and Larson, P. D. (2001) Logistics Skills and Competencies for Supply Chain Management, *Journal of Business Logistics*. DOI:10.1002/j.2158-1592.2001.tb00002.x.

Gandomi, A. and Haider, M. (2015) Beyond the hype: Big data concepts, methods, and analytics, *International Journal of Information Management*, 35 (2), pp. 137–144. DOI:10.1016/j.ijinfomgt.2014.10.007.

Garland, R. (1991) The mid-point on a rating scale: Is it desirable, *Marketing Bulletin*, 2 (1), pp. 66–70.

Garyaev, N. and Garyaeva, V. (2019) Big data technology in construction, in: *E3S Web of Conferences*.

Gavious, I., Segev, E. and Yosef, R. (2012) Female directors and earnings management in high-technology firms, *Pacific Accounting Review*. DOI:10.1108/01140581211221533.

Germain, R. (1996) The role of context and structure in radical and incremental logistics innovation adoption, *Journal of Business Research*. DOI:10.1016/0148-2963(95)00053-4.

Ghaffarianhoseini, A., Tookey, J., Ghaffarianhoseini, A., Naismith, N., Azhar, S., Efimova, O. and Raahemifar, K. (2017) Building Information Modelling (BIM) uptake: Clear benefits, understanding its implementation, risks and challenges, *Renewable and Sustainable Energy Reviews*. DOI:10.1016/j.rser.2016.11.083.

Gheisari, M., Goodman, S., Schmidt, J., Williams, G. and Irizarry, J. (2014) Exploring BIM and mobile augmented reality use in facilities management, in: *Construction Research Congress 2014: Construction in a Global Network - Proceedings of the 2014 Construction Research Congress*.

Giacomo, E. (2015) *BIM, trends from all around the world*. European BIM Summit, Barcelona 2015.

Gibbs, G. R. (2007) Analyzing Qualitative Data 4 Thematic coding and categorizing, *Analzing Qualitative Data*. DOI:10.4135/9781849208574.

Gilson, L. L. and Shalley, C. E. (2004) A little creativity goes a long way: An examination of teams' engagement in creative processes, *Journal of Management*. DOI:10.1016/j.jm.2003.07.001.

Giudice, M. Del and Straub, D. (2011) IT and entrepreneurism: an on-again, off-again love affair or a marriage?, *MIS Quarterly*, 35 (4), pp. 3–11.

Gong, Y. (2018) Assessment of Human Factors Analysis and Classification, 2 (January 2019). DOI:10.1007/978-3-319-60525-8.

Good, G. E., Borst, T. S. and Wallace, D. L. (1994) Masculinity research: A review and critique, *Applied and Preventive Psychology*. DOI:10.1016/S0962-1849(05)80104-0.

Goulding, C. (2002) *Grounded Theory: A Practical Guide for Management. Business and Market Researchers*. London: Sage Publications.

Grant, R. M. (1996) Toward a knowledge-based theory of the firm, *Strategic Management Journal*. DOI:10.1002/smj.4250171110.

Gray, C. D. (2012) *IBM SPSS Statistics 19 Made Simple*, *IBM SPSS Statistics 19 Made Simple*. DOI:10.4324/9780203723524.

Green, B. (2016) *Productivity in Construction : Creating a Framework*.

Gu, N. and London, K. (2010) Understanding and facilitating BIM adoption in the AEC industry, *Automation in Construction*. DOI:10.1016/j.autcon.2010.09.002.

Guba, E. G. and Lincoln, Y. S. (1994) Competing paradigms in qualitative research, in: *Handbook of qualitative research*.

Haan, J., Voordijk, H. and Joosten, G. J. (2002) Market strategies and core capabilities in the building industry, *Construction Management and Economics*, 20 (2), pp. 109–118. DOI:10.1080/01446190110108662.

Hackitt, J. a S. F.-I. R. of B. R. and F. S. I. R. (2017) *Building a Safer Future Independent Review of Building Regulations and Fire Safety: Interim Report*, *HM Government*. DOI:ID CCS1117446840.

Hage, J. (1965) An Axiomatic Theory of Organizations, *Administrative Science Quarterly*. DOI:10.2307/2391470.

Hage, J. T. (1999) Organizational Innovation and Organizational Change, *Annual Review of Sociology*. DOI:10.1146/annurev.soc.25.1.597.

Hage, J., Zaltman, G., Duncan, R. and Holbek, J. (1974) Innovation and Organizations., *Administrative Science Quarterly*. DOI:10.2307/2393906.

Hameed, M. A., Counsell, S. and Swift, S. (2012) A meta-analysis of relationships between organizational characteristics and IT innovation adoption in organizations, *Information and Management*. DOI:10.1016/j.im.2012.05.002.

References

Hammersley, M. (2000) Varieties of social research: A typology, *International Journal of Social Research Methodology*, 3 (3), pp. 221–229. DOI:10.1080/13645570050083706.

Hamzah, N., Khoiry, M. A., Arshad, I., Tawil, N. M. and Che Ani, A. I. (2011) Cause of construction delay - Theoretical framework, in: *Procedia Engineering*.

Han, K. K. and Golparvar-Fard, M. (2017) Potential of big visual data and building information modeling for construction performance analytics: An exploratory study, *Automation in Construction*, 73, pp. 184–198. DOI:10.1016/j.autcon.2016.11.004.

Handy, C. (1985) *Understanding organizations*. 4th ed. Penguin Books Limited.

Handy, C. B. (1992) The Age of Unreason., *Organization Studies (Walter de Gruyter GmbH & Co. KG.)*.

Hardie, M. and Newell, G. (2011) Factors influencing technical innovation in construction SMEs: An Australian perspective, *Engineering, Construction and Architectural Management*. DOI:10.1108/09699981111180926.

Hartline, M. D., Maxham, J. G. and McKee, D. O. (2000) Corridors of influence in the dissemination of customer-oriented strategy to customer contact service employees, *Journal of Marketing*. DOI:10.1509/jmkg.64.2.35.18001.

Hartmann, T., Gao, J. and Fischer, M. (2008) Areas of application for 3D and 4D models on construction projects, *Journal of Construction Engineering and Management*. DOI:10.1061/(ASCE)0733-9364(2008)134:10(776).

Heiskanen, A. (2017) The technology of trust: How the Internet of Things and blockchain could usher in a new era of construction productivity, *Construction Research and Innovation*. DOI:10.1080/20450249.2017.1337349.

Heller, F. A. and Porter, L. W. (1966) Perceptions of Managerial Needs and Skills in Two National Samples., *Occupational Psychology*.

Helson, R. (1979) Masculinity and Femininity: Their Psychological Dimensions, Correlates, and Antecedents, *Psychology of Women Quarterly*. DOI:10.1177/036168438000400105.

Henderson, J. R. and Ruikar, K. (2010) Technology implementation strategies for construction organisations, *Engineering, Construction and Architectural Management*. DOI:10.1108/09699981011038097.

References

Henricsson, J. P. E., Ericsson, S., Flanagan, F. and Jewell (2004) Rethinking Competitiveness for the Construction Industry, *Association of Researchers in Construction Management*, 1, pp. 1–3.

Hewitt-Dundas, N. (2006) Resource and capability constraints to innovation in small and large plants, *Small Business Economics*. DOI:10.1007/s11187-005-2140-3.

Hill, A. B. (2015) The environment and disease: association or causation?, *Journal of the Royal Society of Medicine*. DOI:10.1177/0141076814562718.

Hitt, L. M. and Brynjolfsson, E. (1996) Productivity, Business Profitability, and Consumer Surplus: Three Different Measures of Information Technology Value, *MIS Quarterly*, 20 (2), pp. 121. DOI:10.2307/249475.

HM Government (2013) *Industrial Strategy: government and industry in partnership- Construction 2025*. London, UK.

HM Government (2014) *HM Government Horizon Scanning Programme Emerging Technologies : Big Data a Horizon Scanning Research Paper*.

HM Government (2015) *Digital Built Britain Level 3 Building Information Modelling- Strategic Plan*.

HM Government (2017) Invest in Great Britain and Northern Ireland- HM Government. Available from: https://invest.great.gov.uk/us/industries/technology/data-analytics/#the-uks-data-infrastructure-and-talent [Accessed

Hofstede, G. (1991) *Cultures and Organizations*, *Cultures and Organizations*. DOI:10.1007/s11569-007-0005-8.

Hofstede, G. (2001) Culture's Consequences, Second Edition: Comparing Values, Behaviors, Institutions and Organizations Across Nations, in: *Edn, Sage Publications, Inc, Thousand Oaks*.

Hofstede, G. (2002) Dimensions do not exist: A reply to Brendan McSweeney, *Human Relations*. DOI:10.1177/0018726702055011921.

Hofstede, G. (2011) Dimensionalizing Cultures: The Hofstede Model in Context, in: *Online Readings in Psychology and Culture,*. Berkeley Electronic Press,2, pp. 5–8.

Hofstede, G. H. (1980) *Culture's Consequences: International Differences in Work-related Values*, *Cross-Cultural Research and Methodology series*. DOI:10.5465/AME.2004.12689661.

Hofstede, G., Hostede, G. J. and MinkovMichael (2010) *Cultures and Organizations: Software of the Mind*. London: McGraw-Hill, UK.

References

Hollen, R. M. A., Van Den Bosch, F. A. J. and Volberda, H. W. (2013) The Role of Management Innovation in Enabling Technological Process Innovation: An inter-organizational perspective, *European Management Review*. DOI:10.1111/emre.12003.

Holti, R., Nicolini, D. and Smalley, M. (1999) Building Down Barriers-Prime Contractor Handbook of Supply Chain Management, (March), pp. 1–17. Available from: http://www.mod.uk/NR/rdonlyres/B935410C-ACA9-4F1E-B4BC-FCF91D202B93/0/supplychainhandbook.pdf [Accessed

Howard, R. and Björk, B. C. (2008) Building information modelling - Experts' views on standardisation and industry deployment, *Advanced Engineering Informatics*. DOI:10.1016/j.aei.2007.03.001.

Hull, F. and Hage, J. (1982) Organizing for innovation: Beyond burns and stalker's organic type, *Sociology*. DOI:10.1177/0038038582016004006.

IMD (2004) *World Competitiveness Yearbook 2003*. Lausanne, Switzerland.

Infrastructure and Projects Authority (2016) *UK Government Construction Strategy 2016-20*.

Irani, Z. (2002) Information systems evaluation: Navigating through the problem domain, *Information and Management*. DOI:10.1016/S0378-7206(01)00128-8.

Ismail, Z., Doostdar, S. and Harun, Z. (2012) Factors influencing the implementation of a safety management system for construction sites, *Safety Science*. DOI:10.1016/j.ssci.2011.10.001.

Ive, G., Gruneberg, S., Meikle, J. and Crosthwaite, D. (2004) Measuring the Competitiveness of the UK Construction Industry, *Department of Trade and Industry (DTI)*, 1.

Jaafar, M. H., Arifin, K., Aiyub, K., Razman, M. R. and Kamaruddin, M. A. (2018) Human element as the contributing factor towards construction accidents from the perspective of Malaysian residential construction industry, in: *Advances in Intelligent Systems and Computing*.

Jang, S. and Lee, G. (2018) Process, productivity, and economic analyses of BIM–based multi-trade prefabrication—A case study, *Automation in Construction*. DOI:10.1016/j.autcon.2017.12.035.

Jansen, J. J. P., Van Den Bosch, F. A. J. and Volberda, H. W. (2006) Exploratory innovation, exploitative innovation, and performance: Effects of organizational antecedents and environmental moderators, *Management Science*. DOI:10.1287/mnsc.1060.0576.

Jaques, E. (1985) A Look at the Future of Human Resources Work via Stratified Systems Theory, *Human Resource Planning*.

Jassawalla, A. R. and Sashittal, H. C. (2002) Cultures that support product innovation processes, *Academy of Management Executive,* 16 (3), pp. 42–53.

Javed, A. A., Pan, W., Chen, L. and Zhan, W. (2018) A systemic exploration of drivers for and constraints on construction productivity enhancement, *Built Environment Project and Asset Management*, 8 (3), pp. 239–252. DOI:10.1108/BEPAM-10-2017-0099.

Jia, M., Komeily, A., Wang, Y. and Srinivasan, R. S. (2019) Adopting Internet of Things for the development of smart buildings: A review of enabling technologies and applications, *Automation in Construction*. DOI:10.1016/j.autcon.2019.01.023.

Jiao, Y., Wang, Y., Zhang, S., Li, Y., Yang, B. and Yuan, L. (2013a) A cloud approach to unified lifecycle data management in architecture, engineering, construction and facilities management: Integrating BIMs and SNS, *Advanced Engineering Informatics*. DOI:10.1016/j.aei.2012.11.006.

Jiao, Y., Zhang, S., Li, Y., Wang, Y. and Yang, B. (2013b) Towards cloud Augmented Reality for construction application by BIM and SNS integration, *Automation in Construction*. DOI:10.1016/j.autcon.2012.09.018.

Jiao, Y., Zhang, S., Li, Y., Wang, Y., Yang, B. and Wang, L. (2014) An augmented MapReduce framework for Building Information Modeling applications, in: *Proceedings of the 2014 IEEE 18th International Conference on Computer Supported Cooperative Work in Design, CSCWD 2014*.

Johnson, G., Scholes, K. and Whittington, R. (2008) *Exploring Corporate Strategy (8th Edition)*, *Exploring Corporate Strategy (8th Edition)*.

Johnson, G., Scholes, K. and Whittington, R. (2014) *Exploring Strategy, 10th edition*, *Exploring Strategy: text and cases*.

Journal, S., Studies, I. B., Quarter, F. and Global, I. (1993) Influence of formalization on role stress , organizational commitment , and wor ..., *Journal of International Business Studies*.

Jukic, N., Sharma, A., Nestorov, S. and Jukic, B. (2015) Augmenting data warehouses with Big Data, *Information Systems Management*, 32 (3), pp. 200–209.

Kache, F. and Seuring, S. (2017) Challenges and opportunities of digital information at the intersection of Big Data Analytics and supply chain management, *International Journal of Operations and Production Management*. DOI:10.1108/IJOPM-02-2015-0078.

References

Kähkönen, K. and Rannisto, J. (2015) Understanding fundamental and practical ingredients of construction project data management, *Construction Innovation*. DOI:10.1108/CI-04-2014-0026.

Kale, S. (2002) *Competitive advantage in the construction industry: firm-specific resources and strategy*. MI.

Kale, S. and Arditi, D. (2002) Competitive Positioning in United States Construction Industry, *Journal of Construction Engineering and Management*, 128 (3), pp. 238–247. DOI:10.1061/(ASCE)0733-9364(2002)128:3(238).

Kamal, E. M. and Flanagan, R. (2012) Understanding absorptive capacity in Malaysian small and medium sized (SME) construction companies, *Journal of Engineering, Design and Technology*. DOI:10.1108/17260531211241176.

Kanan, R., Elhassan, O. and Bensalem, R. (2018) An IoT-based autonomous system for workers' safety in construction sites with real-time alarming, monitoring, and positioning strategies, *Automation in Construction*. DOI:10.1016/j.autcon.2017.12.033.

Kanter, R. M. (1983) *The Change Masters - Innovation and Entrepreneurship in the American Corporation*, *New York Simon Schuster Inc*.

Kanter, R. M. (2005) Leadership for Change: Enduring Skills for Change Masters, *Harvard Business School Publishing*.

Kassem, M., Jenaban, M., Craggs, D. and Dawood, N. (2016) A Tool for Assessing the Compliance of Project Activities and Deliverables Against the Requirements of Bim Level 2, in: *13th International Conference on Construction Applications of Virtual Reality*.

Kassim, Y., Underwood, J. and Raphael, B. (2009a) Data envelopment analysis of IT-enabled strategy for construction organisations, in: *Association of Researchers in Construction Management, ARCOM 2009 - Proceedings of the 25th Annual Conference*.

Kassim, Y., Underwood, J. and Raphael, B. (2009b) Modeling IT Business Value for Construction Industry: A Conceptual Approach, in: *Proceeding of the 9th …*.

Katz, M. L. and Shapiro, C. (1986) Technology Adoption in the Presence of Network Externalities, *Journal of Political Economy*. DOI:10.1086/261409.

Katz, R. L. (1955) Skills of an Effective Administrator., *Harvard Business Review*. DOI:Article.

Kelly, D. A. (2018) Who Needs A Strategy, Anyway?, *Teradata Magazine*, pp. 4–10.

References

Kemp, A. and Saxon CBE, R. (2016) BIM in the UK : Past , Present & Future, *UK BIM Alliance*.

Ketels, C. (2016) *Review of Competitiveness Frameworks*.

Khosrowshahi, F. and Arayici, U. (2012a) Roadmap for implementation of BIM in the UK construction industry, *Engineering, Construction and Architectural Management*, 19 (6), pp. 610–635.

Khosrowshahi, F. and Arayici, Y. (2012b) Roadmap for implementation of BIM in the UK construction industry, *Engineering, Construction and Architectural Management*. DOI:10.1108/09699981211277531.

Kim, H., Soibelman, L. and Grobler, F. (2008) Factor selection for delay analysis using Knowledge Discovery in Databases, *Automation in Construction*. DOI:10.1016/j.autcon.2007.10.001.

Kimberly, J. R., Nord, W. R. and Tucker, S. (1988) Implementating Routine and Radical Innovations., *Administrative Science Quarterly*. DOI:10.2307/2393064.

Koonce, D., Huang, L. and Judd, R. (1998) EQL an Express Query Language, *Computers and Industrial Engineering*.

Kopanakis, I. and Mastorakis, G. (2016) Big Data in Data-driven Innovation : The Impact in E nterprises ' Performance, in: *11th Management of Innovative Business, Education & Support systems International Conference*.

Koseleva, N. and Ropaite, G. (2017) Big Data in Building Energy Efficiency: Understanding of Big Data and Main Challenges, in: *Procedia Engineering*.172, pp. 544–549.

Kumar, B. (2016) *Practical Guide to Adopting BIM in Construction Projects*, *Language*.

Kumar, K., Boesso, G., Favotto, F. and Menini, A. (2012) Strategic orientation, innovation patterns and performances of SMEs and large companies, *Journal of Small Business and Enterprise Development*. DOI:10.1108/14626001211196442.

Kwon, O., Lee, N. and Shin, B. (2014) Data quality management, data usage experience and acquisition intention of big data analytics, *International Journal of Information Management*. DOI:10.1016/j.ijinfomgt.2014.02.002.

Lall, S. (2001) Competitiveness indices and developing countries: An economic evaluation of the global competitiveness report, *World Development*. DOI:10.1016/S0305-750X(01)00051-1.

Lam, T. T., Mahdjoubi, L. and Mason, J. (2017) A framework to assist in the analysis of risks and rewards of adopting BIM for SMEs in the UK, *Journal of Civil Engineering and Management*. DOI:10.3846/13923730.2017.1281840.

Laney, D. (2001) 3D Data Management: Controlling Data Volume, Velocity, and Variety., *Application Delivery Strategies*. DOI:10.1016/j.infsof.2008.09.005.

Langford, D. and Male, S. (2001) *Strategic Management in Construction*. 2nd ed. Oxford: Blackwell Science.

Leavitt, H. J. (2004) Top Down: Why Hierarchies Are Here to Stay and How to Manage Them More Effectively , in: *Harvard Business School Press Books*.

Lee, J. G. and Kang, M. (2015) Geospatial Big Data: Challenges and Opportunities, *Big Data Research*. DOI:10.1016/j.bdr.2015.01.003.

Leonard, D. B. (1995) Wellspring of knowledge, *Boston: Harvard Business School*, pp. 1–17.

Li, J., Greenwood, D. and Kassem, M. (2019) Blockchain in the built environment and construction industry: A systematic review, conceptual models and practical use cases, *Automation in Construction*. DOI:10.1016/j.autcon.2019.02.005.

Lichtenthaler, U. (2009) Absorptive capacity, environmental turbulence, and the complementarity of organizational learning processes, *Academy of Management Journal*. DOI:10.5465/AMJ.2009.43670902.

Lin, E. T. A., Ofori, G., Tjandra, I. and Kim, H. (2017) Framework for productivity and safety enhancement system using BIM in Singapore, *Engineering, Construction and Architectural Management*, 24 (6), pp. 1350–1371. DOI:10.1108/ECAM-05-2016-0122.

Lin, J. R., Hu, Z. Z., Zhang, J. P. and Yu, F. Q. (2016) A Natural-Language-Based Approach to Intelligent Data Retrieval and Representation for Cloud BIM, *Computer-Aided Civil and Infrastructure Engineering*. DOI:10.1111/mice.12151.

Liu, S., Xie, B., Tivendal, L. and Liu, C. (2015a) Critical Barriers to BIM Implementation in the AEC Industry, *International Journal of Marketing Studies*, 7 (6), pp. 162.

Liu, Y. (2014) Big Data and Predictive Business Analytics, *The Journal of Business Forecasting*.

Liu, Y., Zhong, D., Cui, B., Zhong, G. and Wei, Y. (2015b) Study on real-time construction quality monitoring of storehouse surfaces for RCC dams, *Automation in Construction*. DOI:10.1016/j.autcon.2014.10.003.

References

Lock, M. (2012) *Data Management for BI: Big Data, Bigger Insight, Data Management for BI: Big Data, Bigger Insight, Superior Performance*.

Löfgren, K., Niemi, E., Mäkitalo-Siegl, K., Mekota, A.-M., Ojala, M., Fischer, F., *et al.* (2013) Meeting the Challenges of Generational Change in the Teaching Profession: Towards a European Model for Intergenerational Teacher Collaboration, *Educational Research EJournal*. DOI:10.5838/erej.2013.22.03.

Louis, M. R., Burrell, G. and Morgan, G. (2006) Sociological Paradigms and Organizational Analysis., *Administrative Science Quarterly*. DOI:10.2307/2392394.

Love, P. E. D. and Irani, Z. (2004) An exploratory study of information technology evaluation and benefits management practices of SMEs in the construction industry, *Information and Management*. DOI:10.1016/j.im.2003.12.011.

Lovelace, R. F. (1986) Stimulating creativity through managerial intervention, *R&D Management*. DOI:10.1111/j.1467-9310.1986.tb01169.x.

Lu, W. (2006) *A system for assessing and communicating contractors' competitiveness: (WEF) The Global Competitiveness Report, World Economic Forum*. The Hong Kong Polytechnic University.

Lu, W., Chen, X., Peng, Y. and Shen, L. (2015) Benchmarking construction waste management performance using big data, *Resources, Conservation and Recycling*, 105, pp. 49–58. DOI:10.1016/j.resconrec.2015.10.013.

Lundberg, C. C. and Mintzberg, H. (1991) Mintzberg on Management: Inside Our Strange World of Organizations., *Industrial and Labor Relations Review*. DOI:10.2307/2524475.

Madanayake, U. and Egbu, C. (2017) A Systematic Review for the Challenges Related to the Implementation of Building Information Modelling, Big Data Analytics and Internet of Things (BBI) in the Construction Sector, in: *International Conference on Sustainable Futures- ICSF 2017 26 – 27 November 2017*. Amwaj Islands, Kingdom of Bahrain: Applied Science University, pp. 409–420.

Male, S. and Stocks, R. (1991) *Competitive Advantage in Construction*. Surrey: Butterworth-Heinemann Ltd.

Mansouri, S. and Akhavian, R. (2018) The Status Quo and Future Potentials of Data Analytics in AEC/FM: A Quantitative Analysis of Academic Research and Industry Outlook, in: *Construction Research Congress 2018: Infrastructure and Facility Management - Selected Papers from the Construction Research Congress 2018*.

References

Manyika, J., Chui Brown, M., B. J., B., Dobbs, R., Roxburgh, C. and Hung Byers, A. (2011a) Big data: The next frontier for innovation, competition and productivity, *McKinsey Global Institute*.

Manyika, J., Chui, M., Brown, B., Bughin, J., Dobbs, R., Roxburgh, C. and Byres, A. H. (2011b) Big data: The next frontier for innovation, competition, and productivity, *McKinsey Global Institute*, (June), pp. 156. DOI:10.1080/01443610903114527.

March, J. G. (1991) Exploration and Exploitation in Organizational Learning, *Organization Science*. DOI:10.1287/orsc.2.1.71.

Marjani, M., Nasaruddin, F., Gani, A., Karim, A., Hashem, I. A. T., Siddiqa, A. and Yaqoob, I. (2017) Big IoT Data Analytics: Architecture, Opportunities, and Open Research Challenges, *IEEE Access*. DOI:10.1109/ACCESS.2017.2689040.

Marr, B. (2018) How Much Data Do We Create Every Day? The Mind-Blowing Stats Everyone Should Read, *Forbes*.

Marsh, R. M. and Mannari, H. (1981) Technology and Size as Determinants of the Organizational Structure of Japanese Factories, *Administrative Science Quarterly*. DOI:10.2307/2392598.

Martin, G. and Reddington, M. (2009) Reconceptualising absorptive capacity to explain the e-enablement of the HR function (e-HR) in organizations, *Employee Relations*. DOI:10.1108/01425450910979266.

Martínez-Rojas, M., Marín, N. and Vila, M. A. (2016) The role of information technologies to address data handling in construction project management, *Journal of Computing in Civil Engineering*. DOI:10.1061/(ASCE)CP.1943-5487.0000538.

Marzouk, M. and Enaba, M. (2019) Analyzing project data in BIM with descriptive analytics to improve project performance, *Built Environment Project and Asset Management*. DOI:10.1108/BEPAM-04-2018-0069.

Mason, J. (2002) *Qualitative Researching 2nd Edition*, *Qualitative Research Book*. DOI:10.1159/000105503.

Mata, F. J., Fuerst, W. L. and Barney, J. B. (1995) Information technology and sustained competitive advantage: A resource-based analysis, *MIS Quarterly: Management Information Systems*.

Mayer-Schonberger, V. and Cukier, K. (2012) *Big Data: A Revolution that will transform how we live, work and think*, *CEUR Workshop Proceedings*. DOI:10.1017/CBO9781107415324.004.

References

Mazairac, W. and Beetz, J. (2013) BIMQL - An open query language for building information models, *Advanced Engineering Informatics*. DOI:10.1016/j.aei.2013.06.001.

Mcafee, A. and Brynjolfsson, E. (2009) Investing in the IT That Makes a Competititve Difference, *Harvard Business Review*. DOI:0546.

McGraw Hill Construction (2014) *The business value of BIM for construction in major global markets*, *SmartMarket Report*.

Mckinsey Global Institute (2016) *How digitally advanced in your sector*.

Meadati, P., Irizarry, J. and Akhnoukh, A. K. (2010) BIM and RFID Integration: A Pilot Study, *Second International Conference on Construction in Developing Countries*.

Melville, N., Kraemer, K. and Gurbaxani, V. (2004) Review: Information technology and organizational performance: An integrative model of it business value, *MIS Quarterly: Management Information Systems*.

Merkin, R. S. (2006) Uncertainty avoidance and facework: A test of the Hofstede model, *International Journal of Intercultural Relations*. DOI:10.1016/j.ijintrel.2005.08.001.

Michaels, R. E., Dubinsky, A. J., Kotabe, M. and Un Lim, C. (1996) The effects of organizational formalization on organizational commitment and work alienation in US, Japanese and Korean industrial salesforces, *European Journal of Marketing*. DOI:10.1108/03090569610123799.

Mikalef, P., Giannakos, M. N., Pappas, I. O. and Krogstie, J. (2018) The human side of big data: Understanding the skills of the data scientist in education and industry, in: *IEEE Global Engineering Education Conference, EDUCON*.

Mikalef, P. and Krogstie, J. (2019) Investigating the data science skill gap: An empirical analysis, in: *IEEE Global Engineering Education Conference, EDUCON*.

Miles, M. B. and Huberman, A. M. (1994) *An expanded sourcebook: Qualitative data analysis (2nd Edition)*, *Sage Publications*. DOI:10.1016/0149-7189(96)88232-2.

Miller, D. (1983) The Correlates of Entrepreneurship in Three Types of Firms, *Management Science*. DOI:10.1287/mnsc.29.7.770.

Minsky, M. (1992) A Framework for Representing Knowledge, *The Psychology of Computer Vision*, MIT-AI Lab (1972), pp. 1–116.

Mintzberg, H. (1987a) The strategy concept: Five Ps for strategy, *California Management Review*, 1

(30), pp. 11–24.

Mintzberg, H. (1987b) The Strategy Concept 1: 5 Ps for Strategy, *California Management Review*.

Mintzberg, H. (1990) Strategy formation: Schools of thought, in: *Perspectives on Strategic Management*. pp. 105–237.

Mishra, D., Luo, Z., Jiang, S., Papadopoulos, T. and Dubey, R. (2017) A bibliographic study on big data: concepts, trends and challenges, *Business Process Management Journal*, 23 (3), pp. 555–573. DOI:10.1108/BPMJ-10-2015-0149.

Mishra, R. and Sharma, R. (2015) Big data: opportunities and challenges, *International Journal of Computer Science and Mobile Computing*, 4 (6), pp. 27–35.

Mobley, W. H., Wang, L. and Fang, K. (2005) Organizational Culture: Measuring and Developing It in Your Organization, *Harvard Business Review China*, pp. 128–139. DOI:10.1111/j.1740-8784.2006.00050.x.

Momaya, K. (1998) Evaluating international competitiveness at the industry level, *Vikalpa*, 23 (2), pp. 39–46. DOI:10.1177/0256090919980206.

Momaya, K. and Selby, K. (1998) International competitiveness of the Canadian construction industry: a comparison with Japan and the United States, *Canadian Journal of Civil Engineering*, 25 (4), pp. 640–652. DOI:10.1139/cjce-25-4-640.

Moon, H. C., Rugman, A. M. and Verbeke, A. (1995) The generalized double diamond approach to international competitiveness, in: Rugman, A. M. (ed.) *Beyond The Diamond-Research in Global Strategic Management: A Research Annual*. Greenwich: JAI Press, pp. 97–114.

Moon, H. C., Rugman, A. M. and Verbeke, A. (1998) A generalized double diamond approach to the global competitiveness of Korea and Singapore, *International Business Review*, 7 (2), pp. 135–150. DOI:10.1016/S0969-5931(98)00002-X.

Moon, H. S., Kim, H. S., Kang, L. S. and Kim, C. H. (2012) BIM functions for optimized construction management in civil engineering, in: *2012 Proceedings of the 29th International Symposium of Automation and Robotics in Construction, ISARC 2012*.

Motawa, I. (2017) Spoken dialogue BIM systems – an application of big data in construction, *Facilities*. DOI:10.1108/F-01-2016-0001.

Motawa, I. and Almarshad, A. (2013) A knowledge-based BIM system for building maintenance, *Automation in Construction*. DOI:10.1016/j.autcon.2012.09.008.

Mumford, A. (1987) Learning Styles and Learning, *Personnel Review*. DOI:10.1108/eb055565.

Mumford, A. (1995) Four approaches to learning from experience, *Industrial and Commercial Training*. DOI:10.1108/00197859510791567.

Mumford, M. D., Zaccaro, S. J., Connelly, M. S. and Marks, M. A. (2000) Leadership skills: Conclusions and future directions, *Leadership Quarterly*. DOI:10.1016/S1048-9843(99)00047-8.

Nam, C. H. and Tatum, C. B. (1997) Leaders and champions for construction innovation, *Construction Management and Economics*. DOI:10.1080/014461997372999.

Naoum, S. G. (2012) *Dissertation Research and Writing for Construction Students*. Third. Routledge.

Navendren, D., Manu, P., Mahamadu, A.-M., Shelbourn, M. and Wildin, K. (2014) Briefing: Towards exploring profession-specific BIM challenges in the UK, *Management, Procurement and Law*, 167 (4), pp. 163–172.

Nayir, D. Z., Tamm, U. and Durmusoglu, S. S. (2014) How formalization hinders different firm innovativeness types: Opening the black box with evidence from a service industry, *International Journal of Innovation and Technology Management*. DOI:10.1142/S0219877014500291.

NBS (2016) *NBS International BIM Report 2016*.

NBS (2019) National BIM Report 2019, *National BIM Report 2019 The Definitive Industry Update*. DOI:10.1017/CBO9781107415324.004.

Neuman, L. (2011) *Social Research Methods: Qualitative and quantitative approaches*. 7th ed. USA: Parson.

Newbould, G. D. and Wilson, K. W. (1977) Alternative measures of company size:- A note for researchers, *Ournal of Business Finance & Accounting*, 4 (1), pp. 131- 132.

Newcombe, R., Langford, D. and Fellows, R. (1990) *Construction Management*. London, UK: Mitchell in association with the Chartered Institute of Building.

Newton, C. and ôConsultant (1983) The competent manager: A model for effective performance, *Long Range Planning*. DOI:10.1016/0024-6301(83)90170-x.

Newton, K. L. and Chileshe, N. (2012) Awareness, usage and benefits of BIM adoption – the case of south Australian construction organizations, in: Smith, S. D. (ed.) *28th Annual ARCOM Conference*.

Edinburgh, UK: Association of Researchers in Construction Management, pp. 3–12.

Ng, S. tong T., Wong, J. M. W., Chiang, Y. H. and Lam, P. T. I. (2018) Improving the competitive advantages of construction firms in developed countries, *Proceedings of the Institution of Civil Engineers: Municipal Engineer*. DOI:10.1680/jmuen.17.00002.

Nitithamyong, P. and Skibniewski, M. J. (2004) Web-based construction project management systems: How to make them successful?, *Automation in Construction*. DOI:10.1016/j.autcon.2004.02.003.

Nonaka, I. (1994) A Dynamic Theory of Organizational Knowledge Creation, *Organization Science*. DOI:10.1287/orsc.5.1.14.

Nonaka, I. and Takeuchi, H. (1995) Knowledge-Creating Company, *Knowledge-Creating Company*. DOI:10.1016/S0969-4765(04)00066-9.

Nor, F. M. and Egbu, C. (2010) An insight into knowledge sharing practices in Quantity Surveying firms in Malaysia, in: *Association of Researchers in Construction Management, ARCOM 2010 - Proceedings of the 26th Annual Conference*.

Nord, J. H., Koohang, A. and Paliszkiewicz, J. (2019) The Internet of Things: Review and theoretical framework, *Expert Systems with Applications*. DOI:10.1016/j.eswa.2019.05.014.

Nummelin, J. (2005) Uncertainty Management Concerning Cultural Dynamics in Project Management- Case Study, in: *19th IPMA World Congress*. New Delhi,.

Office for National Statistics (2020) Construction output in Great Britain: January 2020, *ons.gov.uk*.

Oh, W. and Pinsonneault, A. (2007) On the assessment of the strategic value of information technologies: Conceptual and analytical approaches, *MIS Quarterly: Management Information Systems*.

Ones, D., Anderson, N., Sinangil, H., Viswesvaran, C., Anderson, N., Potočnik, K., Bledow, R., Hülsheger, U. R. and Rosing, K. (2017) Innovation and Creativity in Organizations, in: *The SAGE Handbook of Industrial, Work and Organizational Psychology*.

Ouchi, W. G. (2006) Power to the principals: Decentralization in three large school districts, *Organization Science*. DOI:10.1287/orsc.1050.0172.

Oyedele, L. O. (2016) *Big Data and Sustainability: The next step for Circular Economy*.

Pallant, J. (2011) *SPSS survival manual: a step by step guide to data analysis using IBM SPSS (4th* *ed.), Allen & Unwin, 83 Alexander Street - Crows Nest NSW 2065 - Autralia*. DOI:10.1046/j.1365-2648.2001.2027c.x.

Pallant, J. (2013) *SPSS Survival Manual 5th ed.*, *Allen & Unwin*.

Panuwatwanich, K. and Peansupap, V. (2013) Factors affecting the current diffusion of BIM: a qualitative study of online professional network, *In Creative Construction Conference, Budapest, Hungary*.

Parker, R. (2017) AEC sector dominates BIM use in world survey, *Modern Building Services*.

Pasini, D., Mastrolembo Ventura, S., Rinaldi, S., Bellagente, P., Flammini, A. and Ciribini, A. L. C. (2016) Exploiting internet of things and building information modeling framework for management of cognitive buildings, in: *IEEE 2nd International Smart Cities Conference: Improving the Citizens Quality of Life, ISC2 2016 - Proceedings*.

Pathirage, C. P., Amaratunga, D. G. and Haigh, R. P. (2007) Tacit knowledge and organisational performance: Construction industry perspective, *Journal of Knowledge Management*. DOI:10.1108/13673270710728277.

Penrose, E. (1959) *Theory of the growth of the firm*, *Theory of the Growth of the Firm*.

Penrose, E. T. (1955) Limits to the Growth and Size of Firms, *American Economic Review*. DOI:10.1257/jep.6.3.79.

Perner, P. (2015) *Big Data Analysis and Reporting with Decision Tree Induction*, Mastorakis, N. E. and Rudas, I. J. (eds.) *Advances in Information Science and Computer Engineering, CEA`15, Feb. 22-24*.

Pertusa-Ortega, E. M., Zaragoza-Sáez, P. and Claver-Cortés, E. (2010) Can formalization, complexity, and centralization influence knowledge performance?, *Journal of Business Research*. DOI:10.1016/j.jbusres.2009.03.015.

Phaal, R. (2004) Technology roadmapping - A planning framework for evolution and revolution, *Technological Forecasting and Social Change*. DOI:10.1016/S0040-1625(03)00072-6.

Pierce, J. L. and Delbecq, A. L. (1977) Organization Structure, Individual Attitudes and Innovation., *Academy of Management Review*. DOI:10.5465/amr.1977.4409154.

Pinto, J. K. and Slevin, D. P. (1987) Critical Factors in Successful Project Implementation, *IEEE Transactions on Engineering Management*. DOI:10.1109/TEM.1987.6498856.

References

Polansky, S. H. and Hughes, D. W. W. (1986) Managerial Innovation in Newspaper Organizations, *Newspaper Research Journal*. DOI:10.1177/073953298600800101.

Porter, M. E. (1980a) Competitive Strategy- Techniques for Analyzing Industries and Competitors, *Techniques for Analyzing Industries and Competitors : With a New Introduction*. DOI:10.1002/jsc.540.

Porter, M. E. (1980b) *Competitive strategy: Techniques for analyzing industries and companies*, *New York*. DOI:10.1002/smj.4250020110.

Porter, M. E. (1985) Competitive Advantage: Creating and Sustaining Superior Performance, *Competitive Advantage*, 15, pp. 1–30. DOI:10.1182/blood-2005-11-4354.

Porter, M. E. (1990) *The Competitive Advantage of Nations*. Republishe. New York: Free Press.

Porter, M. E. (1996) What is Strategy?, *Harvard Business Review*, pp. 1–20. DOI:10.1016/j.cell.2005.09.009.

Porter, M. E. and Millar, V. E. (1985) How information gives you competitive advantage, *Harvard Buiness Review*, 63 (4), pp. 149. DOI:10.1038/bdj.2007.481.

Porwal, A. and Hewage, K. (2013) Building Information Modeling (BIM) partnering framework for public construction projects, *Automation in Construction*, 31, pp. 210–218. Available from: http://www.sciencedirect.com/science/article/pii/S0926580512002439 [Accessed

Prahalad, C. and Hamel, G. (1990) The Core Competence of the Corporation, *Harvard Business Review*, 68 (3), pp. 79. DOI:10.1007/3-540-30763-X_14.

Prahalad, C. K. and Hamel, G. (2007) The core competence of the corporation, in: *Software Management, Seventh Edition*.

Pugh, D. S., Hickson, D. J., Hinings, C. R. and Turner, C. (1968) Dimensions of Organization Structure, *Administrative Science Quarterly*. DOI:10.2307/2391262.

Puying, L., Parsa, A., Huston, S. and Kashyap, A. (2017) The International Competitiveness of Chinese Construction Firms, in: *European Real Estate Society 24th Annual Conference*. Netherlands,.

PwC (2019) Financial Services Technology 2020 and Beyond: Embracing disruption, *Civil Engineering Magazine Archive*. DOI:10.1061/ciegag.0001345.

Raguseo, E. (2018) Big data technologies: An empirical investigation on their adoption, benefits and risks for companies, *International Journal of Information Management*.

DOI:10.1016/j.ijinfomgt.2017.07.008.

Rahman, R. A., Alsafouri, S., Tang, P. and Ayer, S. K. (2016) Comparing Building Information Modeling Skills of Project Managers and BIM Managers Based on Social Media Analysis, in: *Procedia Engineering*.

Rahman, R. A. and Ayer, S. K. (2019) Enhancing the non-technological skills required for effective building information modeling through problem-based learning, *Journal of Information Technology in Construction*.

Rahmat, I. and Ali, A. S. (2010) The effects of formalisation on coordination and effectiveness of refurbishment projects, *Facilities*. DOI:10.1108/02632771011066576.

Ram, J., Afridi, N. K. and Khan, K. A. (2019) Adoption of Big Data analytics in construction: development of a conceptual model, *Built Environment Project and Asset Management*. DOI:10.1108/BEPAM-05-2018-0077.

Ransbotham, S., Kiron, D. and Prentice, P. K. (2015) Minding the analytics gap, *MIT Sloan Management Review*.

Reinhard, G., Jesper, V. and Stefan, S. (2016) Industry 4.0: Building the digital enterprise, *2016 Global Industry 4.0 Survey*. DOI:10.1080/01969722.2015.1007734.

Reyes, P., Suresh, S. and Renukappa, S. (2019) The adoption of big data concepts for sustainable practices implementation in the construction industry, in: *Proceedings - 11th IEEE/ACM International Conference on Utility and Cloud Computing Companion, UCC Companion 2018*.

Reza Hosseini, M., Pärn, E. A., Edwards, D. J., Papadonikolaki, E. and Oraee, M. (2018) Roadmap to Mature BIM Use in Australian SMEs: Competitive Dynamics Perspective, *Journal of Management in Engineering*. DOI:10.1061/(ASCE)ME.1943-5479.0000636.

Roberts, N. and Grover, V. (2012) Leveraging Information Technology Infrastructure to Facilitate a Firm's Customer Agility and Competitive Activity: An Empirical Investigation, *Journal of Management Information Systems*, 28 (4), pp. 231–270. DOI:10.2753/MIS0742-1222280409.

Robson, A., Boyd, D. and Thurairajah, N. (2016) UK Construction Supply Chain Attitudes to BIM, 2016 (2003).

Robson, C. (2002) *Real World Research*. 2nd ed. Oxford: Blackwell.

Rogers, E. M. (1995) *Diffusion of Innovations-Fourth Edition*, *Everett M. Rogers*. DOI:citeulikearticle-id:126680.

Rothwell, R. and Gardiner, P. (1985) Invention, innovation, re-innovation and the role of the user: A case study of British hovercraft development, *Technovation*. DOI:10.1016/0166-4972(85)90012-4.

Rugman, A. M. and D'Cruz, J. R. (1993) The 'Double Diamond' Model of International Competitiveness: The Canadian Experience, *Management International Review*, 33, pp. 17–39. DOI:10.2307/40228188.

Ruikar, K., Anumba, C. J. and Egbu, C. (2007) Integrated use of technologies and techniques for construction knowledge management, *Knowledge Management Research and Practice*. DOI:10.1057/palgrave.kmrp.8500154.

Rumelt, R. P. (2005) Theory, Strategy, and Entrepreneurship, in: *Handbook of Entrepreneurship Research*.

Russom, P. (2013) *Managing Big Data*.

Sacks, Rafael, Eastman, Charles M., Lee, Ghang, Teicholz, P. M. (2018) *BIM Handbook A Guide to Building Information Modeling for Owners, Designers, Engineers, Contractors, and Facility Managers*, *Wiley*. DOI:10.1017/CBO9781107415324.004.

Safa, M. and Hill, L. (2019) Necessity of big data analysis in construction management, *Strategic Direction*. DOI:10.1108/SD-09-2018-0181.

Sangole, A. and Ranit, A. (2015) Identifying Factors Affecting Construction Labour Productivity in Amravati, *International Journal of Science and Research (IJSR)*, 4 (5), pp. 1585–1588.

Santoro, G., Vrontis, D., Thrassou, A. and Dezi, L. (2018) The Internet of Things: Building a knowledge management system for open innovation and knowledge management capacity, *Technological Forecasting and Social Change*. DOI:10.1016/j.techfore.2017.02.034.

Sanyal, J. and New, J. (2013) Simulation and big data challenges in tuning building energy models, in: *2013 Workshop on Modeling and Simulation of Cyber-Physical Energy Systems (MSCPES)*. pp. 1–6.

Sanz-Valle, R., Naranjo-Valencia, J. C., Jiménez-Jiménez, D. and Perez-Caballero, L. (2011) Linking organizational learning with technical innovation and organizational culture, *Journal of Knowledge Management*. DOI:10.1108/13673271111179334.

References

SAS (2016) *The Value of Big Data and the Internet of Things to the UK Economy*, *Report for SAS by Centre for economic reforms*.

Saunders, M., Lewis, P. and Thornhill, A. (2009) *Rsearch Methods for Business Students*. Fifth. Harlow: Pearson Education Limited.

Schweigkofler, A., Monizza, G. P., Domi, E., Popescu, A., Ratajczak, J., Marcher, C., Riedl, M. and Matt, D. (2018) Development of a digital platform based on the integration of augmented reality and BIM for the management of information in construction processes, in: *IFIP Advances in Information and Communication Technology*.

Scuotto, V., Ferraris, A. and Bresciani, S. (2016) Internet of Things: Applications and challenges in smart cities: a case study of IBM smart city projects, *Business Process Management Journal*. DOI:10.1108/BPMJ-05-2015-0074.

Sekaran, U. (2006) Research Method for Business: A skill building approach, in: *John Wiley and Sons.*

Senna, P., Ferreira, L., Barros, A. and Magalhães, V. (2019) Barriers to Adoption Industry 4 . 0 : ISM & MICMAC analysis with TOE categorization, *Academy of Management Journal and Academy of Management Review*.

Sepasgozar, S. M. E., Bernold, L. E., Gha, A. A., Tookey, J., Gha, A. A., Naismith, N., *et al.* (2013) Factors Influencing Construction Technology Adoption, *Automation in Construction*. DOI:10.1016/j.autcon.2013.09.001.

Sethi, R. (2000) New product quality and product development teams, *Journal of Marketing*. DOI:10.1509/jmkg.64.2.1.17999.

Shelton, J., Martek, I. and Chen, C. (2016) Implementation of innovative technologies in small-scale construction firms: Five Australian case studies, *Engineering, Construction and Architectural Management*. DOI:10.1108/ECAM-01-2015-0006.

Shen, L., Lu, W. and Yam, M. (2006) Contractor key competitiveness indicators: A China study, *Journal of Construction Engineering and Management*, 132 (April), pp. 416–424. DOI:10.1061/(ASCE)0733-9364(2006)132:4(416).

Shen, L. and Tan, Y. (2005) Applying the fuzzy resources allocation (Fra) model by different contractors for different types of projects, in: *CRIOCM 2005 International Symposium on Advancement of Construction Management and Real Estate*. HangZhou, China, pp. 212–23.

Shepard, H. A. (1967) Innovation-Resisting and Innovation-Producing Organizations, *The Journal of*

Business. DOI:10.1086/295012.

Simonton, D. K., West, M. A. and Farr, J. L. (1992) Innovation and Creativity at Work: Psychological and Organizational Strategies., *Administrative Science Quarterly*. DOI:10.2307/2393481.

Siudek, T. and Zawojska, A. (2014) Competitiveness in the Economic Concepts, Theories and Emperical Research, *Oeconomia*, 13 (1), pp. 91–108.

Sivarajah, U., Kamal, M. M., Irani, Z. and Weerakkody, V. (2017) Critical analysis of Big Data challenges and analytical methods, *Journal of Business Research*, 70, pp. 263–286.

Skillett, G. (2017) An Introduction to Big Data in Construction, *Rhumbix Blog*. Available from: http://blog.rhumbix.com/introduction-to-big-data-in-construction [Accessed 23 August 2017].

Smircich, L. (1983) Concepts of culture and organisational analysis, *Administrative Science Quarterly*, 28 (3), pp. 58–339.

Smith, D. K. and Tardiff, M. (2009) *Building Information Modeling: A Strategic Implementation Guide for Architects, Engineers, Constructors, and Real Estate Asset Managers*, *Building Information Modeling: A Strategic Implementation Guide for Architects, Engineers, Constructors, and Real Estate Asset Managers*. DOI:10.1002/9780470432846.

Song, X. M., Montoya-Weiss, M. M. and Schmidt, J. B. (1997) Antecedents and Consequences of Cross-Functional Cooperation: A Comparison of R&D, Manufacturing, and Marketing Perspectives, *Journal of Product Innovation Management*. DOI:10.1111/1540-5885.1410035.

Sonmez, M., Holt, G. D., Yang, J. B. and Graham, G. (2002) Applying Evidential Reasoning to Prequalifying Construction Contractors, *Journal of Management in Engineering*, 9 (4).

Souitaris, V. (2001) Strategic Influences of Technological Innovation in Greece, *British Journal of Management*. DOI:10.1111/1467-8551.00190.

Spender, J.-C. (1996) Making knowledge the basis of a dynamic theory of the firm, *Strategic Management Journal*. DOI:10.1002/smj.4250171106.

STAMP, G. (1981) Levels and Types of Managerial Capability, *Journal of Management Studies*. DOI:10.1111/j.1467-6486.1981.tb00103.x.

Steele, J. L. and Map, M. (1999) ‘Constructing the Team’ – A multi-cultural experience, *In Proceedings of the Chartered Institute of Building Services Engineers (CIBSE) National Conference. September 2000; Dublin.*

Steele, J. and Murray, M. (2004) Creating, supporting and sustaining a culture of innovation, *Engineering, Construction and Architectural Management*. DOI:10.1108/09699980410558502.

Stewart, R. A. (2007) IT enhanced project information management in construction: Pathways to improved performance and strategic competitiveness, *Automation in Construction*. DOI:10.1016/j.autcon.2006.09.001.

Succar, B. (2009) Building information modelling framework: A research and delivery foundation for industry stakeholders, *Automation in Construction*, 18 (3), pp. 357–375. DOI:10.1016/j.autcon.2008.10.003.

Succar, B. and Sher, W. (2014) A Competency Knowledge-Base for BIM Learning, *Australasian Journal of Construction Economics and Building - Conference Series*. DOI:10.5130/ajceb-cs.v2i2.3883.

Succar, B., Sher, W. and Williams, A. (2013) An integrated approach to BIM competency assessment, acquisition and application, *Automation in Construction*. DOI:10.1016/j.autcon.2013.05.016.

Sunindijo, R. Y. (2015) Project manager skills for improving project performance, *International Journal of Business Performance Management*. DOI:10.1504/IJBPM.2015.066041.

Tabachnick, B. G. and Fidell, L. S. (2007) *Using Multivariate Statistics: Pearson Education Inc*, *Boston, MA*. DOI:10.1126/science.1157897.

Tabachnick, B. G. and Fidell, L. S. (2012) *Using multivariate statistics (6th ed.)*, *New York: Harper and Row*. DOI:10.1037/022267.

Tambe, P. (2014) Big data investment, skills, and firm value, *Management Science*. DOI:10.1287/mnsc.2014.1899.

Tang, J., Pee, L. G. and Iijima, J. (2013) Investigating the effects of business process orientation on organizational innovation performance, *Information and Management*. DOI:10.1016/j.im.2013.07.002.

Teddlie, C. and Tashakkori, A. (2006) A General Typology of Research Designs Featuring Mixed Methods, *Research in the Schools*, 13 (1), pp. 12–28. DOI:Article.

Teece, D. J. (2003) Towards an economic theory of the multiproduct firm, in: *Essays in Technology Management and Policy: Selected Papers of David J. Teece*.

Teece, D. J., Pisano, G. and Shuen, A. (1997) Dynamic capabilities and strategic management, *Strategic Management Journal*, 18 (7), pp. 509–533. DOI:10.1002/(SICI)1097-0266(199708)18:7<509::AID-SMJ882>3.0.CO;2-Z.

Teece, D. and Pisano, G. (1994) The dynamic capabilities of firms: An introduction, *Industrial and Corporate Change*. DOI:10.1093/icc/3.3.537-a.

Teizer, J. (2015) Status quo and open challenges in vision-based sensing and tracking of temporary resources on infrastructure construction sites, *Advanced Engineering Informatics*. DOI:10.1016/j.aei.2015.03.006.

Teizer, J., Wolf, M., Golovina, O., Perschewski, M., Propach, M., Neges, M. and König, M. (2017) Internet of Things (IoT) for integrating environmental and localization data in Building Information Modeling (BIM), in: *ISARC 2017 - Proceedings of the 34th International Symposium on Automation and Robotics in Construction*.

Temporal, P. (2005) Branding for survival in Asia, *Journal of Brand Management*. DOI:10.1057/palgrave.bm.2540232.

Thorpe, D., Ryan, N. and Charles, M. B. (2009) Innovation and small residential builders: An Australian study, *Construction Innovation*. DOI:10.1108/14714170910950821.

Tiemessen, L., Lane, H. ., Crossan, M. and Inkpen, A. C. (1997) knowledge management in international joint ventures, in: Beamish, B. W. and Killings, J. P. (eds.) *Coorporative Strategies North American perspective*. San Francisco: New Lexington Press, pp. 370–399.

Toor, S. U. R. and Ofori, G. (2008) Developing construction professionals of the 21st century: Renewed vision for leadership, *Journal of Professional Issues in Engineering Education and Practice*. DOI:10.1061/(ASCE)1052-3928(2008)134:3(279).

Townsend, J. T. and Ashby, F. G. (1984) Measurement scales and statistics: The misconception misconceived, *Psychological Bulletin*. DOI:10.1037/0033-2909.96.2.394.

Tranfield, D., Denyer, D. and Smart, P. (2003) Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review, *British Journal of Management*, 14 (7), pp. 207–222.

Triandis, H. and Hofstede, G. (1993) Cultures and Organizations: Software of the Mind., *Administrative Science Quarterly*. DOI:10.2307/2393257.

Uit Beijerse, R. P. (1999) Questions in knowledge management: Defining and conceptualising a phenomenon, *Journal of Knowledge Management*. DOI:10.1108/13673279910275512.

van der Panne, G., van Beers, C. and Kleinknecht, A. (2003) Success and Failure of Innovation: A Literature Review, *International Journal of Innovation Management*. DOI:10.1142/s1363919603000830.

Venegas, P. C. and Alarcón, L. F. (1997) Selecting Long-Term Strategies for Construction Firms, *Journal of Construction Engineering and Management*, 123 (4), pp. 388–398. DOI:10.1061/(ASCE)0733-9364(1997)123:4(388).

Volk, R., Stengel, J. and Schultmann, F. (2014) Building Information Modeling (BIM) for existing buildings - Literature review and future needs, *Automation in Construction*. DOI:10.1016/j.autcon.2013.10.023.

Wade, M., Piccoli, G. and Ives, B. (2011) IT-Dependent Strategic Initiatives and Sustained Competitive Advantage: A Review, Synthesis, and an Extension of the Literature, in: *The Oxford Handbook of Management Information Systems: Critical Perspectives and New Directions*.

Wagner, E. R. and Hansen, E. N. (2005) Innovation in large versus small companies: Insights from the US wood products industry, *Management Decision*. DOI:10.1108/00251740510603592.

Waheeduzzaman, A. N. M. and Ryans, J. K. (1996) Definition, Perspectives, and Understanding of International Competitiveness: A Quest for a Common Ground, *Competitiveness Review*, 6 (2), pp. 7–26. DOI:10.1108/eb046333.

Wamba, S. F., Gunasekaran, A., Akter, S., Ren, S. J., Dubey, R. and Childe, S. J. (2016) Big data analytics and firm performance: Effects of dynamic capabilities, *Journal of Business Research*, 70, pp. 356–365. DOI:10.1016/j.jbusres.2016.08.009.

Wang, C. and Cho, Y. K. (2015) Smart scanning and near real-time 3D surface modeling of dynamic construction equipment from a point cloud, *Automation in Construction*. DOI:10.1016/j.autcon.2014.06.003.

Wang, L. and Leite, F. (2013) Knowledge discovery of spatial conflict resolution philosophies in BIM-enabled MEP design coordination using data mining techniques: A proof-of-concept, in: *Computing in Civil Engineering - Proceedings of the 2013 ASCE International Workshop on Computing in Civil Engineering*.

Warszawski, A. (1996) Strategic planning in construction companies., *Journal of Construction Engineering & Management*, 122 (2), pp. 133.

Waterhouse, R. and Philp, D. (2016) *National BIM Report*, *National BIM Library*.

References

Weber, M. (1947) The Theory of Social and Economic Organization, translated by A. M. Henderson and Talcott Parsons, *AM Henderson and Talcott Parsons (New York, 1947)*. DOI:10.2307/2181723.

WEF (2016) *Shaping the Future of Construction A Breakthrough in Mindset and Technology*. Available from: www.weforum.org

Wernerfelt, B. (1984) A resource-based view of the firm, *Strategic Management Journal*, 5 (2), pp. 171–180. DOI:10.1002/smj.4250050207.

Wheelen, T. L. and Hunger, J. D. (2012) *Strategic management and business policy*, *Policy*. Available from: http://books.google.com/books?id=J8YGhhK5keUC&pgis=1

Whetten, D. A. and Cameron, K. S. (2015) Developing Management Skills - Global Edition, *Pearson, New Jersey.10th Sep, 2015*.

Whyte, J. (2012) Building Information Modelling in 2012 : Research Challenges , Contributions , Opportunities, *Design Innovation Research Centre Working Paper*.

Whyte, J., Stasis, A. and Lindkvist, C. (2016) Managing change in the delivery of complex projects: Configuration management, asset information and 'big data', *International Journal of Project Management*. DOI:10.1016/j.ijproman.2015.02.006.

Williams, N., P. Ferdinand, N. and Croft, R. (2014) Project management maturity in the age of big data, *International Journal of Managing Projects in Business*. DOI:10.1108/IJMPB-01-2014-0001.

Williamson, D. (2002) Forward from a critique of Hofstede's model of national culture, *Human Relations*. DOI:10.1177/00187267025511006.

Willmott, H. (1981) The Structuring of Organizational Structure: A Note, *Administrative Science Quarterly*. DOI:10.2307/2392518.

Wing, C. K., Walker, A. and Raftery, J. (1998) The baby and the bathwater: Research methods in Construction management, *Construction Management and Economics*, 16, pp. 99–104.

Winterton, J., Delamare-Le Deist, F. and Stringfellow, E. (2006) *Typology of knowledge, skills and competences*, *Cedefop Reference Series*.

Wionczek, M. S. and Sordo, A. M. (2019) Exploration and Exploitation, in: *Energy Policy in Mexico*.

Won, J. and Lee, G. (2010) Identifying the consideration factors for successful BIM projects, *Construction*.

References

Wong, J., Wang, X., Li, H., Chan, G. and Li, H. (2014) A review of cloud-based bim technology in the construction sector, *Journal of Information Technology in Construction*.

Woodhead, R., Stephenson, P. and Morrey, D. (2018) Digital construction: From point solutions to IoT ecosystem, *Automation in Construction*. DOI:10.1016/j.autcon.2018.05.004.

Wu, M. Y., Taylor, M. and Chen, M. J. (2001) Exploring societal and cultural influences on Taiwanese public relations, *Public Relations Review*. DOI:10.1016/S0363-8111(01)00089-3.

Wu, W. and Issa, R. R. A. (2014) BIM education and recruiting: Survey-based comparative analysis of issues, perceptions, and collaboration opportunities, *Journal of Professional Issues in Engineering Education and Practice*. DOI:10.1061/(ASCE)EI.1943-5541.0000186.

Yahuza Kassim, J. U. (2010) Evaluating IT as Source of Competitive Advantage in Engineering and Construction Organisations, in: *Advancing Project Management for the 21st Century "Concepts, Tools & Techniques for Managing Successful Projects"*. pp. 1–9.

Yang, J., Park, M. W., Vela, P. A. and Golparvar-Fard, M. (2015) Construction performance monitoring via still images, time-lapse photos, and video streams: Now, tomorrow, and the future, *Advanced Engineering Informatics*. DOI:10.1016/j.aei.2015.01.011.

Yasin, F. and Egbu, C. (2010) Exploitation of knowledge mapping benefits in the facilities performance evaluation process: A conceptual framework, in: *Association of Researchers in Construction Management, ARCOM 2010 - Proceedings of the 26th Annual Conference*.

Yiu, C. (2012) *The Big Data Opportunity Making government faster, smarter and more personal*, *Policy Exchange*.

Yu, N., Jiang, Y., Luo, L., Lee, S., Jallow, A., Wu, D., Messner, J. I., Leicht, R. M. and Yen, J. (2013) Integrating BIMserver and OpenStudio for energy efficient building, in: *Computing in Civil Engineering - Proceedings of the 2013 ASCE International Workshop on Computing in Civil Engineering*.

Zahra, S. A. and George, G. (2002) Absorptive capacity: A review, reconceptualization, and extension, *Academy of Management Review*. DOI:10.5465/AMR.2002.6587995.

Zairi, M. and Al-Mashari, M. (2005) Developing a Sustainable Culture of Innovation Management: A Prescriptive Approach, *Knowledge and Process Management*, 12 (3), pp. 197-200.

Zaltman, G., Duncan, R. and Holbek, J. (1973) *Innovations and Organisations*. New York: Wiley.

References

Zee, H. van der (2002) *Measuring the Value of Information Technology*, Khosrow-Pour, M., Travers, J., Appicello, A., Rossi, M., Boyer, M., Whitcomb, L., and Andre, D. (eds.) . Netherlands: IRM Press.

Zhai, D., Goodrum, P. M., Haas, C. T. and Caldas, C. H. (2009) Relationship between Automation and Integration of Construction Information Systems and Labor Productivity, *Journal of Construction Engineering and Management*, 135 (8), pp. 746–753. DOI:10.1061/(asce)co.1943-7862.0000024.

Zheng, R., Jiang, J., Hao, X., Ren, W., Xiong, F. and Ren, Y. (2019) BcBIM: A Blockchain-Based Big Data Model for BIM Modification Audit and Provenance in Mobile Cloud, *Mathematical Problems in Engineering*. DOI:10.1155/2019/5349538.

Zheng, W., Yang, B. and McLean, G. N. (2010) Linking organizational culture, structure, strategy, and organizational effectiveness: Mediating role of knowledge management, *Journal of Business Research*. DOI:10.1016/j.jbusres.2009.06.005.

Zhong, R. Y., Peng, Y., Xue, F., Fang, J., Zou, W., Luo, H., *et al.* (2017) Prefabricated construction enabled by the Internet-of-Things, *Automation in Construction*. DOI:10.1016/j.autcon.2017.01.006.

Zuo, J., Zhao, X., Nguyen, Q. B. M., Ma, T. and Gao, S. (2018) Soft skills of construction project management professionals and project success factors: A structural equation model, *Engineering, Construction and Architectural Management*. DOI:10.1108/ECAM-01-2016-0016.

9 APPENDICES

Appendix A Ethical clearance

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17th May 2018

Dear Upeksha Madanyake,

Re - A strategic approach to exploiting and implementing BIM, Big Data Analytics, and Internet of Things (BBI) for competitive advantage in the construction industry

Thank you for submitting this proposal for ethical review.

I am pleased to inform you that Dr Yamuna Kaluarachchi, on behalf of the School of the Built Environment & Architecture, has given full Chair's Approval for your review.

I wish you every success with your research.

Yours sincerely,

Yamuna Kaluarachchi

Chair, Research Ethics Coordinator
School of the Built Environment & Architecture
London South Bank University

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Appendix B Semi structured Interviews

Name of Company:
Company Address:
Name of the Manager:
Date:
Commencement of Interview (Time):
End of Interview (Time):
Total Interview Time:

APPENDICES

Please note, throughout the questionnaire, following three domains are used as abbreviations

Domain 1-BIM (Building Information Modelling- *Process of designing a building collaboratively using one coherent system of computer models rather than as separate sets of drawings***)**

Domain 2- BDA (Big Data Analytics- *Process of examining large and varied data sets to uncover hidden patterns, unknown correlations, market trends***)**

Domain 3- IoT- (Internet of Things- *inter-networking of physical devices/ connected devices and smart devices***)**

Collective Domain- BBI (Collective concept of Building Information Modelling, Big Data Analytics, and Internet of Things)

Implementation - the process of putting a decision or plan into effect/operation/ execution.

Exploitation - the action of making beneficial use from resources

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Section A: General Information
Section-B: BBI implementation and exploitation
Section-C: Skills and training needs for BBI

Section A: General Information- Filled by the interviewer

1. History of company: Year of establishment (Not necessary)
2. Company size: Number of employees, average annual turnover of company
3. Job role of the interviewee
4. experience (no of years) in present job role

This interview is conducted to ascertain the managers' perception on the implementation and exploitation of BIM, Big Data Analytics, and Internet of Things for organisational competitive advantage. The interview is consisting of 30 questions. Please note that both your identity and that of the company you work for will remain strictly confidential and anonymous.

Section B: BIM, Big Data Analytics and Internet of Things Implementation and exploitation

1. Please can you describe the extent to which your company is using BIM/BDA/IOT if at all? Can you describe your company's BIM/BDA/IOT journey please?

- (if no), what do you think about the companies that use BIM/BDA/IOT?
- (If no), why your company is not using BIM/BDA/IOT?

2. Can you please explain to me how BIM/BDA/IOT implementation has been realised in your company? Has it been planned and implemented strategically to achieve some specific business goals? (strategic, tactical, operational, and short, medium, long-term)
3. Does employing BIM/BDA/IOT provide competitive advantage to your company over your peer competitors?

- (If yes), how has it given your company a competitive advantage? Can I ask you to kindly explain that with few examples please if any?
- (if no), What other reasons triggered your company to use BIM/BDA/IOT?

4. The next question I am going to ask you is about the factors that impact on the use of BIM, BDA and IOT. One of the main factors that impact on construction firms' ability to leverage BIM or BDA or IOT is the organisational culture. In general speaking, culture is how we do things around in daily basis and I am using a framework to better understand organisational culture, consisting of four dimensions. I would appreciate if you could kindly enlighten me about the impact of these cultural dimensions on the use of BIM first, Big Data Analytics second and Internet of Things third in-case if they affect differently. Let us start with the first cultural dimension

- Could you please tell me how the power and authority is distributed in your company? Do you think it is distributed equally where subordinates have freedom to express disagreement with their superiors?
- Do you think this power distribution and individuals' right of disagreement has an impact on BIM <u>implementation</u> and then its <u>exploitation for competitive advantage?</u> If yes how?
- If it affects differently, please can you kindly share your thoughts in the same way for Big Data Analytics? Or do you think it affects in the same way as for BIM?
- If it affects differently, please can you kindly share your thoughts in the same way for Internet of Things?

5. Please can you explain me to what extent the responsibilities and requirements of each job role are clear in your company?

- How secure do people feel about their employment in your company?
- Do you think having a clearly defined and secured job role has an impact on BIM/BDA/IOT <u>implementation</u> and then its <u>exploitation for competitive advantage?</u> If yes, how?

6. Could you please tell me how well your company encourage the principle of being independent and self-reliance in daily tasks?
- Do you think being independent and self-reliance has an impact on BIM/BDA/IOT implementation and then its exploitation for competitive advantage? If yes how?

7. To what extent does your company encourage works performed collectively (teamwork)?
- Do you think there is an impact of collective task performing on BIM/BDA/IOT implementation and then its exploitation for competitive advantage? If yes how?

8. Please can you describe me how friendly and sociable is the working atmosphere in your company?
- Do you think having a friendly and sociable culture has an impact on BIM/BDA/IOT implementation and then its exploitation for competitive advantage? If yes how?

9. To what extent is your company's internal culture being competitive, risk-taking and result-focused? (i.e. being keen on the goal achievement, profitability, market share)
- Do you think this competitiveness or result oriented-ness has an impact on BIM/BDA/IOT implementation and then its exploitation for competitive advantage? If yes how?

10. What benefits does size (in terms of number of employees) give you in BIM/BDA/IOT implementation and then its exploitation for competitive advantage? Or do you think it inhibits?

11. What benefits do size in terms of annual turnover gives in BIM/BDA/IOT implementation and then its exploitation for competitive advantage? Or do you think it inhibits?

12. Please, could you explain me how the decisions are usually taken in your company? Is it centralised or decentralised?
- Do you think centralised/decentralised decision making has an impact on BIM/BDA/IOT implementation and then its exploitation for competitive advantage? If yes how?

13. Please can you explain to me how formalised and structured is your work environment? To what extent rules and procedures decide what people do?

- Do you think this way in which the rules and procedures are respected has an impact on BIM/BDA/IOT implementation and then its exploitation for competitive advantage? If yes how?

14. Could you please tell me how many managers do you report to and how many people that report to you as a part of your daily tasks? Considering the hierarchical arrangement of your company divided into different layers (strata) based on positions how stratified is your company structure?

- Do you think the level of stratification in the hierarchy in you company has an impact on BIM/BDA/IOT implementation and then its exploitation for competitive advantage? If yes how?

15. Please can you tell me how many specialised divisions/units are there in your company based on the nature of the tasks performed? (i.e. commercial, production, procurement, innovation, etc). To what extent your offices, plants, and personnel are dispersed geographically?

- Do you think having these interrelated units and geographical coverage has an impact on BIM/BDA/IOT implementation and then its exploitation for competitive advantage? If yes how?

Section C: Skills and Training needs for BBI implementation and exploitation

16. Next, I am trying to ascertain the key skill/ knowledge dimensions that professionals like you need to possess. It is generally accepted that an organisation is its individuals' knowledge and skills because skills and knowledge are the core capabilities of a firm. According to your view what are the most important and specific skills and knowledge that a professional like you need to possess to enable BIM **implementation** and then its **exploitation for competitive advantage** in case if they differ?
17. Adding another branch to that same question, once the skills/ knowledge dimensions you just mentioned are identified, to what extent do you think that they require training in your company?
18. Considering the future (next five years) is there any difference in these skills/ knowledges and the training requirement? If so, how that differs from current requirements?

19. Let’s move on to Big Data analytics, what are the most important and specific skills and knowledge that a professional like you needs to possess to enable Big Data Analytics **implementation** and then its **exploitation for competitive advantage** in case if they differ?
20. Adding another branch to that same question, once the skills/ knowledge dimensions you just mentioned are identified, to what extent do you think that they require training in your company?
21. Considering the future (next five years) is there any difference in these skills/ knowledges and the training requirement? If so, how that differs from current requirements?
22. Finally, for Internet of Things, what are the most important and specific skills and knowledge that a professional like you needs to possess to enable Internet of Things **implementation** and then its **exploitation for competitive advantage** in case if they differ?
23. Adding another branch to that same question, once the skills/ knowledge dimensions you just mentioned are identified, to what extent do you think that they require training in your company?
24. Considering the future (next five years), are they likely to change? If so, how that differs from current requirements?

Appendix C Questionnaire survey coding with questions

1. Which category (ies) best describes your organisation? Please tick as many boxes as apply	ORGCAT
1.a. If you selected Other, please specify:	ORGCATO
2. Please select the category that best describes your current job role	JOBR
3. Please state your username	USR
4. Please state your email address	EMAIL
5. What is the name of your company?	ORGNM
6. What is the size of your company in terms of number of employees?	ORGSIZ
7. What is the type of your company (e.g. main contractor, sub-contractor, consultant etc)?	ORGTYP
8.1 Does your company currently adopt Building Information Modelling (BIM)?	ORGBIMADOP
8.2 Do you currently use Building Information Modelling (BIM)?	UBIMUSE
9. 1 Does your company currently adopt Big Data Analytics (BDA)?	ORGBDAADOP
9. 2 Do you currently use Big Data Analytics (BDA)?	UBDAUSE
10.1 Does your company currently adopt Internet of Things (IOT)?	ORGIOTADOP
10 2 Do you currently use Internet of Things (IOT)?	UIOTUSE
11. What is your designation?	DESIG
12. Please select the extent to which you use BIM (Building Information Modelling) as a part of your current job role	UBIMEXT
13. Please select the extent to which you use BDA (Big Data Analytics) as a part of your current job role	UBDAEXT
14. Please select the extent to which you use IOT (Internet of Things) as a part of your current job role	UIOTEXT
15. How long have you been using Building Information Modelling?	BIMEXPERI
16.1. The senior management of our company gives the required strategic leadership and support on the entire BIM process	EXPBIM1
16.2. We are deploying appropriate BIM tools, applications, and workflows in our company day-to-day activities	EXPBIM2

16.3. The BIM team in our company is appropriately selected with right skills and they are receiving a proper training	EXPBIM3
16.4. We have set realistic BIM goals (i.e. short term/ medium term/ long term)	EXPBIM4
16.5. We are using appropriate standards and policy initiatives that help selection, execution, and refinement of BIM workflows	EXPBIM5
16.6. The individuals who work with BIM typically create new uses for them (e.g. 3D models help not only visualize reality but also automated clash/ error detection)	EXPBIM6
16.7. The individuals who work with BIM manage to perform their daily tasks more effectively	EXPBIM7
16.8. The individuals who work with BIM extend and leverage their existing individual competencies on the technology by incorporating the new system into their regular job role	EXPBIM8
16.9. After adopting and diffusing BIM within the organisation, the company is gradually beginning to operate more efficiently than before	EXPBIM9
16.10. After adopting and diffusing BIM within the organisation, the company embraces new routines and processes to use the system in a better way	EXPBIM10
17.1.a. Reduction in the whole life cost of built assets - Building Information Modelling (BIM)	BENBIM1
17.2.a. Ease of information abstraction through simulations and collaborated visualisation techniques - Building Information Modelling (BIM)	BENBIM2
17.3.a. Reduction in the overall time, from inception to completion of a construction (with less need for rework and early risk/ clash detection) - Building Information Modelling (BIM)	BENBIM3
17.4.a. Enable faster and better decisions through greater collaboration - Building Information Modelling (BIM)	BENBIM4
18.1.a. Lack of in-house expertise and therefore salary premium of employing personnel trained in BIM - Building Information Modelling (BIM)	CHBIM1
18.2.a. Hardware upgrading and software licensing costs - Building Information Modelling (BIM)	CHBIM2
18.3.a. Treating virtual as superficial and not trust worth- thereby lack of client demand - Building Information Modelling (BIM)	CHBIM3
18.4.a. The general unavailability of vendor-neutral data formats and standard- Interoperability/ incompatibility - Building Information Modelling (BIM)	CHBIM4
19. How long have you been using Big Data Analytics?	BDAEXPERI
20.1. The senior management of our company gives the required strategic leadership and support on the entire Big Data Analytics process	EXPBDA1
20.2. We are deploying big data sets for both tangible (e.g. plant, material data) and intangible (e.g. brands, customer relationships data) assets to enable big data analytics and they are properly stored thin such a way that allow access to all members involved.	EXPBDA2
20.3. The Big Data team in our company is appropriately selected with right skills and they are receiving a proper training	EXPBDA3
20.4. We have set realistic Big Data goals (i.e. short term/ medium term/ long term)	EXPBDA4

20.5. We are using appropriate standards and policy initiatives that help selection, execution, and refinement of Big Data processes	EXPBDA5
20.6. The individuals who work with BDA typically create new uses for them (e.g. uncover hidden patterns, unknown correlations, market trends, customer preferences and other useful information)	EXPBDA6
20.7. The individuals who work with BDA manage to perform their daily tasks more effectively (e.g. automation of managing and analysing voluminous, complexly varied, and high velocity data enhances effectiveness)	EXPBDA7
20.8. The individuals who work with BDA extend and leverage their existing individual competencies on technology	EXPBDA8
20.9. After adopting and diffusing BDA within the organisation, the company is gradually beginning to operate more efficiently than before (e.g. informed organisational business decisions enhance efficiency)	EXPBDA9
20.10. After adopting and diffusing BDA within the organisation, the company embraces new routines and processes to use the system in a better way	EXPBDA10
21.1.a. Time and cost reduction (Big Data tools offer more efficient ways of storing, managing analysing them) - Big Data Analytics (BDA)	BENBDA1
21.2.a. Identification of important information (through advanced analytics) improves the quality of decision making - Big Data Analytics (BDA)	BENBDA2
21.3.a. Minimising potential risks with foresighted situational awareness & predictability - Big Data Analytics (BDA)	BENBDA3
21.4.a. New product/ service innovation (knowing client needs and habits) - Big Data Analytics (BDA)	BENBDA4
22.1.a. Getting meaningful insights using big data analytics - Big Data Analytics (BDA)	CHBDA1
22.2.a. Lack of in-house expertise and therefore training and education costs for data centric roles - Big Data Analytics (BDA)	CHBDA2
22.3.a. legal issues regarding data ownership, copyright, and data protection - Big Data Analytics (BDA)	CHBDA3
22.4.a. Insurance, uncertainty and issues with cyber security and privacy of data - Big Data Analytics (BDA)	CHBDA4
23. How long have you been using Internet of Things?	IOTEXPERI
24.1. The senior management of our company gives the required strategic leadership and support on the entire IOT process	EXPIOT1
24.2. We are deploying appropriately selected IOT tools and applications along with the required IOT infrastructure (e.g. for cloud connectivity, IOT platforms, connected devices) that enable IOT performance	EXPIOT2
24.3. The IOT team in our company is appropriately selected with right skills and they are receiving a proper training	EXPIOT3
24.4. We have set realistic IOT goals (i.e. short term/ medium term/ long term)	EXPIOT4
24.5. We are using appropriate standards and policy initiatives that help selection, execution, and refinement of integrated IOT processes	EXPIOT5
24.6. The individuals who work with IOT typically create new uses for them	EXPIOT6

24.7. The individuals who work with IOT manage to perform their daily tasks more effectively (e.g. generation and passing large amount of useful data through connected devices enables instant error detection, therefore effective)	EXPIOT7
24.8. The individuals who work with IOT extend and leverage their existing individual competencies on technology	EXPIOT8
24.9. After adopting and diffusing IOT within the organisation, the company is gradually beginning to operate more efficiently than before	EXPIOT9
24.10. After adopting and diffusing IOT within the organisation, the company embraces new routines and processes to use the system in a better way	EXPIOT10
25.1.a. Cloud connection allows real time data sharing which contributes to quicker information sharing as well as completion of a task. - Internet of Things (IOT)	BENIOT1
25.2.a. RFID data helps mitigating the effects of any downstream delays/ failures in any type of performance and thereby performance optimisation. - Internet of Things (IOT)	BENIOT2
25.3.a. Remote/ automated operation and usage monitoring for controlling purposes (e.g. energy generation, storage, distribution, and usage monitoring for energy conservation) - Internet of Things (IOT)	BENIOT3
25.4.a. Improved worker safety (i.e. real time information with historical data provided by GPS helps tracking, tracing, and monitoring fleet through RFID IOT sensors - Internet of Things (IOT)	BENIOT4
26.1.a. Lack of standardised guidelines, policies and contractual aspects embedded in current procurement and legal structures - Internet of Things (IOT)	CHIOT1
26.2.a. Privacy and security of transferred data - Internet of Things (IOT)	CHIOT2
26.3.a. Lack of IoT specific experts/ professions and Lack of skills, knowledge, and training - Internet of Things (IOT)	CHIOT3
26.4.a. Issue of compatibility and connectivity when sharing data in multiple formats - Internet of Things (IOT)	CHIOT4
27.1.a. The impact of empowering employees, and including them in decision-making on achieving the best possible use of - Section A- BIM	CULTBIM1
27.1.b. The impact of empowering employees, and including them in decision-making on achieving the best possible use of - Section B- BDA	CULTBDA1
27.1.c. The impact of empowering employees, and including them in decision-making on achieving the best possible use of - Section C- IOT	CULTIOT1
27.2.a. The impact of having clear job responsibilities and job security on achieving the best possible use of - Section A- BIM	CULTBIM2
27.2.b. The impact of having clear job responsibilities and job security on achieving the best possible use of - Section B- BDA	CULTBDA2
27.2.c. The impact of having clear job responsibilities and job security on achieving the best possible use of - Section C- IOT	CULTIOT2
27.3.a. The impact of group/ team work on achieving the best possible use of - Section A- BIM	CULTBIM3
27.3.b. The impact of group/ team work on achieving the best possible use of - Section B- BDA	CULTBDA3
27.3.c. The impact of group/ team work on achieving the best possible use of - Section C- IOT	CULTIOT3
27.4.a. The impact of competitive, result-focused, and risk-taking work environment on achieving the best possible use of - Section A- BIM	CULTBIM4

27.4.b. The impact of competitive, result-focused, and risk-taking work environment on achieving the best possible use of - Section B- BDA	CULTBDA4
27.4.c. The impact of competitive, result-focused, and risk-taking work environment on achieving the best possible use of - Section C- IOT	CULTIOT4
28.1.a. The impact of centralised decision making, authority and flow of communication at the top management without employees' participation on achieving the best possible use of - Section A- BIM	STRUCBIM1
28.1.b. The impact of centralised decision making, authority and flow of communication at the top management without employees' participation on achieving the best possible use of - Section B- BDA	STRUCBDA1
28.1.c. The impact of centralised decision making, authority and flow of communication at the top management without employees' participation on achieving the best possible use of - Section C- IOT	STRUCIOT1
28.2.a. The impact of having highly formal rules and procedures on achieving the best possible use of - Section A- BIM	STRUCBIM2
28.2.b. The impact of having highly formal rules and procedures on achieving the best possible use of - Section B- BDA	STRUCBDA2
28.2.c. The impact of having highly formal rules and procedures on achieving the best possible use of - Section C- IOT	STRUCIOT2
28.3.a. The impact of having substantial number of status, layers, levels of professional roles on achieving the best possible use of - Section A- BIM	STRUCBIM3
28.3.b. The impact of having substantial number of status, layers, levels of professional roles on achieving the best possible use of - Section B- BDA	STRUCBDA3
28.3.c. The impact of having substantial number of status, layers, levels of professional roles on achieving the best possible use of - Section C- IOT	STRUCIOT3
29.1.a. The impact of number of full-time employees on achieving the best possible use of - Section A- BIM	SIZBIM1
29.1.b. The impact of number of full-time employees on achieving the best possible use of - Section B- BDA	SIZBDA1
29.1.c. The impact of number of full-time employees on achieving the best possible use of - Section C- IOT	SIZIOT1
29.2.a. The impact of annual turnover on achieving the best possible use of - Section A- BIM	SIZBIM2
29.2.b. The impact of annual turnover on achieving the best possible use of - Section B- BDA	SIZBDA2
29.2.c. The impact of annual turnover on achieving the best possible use of - Section C- IOT	SIZIOT2
30.1.a. Employees' satisfaction/ retention were enhanced - By Exploiting BIM (Building Information Modelling)	COMPBIM1
30.1.b. Employees' satisfaction/ retention were enhanced - By Exploiting BDA (Big Data Analytics)	COMPBDA1
30.1.c. Employees' satisfaction/ retention were enhanced - By Exploiting IOT (Internet of Things)	COMPIOT1
30.2.a. Appropriate skills and intellectual assets of people were identified and promoted - By Exploiting BIM (Building Information Modelling)	COMPBIM2
30.2.b. Appropriate skills and intellectual assets of people were identified and promoted - By Exploiting BDA (Big Data Analytics)	COMPBDA2
30.2.c. Appropriate skills and intellectual assets of people were identified and promoted - By Exploiting IOT (Internet of Things)	COMPIOT2
30.3.a. The company brand and reputation were enhanced - By Exploiting BIM (Building Information Modelling)	COMPBIM3

30.3.b. The company brand and reputation were enhanced - By Exploiting BDA (Big Data Analytics)	COMPBDA3
30.3.c. The company brand and reputation were enhanced - By Exploiting IOT (Internet of Things)	COMPIOT3
30.4.a. The existing technological capability was enhanced - By Exploiting BIM (Building Information Modelling)	COMPBIM4
30.4.b. The existing technological capability was enhanced - By Exploiting BDA (Big Data Analytics)	COMPBDA4
30.4.c. The existing technological capability was enhanced - By Exploiting IOT (Internet of Things)	COMPIOT4
30.5.a. The effect of plant and material was enhanced - By Exploiting BIM (Building Information Modelling)	COMPBIM5
30.5.b. The effect of plant and material was enhanced - By Exploiting BDA (Big Data Analytics)	COMPBDA5
30.5.c. The effect of plant and material was enhanced - By Exploiting IOT (Internet of Things)	COMPIOT5
30.6.a. Source of finance-Financial capital and financing ability was increased - By Exploiting BIM (Building Information Modelling)	COMPBIM6
30.6.b. Source of finance-Financial capital and financing ability was increased - By Exploiting BDA (Big Data Analytics)	COMPBDA6
30.6.c. Source of finance-Financial capital and financing ability was increased - By Exploiting IOT (Internet of Things)	COMPIOT6
30.7.a. The company governance was upgraded - By Exploiting BIM (Building Information Modelling)	COMPBIM7
30.7.b. The company governance was upgraded - By Exploiting BDA (Big Data Analytics)	COMPBDA7
30.7.c. The company governance was upgraded - By Exploiting IOT (Internet of Things)	COMPIOT7
30.8.a. Company marketing and production operation tasks were made easy and efficient - By Exploiting BIM (Building Information Modelling)	COMPBIM8
30.8.b. Company marketing and production operation tasks were made easy and efficient - By Exploiting BDA (Big Data Analytics)	COMPBDA8
30.8.c. Company marketing and production operation tasks were made easy and efficient - By Exploiting IOT (Internet of Things)	COMPIOT8
30.9.a. Training and education was improved - By Exploiting BIM (Building Information Modelling)	COMPBIM9
30.9.b. Training and education was improved - By Exploiting BDA (Big Data Analytics)	COMPBDA9
30.9.c. Training and education was improved - By Exploiting IOT (Internet of Things)	COMPIOT9
30.10.a. Organisational culture and structure was enabled - By Exploiting BIM (Building Information Modelling)	COMPBIM10
30.10.b. Organisational culture and structure was enabled - By Exploiting BDA (Big Data Analytics)	COMPBDA10
30.10.c. Organisational culture and structure was enabled - By Exploiting IOT (Internet of Things)	COMPIOT10
30.11.a. Company business strategy and alliances with collaborative partnering was improved - By Exploiting BIM (Building Information Modelling)	COMPBIM11
30.11.b. Company business strategy and alliances with collaborative partnering was improved - By Exploiting BDA (Big Data Analytics)	COMPBDA11
30.11.c. Company business strategy and alliances with collaborative partnering was improved - By Exploiting IOT (Internet of Things)	COMPIOT11
30.12.a. Research and development was improved - By Exploiting BIM (Building Information Modelling)	COMPBIM12

30.12.b. Research and development was improved - By Exploiting BDA (Big Data Analytics)	COMPBDA12
30.12.c. Research and development was improved - By Exploiting IOT (Internet of Things)	COMPIOT12
30.13.a. Company profitability was increased - By Exploiting BIM (Building Information Modelling)	COMPBIM13
30.13.b. Company profitability was increased - By Exploiting BDA (Big Data Analytics)	COMPBDA13
30.13.c. Company profitability was increased - By Exploiting IOT (Internet of Things)	COMPIOT13
30.14.a. Company productivity was increased - By Exploiting BIM (Building Information Modelling)	COMPBIM14
30.14.b. Company productivity was increased - By Exploiting BDA (Big Data Analytics)	COMPBDA14
30.14.c. Company productivity was increased - By Exploiting IOT (Internet of Things)	COMPIOT14
30.15.a. Performance efficiency and predictability was increased - By Exploiting BIM (Building Information Modelling)	COMPBIM15
30.15.b. Performance efficiency and predictability was increased - By Exploiting BDA (Big Data Analytics)	COMPBDA15
30.15.c. Performance efficiency and predictability was increased - By Exploiting IOT (Internet of Things)	COMPIOT15
30.16.a. The market Share and the rate of market penetration was increased - By Exploiting BIM (Building Information Modelling)	COMPBIM16
30.16.b. The market Share and the rate of market penetration was increased - By Exploiting BDA (Big Data Analytics)	COMPBDA16
30.16.c. The market Share and the rate of market penetration was increased - By Exploiting IOT (Internet of Things)	COMPIOT16
30.17.a. The customer loyalty and retention were improved - By Exploiting BIM (Building Information Modelling)	COMPBIM17
30.17.b. The customer loyalty and retention were improved - By Exploiting BDA (Big Data Analytics)	COMPBDA17
30.17.c. The customer loyalty and retention were improved - By Exploiting IOT (Internet of Things)	COMPIOT17
30.18.a. Differentiation/ uniqueness in services was enhanced - By Exploiting BIM (Building Information Modelling)	COMPBIM18
30.18.b. Differentiation/ uniqueness in services was enhanced - By Exploiting BDA (Big Data Analytics)	COMPBDA18
30.18.c. Differentiation/ uniqueness in services was enhanced - By Exploiting IOT (Internet of Things)	COMPIOT18
30.19.a. Cost were reduced - By Exploiting BIM (Building Information Modelling)	COMPBIM19
30.19.b. Cost were reduced - By Exploiting BDA (Big Data Analytics)	COMPBDA19
30.19.c. Cost were reduced - By Exploiting IOT (Internet of Things)	COMPIOT19
30.20.a. Speed and quality of delivery was enhanced - By Exploiting BIM (Building Information Modelling)	COMPBIM20
30.20.b. Speed and quality of delivery was enhanced - By Exploiting BDA (Big Data Analytics)	COMPBDA20
30.20.c. Speed and quality of delivery was enhanced - By Exploiting IOT (Internet of Things)	COMPIOT20
30.21.a. Value added ability to society, corporate social responsibility and sustainability was enhanced - By Exploiting BIM (Building Information Modelling)	COMPBIM21

30.21.b. Value added ability to society, corporate social responsibility and sustainability was enhanced - By Exploiting BDA (Big Data Analytics)	COMPBDA21
30.21.c. Value added ability to society, corporate social responsibility and sustainability was enhanced - By Exploiting IOT (Internet of Things)	COMPIOT21
31.1.a. Leadership (i.e. leading and guiding others through the overall process of implementing/exploiting BIM systems and workflows) - Section A Implementation Current (Now)	SKBIMIMPNOW1
31.1.b. Leadership (i.e. leading and guiding others through the overall process of implementing/exploiting BIM systems and workflows) - Section A Exploitation Current (Now)	SKBIMEXPNOW1
31.1.c. Leadership (i.e. leading and guiding others through the overall process of implementing/exploiting BIM systems and workflows) - Section A Need for training Current (Now)	SKBIMNFTNOW1
31.1.d. Leadership (i.e. leading and guiding others through the overall process of implementing/exploiting BIM systems and workflows) - Section B Implementation In five years (Future)	SKBIMIMPFUT1
31.1.e. Leadership (i.e. leading and guiding others through the overall process of implementing/exploiting BIM systems and workflows) - Section B Exploitation In five years (Future)	SKBIMEXPFUT1
31.1.f. Leadership (i.e. leading and guiding others through the overall process of implementing/exploiting BIM systems and workflows) - Section B Need for training in five years (Future)	SKBIMNFTFUT1
31.2.a. Communication- oral/written (i.e. communicating overall managerial goals of BIM systems and workflows) - Section A Implementation Current(Now)	SKBIMIMPNOW2
31.2.b. Communication- oral/written (i.e. communicating overall managerial goals of BIM systems and workflows) - Section A Exploitation Current(Now)	SKBIMEXPNOW2
31.2.c. Communication- oral/written (i.e. communicating overall managerial goals of BIM systems and workflows) - Section A Need for training Current(Now)	SKBIMNFTNOW2
31.2.d. Communication- oral/written (i.e. communicating overall managerial goals of BIM systems and workflows) - Section B Implementation In five years (Future)	SKBIMIMPFUT2
31.2.e. Communication- oral/written (i.e. communicating overall managerial goals of BIM systems and workflows) - Section B Exploitation In five years (Future)	SKBIMEXPFUT2
31.2.f. Communication- oral/written (i.e. communicating overall managerial goals of BIM systems and workflows) - Section B Need for training in five years (Future)	SKBIMNFTFUT2
31.3.a. Negotiation (i.e. negotiating with business partners/ clients/ supply chain members for maximizing the delivery value as well as for business development) - Section A Implementation Current (Now)	SKBIMIMPNOW3
31.3.b. Negotiation (i.e. negotiating with business partners/ clients/ supply chain members for maximizing the delivery value as well as for business development) - Section A Exploitation Current (Now)	SKBIMEXPNOW3
31.3.c. Negotiation (i.e. negotiating with business partners/ clients/ supply chain members for maximizing the delivery value as well as for business development) - Section A Need for training Current (Now)	SKBIMNFTNOW3
31.3.d. Negotiation (i.e. negotiating with business partners/ clients/ supply chain members for maximizing the delivery value as well as for business development) - Section B Implementation In five years (Future)	SKBIMIMPFUT3
31.3.e. Negotiation (i.e. negotiating with business partners/ clients/ supply chain members for maximizing the delivery value as well as for business development) - Section B Exploitation In five years (Future)	SKBIMEXPFUT3

31.3.f. Negotiation (i.e. negotiating with business partners/ clients/ supply chain members for maximizing the delivery value as well as for business development) - Section B Need for training in five years (Future)	SKBIMNFTFUT3
31.4.a. Motivation (i.e. encouraging employees to use and share BIM tools and processes productively and effectively) - Section A Implementation Current(Now)	SKBIMIMPNOW4
31.4.b. Motivation (i.e. encouraging employees to use and share BIM tools and processes productively and effectively) - Section A Exploitation Current(Now)	SKBIMEXPNOW4
31.4.c. Motivation (i.e. encouraging employees to use and share BIM tools and processes productively and effectively) - Section A Need for training Current(Now)	SKBIMNFTNOW4
31.4.d. Motivation (i.e. encouraging employees to use and share BIM tools and processes productively and effectively) - Section B Implementation In five years (Future)	SKBIMIMPFUT4
31.4.e. Motivation (i.e. encouraging employees to use and share BIM tools and processes productively and effectively) - Section B Exploitation In five years (Future)	SKBIMEXPFUT4
31.4.f. Motivation (i.e. encouraging employees to use and share BIM tools and processes productively and effectively) - Section B Need for training in five years (Future)	SKBIMNFTFUT4
31.5.a. Teamwork (i.e. managing collaborative teams involved in the delivery of BIM projects, including BIM steering committee recruitment and delegation of authority according to everyone's competencies) - Section A Implementation Current (Now)	SKBIMIMPNOW5
31.5.b. Teamwork (i.e. managing collaborative teams involved in the delivery of BIM projects, including BIM steering committee recruitment and delegation of authority according to everyone's competencies) - Section A Exploitation Current (Now)	SKBIMEXPNOW5
31.5.c. Teamwork (i.e. managing collaborative teams involved in the delivery of BIM projects, including BIM steering committee recruitment and delegation of authority according to everyone's competencies) - Section A Need for training Current (Now)	SKBIMNFTNOW5
31.5.d. Teamwork (i.e. managing collaborative teams involved in the delivery of BIM projects, including BIM steering committee recruitment and delegation of authority according to everyone's competencies) - Section B Implementation In five years (Future)	SKBIMIMPFUT5
31.5.e. Teamwork (i.e. managing collaborative teams involved in the delivery of BIM projects, including BIM steering committee recruitment and delegation of authority according to everyone's competencies) - Section B Exploitation In five years (Future)	SKBIMEXPFUT5
31.5.f. Teamwork (i.e. managing collaborative teams involved in the delivery of BIM projects, including BIM steering committee recruitment and delegation of authority according to each individual's competencies) - Section B Need for training in five years (Future)	SKBIMNFTFUT5
31.6.a. Decision Making (i.e. making the right decisions to achieve organisational or managerial objectives) - Section A Implementation Current (Now)	SKBIMIMPNOW6
31.6.b. Decision Making (i.e. making the right decisions to achieve organisational or managerial objectives) - Section A Exploitation Current (Now)	SKBIMEXPNOW6
31.6.c. Decision Making (i.e. making the right decisions to achieve organisational or managerial objectives) - Section A Need for training Current (Now)	SKBIMNFTNOW6
31.6.d. Decision Making (i.e. making the right decisions to achieve organisational or managerial objectives) - Section B Implementation In five years (Future)	SKBIMIMPFUT6
31.6.e. Decision Making (i.e. making the right decisions to achieve organisational or managerial objectives) - Section B Exploitation In five years (Future)	SKBIMEXPFUT6
31.6.f. Decision Making (i.e. making the right decisions to achieve organisational or managerial objectives) - Section B Need for training in five years (Future)	SKBIMNFTFUT6
31.7.a. Strategic Planning (i.e. Identify strategic objectives and implement strategies) - Section A Implementation Current (Now)	SKBIMIMPNOW7
31.7.b. Strategic Planning (i.e. Identify strategic objectives and implement strategies) - Section A Exploitation Current (Now)	SKBIMEXPNOW7

31.7.c. Strategic Planning (i.e. Identify strategic objectives and implement strategies) - Section A Need for training Current (Now)	SKBIMNFTNOW7
31.7.d. Strategic Planning (i.e. Identify strategic objectives and implement strategies) - Section B Implementation In five years (Future)	SKBIMIMPFUT7
31.7.e. Strategic Planning (i.e. Identify strategic objectives and implement strategies) - Section B Exploitation In five years (Future)	SKBIMEXPFUT7
31.7.f. Strategic Planning (i.e. Identify strategic objectives and implement strategies) - Section B Need for training in five years (Future)	SKBIMNFTFUT7
31.8.a. Partnership and Alliancing (i.e. initiating partnerships and alliances with other organisations based on BIM deliverables for business development) - Section A Implementation Current (Now)	SKBIMIMPNOW8
31.8.b. Partnership and Alliancing (i.e. initiating partnerships and alliances with other organisations based on BIM deliverables for business development) - Section A Exploitation Current (Now)	SKBIMEXPNOW8
31.8.c. Partnership and Alliancing (i.e. initiating partnerships and alliances with other organisations based on BIM deliverables for business development) - Section A Need for training Current (Now)	SKBIMNFTNOW8
31.8.d. Partnership and Alliancing (i.e. initiating partnerships and alliances with other organisations based on BIM deliverables for business development) - Section B Implementation In five years (Future)	SKBIMIMPFUT8
31.8.e. Partnership and Alliancing (i.e. initiating partnerships and alliances with other organisations based on BIM deliverables for business development) - Section B Exploitation In five years (Future)	SKBIMEXPFUT8
31.8.f. Partnership and Alliancing (i.e. initiating partnerships and alliances with other organisations based on BIM deliverables for business development) - Section B Need for training in five years (Future)	SKBIMNFTFUT8
31.9.a. Finance Accounting and Budgeting (planning, allocating, monitoring, and controlling the costs associated with BIM implementation/ exploitation) - Section A Implementation Current (Now)	SKBIMIMPNOW9
31.9.b. Finance Accounting and Budgeting (planning, allocating, monitoring, and controlling the costs associated with BIM implementation/ exploitation) - Section A Exploitation Current (Now)	SKBIMEXPNOW9
31.9.c. Finance Accounting and Budgeting (planning, allocating, monitoring, and controlling the costs associated with BIM implementation/ exploitation) - Section A Need for training Current (Now)	SKBIMNFTNOW9
31.9.d. Finance Accounting and Budgeting (planning, allocating, monitoring, and controlling the costs associated with BIM implementation/ exploitation) - Section B Implementation In five years (Future)	SKBIMIMPFUT9
31.9.e. Finance Accounting and Budgeting (planning, allocating, monitoring, and controlling the costs associated with BIM implementation/ exploitation) - Section B Exploitation In five years (Future)	SKBIMEXPFUT9
31.9.f. Finance Accounting and Budgeting (planning, allocating, monitoring, and controlling the costs associated with BIM implementation/ exploitation) - Section B Need for training in five years (Future)	SKBIMNFTFUT9
31.10.a. Marketing (i.e. promoting organisation's BIM capability to its clients and business partners, carry out research on the market position, absorptive capacity, and appetite for BIM deliverables) - Section A Implementation Current (Now)	SKBIMIMPNOW10
31.10.b. Marketing (i.e. promoting organisation's BIM capability to its clients and business partners, carry out research on the market position, absorptive capacity, and appetite for BIM deliverables) - Section A Exploitation Current (Now)	SKBIMEXPNOW10

31.10.c. Marketing (i.e. promoting organisation's BIM capability to its clients and business partners, carry out research on the market position, absorptive capacity, and appetite for BIM deliverables) - Section A Need for training Current (Now)	SKBIMNFTNOW10
31.10.d. Marketing (i.e. promoting organisation's BIM capability to its clients and business partners, carry out research on the market position, absorptive capacity, and appetite for BIM deliverables) - Section B Implementation In five years (Future)	SKBIMIMPFUT10
31.10.e. Marketing (i.e. promoting organisation's BIM capability to its clients and business partners, carry out research on the market position, absorptive capacity, and appetite for BIM deliverables) - Section B Exploitation In five years (Future)	SKBIMEXPFUT10
31.10.f. Marketing (i.e. promoting organisation's BIM capability to its clients and business partners, carry out research on the market position, absorptive capacity, and appetite for BIM deliverables) - Section B Need for training in five years (Future)	SKBIMNFTFUT10
31.11.a. Tendering and Procurement (i.e. facilitating and steering the procurement of BIM products and services including managing the contractual obligations underlying collaborative BIM Projects and workflows) - Section A Implementation Current (Now)	SKBIMIMPNOW11
31.11.b. Tendering and Procurement (i.e. facilitating and steering the procurement of BIM products and services including managing the contractual obligations underlying collaborative BIM Projects and workflows) - Section A Exploitation Current (Now)	SKBIMEXPNOW11
31.11.c. Tendering and Procurement (i.e. facilitating and steering the procurement of BIM products and services including managing the contractual obligations underlying collaborative BIM Projects and workflows) - Section A Need for training Current (Now)	SKBIMNFTNOW11
31.11.d. Tendering and Procurement (i.e. facilitating and steering the procurement of BIM products and services including managing the contractual obligations underlying collaborative BIM Projects and workflows) - Section B Implementation In five years (Future)	SKBIMIMPFUT11
31.11.e. Tendering and Procurement (i.e. facilitating and steering the procurement of BIM products and services including managing the contractual obligations underlying collaborative BIM Projects and workflows) - Section B Exploitation In five years (Future)	SKBIMEXPFUT11
31.11.f. Tendering and Procurement (i.e. facilitating and steering the procurement of BIM products and services including managing the contractual obligations underlying collaborative BIM Projects and workflows) - Section B Need for training in five years (Future)	SKBIMNFTFUT11
31.12.a. Risk Management (i.e. managing the risks associated with using BIM tools and collaborative workflows) - Section A Implementation Current (Now)	SKBIMIMPNOW12
31.12.b. Risk Management (i.e. managing the risks associated with using BIM tools and collaborative workflows) - Section A Exploitation Current (Now)	SKBIMEXPNOW12
31.12.c. Risk Management (i.e. managing the risks associated with using BIM tools and collaborative workflows) - Section A Need for training Current (Now)	SKBIMNFTNOW12
31.12.d. Risk Management (i.e. managing the risks associated with using BIM tools and collaborative workflows) - Section B Implementation In five years (Future)	SKBIMIMPFUT12
31.12.e. Risk Management (i.e. managing the risks associated with using BIM tools and collaborative workflows) - Section B Exploitation In five years (Future)	SKBIMEXPFUT12
31.12.f. Risk Management (i.e. managing the risks associated with using BIM tools and collaborative workflows) - Section B Need for training in five years (Future)	SKBIMNFTFUT12
31.13.a. Quality Management (i.e. establishing, managing, and controlling the quality of BIM models, and other project Deliverables) - Section A Implementation Current (Now)	SKBIMIMPNOW13

31.13.b. Quality Management (i.e. establishing, managing, and controlling the quality of BIM models, and other project Deliverables) - Section A Exploitation Current (Now)	SKBIMEXPNOW13
31.13.c. Quality Management (i.e. establishing, managing, and controlling the quality of BIM models, and other project Deliverables) - Section A Need for training Current (Now)	SKBIMNFTNOW13
31.13.d. Quality Management (i.e. establishing, managing, and controlling the quality of BIM models, and other project Deliverables) - Section B Implementation In five years (Future)	SKBIMIMPFUT13
31.13.e. Quality Management (i.e. establishing, managing, and controlling the quality of BIM models, and other project Deliverables) - Section B Exploitation In five years (Future)	SKBIMEXPFUT13
31.13.f. Quality Management (i.e. establishing, managing and controlling the quality of BIM models, and other project Deliverables) - Section B Need for training in five years (Future)	SKBIMNFTFUT13
31.14.a. Performance Management (i.e. evaluating the organisational BIM capability/ maturity against a benchmark) - Section A Implementation Current (Now)	SKBIMIMPNOW14
31.14.b. Performance Management (i.e. evaluating the organisational BIM capability/ maturity against a benchmark) - Section A Exploitation Current (Now)	SKBIMEXPNOW14
31.14.c. Performance Management (i.e. evaluating the organisational BIM capability/ maturity against a benchmark) - Section A Need for training Current (Now)	SKBIMNFTNOW14
31.14.d. Performance Management (i.e. evaluating the organisational BIM capability/ maturity against a benchmark) - Section B Implementation In five years (Future)	SKBIMIMPFUT14
31.14.e. Performance Management (i.e. evaluating the organisational BIM capability/ maturity against a benchmark) - Section B Exploitation In five years (Future)	SKBIMEXPFUT14
31.14.f. Performance Management (i.e. evaluating the organisational BIM capability/ maturity against a benchmark) - Section B Need for training in five years (Future)	SKBIMNFTFUT14
31.15.a. Operational Management (i.e. general modelling, capturing, representing, simulating, quantifying, monitoring, controlling, linking and extending the BIM model with model-based collaboration) - Section A Implementation Current (Now)	SKBIMIMPNOW15
31.15.b. Operational Management (i.e. general modelling, capturing, representing, simulating, quantifying, monitoring, controlling, linking and extending the BIM model with model-based collaboration) - Section A Exploitation Current (Now)	SKBIMEXPNOW15
31.15.c. Operational Management (i.e. general modelling, capturing, representing, simulating, quantifying, monitoring, controlling, linking and extending the BIM model with model-based collaboration) - Section A Need for training Current (Now)	SKBIMNFTNOW15
31.15.d. Operational Management (i.e. general modelling, capturing, representing, simulating, quantifying, monitoring, controlling, linking and extending the BIM model with model-based collaboration) - Section B Implementation In five years (Future)	SKBIMIMPFUT15
31.15.e. Operational Management (i.e. general modelling, capturing, representing, simulating, quantifying, monitoring, controlling, linking and extending the BIM model with model-based collaboration) - Section B Exploitation In five years (Future)	SKBIMEXPFUT15
31.15.f. Operational Management (i.e. general modelling, capturing, representing, simulating, quantifying, monitoring, controlling, linking and extending the BIM model with model-based collaboration) - Section B Need for training in five years (Future)	SKBIMNFTFUT15

31.16.a. Technological infrastructure Management (i.e. installing, managing, and maintaining general IT infrastructure, including network support with specific software and hardware equipment requirements) - Section A Implementation Current(Now)	SKBIMIMPNOW16
31.16.b. Technological infrastructure Management (i.e. installing, managing, and maintaining general IT infrastructure, including network support with specific software and hardware equipment requirements) - Section A Exploitation Current(Now)	SKBIMEXPNOW16
31.16.c. Technological infrastructure Management (i.e. installing, managing, and maintaining general IT infrastructure, including network support with specific software and hardware equipment requirements) - Section A Need for training Current(Now)	SKBIMNFTNOW16
31.16.d. Technological infrastructure Management (i.e. installing, managing, and maintaining general IT infrastructure, including network support with specific software and hardware equipment requirements) - Section B Implementation In five years (Future)	SKBIMIMPFUT16
31.16.e. Technological infrastructure Management (i.e. installing, managing, and maintaining general IT infrastructure, including network support with specific software and hardware equipment requirements) - Section B Exploitation In five years (Future)	SKBIMEXPFUT16
31.16.f. Technological infrastructure Management (i.e. installing, managing and maintaining general IT infrastructure, including network support with specific software and hardware equipment requirements) - Section B Need for training in five years (Future)	SKBIMNFTFUT16
31.17.a. Legislation Management (i.e. understanding the legal requirements of BIM tools and workflows- policies, regulations and procedures for BIM standards and specifications) - Section A Implementation Current(Now)	SKBIMIMPNOW17
31.17.b. Legislation Management (i.e. understanding the legal requirements of BIM tools and workflows- policies, regulations and procedures for BIM standards and specifications) - Section A Exploitation Current(Now)	SKBIMEXPNOW17
31.17.c. Legislation Management (i.e. understanding the legal requirements of BIM tools and workflows- policies, regulations and procedures for BIM standards and specifications) - Section A Need for training Current(Now)	SKBIMNFTNOW17
31.17.d. Legislation Management (i.e. understanding the legal requirements of BIM tools and workflows- policies, regulations and procedures for BIM standards and specifications) - Section B Implementation In five years (Future)	SKBIMIMPFUT17
31.17.e. Legislation Management (i.e. understanding the legal requirements of BIM tools and workflows- policies, regulations and procedures for BIM standards and specifications) - Section B Exploitation In five years (Future)	SKBIMEXPFUT17
31.17.f. Legislation Management (i.e. understanding the legal requirements of BIM tools and workflows- policies, regulations and procedures for BIM standards and specifications) - Section B Need for training in five years (Future)	SKBIMNFTFUT17
31.18.a. Innovation Management (i.e. support and facilitate experimenting new beneficial uses of the innovation processes for continuous improvement and change management) - Section A Implementation Current(Now)	SKBIMIMPNOW18
31.18.b. Innovation Management (i.e. support and facilitate experimenting new beneficial uses of the innovation processes for continuous improvement and change management) - Section A Exploitation Current(Now)	SKBIMEXPNOW18
31.18.c. Innovation Management (i.e. support and facilitate experimenting new beneficial uses of the innovation processes for continuous improvement and change management) - Section A Need for training Current(Now)	SKBIMNFTNOW18
31.18.d. Innovation Management (i.e. support and facilitate experimenting new beneficial uses of the innovation processes for continuous improvement and change management) - Section B Implementation In five years (Future)	SKBIMIMPFUT18

31.18.e. Innovation Management (i.e. support and facilitate experimenting new beneficial uses of the innovation processes for continuous improvement and change management) - Section B Exploitation In five years (Future)	SKBIMEXPFUT18
31.18.f. Innovation Management (i.e. support and facilitate experimenting new beneficial uses of the innovation processes for continuous improvement and change management) - Section B Need for training in five years (Future)	SKBIMNFTFUT18
31.19.a. Supply Chain Management (i.e. design, plan, execute, control, and monitor supply chain activities related to BIM processes to provide best value) - Section A Implementation Current(Now)	SKBIMIMPNOW19
31.19.b. Supply Chain Management (i.e. design, plan, execute, control, and monitor supply chain activities related to BIM processes to provide best value) - Section A Exploitation Current(Now)	SKBIMEXPNOW19
31.19.c. Supply Chain Management (i.e. design, plan, execute, control, and monitor supply chain activities related to BIM processes to provide best value) - Section A Need for training Current(Now)	SKBIMNFTNOW19
31.19.d. Supply Chain Management (i.e. design, plan, execute, control, and monitor supply chain activities related to BIM processes to provide best value) - Section B Implementation In five years (Future)	SKBIMIMPFUT19
31.19.e. Supply Chain Management (i.e. design, plan, execute, control, and monitor supply chain activities related to BIM processes to provide best value) - Section B Exploitation In five years (Future)	SKBIMEXPFUT19
31.19.f. Supply Chain Management (i.e. design, plan, execute, control, and monitor supply chain activities related to BIM processes to provide best value) - Section B Need for training in five years (Future)	SKBIMNFTFUT19
31.20.a. Information Management (i.e. acquisition of information from varied sources in varied formats to storing, processing and distribution of them) - Section A Implementation Current(Now)	SKBIMIMPNOW20
31.20.b. Information Management (i.e. acquisition of information from varied sources in varied formats to storing, processing and distribution of them) - Section A Exploitation Current(Now)	SKBIMEXPNOW20
31.20.c. Information Management (i.e. acquisition of information from varied sources in varied formats to storing, processing and distribution of them) - Section A Need for training Current(Now)	SKBIMNFTNOW20
31.20.d. Information Management (i.e. acquisition of information from varied sources in varied formats to storing, processing and distribution of them) - Section B Implementation In five years (Future)	SKBIMIMPFUT20
31.20.e. Information Management (i.e. acquisition of information from varied sources in varied formats to storing, processing and distribution of them) - Section B Exploitation In five years (Future)	SKBIMEXPFUT20
31.20.f. Information Management (i.e. acquisition of information from varied sources in varied formats to storing, processing and distribution of them) - Section B Need for training in five years (Future)	SKBIMNFTFUT20
32.1.a. Leadership (i.e. leading and guiding others through the overall process of implementing/exploiting Big Data systems) - Section A Implementation Current(Now)	SKBDAIMPNOW1
32.1.b. Leadership (i.e. leading and guiding others through the overall process of implementing/exploiting Big Data systems) - Section A Exploitation Current(Now)	SKBDAEXPNOW1
32.1.c. Leadership (i.e. leading and guiding others through the overall process of implementing/exploiting Big Data systems) - Section A Need for training Current(Now)	SKBDANFTNOW1

32.1.d. Leadership (i.e. leading and guiding others through the overall process of implementing/exploiting Big Data systems) - Section B Implementation In five years (Future)	SKBDAIMPFUT1
32.1.e. Leadership (i.e. leading and guiding others through the overall process of implementing/exploiting Big Data systems) - Section B Exploitation In five years (Future)	SKBDAEXPFUT1
32.1.f. Leadership (i.e. leading and guiding others through the overall process of implementing/exploiting Big Data systems) - Section B Need for training in five years (Future)	SKBDANFTFUT1
32.2.a. Communication- oral/written (i.e. communicating overall managerial goals of Big Data systems) - Section A Implementation Current(Now)	SKBDAIMPNOW2
32.2.b. Communication- oral/written (i.e. communicating overall managerial goals of Big Data systems) - Section A Exploitation Current(Now)	SKBDAEXPNOW2
32.2.c. Communication- oral/written (i.e. communicating overall managerial goals of Big Data systems) - Section A Need for training Current(Now)	SKBDANFTNOW2
32.2.d. Communication- oral/written (i.e. communicating overall managerial goals of Big Data systems) - Section B Implementation In five years (Future)	SKBDAIMPFUT2
32.2.e. Communication- oral/written (i.e. communicating overall managerial goals of Big Data systems) - Section B Exploitation In five years (Future)	SKBDAEXPFUT2
32.2.f. Communication- oral/written (i.e. communicating overall managerial goals of Big Data systems) - Section B Need for training in five years (Future)	SKBDANFTFUT2
32.3.a. Negotiation (i.e. negotiating with business partners/ clients/ supply chain members for maximizing the delivery value as well as for business development) - Section A Implementation Current(Now)	SKBDAIMPNOW3
32.3.b. Negotiation (i.e. negotiating with business partners/ clients/ supply chain members for maximizing the delivery value as well as for business development) - Section A Exploitation Current(Now)	SKBDAEXPNOW3
32.3.c. Negotiation (i.e. negotiating with business partners/ clients/ supply chain members for maximizing the delivery value as well as for business development) - Section A Need for training Current(Now)	SKBDANFTNOW3
32.3.d. Negotiation (i.e. negotiating with business partners/ clients/ supply chain members for maximizing the delivery value as well as for business development) - Section B Implementation In five years (Future)	SKBDAIMPFUT3
32.3.e. Negotiation (i.e. negotiating with business partners/ clients/ supply chain members for maximizing the delivery value as well as for business development) - Section B Exploitation In five years (Future)	SKBDAEXPFUT3
32.3.f. Negotiation (i.e. negotiating with business partners/ clients/ supply chain members for maximizing the delivery value as well as for business development) - Section B Need for training in five years (Future)	SKBDANFTFUT3
32.4.a. Motivation (i.e. encouraging employees to use and share Big Data tools and processes productively and effectively) - Section A Implementation Current(Now)	SKBDAIMPNOW4
32.4.b. Motivation (i.e. encouraging employees to use and share Big Data tools and processes productively and effectively) - Section A Exploitation Current(Now)	SKBDAEXPNOW4
32.4.c. Motivation (i.e. encouraging employees to use and share Big Data tools and processes productively and effectively) - Section A Need for training Current(Now)	SKBDANFTNOW4
32.4.d. Motivation (i.e. encouraging employees to use and share Big Data tools and processes productively and effectively) - Section B Implementation In five years (Future)	SKBDAIMPFUT4
32.4.e. Motivation (i.e. encouraging employees to use and share Big Data tools and processes productively and effectively) - Section B Exploitation In five years (Future)	SKBDAEXPFUT4

32.4.f. Motivation (i.e. encouraging employees to use and share Big Data tools and processes productively and effectively) - Section B Need for training in five years (Future)	SKBDANFTFUT4
32.5.a. Teamwork (i.e. managing collaborative teams involved in the delivery of Big Data projects, including Data analysing steering committee recruitment and delegation of authority according to each individual's competencies) - Section A Implementation Current(Now)	SKBDAIMPNOW5
32.5.b. Teamwork (i.e. managing collaborative teams involved in the delivery of Big Data projects, including Data analysing steering committee recruitment and delegation of authority according to each individual's competencies) - Section A Exploitation Current(Now)	SKBDAEXPNOW5
32.5.c. Teamwork (i.e. managing collaborative teams involved in the delivery of Big Data projects, including Data analysing steering committee recruitment and delegation of authority according to each individual's competencies) - Section A Need for training Current(Now)	SKBDANFTNOW5
32.5.d. Teamwork (i.e. managing collaborative teams involved in the delivery of Big Data projects, including Data analysing steering committee recruitment and delegation of authority according to each individual's competencies) - Section B Implementation In five years (Future)	SKBDAIMPFUT5
32.5.e. Teamwork (i.e. managing collaborative teams involved in the delivery of Big Data projects, including Data analysing steering committee recruitment and delegation of authority according to each individual's competencies) - Section B Exploitation In five years (Future)	SKBDAEXPFUT5
32.5.f. Team Work (i.e. managing collaborative teams involved in the delivery of Big Data projects, including Data analysing steering committee recruitment and delegation of authority according to each individual's competencies) - Section B Need for training In five years (Future)	SKBDANFTFUT5
32.6.a. Decision Making (i.e. making the right decisions to achieve organisational or managerial objectives) - Section A Implementation Current(Now)	SKBDAIMPNOW6
32.6.b. Decision Making (i.e. making the right decisions to achieve organisational or managerial objectives) - Section A Exploitation Current(Now)	SKBDAEXPNOW6
32.6.c. Decision Making (i.e. making the right decisions to achieve organisational or managerial objectives) - Section A Need for training Current(Now)	SKBDANFTNOW6
32.6.d. Decision Making (i.e. making the right decisions to achieve organisational or managerial objectives) - Section B Implementation In five years (Future)	SKBDAIMPFUT6
32.6.e. Decision Making (i.e. making the right decisions to achieve organisational or managerial objectives) - Section B Exploitation In five years (Future)	SKBDAEXPFUT6
32.6.f. Decision Making (i.e. making the right decisions to achieve organisational or managerial objectives) - Section B Need for training in five years (Future)	SKBDANFTFUT6
32.7.a. Strategic Planning (i.e. Identify strategic objectives and implement strategies) - Section A Implementation Current(Now)	SKBDAIMPNOW7
32.7.b. Strategic Planning (i.e. Identify strategic objectives and implement strategies) - Section A Exploitation Current(Now)	SKBDAEXPNOW7
32.7.c. Strategic Planning (i.e. Identify strategic objectives and implement strategies) - Section A Need for training Current(Now)	SKBDANFTNOW7
32.7.d. Strategic Planning (i.e. Identify strategic objectives and implement strategies) - Section B Implementation In five years (Future)	SKBDAIMPFUT7
32.7.e. Strategic Planning (i.e. Identify strategic objectives and implement strategies) - Section B Exploitation In five years (Future)	SKBDAEXPFUT7
32.7.f. Strategic Planning (i.e. Identify strategic objectives and implement strategies) - Section B Need for training in five years (Future)	SKBDANFTFUT7
32.8.a. Partnership and Alliancing (i.e. initiating partnerships and alliances with other organisations based on Big Data inputs and outputs for business development) - Section A Implementation Current(Now)	SKBDAIMPNOW8
32.8.b. Partnership and Alliancing (i.e. initiating partnerships and alliances with other organisations based on Big Data inputs and outputs for business development) - Section A Exploitation Current(Now)	SKBDAEXPNOW8

32.8.c. Partnership and Alliancing (i.e. initiating partnerships and alliances with other organisations based on Big Data inputs and outputs for business development) - Section A Need for training Current(Now)	SKBDANFTNOW8
32.8.d. Partnership and Alliancing (i.e. initiating partnerships and alliances with other organisations based on Big Data inputs and outputs for business development) - Section B Implementation In five years (Future)	SKBDAIMPFUT8
32.8.e. Partnership and Alliancing (i.e. initiating partnerships and alliances with other organisations based on Big Data inputs and outputs for business development) - Section B Exploitation In five years (Future)	SKBDAEXPFUT8
32.8.f. Partnership and Alliancing (i.e. initiating partnerships and alliances with other organisations based on Big Data inputs and outputs for business development) - Section B Need for training in five years (Future)	SKBDANFTFUT8
32.9.a. Finance Accounting and Budgeting (i.e. planning, allocating, monitoring, and controlling the costs associated with BDA implementation/ exploitation) - Section A Implementation Current(Now)	SKBDAIMPNOW9
32.9.b. Finance Accounting and Budgeting (i.e. planning, allocating, monitoring, and controlling the costs associated with BDA implementation/ exploitation) - Section A Exploitation Current(Now)	SKBDAEXPNOW9
32.9.c. Finance Accounting and Budgeting (i.e. planning, allocating, monitoring, and controlling the costs associated with BDA implementation/ exploitation) - Section A Need for training Current(Now)	SKBDANFTNOW9
32.9.d. Finance Accounting and Budgeting (i.e. planning, allocating, monitoring, and controlling the costs associated with BDA implementation/ exploitation) - Section B Implementation In five years (Future)	SKBDAIMPFUT9
32.9.e. Finance Accounting and Budgeting (i.e. planning, allocating, monitoring, and controlling the costs associated with BDA implementation/ exploitation) - Section B Exploitation In five years (Future)	SKBDAEXPFUT9
32.9.f. Finance Accounting and Budgeting (i.e. planning, allocating, monitoring and controlling the costs associated with BDA implementation/ exploitation) - Section B Need for training in five years (Future)	SKBDANFTFUT9
32.10.a. Marketing (i.e. promoting organisation's BDA capability to its clients and business partners, carry out research on the market position, absorptive capacity, and appetite for Data- centric deliverables) - Section A Implementation Current(Now)	SKBDAIMPNOW10
32.10.b. Marketing (i.e. promoting organisation's BDA capability to its clients and business partners, carry out research on the market position, absorptive capacity, and appetite for Data- centric deliverables) - Section A Exploitation Current(Now)	SKBDAEXPNOW10
32.10.c. Marketing (i.e. promoting organisation's BDA capability to its clients and business partners, carry out research on the market position, absorptive capacity, and appetite for Data- centric deliverables) - Section A Need for training Current(Now)	SKBDANFTNOW10
32.10.d. Marketing (i.e. promoting organisation's BDA capability to its clients and business partners, carry out research on the market position, absorptive capacity, and appetite for Data- centric deliverables) - Section B Implementation In five years (Future)	SKBDAIMPFUT10
32.10.e. Marketing (i.e. promoting organisation's BDA capability to its clients and business partners, carry out research on the market position, absorptive capacity, and appetite for Data- centric deliverables) - Section B Exploitation In five years (Future)	SKBDAEXPFUT10
32.10.f. Marketing (i.e. promoting organisation's BDA capability to its clients and business partners, carry out research on the market position, absorptive capacity and appetite for Data- centric deliverables) - Section B Need for training In five years (Future)	SKBDANFTFUT10

32.11.a. Tendering and Procurement (i.e. facilitating and steering the procurement of Big Data products and services including managing the contractual obligations underlying collaborative Big Data Projects) - Section A Implementation Current(Now)	SKBDAIMPNOW1 1
32.11.b. Tendering and Procurement (i.e. facilitating and steering the procurement of Big Data products and services including managing the contractual obligations underlying collaborative Big Data Projects) - Section A Exploitation Current(Now)	SKBDAEXPNOW1 1
32.11.c. Tendering and Procurement (i.e. facilitating and steering the procurement of Big Data products and services including managing the contractual obligations underlying collaborative Big Data Projects) - Section A Need for training Current(Now)	SKBDANFTNOW1 1
32.11.d. Tendering and Procurement (i.e. facilitating and steering the procurement of Big Data products and services including managing the contractual obligations underlying collaborative Big Data Projects) - Section B Implementation In five years (Future)	SKBDAIMPFUT11
32.11.e. Tendering and Procurement (i.e. facilitating and steering the procurement of Big Data products and services including managing the contractual obligations underlying collaborative Big Data Projects) - Section B Exploitation In five years (Future)	SKBDAEXPFUT11
32.11.f. Tendering and Procurement (i.e. facilitating and steering the procurement of Big Data products and services including managing the contractual obligations underlying collaborative Big Data Projects) - Section B Need for training in five years (Future)	SKBDANFTFUT11
32.12.a. Risk Management (i.e. managing the risks associated with using Big Data tools/ techniques and collaborative workflows) - Section A Implementation Current(Now)	SKBDAIMPNOW1 2
32.12.b. Risk Management (i.e. managing the risks associated with using Big Data tools/ techniques and collaborative workflows) - Section A Exploitation Current(Now)	SKBDAEXPNOW1 2
32.12.c. Risk Management (i.e. managing the risks associated with using Big Data tools/ techniques and collaborative workflows) - Section A Need for training Current(Now)	SKBDANFTNOW1 2
32.12.d. Risk Management (i.e. managing the risks associated with using Big Data tools/ techniques and collaborative workflows) - Section B Implementation In five years (Future)	SKBDAIMPFUT12
32.12.e. Risk Management (i.e. managing the risks associated with using Big Data tools/ techniques and collaborative workflows) - Section B Exploitation In five years (Future)	SKBDAEXPFUT12
32.12.f. Risk Management (i.e. managing the risks associated with using Big Data tools/ techniques and collaborative workflows) - Section B Need for training in five years (Future)	SKBDANFTFUT12
32.13.a. Quality Management (i.e. establishing, managing, and controlling the quality of Big Data analytical techniques as well as outputs) - Section A Implementation Current(Now)	SKBDAIMPNOW1 3
32.13.b. Quality Management (i.e. establishing, managing, and controlling the quality of Big Data analytical techniques as well as outputs) - Section A Exploitation Current(Now)	SKBDAEXPNOW1 3
32.13.c. Quality Management (i.e. establishing, managing, and controlling the quality of Big Data analytical techniques as well as outputs) - Section A Need for training Current(Now)	SKBDANFTNOW1 3
32.13.d. Quality Management (i.e. establishing, managing, and controlling the quality of Big Data analytical techniques as well as outputs) - Section B Implementation In five years (Future)	SKBDAIMPFUT13

32.13.e. Quality Management (i.e. establishing, managing, and controlling the quality of Big Data analytical techniques as well as outputs) - Section B Exploitation In five years (Future)	SKBDAEXPFUT13
32.13.f. Quality Management (i.e. establishing, managing and controlling the quality of Big Data analytical techniques as well as outputs) - Section B Need for training in five years (Future)	SKBDANFTFUT13
32.14.a. Performance Management (i.e. evaluating the organisational BDA capability against a benchmark and business intelligence to derive insights through presented big data) - Section A Implementation Current(Now)	SKBDAIMPNOW1 4
32.14.b. Performance Management (i.e. evaluating the organisational BDA capability against a benchmark and business intelligence to derive insights through presented big data) - Section A Exploitation Current(Now)	SKBDAEXPNOW1 4
32.14.c. Performance Management (i.e. evaluating the organisational BDA capability against a benchmark and business intelligence to derive insights through presented big data) - Section A Need for training Current(Now)	SKBDANFTNOW1 4
32.14.d. Performance Management (i.e. evaluating the organisational BDA capability against a benchmark and business intelligence to derive insights through presented big data) - Section B Implementation In five years (Future)	SKBDAIMPFUT14
32.14.e. Performance Management (i.e. evaluating the organisational BDA capability against a benchmark and business intelligence to derive insights through presented big data) - Section B Exploitation In five years (Future)	SKBDAEXPFUT14
32.14.f. Performance Management (i.e. evaluating the organisational BDA capability against a benchmark and business intelligence to derive insights through presented big data) - Section B Need for training in five years (Future)	SKBDANFTFUT14
32.15.a. Operational Management (i.e. understanding of data structures, types, formats, platforms, data analytical techniques like data mining, machine learning, data warehousing, data engineering and visualisation techniques) - Section A Implementation Current(Now)	SKBDAIMPNOW1 5
32.15.b. Operational Management (i.e. understanding of data structures, types, formats, platforms, data analytical techniques like data mining, machine learning, data warehousing, data engineering and visualisation techniques) - Section A Exploitation Current(Now)	SKBDAEXPNOW1 5
32.15.c. Operational Management (i.e. understanding of data structures, types, formats, platforms, data analytical techniques like data mining, machine learning, data warehousing, data engineering and visualisation techniques) - Section A Need for training Current(Now)	SKBDANFTNOW1 5
32.15.d. Operational Management (i.e. understanding of data structures, types, formats, platforms, data analytical techniques like data mining, machine learning, data warehousing, data engineering and visualisation techniques) - Section B Implementation In five years (Future)	SKBDAIMPFUT15
32.15.e. Operational Management (i.e. understanding of data structures, types, formats, platforms, data analytical techniques like data mining, machine learning, data warehousing, data engineering and visualisation techniques) - Section B Exploitation In five years (Future)	SKBDAEXPFUT15
32.15.f. Operational Management (i.e. understanding of data structures, types, formats, platforms, data analytical techniques like data mining, machine learning, data warehousing, data engineering and visualisation techniques) - Section B Need for training In five years (Future)	SKBDANFTFUT15
32.16.a. Technological infrastructure Management (i.e. installing, managing, and maintaining general IT infrastructure, including network support with specific software and hardware equipment requirements) - Section A Implementation Current(Now)	SKBDAIMPNOW1 6
32.16.b. Technological infrastructure Management (i.e. installing, managing, and maintaining general IT infrastructure, including network support with specific software and hardware equipment requirements) - Section A Exploitation Current(Now)	SKBDAEXPNOW1 6

32.16.c. Technological infrastructure Management (i.e. installing, managing, and maintaining general IT infrastructure, including network support with specific software and hardware equipment requirements) - Section A Need for training Current(Now)	SKBDANFTNOW16
32.16.d. Technological infrastructure Management (i.e. installing, managing, and maintaining general IT infrastructure, including network support with specific software and hardware equipment requirements) - Section B Implementation In five years (Future)	SKBDAIMPFUT16
32.16.e. Technological infrastructure Management (i.e. installing, managing, and maintaining general IT infrastructure, including network support with specific software and hardware equipment requirements) - Section B Exploitation In five years (Future)	SKBDAEXPFUT16
32.16.f. Technological infrastructure Management (i.e. installing, managing and maintaining general IT infrastructure, including network support with specific software and hardware equipment requirements) - Section B Need for training in five years (Future)	SKBDANFTFUT16
32.17.a. Legislation Management (i.e. understanding the legal requirements of Big Data protocols- regulations, data ethics, privacy, ownership, security) - Section A Implementation Current(Now)	SKBDAIMPNOW17
32.17.b. Legislation Management (i.e. understanding the legal requirements of Big Data protocols- regulations, data ethics, privacy, ownership, security) - Section A Exploitation Current(Now)	SKBDAEXPNOW17
32.17.c. Legislation Management (i.e. understanding the legal requirements of Big Data protocols- regulations, data ethics, privacy, ownership, security) - Section A Need for training Current(Now)	SKBDANFTNOW17
32.17.d. Legislation Management (i.e. understanding the legal requirements of Big Data protocols- regulations, data ethics, privacy, ownership, security) - Section B Implementation In five years (Future)	SKBDAIMPFUT17
32.17.e. Legislation Management (i.e. understanding the legal requirements of Big Data protocols- regulations, data ethics, privacy, ownership, security) - Section B Exploitation In five years (Future)	SKBDAEXPFUT17
32.17.f. Legislation Management (i.e. understanding the legal requirements of Big Data protocols- regulations, data ethics, privacy, ownership, security) - Section B Need for training in five years (Future)	SKBDANFTFUT17
32.18.a. Innovation Management (i.e. support and facilitate experimenting new beneficial uses of the innovation processes for continuous improvement and change management) - Section A Implementation Current(Now)	SKBDAIMPNOW18
32.18.b. Innovation Management (i.e. support and facilitate experimenting new beneficial uses of the innovation processes for continuous improvement and change management) - Section A Exploitation Current(Now)	SKBDAEXPNOW18
32.18.c. Innovation Management (i.e. support and facilitate experimenting new beneficial uses of the innovation processes for continuous improvement and change management) - Section A Need for training Current(Now)	SKBDANFTNOW18
32.18.d. Innovation Management (i.e. support and facilitate experimenting new beneficial uses of the innovation processes for continuous improvement and change management) - Section B Implementation In five years (Future)	SKBDAIMPFUT18
32.18.e. Innovation Management (i.e. support and facilitate experimenting new beneficial uses of the innovation processes for continuous improvement and change management) - Section B Exploitation In five years (Future)	SKBDAEXPFUT18
32.18.f. Innovation Management (i.e. support and facilitate experimenting new beneficial uses of the innovation processes for continuous improvement and change management) - Section B Need for training in five years (Future)	SKBDANFTFUT18

32.19.a. Supply Chain Management (i.e. design, plan, execute, control, and monitor supply chain activities related to Big Data processes to provide best value) - Section A Implementation Current(Now)	SKBDAIMPNOW19
32.19.b. Supply Chain Management (i.e. design, plan, execute, control, and monitor supply chain activities related to Big Data processes to provide best value) - Section A Exploitation Current(Now)	SKBDAEXPNOW19
32.19.c. Supply Chain Management (i.e. design, plan, execute, control, and monitor supply chain activities related to Big Data processes to provide best value) - Section A Need for training Current(Now)	SKBDANFTNOW19
32.19.d. Supply Chain Management (i.e. design, plan, execute, control, and monitor supply chain activities related to Big Data processes to provide best value) - Section B Implementation In five years (Future)	SKBDAIMPFUT19
32.19.e. Supply Chain Management (i.e. design, plan, execute, control, and monitor supply chain activities related to Big Data processes to provide best value) - Section B Exploitation In five years (Future)	SKBDAEXPFUT19
32.19.f. Supply Chain Management (i.e. design, plan, execute, control, and monitor supply chain activities related to Big Data processes to provide best value) - Section B Need for training in five years (Future)	SKBDANFTFUT19
32.20.a. Information Management (i.e. acquisition of information from varied sources in varied formats to storing, processing and distribution of them) - Section A Implementation Current(Now)	SKBDAIMPNOW20
32.20.b. Information Management (i.e. acquisition of information from varied sources in varied formats to storing, processing and distribution of them) - Section A Exploitation Current(Now)	SKBDAEXPNOW20
32.20.c. Information Management (i.e. acquisition of information from varied sources in varied formats to storing, processing and distribution of them) - Section A Need for training Current(Now)	SKBDANFTNOW20
32.20.d. Information Management (i.e. acquisition of information from varied sources in varied formats to storing, processing and distribution of them) - Section B Implementation In five years (Future)	SKBDAIMPFUT20
32.20.e. Information Management (i.e. acquisition of information from varied sources in varied formats to storing, processing and distribution of them) - Section B Exploitation In five years (Future)	SKBDAEXPFUT20
32.20.f. Information Management (i.e. acquisition of information from varied sources in varied formats to storing, processing and distribution of them) - Section B Need for training in five years (Future)	SKBDANFTFUT20
33.1.a. Leadership (i.e. leading and guiding others through the overall process of implementing/exploiting interconnected IOT systems) - Section A Implementation Current(Now)	SKIOTIMPNOW1
33.1.b. Leadership (i.e. leading and guiding others through the overall process of implementing/exploiting interconnected IOT systems) - Section A Exploitation Current(Now)	SKIOTEXPNOW1
33.1.c. Leadership (i.e. leading and guiding others through the overall process of implementing/exploiting interconnected IOT systems) - Section A Need for training Current(Now)	SKIOTNFTNOW1
33.1.d. Leadership (i.e. leading and guiding others through the overall process of implementing/exploiting interconnected IOT systems) - Section B Implementation In five years (Future)	SKIOTIMPFUT1

33.1.e. Leadership (i.e. leading and guiding others through the overall process of implementing/exploiting interconnected IOT systems) - Section B Exploitation In five years (Future)	SKIOTEXPFUT1
33.1.f. Leadership (i.e. leading and guiding others through the overall process of implementing/exploiting interconnected IOT systems) - Section B Need for training in five years (Future)	SKIOTNFTFUT1
33.2.a. Communication- oral/written (i.e. communicating overall managerial goals of IOT systems) - Section A Implementation Current(Now)	SKIOTIMPNOW2
33.2.b. Communication- oral/written (i.e. communicating overall managerial goals of IOT systems) - Section A Exploitation Current(Now)	SKIOTEXPNOW2
33.2.c. Communication- oral/written (i.e. communicating overall managerial goals of IOT systems) - Section A Need for training Current(Now)	SKIOTNFTNOW2
33.2.d. Communication- oral/written (i.e. communicating overall managerial goals of IOT systems) - Section B Implementation In five years (Future)	SKIOTIMPFUT2
33.2.e. Communication- oral/written (i.e. communicating overall managerial goals of IOT systems) - Section B Exploitation In five years (Future)	SKIOTEXPFUT2
33.2.f. Communication- oral/written (i.e. communicating overall managerial goals of IOT systems) - Section B Need for training in five years (Future)	SKIOTNFTFUT2
33.3.a. Negotiation (i.e. negotiating with business partners/ clients/ supply chain members for maximizing the delivery value as well as for business development) - Section A Implementation Current(Now)	SKIOTIMPNOW3
33.3.b. Negotiation (i.e. negotiating with business partners/ clients/ supply chain members for maximizing the delivery value as well as for business development) - Section A Exploitation Current(Now)	SKIOTEXPNOW3
33.3.c. Negotiation (i.e. negotiating with business partners/ clients/ supply chain members for maximizing the delivery value as well as for business development) - Section A Need for training Current(Now)	SKIOTNFTNOW3
33.3.d. Negotiation (i.e. negotiating with business partners/ clients/ supply chain members for maximizing the delivery value as well as for business development) - Section B Implementation In five years (Future)	SKIOTIMPFUT3
33.3.e. Negotiation (i.e. negotiating with business partners/ clients/ supply chain members for maximizing the delivery value as well as for business development) - Section B Exploitation In five years (Future)	SKIOTEXPFUT3
33.3.f. Negotiation (i.e. negotiating with business partners/ clients/ supply chain members for maximizing the delivery value as well as for business development) - Section B Need for training in five years (Future)	SKIOTNFTFUT3
33.4.a. Motivation (i.e. encouraging employees to use and share IOT tools and processes productively and effectively) - Section A Implementation Current(Now)	SKIOTIMPNOW4
33.4.b. Motivation (i.e. encouraging employees to use and share IOT tools and processes productively and effectively) - Section A Exploitation Current(Now)	SKIOTEXPNOW4
33.4.c. Motivation (i.e. encouraging employees to use and share IOT tools and processes productively and effectively) - Section A Need for training Current(Now)	SKIOTNFTNOW4
33.4.d. Motivation (i.e. encouraging employees to use and share IOT tools and processes productively and effectively) - Section B Implementation In five years (Future)	SKIOTIMPFUT4
33.4.e. Motivation (i.e. encouraging employees to use and share IOT tools and processes productively and effectively) - Section B Exploitation In five years (Future)	SKIOTEXPFUT4
33.4.f. Motivation (i.e. encouraging employees to use and share IOT tools and processes productively and effectively) - Section B Need for training in five years (Future)	SKIOTNFTFUT4

33.5.a. Teamwork (i.e. managing collaborative teams involved in the delivery of IOT projects including steering committee recruitment and delegation of authority according to each individual's competencies) - Section A Implementation Current(Now)	SKIOTIMPNOW5
33.5.b. Teamwork (i.e. managing collaborative teams involved in the delivery of IOT projects including steering committee recruitment and delegation of authority according to each individual's competencies) - Section A Exploitation Current(Now)	SKIOTEXPNOW5
33.5.c. Teamwork (i.e. managing collaborative teams involved in the delivery of IOT projects including steering committee recruitment and delegation of authority according to each individual's competencies) - Section A Need for training Current(Now)	SKIOTNFTNOW5
33.5.d. Teamwork (i.e. managing collaborative teams involved in the delivery of IOT projects including steering committee recruitment and delegation of authority according to each individual's competencies) - Section B Implementation In five years (Future)	SKIOTIMPFUT5
33.5.e. Teamwork (i.e. managing collaborative teams involved in the delivery of IOT projects including steering committee recruitment and delegation of authority according to each individual's competencies) - Section B Exploitation In five years (Future)	SKIOTEXPFUT5
33.5.f. Teamwork (i.e. managing collaborative teams involved in the delivery of IOT projects including steering committee recruitment and delegation of authority according to each individual's competencies) - Section B Need for training in five years (Future)	SKIOTNFTFUT5
33.6.a. Decision Making (i.e. making the right decisions to achieve organisational or managerial objectives) - Section A Implementation Current(Now)	SKIOTIMPNOW6
33.6.b. Decision Making (i.e. making the right decisions to achieve organisational or managerial objectives) - Section A Exploitation Current(Now)	SKIOTEXPNOW6
33.6.c. Decision Making (i.e. making the right decisions to achieve organisational or managerial objectives) - Section A Need for training Current(Now)	SKIOTNFTNOW6
33.6.d. Decision Making (i.e. making the right decisions to achieve organisational or managerial objectives) - Section B Implementation In five years (Future)	SKIOTIMPFUT6
33.6.e. Decision Making (i.e. making the right decisions to achieve organisational or managerial objectives) - Section B Exploitation In five years (Future)	SKIOTEXPFUT6
33.6.f. Decision Making (i.e. making the right decisions to achieve organisational or managerial objectives) - Section B Need for training in five years (Future)	SKIOTNFTFUT6
33.7.a. Strategic Planning (i.e. Identify strategic objectives and implement strategies) - Section A Implementation Current(Now)	SKIOTIMPNOW7
33.7.b. Strategic Planning (i.e. Identify strategic objectives and implement strategies) - Section A Exploitation Current(Now)	SKIOTEXPNOW7
33.7.c. Strategic Planning (i.e. Identify strategic objectives and implement strategies) - Section A Need for training Current(Now)	SKIOTNFTNOW7
33.7.d. Strategic Planning (i.e. Identify strategic objectives and implement strategies) - Section B Implementation In five years (Future)	SKIOTIMPFUT7
33.7.e. Strategic Planning (i.e. Identify strategic objectives and implement strategies) - Section B Exploitation In five years (Future)	SKIOTEXPFUT7
33.7.f. Strategic Planning (i.e. Identify strategic objectives and implement strategies) - Section B Need for training in five years (Future)	SKIOTNFTFUT7
33.8.a. Partnership and Alliancing (i.e. initiating partnerships and alliances with other organisations based on IOT deliverables for business development) - Section A Implementation Current(Now)	SKIOTIMPNOW8
33.8.b. Partnership and Alliancing (i.e. initiating partnerships and alliances with other organisations based on IOT deliverables for business development) - Section A Exploitation Current(Now)	SKIOTEXPNOW8
33.8.c. Partnership and Alliancing (i.e. initiating partnerships and alliances with other organisations based on IOT deliverables for business development) - Section A Need for training Current(Now)	SKIOTNFTNOW8

33.8.d. Partnership and Alliancing (i.e. initiating partnerships and alliances with other organisations based on IOT deliverables for business development) - Section B Implementation In five years (Future)	SKIOTIMPFUT8
33.8.e. Partnership and Alliancing (i.e. initiating partnerships and alliances with other organisations based on IOT deliverables for business development) - Section B Exploitation In five years (Future)	SKIOTEXPFUT8
33.8.f. Partnership and Alliancing (i.e. initiating partnerships and alliances with other organisations based on IOT deliverables for business development) - Section B Need for training in five years (Future)	SKIOTNFTFUT8
33.9.a. Finance Accounting and Budgeting (i.e. planning, allocating, monitoring, and controlling the costs associated with IOT implementation/ exploitation) - Section A Implementation Current(Now)	SKIOTIMPNOW9
33.9.b. Finance Accounting and Budgeting (i.e. planning, allocating, monitoring, and controlling the costs associated with IOT implementation/ exploitation) - Section A Exploitation Current(Now)	SKIOTEXPNOW9
33.9.c. Finance Accounting and Budgeting (i.e. planning, allocating, monitoring, and controlling the costs associated with IOT implementation/ exploitation) - Section A Need for training Current(Now)	SKIOTNFTNOW9
33.9.d. Finance Accounting and Budgeting (i.e. planning, allocating, monitoring, and controlling the costs associated with IOT implementation/ exploitation) - Section B Implementation In five years (Future)	SKIOTIMPFUT9
33.9.e. Finance Accounting and Budgeting (i.e. planning, allocating, monitoring, and controlling the costs associated with IOT implementation/ exploitation) - Section B Exploitation In five years (Future)	SKIOTEXPFUT9
33.9.f. Finance Accounting and Budgeting (i.e. planning, allocating, monitoring and controlling the costs associated with IOT implementation/ exploitation) - Section B Need for training in five years (Future)	SKIOTNFTFUT9
33.10.a. Marketing (i.e. promoting organisation's IOT capability to its clients and business partners, carry out research on the market position, absorptive capacity, and appetite for IOT deliverables) - Section A Implementation Current(Now)	SKIOTIMPNOW1 0
33.10.b. Marketing (i.e. promoting organisation's IOT capability to its clients and business partners, carry out research on the market position, absorptive capacity, and appetite for IOT deliverables) - Section A Exploitation Current(Now)	SKIOTEXPNOW10
33.10.c. Marketing (i.e. promoting organisation's IOT capability to its clients and business partners, carry out research on the market position, absorptive capacity, and appetite for IOT deliverables) - Section A Need for training Current(Now)	SKIOTNFTNOW10
33.10.d. Marketing (i.e. promoting organisation's IOT capability to its clients and business partners, carry out research on the market position, absorptive capacity, and appetite for IOT deliverables) - Section B Implementation In five years (Future)	SKIOTIMPFUT10
33.10.e. Marketing (i.e. promoting organisation's IOT capability to its clients and business partners, carry out research on the market position, absorptive capacity, and appetite for IOT deliverables) - Section B Exploitation In five years (Future)	SKIOTEXPFUT10
33.10.f. Marketing (i.e. promoting organisation's IOT capability to its clients and business partners, carry out research on the market position, absorptive capacity and appetite for IOT deliverables) - Section B Need for training in five years (Future)	SKIOTNFTFUT10
33.11.a. Tendering and Procurement (i.e. facilitating and steering the procurement of IOT products and services including managing the contractual obligations underlying collaborative IOT Projects). - Section A Implementation Current(Now)	SKIOTIMPNOW1 1

33.11.b. Tendering and Procurement (i.e. facilitating and steering the procurement of IOT products and services including managing the contractual obligations underlying collaborative IOT Projects). - Section A Exploitation Current(Now)	SKIOTEXPNOW11
33.11.c. Tendering and Procurement (i.e. facilitating and steering the procurement of IOT products and services including managing the contractual obligations underlying collaborative IOT Projects). - Section A Need for training Current(Now)	SKIOTNFTNOW11
33.11.d. Tendering and Procurement (i.e. facilitating and steering the procurement of IOT products and services including managing the contractual obligations underlying collaborative IOT Projects). - Section B Implementation In five years (Future)	SKIOTIMPFUT11
33.11.e. Tendering and Procurement (i.e. facilitating and steering the procurement of IOT products and services including managing the contractual obligations underlying collaborative IOT Projects). - Section B Exploitation In five years (Future)	SKIOTEXPFUT11
33.11.f. Tendering and Procurement (i.e. facilitating and steering the procurement of IOT products and services including managing the contractual obligations underlying collaborative IOT Projects). - Section B Need for training in five years (Future)	SKIOTNFTFUT11
33.12.a. Risk Management (i.e. managing the risks associated with using IOT tools and interconnected systems) - Section A Implementation Current(Now)	SKIOTIMPNOW1 2
33.12.b. Risk Management (i.e. managing the risks associated with using IOT tools and interconnected systems) - Section A Exploitation Current(Now)	SKIOTEXPNOW12
33.12.c. Risk Management (i.e. managing the risks associated with using IOT tools and interconnected systems) - Section A Need for training Current(Now)	SKIOTNFTNOW12
33.12.d. Risk Management (i.e. managing the risks associated with using IOT tools and interconnected systems) - Section B Implementation In five years (Future)	SKIOTIMPFUT12
33.12.e. Risk Management (i.e. managing the risks associated with using IOT tools and interconnected systems) - Section B Exploitation In five years (Future)	SKIOTEXPFUT12
33.12.f. Risk Management (i.e. managing the risks associated with using IOT tools and interconnected systems) - Section B Need for training in five years (Future)	SKIOTNFTFUT12
33.13.a. Quality Management (i.e. establishing, managing, and controlling the quality of IOT systems - Section A Implementation Current(Now)	SKIOTIMPNOW1 3
33.13.b. Quality Management (i.e. establishing, managing, and controlling the quality of IOT systems - Section A Exploitation Current(Now)	SKIOTEXPNOW13
33.13.c. Quality Management (i.e. establishing, managing, and controlling the quality of IOT systems - Section A Need for training Current(Now)	SKIOTNFTNOW13
33.13.d. Quality Management (i.e. establishing, managing, and controlling the quality of IOT systems - Section B Implementation In five years (Future)	SKIOTIMPFUT13
33.13.e. Quality Management (i.e. establishing, managing, and controlling the quality of IOT systems - Section B Exploitation In five years (Future)	SKIOTEXPFUT13
33.13.f. Quality Management (i.e. establishing, managing and controlling the quality of IOT systems - Section B Need for training in five years (Future)	SKIOTNFTFUT13
33.14.a. Performance Management (i.e. evaluating the organisational IOT capability against a benchmark and Business Intelligence to gain insights though monitored IOT data) - Section A Implementation Current(Now)	SKIOTIMPNOW1 4
33.14.b. Performance Management (i.e. evaluating the organisational IOT capability against a benchmark and Business Intelligence to gain insights though monitored IOT data) - Section A Exploitation Current(Now)	SKIOTEXPNOW14
33.14.c. Performance Management (i.e. evaluating the organisational IOT capability against a benchmark and Business Intelligence to gain insights though monitored IOT data) - Section A Need for training Current(Now)	SKIOTNFTNOW14

33.14.d. Performance Management (i.e. evaluating the organisational IOT capability against a benchmark and Business Intelligence to gain insights though monitored IOT data) - Section B Implementation In five years (Future)	SKIOTIMPFUT14
33.14.e. Performance Management (i.e. evaluating the organisational IOT capability against a benchmark and Business Intelligence to gain insights though monitored IOT data) - Section B Exploitation In five years (Future)	SKIOTEXPFUT14
33.14.f. Performance Management (i.e. evaluating the organisational IOT capability against a benchmark and Business Intelligence to gain insights though monitored IOT data) - Section B Need for training in five years (Future)	SKIOTNFTFUT14
33.15.a. Operational Management (i.e. wireless protocols like Bluetooth/3G/4G low energy connections and automation of IoT hardware devices with sensor systems and intelligence software- automated room control systems, smart building) - Section A Implementation Current(Now)	SKIOTIMPNOW15
33.15.b. Operational Management (i.e. wireless protocols like Bluetooth/3G/4G low energy connections and automation of IoT hardware devices with sensor systems and intelligence software- automated room control systems, smart building) - Section A Exploitation Current(Now)	SKIOTEXPNOW15
33.15.c. Operational Management (i.e. wireless protocols like Bluetooth/3G/4G low energy connections and automation of IoT hardware devices with sensor systems and intelligence software- automated room control systems, smart building) - Section A Need for training Current(Now)	SKIOTNFTNOW15
33.15.d. Operational Management (i.e. wireless protocols like Bluetooth/3G/4G low energy connections and automation of IoT hardware devices with sensor systems and intelligence software- automated room control systems, smart building) - Section B Implementation In five years (Future)	SKIOTIMPFUT15
33.15.e. Operational Management (i.e. wireless protocols like Bluetooth/3G/4G low energy connections and automation of IoT hardware devices with sensor systems and intelligence software- automated room control systems, smart building) - Section B Exploitation In five years (Future)	SKIOTEXPFUT15
33.15.f. Operational Management (i.e. wireless protocols like Bluetooth/3G/4G low energy connections and automation of IoT hardware devices with sensor systems and intelligence software- automated room control systems, smart building) - Section B Need for training In five years (Future)	SKIOTNFTFUT15
33.16.a. Technological infrastructure Management (i.e. installing, managing, and maintaining general IT infrastructure, including cloud platform connectivity with specific software and hardware equipment requirements) - Section A Implementation Current(Now)	SKIOTIMPNOW16
33.16.b. Technological infrastructure Management (i.e. installing, managing, and maintaining general IT infrastructure, including cloud platform connectivity with specific software and hardware equipment requirements) - Section A Exploitation Current(Now)	SKIOTEXPNOW16
33.16.c. Technological infrastructure Management (i.e. installing, managing, and maintaining general IT infrastructure, including cloud platform connectivity with specific software and hardware equipment requirements) - Section A Need for training Current(Now)	SKIOTNFTNOW16
33.16.d. Technological infrastructure Management (i.e. installing, managing, and maintaining general IT infrastructure, including cloud platform connectivity with specific software and hardware equipment requirements) - Section B Implementation In five years (Future)	SKIOTIMPFUT16
33.16.e. Technological infrastructure Management (i.e. installing, managing, and maintaining general IT infrastructure, including cloud platform connectivity with specific software and hardware equipment requirements) - Section B Exploitation In five years (Future)	SKIOTEXPFUT16
33.16.f. Technological infrastructure Management (i.e. installing, managing and maintaining general IT infrastructure, including cloud platform connectivity with specific software and hardware equipment requirements) - Section B Need for training in five years (Future)	SKIOTNFTFUT16
33.17.a. Legislation Management (i.e. understanding the legal requirements of IOT protocols- regulations, privacy, security, and copyright of IoT data) - Section A Implementation Current(Now)	SKIOTIMPNOW17

33.17.b. Legislation Management (i.e. understanding the legal requirements of IOT protocols- regulations, privacy, security, and copyright of IoT data) - Section A Exploitation Current(Now)	SKIOTEXPNOW17
33.17.c. Legislation Management (i.e. understanding the legal requirements of IOT protocols- regulations, privacy, security, and copyright of IoT data) - Section A Need for training Current(Now)	SKIOTNFTNOW17
33.17.d. Legislation Management (i.e. understanding the legal requirements of IOT protocols- regulations, privacy, security, and copyright of IoT data) - Section B Implementation In five years (Future)	SKIOTIMPFUT17
33.17.e. Legislation Management (i.e. understanding the legal requirements of IOT protocols- regulations, privacy, security, and copyright of IoT data) - Section B Exploitation In five years (Future)	SKIOTEXPFUT17
33.17.f. Legislation Management (i.e. understanding the legal requirements of IOT protocols- regulations, privacy, security and copyright of IoT data) - Section B Need for training in five years (Future)	SKIOTNFTFUT17
33.18.a. Innovation Management (i.e. support and facilitate experimenting new beneficial uses of the innovation processes for continuous improvement and change management) - Section A Implementation Current(Now)	SKIOTIMPNOW1 8
33.18.b. Innovation Management (i.e. support and facilitate experimenting new beneficial uses of the innovation processes for continuous improvement and change management) - Section A Exploitation Current(Now)	SKIOTEXPNOW18
33.18.c. Innovation Management (i.e. support and facilitate experimenting new beneficial uses of the innovation processes for continuous improvement and change management) - Section A Need for training Current(Now)	SKIOTNFTNOW18
33.18.d. Innovation Management (i.e. support and facilitate experimenting new beneficial uses of the innovation processes for continuous improvement and change management) - Section B Implementation In five years (Future)	SKIOTIMPFUT18
33.18.e. Innovation Management (i.e. support and facilitate experimenting new beneficial uses of the innovation processes for continuous improvement and change management) - Section B Exploitation In five years (Future)	SKIOTEXPFUT18
33.18.f. Innovation Management (i.e. support and facilitate experimenting new beneficial uses of the innovation processes for continuous improvement and change management) - Section B Need for training in five years (Future)	SKIOTNFTFUT18
33.19.a. Supply Chain Management (i.e. design, plan, execute, control, and monitor supply chain activities related to IOT processes to provide best value) - Section A Implementation Current(Now)	SKIOTIMPNOW1 9
33.19.b. Supply Chain Management (i.e. design, plan, execute, control, and monitor supply chain activities related to IOT processes to provide best value) - Section A Exploitation Current(Now)	SKIOTEXPNOW19
33.19.c. Supply Chain Management (i.e. design, plan, execute, control, and monitor supply chain activities related to IOT processes to provide best value) - Section A Need for training Current(Now)	SKIOTNFTNOW19
33.19.d. Supply Chain Management (i.e. design, plan, execute, control, and monitor supply chain activities related to IOT processes to provide best value) - Section B Implementation In five years (Future)	SKIOTIMPFUT19
33.19.e. Supply Chain Management (i.e. design, plan, execute, control, and monitor supply chain activities related to IOT processes to provide best value) - Section B Exploitation In five years (Future)	SKIOTEXPFUT19

33.19.f. Supply Chain Management (i.e. design, plan, execute, control, and monitor supply chain activities related to IOT processes to provide best value) - Section B Need for training in five years (Future)	SKIOTNFTFUT19
33.20.a. Information Management (i.e. acquisition of information from varied sources in varied formats to storing, processing and distribution of them) - Section A Implementation Current(Now)	SKIOTIMPNOW20
33.20.b. Information Management (i.e. acquisition of information from varied sources in varied formats to storing, processing and distribution of them) - Section A Exploitation Current(Now)	SKIOTEXPNOW20
33.20.c. Information Management (i.e. acquisition of information from varied sources in varied formats to storing, processing and distribution of them) - Section A Need for training Current(Now)	SKIOTNFTNOW20
33.20.d. Information Management (i.e. acquisition of information from varied sources in varied formats to storing, processing and distribution of them) - Section B Implementation In five years (Future)	SKIOTIMPFUT20
33.20.e. Information Management (i.e. acquisition of information from varied sources in varied formats to storing, processing and distribution of them) - Section B Exploitation In five years (Future)	SKIOTEXPFUT20
33.20.f. Information Management (i.e. acquisition of information from varied sources in varied formats to storing, processing and distribution of them) - Section B Need for training in five years (Future)	SKIOTNFTFUT20

Appendix D Supportive data for Chapter-4

Appendix D1: Correlation analysis between exploitation and competitive advantage for BIM, BDA and IOT

		COMPBIM1	COMPBIM2	COMPBIM3	COMPBIM4	COMPBIM5	COMPBIM6	COMPBIM7	COMPBIM8	COMPBIM9	COMPBIM1	COMPBIM1	COMPBIM1	COMPBIM1	COMPBIM1	COMPBIM1	COMPBIM1	COMPBIM1	COMPBIM1	COMPBIM1	COMPBIM2	COMPBIM21
EXPBIM1	rho	0.164	.255*	.312**	0.179	.249*	0.177	.215*	.238*	0.182	0.084	.259*	0.186	.271*	.248*	.338**	.401**	.314**	.406**	.328**	.367**	.338**
	sig (2-tailed)	0.134	0.018	0.004	0.102	0.021	0.106	0.048	0.028	0.095	0.445	0.017	0.089	0.012	0.022	0.002	0.000	0.003	0.000	0.002	0.001	0.002
EXPBIM2	rho	.306**	.289**	.424**	.344**	.232*	.236*	.340**	.338**	.285**	0.149	.384**	0.174	.408**	.364**	.298**	.460**	.393**	.499**	.365**	.406**	.415**
	sig (2-tailed)	0.004	0.007	0.000	0.001	0.033	0.030	0.001	0.002	0.008	0.173	0.000	0.112	0.000	0.001	0.006	0.000	0.000	0.000	0.001	0.000	0.000
EXPBIM3	rho	.370**	0.181	.445**	.302**	0.113	.260*	.480**	.387**	.332**	0.137	.324**	.224*	.405**	.400**	.300**	.382**	.399**	.506**	.308**	.241*	.447**
	sig (2-tailed)	0.000	0.097	0.000	0.005	0.305	0.016	0.000	0.000	0.002	0.210	0.002	0.040	0.000	0.000	0.005	0.000	0.000	0.000	0.004	0.026	0.000
EXPBIM4	rho	.389**	.275*	.449**	.424**	0.100	.276*	.479**	.386**	.284**	0.152	.364**	.213*	.337**	.369**	.220*	.387**	.324**	.475**	.365**	0.172	.379**
	sig (2-tailed)	0.000	0.011	0.000	0.000	0.365	0.011	0.000	0.000	0.009	0.166	0.001	0.050	0.002	0.001	0.043	0.000	0.002	0.000	0.001	0.116	0.000
EXPBIM5	rho	.468**	.312**	.317**	.418**	0.174	.284**	.352**	.337**	.430**	0.125	.315**	0.124	.393**	.363**	0.197	.335**	.317**	.467**	.442**	.253*	.483**
	sig (2-tailed)	0.000	0.004	0.003	0.000	0.111	0.009	0.001	0.002	0.000	0.256	0.003	0.256	0.000	0.001	0.070	0.002	0.003	0.000	0.000	0.020	0.000
EXPBIM6	rho	.349**	.250*	.259*	.264*	0.211	.304**	.360**	.351**	.391**	0.125	.278*	0.136	.447**	.420**	0.128	.276*	.403**	.384**	.445**	.277*	.427**
	sig (2-tailed)	0.001	0.021	0.017	0.015	0.052	0.005	0.001	0.001	0.000	0.255	0.010	0.215	0.000	0.000	0.244	0.011	0.000	0.000	0.000	0.010	0.000
EXPBIM7	rho	.315**	0.204	.348**	.344**	0.063	.320**	.338**	.338**	.415**	0.124	.373**	0.102	.375**	.534**	.330**	.326**	.368**	.470**	.428**	.338**	.436**
	sig (2-tailed)	0.003	0.061	0.001	0.001	0.568	0.003	0.002	0.002	0.000	0.259	0.000	0.352	0.000	0.000	0.002	0.002	0.001	0.000	0.000	0.002	0.000
EXPBIM8	rho	.320**	.283**	.270*	.245*	0.027	0.186	.359**	.265*	.321**	-0.011	0.187	0.161	.319**	.439**	.369**	.293**	.313**	.274*	.356**	.263*	.389**
	sig (2-tailed)	0.003	0.009	0.012	0.024	0.807	0.088	0.001	0.014	0.003	0.921	0.086	0.140	0.003	0.000	0.001	0.006	0.004	0.011	0.001	0.015	0.000
EXPBIM9	rho	.221*	0.187	.232*	.295**	0.159	0.167	.384**	.262*	.322**	0.155	.233*	0.172	.445**	.487**	.420**	.324**	.242*	.409**	.356**	.297**	.325**
	sig (2-tailed)	0.043	0.086	0.033	0.006	0.147	0.126	0.000	0.015	0.003	0.158	0.032	0.115	0.000	0.000	0.000	0.002	0.026	0.000	0.001	0.006	0.002
EXPBIM10	rho	.406**	.348**	.317**	.423**	0.144	.348**	.456**	.390**	.480**	0.054	.325**	.337**	.490**	.479**	.373**	.420**	.518**	.524**	.528**	.295**	.592**
	sig (2-tailed)	0.000	0.001	0.003	0.000	0.187	0.001	0.000	0.000	0.000	0.625	0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.000

EXPLOITATION AND COMPETITIVE ADVANTAGE INFERENTIAL- BDA

		COMPBDA1	COMPBDA2	COMPBDA3	COMPBDA4	COMPBDA5	COMPBDA6	COMPBDA7	COMPBDA8	COMPBDA9	COMPBDA10	COMPBDA11	COMPBDA12	COMPBDA13	COMPBDA14	COMPBDA15	COMPBDA16	COMPBDA17	COMPBDA18	COMPBDA19	COMPBDA20	COMPBDA21
EXPBDA1	**rho**	.401**	0.241	.374**	.272*	0.061	0.162	.422**	.272*	0.222	0.146	.375**	0.083	0.077	0.061	-0.009	0.159	0.104	0.170	.348**	0.150	.334**
	sig (2-tailed)	0.002	0.066	0.004	0.040	0.659	0.219	0.001	0.037	0.091	0.269	0.003	0.533	0.561	0.646	0.945	0.228	0.434	0.198	0.007	0.256	0.010
EXPBDA2	**rho**	.292*	0.142	0.115	0.186	0.118	0.214	0.161	0.100	0.090	0.030	0.197	-0.024	0.117	-0.022	-0.018	0.033	-0.104	-0.091	0.151	0.061	0.213
	sig (2-tailed)	0.025	0.283	0.395	0.166	0.392	0.103	0.227	0.452	0.497	0.819	0.135	0.854	0.379	0.872	0.892	0.802	0.435	0.493	0.252	0.646	0.105
EXPBDA3	**rho**	.384**	0.092	0.135	0.155	-0.118	0.250	0.244	-0.016	.291*	0.151	.308*	0.161	0.133	-0.123	-0.118	.285*	0.141	0.219	.450**	0.120	.345**
	sig (2-tailed)	0.003	0.486	0.317	0.248	0.389	0.056	0.065	0.902	0.025	0.253	0.018	0.224	0.314	0.353	0.375	0.029	0.288	0.096	0.000	0.366	0.007
EXPBDA4	**rho**	.362**	0.232	0.208	.433**	-0.040	.314*	0.194	0.093	0.175	0.089	0.152	.348**	0.106	-0.125	-0.069	.366**	0.222	0.234	.339**	-0.064	0.189
	sig (2-tailed)	0.005	0.077	0.121	0.001	0.770	0.015	0.144	0.482	0.184	0.503	0.251	0.007	0.422	0.346	0.605	0.004	0.091	0.074	0.009	0.628	0.152
EXPBDA5	**rho**	.330*	0.083	0.182	.265*	-0.113	0.241	0.223	0.087	.279*	0.102	0.235	0.216	0.106	-0.070	-0.196	.258*	0.167	.261*	.351**	0.022	.370**
	sig (2-tailed)	0.011	0.531	0.177	0.047	0.412	0.066	0.093	0.514	0.032	0.444	0.074	0.100	0.425	0.600	0.136	0.048	0.208	0.045	0.006	0.869	0.004
EXPBDA6	**rho**	.298*	0.056	0.238	0.059	-0.035	0.116	0.215	0.058	0.111	0.131	0.183	0.038	0.047	0.000	0.145	0.062	0.014	0.051	0.159	0.144	0.249
	sig (2-tailed)	0.022	0.676	0.074	0.663	0.798	0.382	0.105	0.665	0.401	0.324	0.166	0.776	0.724	1.000	0.274	0.640	0.918	0.702	0.229	0.277	0.057
EXPBDA7	**rho**	.277*	0.112	0.165	0.219	-0.067	0.179	0.219	0.105	.295*	0.180	0.233	0.055	-0.054	0.080	0.005	0.224	0.101	0.227	.508**	0.010	.287*
	sig (2-tailed)	0.034	0.400	0.221	0.102	0.626	0.175	0.099	0.427	0.023	0.173	0.076	0.681	0.687	0.546	0.967	0.088	0.448	0.084	0.000	0.942	0.028
EXPBDA8	**rho**	.357**	0.060	0.219	0.175	-0.135	.323*	.449**	0.245	.324*	0.172	.309*	0.160	0.045	0.059	-0.011	.302*	.310*	0.188	.394**	0.032	.517**
	sig (2-tailed)	0.006	0.649	0.101	0.194	0.326	0.013	0.000	0.061	0.012	0.193	0.017	0.227	0.737	0.655	0.936	0.020	0.017	0.155	0.002	0.808	0.000
EXPBDA9	**rho**	.389**	0.052	.281*	0.227	-0.184	.279*	.384**	0.120	0.237	0.201	.305*	0.061	0.138	-0.033	-0.062	0.231	0.155	0.212	.460**	0.061	.551**
	sig (2-tailed)	0.002	0.694	0.034	0.089	0.179	0.032	0.003	0.367	0.071	0.127	0.019	0.646	0.298	0.802	0.641	0.078	0.241	0.108	0.000	0.647	0.000
EXPBDA10	**rho**	.433**	0.117	.280*	0.181	-0.240	.273*	.386**	0.065	.326*	0.202	.417**	0.194	0.194	0.062	0.022	.393**	.312*	.332*	.467**	0.188	.523**
	sig (2-tailed)	0.001	0.377	0.035	0.178	0.078	0.037	0.003	0.624	0.012	0.125	0.001	0.140	0.142	0.639	0.867	0.002	0.016	0.010	0.000	0.154	0.000

		COMPIOT1	COMPIOT2	COMPIOT3	COMPIOT4	COMPIOT5	COMPIOT6	COMPIOT7	COMPIOT8	COMPIOT9	COMPIOT10	COMPIOT11	COMPIOT12	COMPIOT13	COMPIOT14	COMPIOT15	COMPIOT16	COMPIOT17	COMPIOT18	COMPIOT19	COMPIOT20	COMPIOT21
EXPIOT1	**rho**	0.119	-0.039	0.158	.276*	.380**	.335*	.347*	-0.071	.358**	.316*	.398**	0.003	0.176	0.182	0.267	0.116	0.058	0.062	.435**	0.043	.432**
	sig (2-tailed)	0.402	0.786	0.264	0.047	0.005	0.015	0.012	0.619	0.009	0.022	0.003	0.981	0.212	0.196	0.056	0.413	0.683	0.661	0.001	0.760	0.001
EXPIOT2	**rho**	0.155	0.034	.277*	0.243	.347*	0.246	.311*	-0.117	0.123	0.202	.345*	-0.195	0.211	0.191	.362**	0.262	0.125	0.250	.433**	.313*	.362**
	sig (2-tailed)	0.273	0.809	0.047	0.082	0.012	0.079	0.025	0.408	0.386	0.152	0.012	0.167	0.133	0.175	0.008	0.061	0.377	0.074	0.001	0.024	0.008
EXPIOT3	**rho**	0.059	-0.010	0.257	.373**	0.195	0.217	.489**	0.060	.346*	.342*	.334*	0.112	0.164	0.079	0.249	0.211	0.261	0.255	.461**	0.183	.300*
	sig (2-tailed)	0.678	0.942	0.066	0.006	0.166	0.122	0.000	0.670	0.012	0.013	0.015	0.429	0.246	0.577	0.075	0.134	0.061	0.068	0.001	0.194	0.031
EXPIOT4	**rho**	-0.128	-0.146	0.133	.290*	.391**	.298*	.330*	-0.005	0.222	0.227	0.259	0.034	-0.044	0.035	0.137	0.196	0.100	0.258	0.171	0.142	.281*
	sig (2-tailed)	0.367	0.301	0.349	0.037	0.004	0.032	0.017	0.972	0.114	0.106	0.064	0.812	0.757	0.808	0.333	0.164	0.479	0.064	0.225	0.315	0.044
EXPIOT5	**rho**	0.063	-0.220	0.152	.344*	.303*	.349*	.338*	0.086	.481**	.343*	.304*	0.146	0.104	0.160	0.207	0.202	0.160	.292*	0.273	0.118	.374**
	sig (2-tailed)	0.660	0.117	0.282	0.012	0.029	0.011	0.014	0.544	0.000	0.013	0.029	0.302	0.464	0.256	0.141	0.152	0.258	0.036	0.050	0.403	0.006
EXPIOT6	**rho**	-0.077	-0.108	.280*	0.119	0.185	.320*	0.260	0.027	0.218	0.193	.297*	0.129	0.098	0.259	0.220	-0.007	0.054	.353*	0.250	0.264	.357**
	sig (2-tailed)	0.587	0.444	0.044	0.399	0.190	0.021	0.062	0.851	0.121	0.171	0.032	0.364	0.490	0.064	0.117	0.962	0.704	0.010	0.074	0.059	0.009
EXPIOT7	**rho**	-0.150	-0.028	0.215	0.120	0.234	0.208	.309*	-0.203	0.075	0.153	0.211	-0.025	0.195	0.268	0.218	0.177	0.179	.360**	.283*	.391**	.328*
	sig (2-tailed)	0.287	0.844	0.126	0.396	0.094	0.138	0.026	0.149	0.597	0.277	0.134	0.861	0.166	0.054	0.120	0.209	0.204	0.009	0.042	0.004	0.018
EXPIOT8	**rho**	0.083	-0.027	0.139	0.148	0.159	.337*	.420**	-0.028	0.078	0.255	.298*	0.140	0.183	.299*	.317*	.280*	.276*	.299*	.306*	.359**	.504**
	sig (2-tailed)	0.558	0.851	0.325	0.293	0.261	0.015	0.002	0.843	0.581	0.068	0.032	0.322	0.193	0.031	0.022	0.044	0.048	0.031	0.027	0.009	0.000
EXPIOT9	**rho**	0.100	0.045	.420**	.308*	.286*	.350*	.534**	0.154	0.240	0.219	.350*	0.091	.316*	.359**	.412**	.367**	.338*	.354*	.468**	.393**	.426**
	sig (2-tailed)	0.480	0.753	0.002	0.026	0.040	0.011	0.000	0.277	0.086	0.119	0.011	0.519	0.022	0.009	0.002	0.007	0.014	0.010	0.000	0.004	0.002
EXPIOT10	**rho**	-0.007	-0.138	.336*	.305*	.277*	.392**	.552**	0.100	.429**	0.229	.402**	0.029	.338*	.303*	.370**	.295*	.391**	0.235	.592**	.353*	.519**
	sig (2-tailed)	0.963	0.328	0.015	0.028	0.047	0.004	0.000	0.483	0.002	0.102	0.003	0.839	0.014	0.029	0.007	0.034	0.004	0.094	0.000	0.010	0.000

Appendix D2: Canonical correlation summary between BENBIM- CHBIM and EXPBIM variables (For BIM)

Canonical Correlations							
	Correlation	Eigenvalue	Wilks Statistic	F	Num D.F	Denom D.F.	Sig.
1	.736	1.181	.160	1.816	80.000	433.511	.000
2	.594	.544	.349	1.270	63.000	389.088	.093
3	.487	.311	.539	.959	48.000	343.571	.554
4	.422	.217	.706	.732	35.000	296.893	.868
5	.248	.065	.859	.461	24.000	248.899	.987
6	.229	.055	.915	.432	15.000	199.162	.968
7	.182	.034	.966	.320	8.000	146.000	.958
8	.035	.001	.999	.030	3.000	74.000	.993
H0 for Wilks test is that the correlations in the current and following rows are zero							

Appendix D3: Canonical correlations between BENBDA- CHBDA and EXPBDA variables (For BDA)

Correlations[a]											
		EXPBDA1	**EXPBDA2**	**EXPBDA3**	**EXPBDA4**	**EXPBDA5**	**EXPBDA6**	**EXPBDA7**	**EXPBDA8**	**EXPBDA9**	**EXPBDA10**
BENBDA1	Correlation	0.672	0.641	0.545	0.468	0.545	0.379	0.533	0.587	0.607	0.626
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000
BENBDA2	Correlation	0.527	0.500	0.404	0.299	0.306	0.335	0.559	0.360	0.480	0.508
	Sig. (2-tailed)	0.000	0.000	0.002	0.021	0.018	0.009	0.000	0.005	0.000	0.000
BENBDA3	Correlation	0.500	0.477	0.522	0.341	0.479	0.214	0.452	0.420	0.553	0.570
	Sig. (2-tailed)	0.000	0.000	0.000	0.008	0.000	0.104	0.000	0.001	0.000	0.000
BENBDA4	Correlation	0.428	0.446	0.454	0.480	0.461	0.269	0.369	0.490	0.605	0.534
	Sig. (2-tailed)	0.001	0.000	0.000	0.000	0.000	0.039	0.004	0.000	0.000	0.000
CHBDA1	Correlation	-0.023	-0.083	-0.064	0.076	0.205	-0.055	-0.019	0.126	0.107	0.152
	Sig. (2-tailed)	0.860	0.531	0.628	0.566	0.120	0.680	0.885	0.343	0.420	0.252
CHBDA2	Correlation	-0.064	-0.115	-0.259	-0.053	0.001	0.061	-0.047	0.092	-0.045	0.065
	Sig. (2-tailed)	0.628	0.385	0.047	0.688	0.992	0.644	0.724	0.490	0.734	0.625

CHBDA3	Correlation	-0.133	-0.081	-0.130	-0.063	-0.096	0.000	0.100	0.095	0.078	-0.067
	Sig. (2-tailed)	0.314	0.541	0.328	0.634	0.468	1.000	0.452	0.472	0.556	0.616
CHBDA4	Correlation	-0.179	-0.233	-0.181	-0.232	-0.045	0.066	0.077	0.089	0.123	0.040
	Sig. (2-tailed)	0.175	0.076	0.171	0.078	0.733	0.617	0.562	0.502	0.355	0.761

Appendix D4: Canonical correlations between BENBDA- CHBDA and COMPBDA variables (For BDA)

		BENBDA1	**BENBDA2**	**BENBDA3**	**BENBDA4**	**CHBDA1**	**CHBDA2**	**CHBDA3**	**CHBDA4**
COMPBDA1	Correlation	.443**	0.205	.490**	.453**	-0.139	0.016	0.009	-0.087
	Sig. (2-tailed)	0.000	0.120	0.000	0.000	0.294	0.904	0.949	0.510
COMPBDA2	Correlation	0.164	0.130	0.238	0.141	-0.122	-0.029	0.015	-0.085
	Sig. (2-tailed)	0.213	0.325	0.070	0.288	0.358	0.825	0.908	0.520
COMPBDA3	Correlation	.276*	0.189	.281*	0.223	-0.001	0.133	-0.037	-.263*
	Sig. (2-tailed)	0.038	0.160	0.035	0.096	0.993	0.324	0.787	0.048
COMPBDA4	Correlation	.417**	.280*	.369**	.333*	-0.016	-0.143	0.031	-0.199
	Sig. (2-tailed)	0.001	0.035	0.005	0.011	0.905	0.287	0.817	0.138
COMPBDA5	Correlation	-0.064	-0.116	-0.005	0.042	-0.070	0.049	0.111	-0.045
	Sig. (2-tailed)	0.643	0.400	0.973	0.759	0.614	0.722	0.422	0.742
COMPBDA6	Correlation	.267*	0.141	0.227	.269*	0.237	0.015	0.065	0.003
	Sig. (2-tailed)	0.041	0.286	0.084	0.039	0.071	0.908	0.623	0.980
COMPBDA7	Correlation	.415**	0.166	.415**	.520**	0.106	-0.055	0.099	-0.120
	Sig. (2-tailed)	0.001	0.212	0.001	0.000	0.429	0.682	0.459	0.369
COMPBDA8	Correlation	0.225	0.003	0.143	0.142	0.028	-0.067	-0.037	-0.253
	Sig. (2-tailed)	0.086	0.981	0.279	0.284	0.831	0.614	0.779	0.053
COMPBDA9	Correlation	.279*	.326*	.329*	.264*	0.176	-0.180	-0.148	0.030

	Sig. (2-tailed)	0.033	0.012	0.011	0.043	0.182	0.173	0.263	0.823
COMPBDA 10	Correlation	0.119	.298*	.413**	0.214	0.117	-0.016	0.064	-0.018
	Sig. (2-tailed)	0.371	0.022	0.001	0.104	0.377	0.905	0.633	0.895
COMPBDA 11	Correlation	.314*	.352**	.438**	.342**	0.110	-0.035	-0.190	-0.193
	Sig. (2-tailed)	0.015	0.006	0.001	0.008	0.407	0.791	0.149	0.143
COMPBDA 12	Correlation	-0.066	0.253	0.208	0.124	0.165	0.108	-0.017	-.388**
	Sig. (2-tailed)	0.621	0.053	0.114	0.350	0.213	0.413	0.901	0.002
COMPBDA 13	Correlation	0.118	0.233	0.229	0.124	-0.142	-0.076	-0.173	-0.229
	Sig. (2-tailed)	0.372	0.075	0.081	0.349	0.282	0.569	0.191	0.082
COMPBDA 14	Correlation	0.012	0.091	-0.113	-0.110	0.062	-0.007	0.079	-0.028
	Sig. (2-tailed)	0.929	0.494	0.395	0.405	0.643	0.961	0.554	0.831
COMPBDA 15	Correlation	-0.126	0.120	-0.122	-0.095	-0.119	0.086	0.110	-0.024
	Sig. (2-tailed)	0.342	0.364	0.356	0.474	0.368	0.518	0.407	0.856
COMPBDA 16	Correlation	0.144	0.255	.271*	0.086	0.069	-0.011	-0.074	-0.230
	Sig. (2-tailed)	0.275	0.051	0.038	0.516	0.602	0.933	0.576	0.079
COMPBDA 17	Correlation	0.013	0.125	0.129	0.154	0.098	0.038	-0.003	-0.031
	Sig. (2-tailed)	0.924	0.344	0.332	0.243	0.461	0.773	0.981	0.816
COMPBDA 18	Correlation	0.003	0.143	0.205	-0.048	-0.018	0.192	-0.048	-0.034
	Sig. (2-tailed)	0.985	0.279	0.119	0.721	0.894	0.145	0.716	0.799
COMPBDA 19	Correlation	.288*	.264*	.344**	.352**	-0.030	0.035	-0.003	0.023
	Sig. (2-tailed)	0.027	0.044	0.008	0.006	0.821	0.795	0.984	0.865
COMPBDA 20	Correlation	-0.126	0.060	0.013	-0.035	-0.180	0.035	0.047	-0.082
	Sig. (2-tailed)	0.342	0.654	0.920	0.793	0.173	0.790	0.722	0.537

COMPBDA 21	Correlation	.394**	0.224	.369**	.464**	0.125	-0.119	-0.231	0.106
	Sig. (2-tailed)	0.002	0.088	0.004	0.000	0.344	0.371	0.078	0.426

Appendix D5: Canonical correlations between BENIOT- CHIOT and EXPIOT variables (For IOT)

Correlations[a]											
		EXPIOT1	**EXPIOT2**	**EXPIOT3**	**EXPIOT4**	**EXPIOT5**	**EXPIOT6**	**EXPIOT7**	**EXPIOT8**	**EXPIOT9**	**EXPIOT10**
BENIOT1	Correlation	0.569	0.609	0.474	0.415	0.428	0.404	0.144	0.300	0.363	0.466
	Sig. (2-tailed)	0.000	0.000	0.000	0.002	0.002	0.003	0.308	0.031	0.008	0.001
BENIOT2	Correlation	0.552	0.309	0.349	0.300	0.356	0.123	0.054	0.209	0.413	0.448
	Sig. (2-tailed)	0.000	0.026	0.011	0.031	0.010	0.383	0.702	0.138	0.002	0.001
BENIOT3	Correlation	0.362	0.398	0.497	0.493	0.492	0.281	0.313	0.339	0.576	0.587
	Sig. (2-tailed)	0.008	0.003	0.000	0.000	0.000	0.043	0.024	0.014	0.000	0.000
BENIOT4	Correlation	0.447	0.332	0.564	0.484	0.381	0.249	0.224	0.287	0.363	0.512
	Sig. (2-tailed)	0.001	0.016	0.000	0.000	0.005	0.075	0.110	0.039	0.008	0.000
CHIOT1	Correlation	-0.427	-0.501	-0.337	-0.208	-0.430	-0.323	-0.234	-0.306	-0.169	-0.373
	Sig. (2-tailed)	0.002	0.000	0.014	0.140	0.001	0.020	0.096	0.027	0.232	0.006
CHIOT2	Correlation	-0.014	-0.077	0.045	0.000	-0.137	0.103	0.095	0.032	-0.080	-0.207
	Sig. (2-tailed)	0.922	0.589	0.750	1.000	0.331	0.468	0.505	0.820	0.571	0.141
CHIOT3	Correlation	-0.181	-0.027	-0.094	-0.252	-0.128	0.043	0.067	0.008	-0.052	-0.158
	Sig. (2-tailed)	0.200	0.848	0.506	0.072	0.364	0.763	0.635	0.955	0.716	0.263
CHIOT4	Correlation	-0.367	-0.170	-0.394	-0.420	-0.375	-0.271	-0.212	-0.378	-0.287	-0.452
	Sig. (2-tailed)	0.007	0.229	0.004	0.002	0.006	0.052	0.132	0.006	0.039	0.001

Appendix D6: Canonical correlations between BENIOT- CHIOT and COMPIOT variables (For IOT)

		BENIOT1	BENIOT2	BENIOT3	BENIOT4	CHIOT1	CHIOT2	CHIOT3	CHIOT4
COMPIOT1	Correlation	0.105	.295*	-0.014	-0.023	-0.195	-0.148	0.117	0.001
	Sig. (2-tailed)	0.459	0.034	0.921	0.873	0.165	0.294	0.408	0.993
COMPIOT2	Correlation	-0.004	0.126	-0.148	0.072	0.040	0.108	0.172	0.141
	Sig. (2-tailed)	0.980	0.374	0.296	0.610	0.777	0.446	0.222	0.318
COMPIOT3	Correlation	0.141	0.119	.356**	0.219	-0.046	0.259	0.231	-0.120
	Sig. (2-tailed)	0.319	0.401	0.010	0.119	0.746	0.064	0.100	0.397
COMPIOT4	Correlation	0.265	0.226	.298*	.364**	-0.015	.296*	0.247	-0.035
	Sig. (2-tailed)	0.057	0.107	0.032	0.008	0.916	0.033	0.077	0.805
COMPIOT5	Correlation	.370**	0.169	.480**	0.273	-0.045	0.186	-0.117	-0.240
	Sig. (2-tailed)	0.007	0.232	0.000	0.051	0.750	0.186	0.411	0.087
COMPIOT6	Correlation	0.263	.415**	0.266	0.137	-0.217	0.101	-0.208	-0.229
	Sig. (2-tailed)	0.060	0.002	0.056	0.332	0.122	0.477	0.139	0.102
COMPIOT7	Correlation	0.242	.352*	.290*	0.251	-0.215	0.021	-0.146	-0.207
	Sig. (2-tailed)	0.084	0.011	0.037	0.073	0.126	0.881	0.303	0.140
COMPIOT8	Correlation	0.056	-0.011	0.114	-0.038	0.124	0.127	-0.061	-0.039
	Sig. (2-tailed)	0.695	0.937	0.419	0.788	0.379	0.371	0.667	0.785
COMPIOT9	Correlation	0.151	.324*	.348*	0.234	-0.252	-0.031	0.098	-0.251
	Sig. (2-tailed)	0.284	0.019	0.012	0.095	0.072	0.829	0.489	0.072
COMPIOT10	Correlation	0.177	.361**	.350*	0.197	-0.258	-0.013	-0.064	-0.204
	Sig. (2-tailed)	0.209	0.009	0.011	0.162	0.065	0.925	0.655	0.147
COMPIOT11	Correlation	.359**	.430**	0.258	0.168	-.287*	0.104	0.228	-0.273
	Sig. (2-tailed)	0.009	0.001	0.064	0.234	0.039	0.465	0.104	0.050
COMPIOT12	Correlation	0.048	0.173	0.037	-0.068	0.139	0.130	.283*	-0.111
	Sig. (2-tailed)	0.736	0.219	0.792	0.631	0.325	0.359	0.042	0.434
COMPIOT13	Correlation	0.033	0.157	.385**	0.141	-0.181	0.077	0.076	-0.268
	Sig. (2-tailed)	0.814	0.267	0.005	0.318	0.198	0.588	0.593	0.055
COMPIOT14	Correlation	0.134	0.252	.286*	0.111	-0.171	0.062	0.131	-0.094

	Sig. (2-tailed)	0.344	0.071	0.040	0.434	0.227	0.663	0.355	0.507
COMPIOT15	Correlation	0.225	0.203	.432**	0.143	-0.170	0.035	0.006	-0.147
	Sig. (2-tailed)	0.109	0.149	0.001	0.312	0.227	0.803	0.965	0.298
COMPIOT16	Correlation	0.151	0.128	0.195	0.221	-0.130	0.128	0.194	-0.179
	Sig. (2-tailed)	0.286	0.365	0.165	0.115	0.359	0.365	0.169	0.204
COMPIOT17	Correlation	0.076	0.102	0.254	0.270	-0.176	0.011	0.054	-0.181
	Sig. (2-tailed)	0.591	0.473	0.069	0.053	0.211	0.937	0.703	0.199
COMPIOT18	Correlation	0.086	0.009	.294*	0.199	0.038	0.034	.339*	-0.023
	Sig. (2-tailed)	0.543	0.949	0.034	0.158	0.792	0.813	0.014	0.870
COMPIOT19	Correlation	.351*	0.163	.310*	0.254	-.278*	0.024	0.124	-0.163
	Sig. (2-tailed)	0.011	0.248	0.025	0.070	0.046	0.868	0.381	0.248
COMPIOT20	Correlation	0.030	0.038	.317*	0.113	0.014	0.097	0.197	-0.075
	Sig. (2-tailed)	0.834	0.787	0.022	0.424	0.921	0.495	0.161	0.597
COMPIOT21	Correlation	.418**	.310*	0.093	0.197	-.319*	0.052	0.233	-.274*
	Sig. (2-tailed)	0.002	0.025	0.513	0.162	0.021	0.715	0.097	0.049

Appendix E Supportive data for Chapter-5

Appendix E1: Hypothesised relationships of inter-organisational culture and BIM exploitation

INDEPENDENT VARIABLE (IV)	**DEPENDENT VARIABLE (DV)**	**CORRELATION**		**CAUSATION**	
		DIRECTION	**STRENGTH**	**DIRECTION**	**STRENGTH (R)**
CULTBIM1	EXPBIM1	Positive	M	CULTBIM1 → EXPBIM1	.511
CULTBIM1	EXPBIM2	Positive	M	CULTBIM1 →EXPBIM2	.548
CULTBIM1	EXPBIM3	Positive	M	CULTBIM1 →EXPBIM3	.591
CULTBIM1	EXPBIM4	Positive	S	CULTBIM1 →EXPBIM4	.519
CULTBIM1	EXPBIM5	Positive	S	CULTBIM1 →EXPBIM5	.465

CULTBIM1	EXPBIM6	Positive	S	CULTBIM1 → EXPBIM6	.343
CULTBIM1	EXPBIM7	Positive	M	CULTBIM1 → EXPBIM7	.445
CULTBIM1	EXPBIM8	Positive	M	CULTBIM1 → EXPBIM8	.421
CULTBIM1	EXPBIM9	Positive	M	CULTBIM1 → EXPBIM9	.485
CULTBIM1	EXPBIM10	Positive	M	CULTBIM1 → EXPBIM10	.428
CULTBIM2	EXPBIM1	Positive	S	CULTBIM2 → EXPBIM1	.511
CULTBIM2	EXPBIM2	Positive	M	CULTBIM2 → EXPBIM2	.548
CULTBIM2	EXPBIM3	Positive	S	CULTBIM2 → EXPBIM3	.591
CULTBIM2	EXPBIM4	Positive	S	CULTBIM2 → EXPBIM4	.519
CULTBIM2	EXPBIM5	Positive	S	CULTBIM2 → EXPBIM5	.465
CULTBIM2	EXPBIM6	Positive	S	CULTBIM2 → EXPBIM6	.343
CULTBIM2	EXPBIM7	Positive	S	CULTBIM2 →EXPBIM7	.445
CULTBIM2	EXPBIM8	Positive	S	CULTBIM2 →EXPBIM8	.421
CULTBIM2	EXPBIM9	Positive	S	CULTBIM2 →EXPBIM9	.485
CULTBIM2	EXPBIM10	Positive	S	CULTBIM2 →EXPBIM10	.428

CULTBIM3	EXPBIM1	Positive	S	CULTBIM3 → EXPBIM1	.511
CULTBIM3	EXPBIM2	Positive	M	CULTBIM3 → EXPBIM2	.548
CULTBIM3	EXPBIM3	Positive	M	CULTBIM3 → EXPBIM3	.591
CULTBIM3	EXPBIM4	Positive	M	CULTBIM3 → EXPBIM4	.519
CULTBIM3	EXPBIM5	Positive	M	CULTBIM3 → EXPBIM5	.465
CULTBIM3	EXPBIM6	Positive	S	CULTBIM3 → EXPBIM6	.343
CULTBIM3	EXPBIM7	Positive	S	CULTBIM3 → EXPBIM7	.445
CULTBIM3	EXPBIM8	Positive	S	CULTBIM3 → EXPBIM8	.421
CULTBIM3	EXPBIM9	Positive	M	CULTBIM3 → EXPBIM9	.485
CULTBIM3	EXPBIM10	Positive	M	CULTBIM3 → EXPBIM10	.428
CULTBIM4	EXPBIM1	Positive	M	CULTBIM4 → EXPBIM1	.511
CULTBIM4	EXPBIM2	Positive	M	CULTBIM4 → EXPBIM2	.548
CULTBIM4	EXPBIM3	Positive	M	CULTBIM4 → EXPBIM3	.591
CULTBIM4	EXPBIM4	Positive	M	CULTBIM4 → EXPBIM4	.519

CULTBIM4	EXPBIM5	Positive	M	CULTBIM4 → EXPBIM5	.465
CULTBIM4	EXPBIM6	Positive	S	CULTBIM4 →EXPBIM6	.343
CULTBIM4	EXPBIM7	Positive	S	CULTBIM4 →EXPBIM7	.445
CULTBIM4	EXPBIM8	Positive	M	CULTBIM4 →EXPBIM8	.421
CULTBIM4	EXPBIM9	Positive	M	CULTBIM4 →EXPBIM9	.485
CULTBIM4	EXPBIM10	Positive	L	CULTBIM4 →EXPBIM10	.428

Appendix E2: Hypothesised relationships of inter-organisational culture and BDA exploitation

INDEPENDENT VARIABLE (IV)	DEPENDENT VARIABLE (DV)	CORRELATION		CAUSATION	
		DIRECTION	STRENGTH	DIRECTION	STRENGTH (R)
CULTBDA1	EXPBDA1	Positive	M	CULTBDA1→ EXPBDA1	.547
CULTBDA1	EXPBDA2	Positive	S	CULTBDA1→ EXPBDA2	.265
CULTBDA1	EXPBDA3	Positive	S	CULTBDA1→ EXPBDA3	.378
CULTBDA1	EXPBDA4	Positive	S	CULTBDA1→ EXPBDA4	.323
CULTBDA1	EXPBDA5	Positive	S	CULTBDA1→ EXPBDA5	.285
CULTBDA1	EXPBDA6	Positive	S	CULTBDA1→ EXPBDA6	.284

CULTBDA1	EXPBDA7	Positive	S	CULTBDA1→ EXPBDA7	.317
CULTBDA1	EXPBDA8	Positive	S	CULTBDA1→ EXPBDA8	.369
CULTBDA1	EXPBDA9	Positive	S	CULTBDA1→ EXPBDA9	.256
CULTBDA1	EXPBDA10	Positive	S	CULTBDA1→ EXPBDA10	.430
CULTBDA2	EXPBDA1	Positive	S	CULTBDA2→ EXPBDA1	.547
CULTBDA2	EXPBDA2	Positive	S	CULTBDA2→ EXPBDA2	.265
CULTBDA2	EXPBDA3	Positive	S	CULTBDA2→ EXPBDA3	.378
CULTBDA2	EXPBDA4	Positive	S	CULTBDA2→ EXPBDA4	.323
CULTBDA2	EXPBDA5	Positive	S	CULTBDA2→ EXPBDA5	.285
CULTBDA2	EXPBDA6	Positive	S	CULTBDA2→ EXPBDA6	.284
CULTBDA2	EXPBDA7	Positive	S	CULTBDA2→ EXPBDA7	.317
CULTBDA2	EXPBDA8	Positive	S	CULTBDA2→ EXPBDA8	.369
CULTBDA2	EXPBDA9	Positive	S	CULTBDA2→ EXPBDA9	.256
CULTBDA2	EXPBDA10	Positive	S	CULTBDA2→ EXPBDA10	.430

CULTBDA3	EXPBDA1	Positive	M	CULTBDA3→ EXPBDA1	.547
CULTBDA3	EXPBDA2	Positive	S	CULTBDA3→ EXPBDA2	.265
CULTBDA3	EXPBDA3	Positive	M	CULTBDA3→ EXPBDA3	.378
CULTBDA3	EXPBDA4	Positive	S	CULTBDA3→ EXPBDA4	.323
CULTBDA3	EXPBDA5	Positive	S	CULTBDA3→ EXPBDA5	.285
CULTBDA3	EXPBDA6	Positive	S	CULTBDA3→ EXPBDA6	.284
CULTBDA3	EXPBDA7	Positive	S	CULTBDA3→ EXPBDA7	.317
CULTBDA3	EXPBDA8	Positive	M	CULTBDA3→ EXPBDA8	.369
CULTBDA3	EXPBDA9	Positive	S	CULTBDA3→ EXPBDA9	.256
CULTBDA3	EXPBDA10	Positive	M	CULTBDA3→ EXPBDA10	.430
CULTBDA4	EXPBDA1	Positive	M	CULTBDA4→ EXPBDA1	.547
CULTBDA4	EXPBDA2	Positive	S	CULTBDA4→ EXPBDA2	.265
CULTBDA4	EXPBDA3	Positive	M	CULTBDA4→ EXPBDA3	.378
CULTBDA4	EXPBDA4	Positive	S	CULTBDA4→ EXPBDA4	.323

CULTBDA4	EXPBDA5	Positive	S	CULTBDA4→ EXPBDA5	.285
CULTBDA4	EXPBDA6	Positive	S	CULTBDA4→ EXPBDA6	.284
CULTBDA4	EXPBDA7	Positive	M	CULTBDA4→ EXPBDA7	.317
CULTBDA4	EXPBDA8	Positive	M	CULTBDA4→ EXPBDA8	.369
CULTBDA4	EXPBDA9	Positive	S	CULTBDA4→ EXPBDA9	.256
CULTBDA4	EXPBDA10	Positive	M	CULTBDA4→ EXPBDA10	.430

Appendix E3: Hypothesised relationships of inter-organisational culture and IOT exploitation

INDEPENDENT VARIABLE (IV)	DEPENDENT VARIABLE (DV)	CORRELATION		CAUSATION	
		DIRECTION	STRENGTH	DIRECTION	STRENGTH (R-value)
CULTIOT1	EXPIOT1	Positive	S	CULTIOT1→ EXPIOT1	.451
CULTIOT1	EXPIOT2	Positive	S	CULTIOT2→ EXPIOT2	.358
CULTIOT1	EXPIOT3	Positive	M	CULTIOT3→ EXPIOT3	.465
CULTIOT1	EXPIOT4	Positive	S	CULTIOT4→ EXPIOT4	.345
CULTIOT1	EXPIOT5	Positive	S	CULTIOT5→ EXPIOT5	.421
CULTIOT1	EXPIOT6	Positive	S	CULTIOT5→ EXPIOT6	.136
CULTIOT1	EXPIOT7	Negative	S	CULTIOT5→ EXPIOT7	.293
CULTIOT1	EXPIOT8	Positive	S	CULTIOT5→ EXPIOT8	.356

CULTIOT1	EXPIOT9	Positive	S	CULTIOT5→ EXPIOT9	.450
CULTIOT1	EXPIOT10	Positive	S	CULTIOT5→ EXPIOT10	.458
CULTIOT2	EXPIOT1	Positive	S	CULTIOT1→ EXPIOT1	.451
CULTIOT2	EXPIOT2	Positive	S	CULTIOT2→ EXPIOT2	.358
CULTIOT2	EXPIOT3	Positive	S	CULTIOT3→ EXPIOT3	.465
CULTIOT2	EXPIOT4	Positive	S	CULTIOT4→ EXPIOT4	.345
CULTIOT2	EXPIOT5	Positive	S	CULTIOT5→ EXPIOT5	.421
CULTIOT2	EXPIOT6	Positive	S	CULTIOT5→ EXPIOT6	.136
CULTIOT2	EXPIOT7	Negative	S	CULTIOT5→ EXPIOT7	.293
CULTIOT2	EXPIOT8	Negative	S	CULTIOT5→ EXPIOT8	.356
CULTIOT2	EXPIOT9	Positive	S	CULTIOT5→ EXPIOT9	.450
CULTIOT2	EXPIOT10	Positive	S	CULTIOT5→ EXPIOT10	.458
CULTIOT3	EXPIOT1	Positive	M	CULTIOT1→ EXPIOT1	.451
CULTIOT3	EXPIOT2	Positive	S	CULTIOT2→ EXPIOT2	.358
CULTIOT3	EXPIOT3	Positive	M	CULTIOT3→ EXPIOT3	.465
CULTIOT3	EXPIOT4	Positive	S	CULTIOT4→ EXPIOT4	.345
CULTIOT3	EXPIOT5	Positive	M	CULTIOT5→ EXPIOT5	.421
CULTIOT3	EXPIOT6	Positive	S	CULTIOT5→ EXPIOT6	.136
CULTIOT3	EXPIOT7	Negative	S	CULTIOT5→ EXPIOT7	.293
CULTIOT3	EXPIOT8	Positive	S	CULTIOT5→ EXPIOT8	.356
CULTIOT3	EXPIOT9	Positive	S	CULTIOT5→ EXPIOT9	.450

CULTIOT3	EXPIOT10	Positive	S	CULTIOT5→ EXPIOT10	.458
CULTIOT4	EXPIOT1	Positive	M	CULTIOT1→ EXPIOT1	.451
CULTIOT4	EXPIOT2	Positive	M	CULTIOT2→ EXPIOT2	.358
CULTIOT4	EXPIOT3	Positive	M	CULTIOT3→ EXPIOT3	.465
CULTIOT4	EXPIOT4	Positive	S	CULTIOT4→ EXPIOT4	.345
CULTIOT4	EXPIOT5	Positive	M	CULTIOT5→ EXPIOT5	.421
CULTIOT4	EXPIOT6	Negative	S	CULTIOT5→ EXPIOT6	.136
CULTIOT4	EXPIOT7	Positive	S	CULTIOT5→ EXPIOT7	.293
CULTIOT4	EXPIOT8	Positive	S	CULTIOT5→ EXPIOT8	.356
CULTIOT4	EXPIOT9	Positive	M	CULTIOT5→ EXPIOT9	.450
CULTIOT4	EXPIOT10	Positive	M	CULTIOT5→ EXPIOT10	.458

Appendix E4: Hypothesised relationships between organisation structure and BIM exploitation

INDEPENDENT VARIABLE (IV)	DEPENDEN TVARIABLE (DV)	CORRELATION		CAUSATION	
		DIRECTION	STRENGTH	DIRECTION	STRENGTH (R)
STRUCBIM1	EXPBIM1	Positive	S	STRUCBIM1 →EXPBIM1	.363
STRUCBIM1	EXPBIM2	Positive	S	STRUCBIM1→ EXPBIM2	.269
STRUCBIM1	EXPBIM3	Positive	S	STRUCBIM1 →EXPBIM3	.315
STRUCBIM1	EXPBIM4	Positive	S	STRUCBIM1 →EXPBIM4	.277
STRUCBIM1	EXPBIM5	Negative	S	STRUCBIM1 →EXPBIM5	.338
STRUCBIM1	EXPBIM6	Positive	S	STRUCBIM1 →EXPBIM6	.301

STRUCBIM1	EXPBIM7	Positive	S	STRUCBIM1 →EXPBIM7	.296
STRUCBIM1	EXPBIM8	Positive	S	STRUCBIM1 →EXPBIM8	.252
STRUCBIM1	EXPBIM9	Negative	S	STRUCBIM1 →EXPBIM9	.280
STRUCBIM1	EXPBIM10	Positive	S	STRUCBIM1 →EXPBIM10	.287
STRUCBIM2	EXPBIM1	Positive	S	STRUCBIM2 → EXPBIM1	.393
STRUCBIM2	EXPBIM2	Positive	S	STRUCBIM2 → EXPBIM2	.234
STRUCBIM2	EXPBIM3	Positive	S	STRUCBDA2→ EXPBIM3	.331
STRUCBIM2	EXPBIM4	Positive	S	STRUCBIM2 → EXPBIM4	.238
STRUCBIM2	EXPBIM5	Positive	S	STRUCBIM2 → EXPBIM5	.329
STRUCBIM2	EXPBIM6	Positive	S	STRUCBIM2 → EXPBIM6	.289
STRUCBIM2	EXPBIM7	Positive	S	STRUCBIM2 → EXPBIM7	.338
STRUCBIM2	EXPBIM8	Positive	S	STRUCBIM2 → EXPBIM8	.221
STRUCBIM2	EXPBIM9	Negative	S	STRUCBIM2 → EXPBIM9	.237
STRUCBIM2	EXPBIM10	Positive	S	STRUCBIM2 →EXPBIM10	.244
STRUCBIM3	EXPBIM1	Negative	S	STRUCBIM3→ EXPBIM1	.349
STRUCBIM3	EXPBIM2	Negative	S	STRUCBIM3 → EXPBIM2	.279
STRUCBIM3	EXPBIM3	Negative	S	STRUCBIM3 → EXPBIM3	.323
STRUCBIM3	EXPBIM4	Negative	S	STRUCBIM3 → EXPBIM4	.284
STRUCBIM3	EXPBIM5	Negative	S	STRUCBIM3 → EXPBIM5	.315
STRUCBIM3	EXPBIM6	Negative	S	STRUCBIM3 → EXPBIM6	.229
STRUCBIM3	EXPBIM7	Positive	S	STRUCBIM3 → EXPBIM7	.264
STRUCBIM3	EXPBIM8	Negative	S	STRUCBIM3 → EXPBIM8	.247
STRUCBIM3	EXPBIM9	Negative	S	STRUCBIM3 → EXPBIM9	.404

STRUCBIM3	EXPBIM10	Negative	S	STRUCBIM3 →EXPBIM10	.216

Appendix E5: Hypothesised relationships between organisation structure and BDA exploitation

INDEPENDENT VARIABLE (IV)	DEPENDEN TVARIABLE (DV)	CORRELATION		CAUSATION	
		DIRECTION	STRENGTH	DIRECTION	STRENGTH (R)
STRUCBDA1	EXPBDA1	Negative	M	STRUCBDA1 →EXPBDA1	.351
STRUCBDA1	EXPBDA2	Negative	S	STRUCBDA1→ EXPBDA2	.233
STRUCBDA1	EXPBDA3	Negative	S	STRUCBDA1 →EXPBDA3	.327
STRUCBDA1	EXPBDA4	Negative	S	STRUCBDA1 →EXPBDA4	.265
STRUCBDA1	EXPBDA5	Negative	S	STRUCBDA1 →EXPBDA5	.342
STRUCBDA1	EXPBDA6	Negative	S	STRUCBDA1 →EXPBDA6	.289
STRUCBDA1	EXPBDA7	Negative	S	STRUCBDA1 →EXPBDA7	.353
STRUCBDA1	EXPBDA8	Negative	S	STRUCBDA1 →EXPBDA8	.244
STRUCBDA1	EXPBDA9	Negative	S	STRUCBDA1 →EXPBDA9	.231
STRUCBDA1	EXPBDA10	Negative	S	STRUCBDA1→EXPBDA10	.254
STRUCBDA2	EXPBDA1	Negative	S	STRUCBDA2 →EXPBDA1	.351
STRUCBDA2	EXPBDA2	Positive	S	STRUCBDA2 →EXPBDA2	.233
STRUCBDA2	EXPBDA3	Positive	S	STRUCBDA2→ EXPBDA3	.327
STRUCBDA2	EXPBDA4	Negative	S	STRUCBDA2 →EXPBDA4	.265
STRUCBDA2	EXPBDA5	Negative	S	STRUCBDA2 →EXPBDA5	.342
STRUCBDA2	EXPBDA6	Negative	S	STRUCBDA2 →EXPBDA6	.289

STRUCBDA2	EXPBDA7	Negative	S	STRUCBDA2 →EXPBDA7	.353
STRUCBDA2	EXPBDA8	Negative	S	STRUCBDA2 →EXPBDA8	.244
STRUCBDA2	EXPBDA9	Negative	S	STRUCBDA2 →EXPBDA9	.231
STRUCBDA2	EXPBDA10	Negative	S	STRUCBDA2→EXPBDA10	.254
STRUCBDA3	EXPBDA1	Negative	S	STRUCBDA3→EXPBDA1	.351
STRUCBDA3	EXPBDA2	Negative	S	STRUCBDA3 →EXPBDA2	.233
STRUCBDA3	EXPBDA3	Positive	S	STRUCBDA3 →EXPBDA3	.327
STRUCBDA3	EXPBDA4	Negative	S	STRUCBDA3 →EXPBDA4	.265
STRUCBDA3	EXPBDA5	Negative	M	STRUCBDA3 →EXPBDA5	.342
STRUCBDA3	EXPBDA6	Negative	S	STRUCBDA3 →EXPBDA6	.289
STRUCBDA3	EXPBDA7	Negative	S	STRUCBDA3 →EXPBDA7	.353
STRUCBDA3	EXPBDA8	Negative	S	STRUCBDA3 →EXPBDA8	.244
STRUCBDA3	EXPBDA9	Positive	S	STRUCBDA3 →EXPBDA9	.231
STRUCBDA3	EXPBDA10	Negative	S	STRUCBDA3→EXPBDA10	.254

Appendix E6: Hypothesised relationships between organisation structure and IOT exploitation

INDEPENDENT VARIABLE (IV)	DEPENDENT VARIABLE (DV)	CORRELATION		CAUSATION	
		DIRECTION	STRENGTH	DIRECTION	STRENGTH (R)
STRUCIOT1	EXPIOT1	Negative	S	STRUCIOT1→ EXPIOT1	.333
STRUCIOT1	EXPIOT2	Negative	S	STRUCIOT1→ EXPIOT2	.194

STRUCIOT1	EXPIOT3	Negative	S	STRUCIOT1→ EXPIOT3	.274
STRUCIOT1	EXPIOT4	Negative	S	STRUCIOT1→ EXPIOT4	.263
STRUCIOT1	EXPIOT5	Negative	S	STRUCIOT1→ EXPIOT5	.278
STRUCIOT1	EXPIOT6	Negative	S	STRUCIOT1→ EXPIOT6	.285
STRUCIOT1	EXPIOT7	Negative	S	STRUCIOT1→ EXPIOT7	.349
STRUCIOT1	EXPIOT8	Negative	S	STRUCIOT1→ EXPIOT8	.361
STRUCIOT1	EXPIOT9	Positive	S	STRUCIOT1→ EXPIOT9	.140
STRUCIOT1	EXPIOT10	Positive	S	STRUCIOT1→ EXPIOT10	.198
STRUCIOT2	EXPIOT1	Positive	S	STRUCIOT2→ EXPIOT1	.333
STRUCIOT2	EXPIOT2	Positive	S	STRUCIOT2→ EXPIOT2	.194
STRUCIOT2	EXPIOT3	Negative	S	STRUCIOT2→ EXPIOT3	.274
STRUCIOT2	EXPIOT4	Positive	S	STRUCIOT2→ EXPIOT4	.263
STRUCIOT2	EXPIOT5	Negative	S	STRUCIOT2→ EXPIOT5	.278
STRUCIOT2	EXPIOT6	Negative	S	STRUCIOT2→ EXPIOT6	.285

STRUCIOT2	EXPIOT7	Positive	S	STRUCIOT2→ EXPIOT7	.349
STRUCIOT2	EXPIOT8	Positive	S	STRUCIOT2→ EXPIOT8	.361
STRUCIOT2	EXPIOT9	Positive	S	STRUCIOT2→ EXPIOT9	.140
STRUCIOT2	EXPIOT10	Positive	S	STRUCIOT2→ EXPIOT10	.198
STRUCIOT3	EXPIOT1	Negative	S	STRUCIOT3→ EXPIOT1	.333
STRUCIOT3	EXPIOT2	Positive	S	STRUCIOT3→ EXPIOT2	.194
STRUCIOT3	EXPIOT3	Positive	S	STRUCIOT3→ EXPIOT3	.274
STRUCIOT3	EXPIOT4	Negative	S	STRUCIOT3→ EXPIOT4	.263
STRUCIOT3	EXPIOT5	Negative	S	STRUCIOT3→ EXPIOT5	.278
STRUCIOT3	EXPIOT6	Negative	S	STRUCIOT3→ EXPIOT6	.285
STRUCIOT3	EXPIOT7	Negative	S	STRUCIOT3→ EXPIOT7	.349
STRUCIOT3	EXPIOT8	Negative	S	STRUCIOT3→ EXPIOT8	.361
STRUCIOT3	EXPIOT9	Positive	S	STRUCIOT3→ EXPIOT9	.140
STRUCIOT3	EXPIOT10	Negative	S	STRUCIOT3→ EXPIOT10	.198

Appendix E7: Hypothesised relationships of organisation size and BIM exploitation

INDEPENDENT VARIABLE (IV)	DEPENDENT VARIABLE (DV)	CORRELATION		CAUSATION	
		DIRECTION	STRENGTH	DIRECTION	STRENGTH (R)
SIZBIM1	EXPBIM1	Positive	S	SIZBIM1 →EXPBIM1	.152
SIZBIM1	EXPBIM2	Positive	S	SIZBIM1 →EXPBIM2	.163
SIZBIM1	EXPBIM3	Positive	S	SIZBIM1 →EXPBIM3	.054
SIZBIM1	EXPBIM4	Positive	S	SIZBIM1 →EXPBIM4	.074
SIZBIM1	EXPBIM5	Positive	S	SIZBIM1 →EXPBIM5	.096
SIZBIM1	EXPBIM6	Positive	S	SIZBIM1 →EXPBIM6	.125
SIZBIM1	EXPBIM7	Positive	S	SIZBIM1 →EXPBIM7	.029
SIZBIM1	EXPBIM8	Positive	S	SIZBIM1 →EXPBIM8	.170
SIZBIM1	EXPBIM9	Positive	S	SIZBIM1 →EXPBIM9	.181
SIZBIM1	EXPBIM10	Positive	S	SIZBIM1 →EXPBIM10	.007
SIZBIM2	EXPBIM1	Positive	S	SIZBIM2 →EXPBIM1	.102
SIZBIM2	EXPBIM2	Negative	S	SIZBIM2 →EXPBIM2	.154
SIZBIM2	EXPBIM3	Negative	S	SIZBIM2 →EXPBIM3	.148
SIZBIM2	EXPBIM4	Negative	S	SIZBIM2 →EXPBIM4	.178
SIZBIM2	EXPBIM5	Negative	S	SIZBIM2 →EXPBIM5	.152
SIZBIM2	EXPBIM6	Positive	S	SIZBIM2 →EXPBIM6	.118
SIZBIM2	EXPBIM7	Positive	S	SIZBIM2 →EXPBIM7	.011

SIZBIM2	EXPBIM8	Negative	S	SIZBIM2 →EXPBIM8	.108
SIZBIM2	EXPBIM9	Positive	S	SIZBIM2 →EXPBIM9	.037
SIZBIM2	EXPBIM10	Positive	S	SIZBIM2 →EXPBIM10	.034

Appendix E8: Hypothesised relationships of organisation size and BDA exploitation

INDEPENDENT VARIABLE (IV)	DEPENDENT VARIABLE (DV)	CORRELATION		CAUSATION	
		DIRECTION	STRENGTH	DIRECTION	STRENGTH (R)
SIZBDA1	EXPBDA1	Positive	S	SIZBDA1 →EXPBDA1	.157
SIZBDA1	EXPBDA2	Positive	S	SIZBDA1 →EXPBDA2	.118
SIZBDA1	EXPBDA3	Positive	S	SIZBDA1 →EXPBDA3	.066
SIZBDA1	EXPBDA4	Negative	S	SIZBDA1 →EXPBDA4	.089
SIZBDA1	EXPBDA5	Positive	S	SIZBDA1 →EXPBDA5	.138
SIZBDA1	EXPBDA6	Positive	S	SIZBDA1 →EXPBDA6	.147
SIZBDA1	EXPBDA7	Positive	S	SIZBDA1 →EXPBDA7	.129
SIZBDA1	EXPBDA8	Positive	S	SIZBDA1 →EXPBDA8	.108
SIZBDA1	EXPBDA9	Positive	S	SIZBDA1 →EXPBDA9	.061
SIZBDA1	EXPBDA10	Positive	S	SIZBDA1 →EXPBDA10	.134
SIZBDA2	EXPBDA1	Negative	S	SIZBDA2 →EXPBDA1	.126
SIZBDA2	EXPBDA2	Negative	S	SIZBDA2 →EXPBDA2	.158
SIZBDA2	EXPBDA3	Negative	S	SIZBDA2 →EXPBDA3	.008
SIZBDA2	EXPBDA4	Negative	S	SIZBDA2 →EXPBDA4	.062
SIZBDA2	EXPBDA5	Negative	S	SIZBDA2 →EXPBDA5	.145

SIZBDA2	EXPBDA6	Positive	S	SIZBDA2 →EXPBDA6	.031
SIZBDA2	EXPBDA7	Positive	S	SIZBDA2 →EXPBDA7	.104
SIZBDA2	EXPBDA8	Positive	S	SIZBDA2 →EXPBDA8	.098
SIZBDA2	EXPBDA9	Negative	S	SIZBDA2 →IMPBDA9	.107
SIZBDA2	EXPBDA10	Negative	S	SIZBDA2 →IMPBDA10	.160

Appendix E9: Hypothesised relationships of organisation size and IOT exploitation

INDEPENDENT VARIABLE (IV)	DEPENDENT VARIABLE (DV)	CORRELATION		CAUSATION	
		DIRECTION	STRENGTH	DIRECTION	STRENGTH (R)
SIZIOT1	EXPIOT1	Negative	S	SIZIOT1 →IMPIOT1	.052
SIZIOT1	EXPIOT2	Negative	S	SIZIOT1 →IMPIOT2	.123
SIZIOT1	EXPIOT3	Negative	S	SIZIOT1 →IMPIOT3	.194
SIZIOT1	EXPIOT4	Negative	S	SIZIOT1 →IMPIOT4	.121
SIZIOT1	EXPIOT5	Negative	S	SIZIOT1 →IMPIOT5	.085
SIZIOT1	EXPIOT6	Negative	S	SIZIOT1 →EXPIOT1	.125
SIZIOT1	EXPIOT7	Positive	S	SIZIOT1 →EXPIOT2	.029
SIZIOT1	EXPIOT8	Positive	S	SIZIOT1 →EXPIOT3	.070
SIZIOT1	EXPIOT9	Positive	S	SIZIOT1 →EXPIOT4	.114
SIZIOT1	EXPIOT10	Positive	S	SIZIOT1 →EXPIOT5	.127
SIZIOT2	EXPIOT1	Negative	S	SIZIOT2 → EXPIOT1	.169
SIZIOT2	EXPIOT2	Negative	S	SIZIOT2 → EXPIOT2	.143
SIZIOT2	EXPIOT3	Positive	S	SIZIOT2 → EXPIOT3	.012
SIZIOT2	EXPIOT4	Negative	S	SIZIOT2 → EXPIOT4	.113

SIZIOT2	EXPIOT5	Positive	S	SIZIOT2 → EXPIOT5	.109
SIZIOT2	EXPIOT6	Negative	S	SIZIOT2 →EXPIOT6	.105
SIZIOT2	EXPIOT7	Positive	S	SIZIOT2 →EXPIOT7	.167
SIZIOT2	EXPIOT8	Positive	S	SIZIOT2 →EXPIOT8	.098
SIZIOT2	EXPIOT9	Positive	S	SIZIOT2 →EXPIOT9	.100
SIZIOT2	EXPIOT10	Negative	S	SIZIOT2 →EXPIOT10	.105

Appendix F Supportive data for Chapter-6

Appendix F1: Summary of interviewees' perceptions on current and future skill-knowledge and training needs for BIM, BDA and IOT

Skills, knowledge, and training needs for Building Information Modelling (BIM)	
Current Skills and training needs	
Quoted Perception	**Key Dimension of the perception**
“In the BIM era, a manager at any level would need both the skills of the traditional project manager and the BIM-related technical skills for the technical coordination of the design” (I-8)	Importance of having both technical and management skills/knowledge for every employee
*“Not everybody needs to know about BIM, but somebody must know how to apply it to make it valuable, Therefore, it’s the availability of information about who knows what, we can then approach the right person without getting ourselves trained for something we actually don’t need in our regular duties”(*I-21)	Not everybody needs to have the technical skills. What's important in technology is to know who’s the best person to contact in any given area
“You don’t get the job if you are not BIM certified. It’s important that people get trained for BIM” (I-16)	Nowadays, BIM training is a must
“We are a member of ‘X’ Training Board and ‘Y’ Working Group. We also facilitate our employees for many training courses offered by ‘Z- academy’ and ‘A- group’ So, we have a good training system for BIM” (I-11). “*I think for BIM, we have a quite good training programme lined-up which does not necessarily require heavy uplifting”* (I-9)	We have sufficient BIM training
*“Yes, we currently have training programmes implemented but we continuously learn and train”(*I-5). *“There’s always room for more training”* (I-19). *“It is always good that we increase our training opportunities, therefore, yes we require more training”* (I-10); “Our Company has started some training programmes, but certainly need more training on these areas. We are looking at partnering with government training agencies” (I-12)	We have implemented training programme to some extent but, there’s still room for improvement
“We are lagging behind other companies in terms of training. We certainly need to establish a good training policy”(I-4); “Our company require more training because our skilled workforce is quite scattered.”(I-14)	The current training is not sufficient

"BIM Training is essential to unlock the full potential of the BIM technology, especially because projects in the AEC industry involve large investments of capital. Therefore, there is limited room for errors. Works must be performed correctly and fast in order to maximise efficiency" (I-25)	BIM Training is highly important for AEC industry
"We have heavily invested in training our staff. An example of that would be having a program that offers a wide range of skills to all our branches. We also have apprenticeship programmes" (I-25)	We have a range of different training methods
Future Skills and training needs	
"I don't believe that the industry will undergo a massive transformation. Because we are not the innovators, we are just the laggards" (I-4). *"Being realistic, I think the training requirement is going to be the same for the next five years. Because we have not filled the training requirement yet. We need to have the whole team or large parts of the team trained-up to understand BIM, BIM data, soft landing, and so on. But when you move into BIM level 3, there is further training requirements. But I do not think it is realistic to expect us to be anywhere near that. We will need the next five years to get equipped for BIM level-2"* (I-2)	A massive transformation of the industry cannot be expected within next five years. Realistically, the training requirement is going to be the same for the next five years.
"In countries like the UK, the demand for BIM skills are rising and BIM is expected to become the standard practice in the coming years" (I-19)	The BIM skill demand will rise in next five years

Skills, knowledge, and training needs for Big Data Analytics (BDA)	
Current Skills and training needs	
Quoted Perception	**Key Dimension of the perception**
"The demand for skilled Data Engineers (or Big Data Engineers) is rapidly growing. Regardless of what your company does, to succeed in today's competitive environment, you need a robust infrastructure to both store and access your company's data. This is a prerequisite for every company. I think, if we are using data analytics in the right way, we need the staff to be trained on all the data related skills and knowledge dimensions" (I-6)	The demand for data management skills is high
"We do have massive training programmes up and running. So, these include the big data analytical part as well. It is well maintained in our company"(I-6)	We are satisfied with our current training policy

"For data protection, we have monthly training, but not for analytics within our site. But, in head offices we do have lot of training going on for data analytics to ensure at least 1,500 people across our direct and indirect workforce undertake an apprenticeship or vocational training" (I-3).	The current training is well sufficient for some areas, but at the same time, inadequate for certain areas
"It is necessary to get your hands dirty. We are trying to gain hands-on experience with the big data tools. Because the technology changes very quickly, short-term courses significantly help to match those short-term requirements. We have such short courses, but I think they need to be improved and we need them frequently. We will need to help existing managers at all levels to make them comfortable with data and analytics. They may not become 'data natives' or experts themselves, but they need to embrace the advantages of data and analytics. Therefore, education is important, especially to create a bridge between the data science and traditional business world" (I-11. *"Our company certainly need more training on these areas" (I-12).* *"The point with all of these things is that big data is nothing without human intervention. I think more training is required in skills around human dimensions like soft skills, including leadership, people management, behavioural science(I-9)*	We need more training
"Generally, we have a very good training policy specifically in big data side. However, there are areas we still need to catch-up on. It is supportive and on-going and at the same time it is sort of a more formal process that result in delays" (I-18)	We have implemented training programmes to some extent but, there's still room for improvement
"There will be more people that are going to enter into the industry and it's going to be considerable need for training" (I-12)	We certainly need more training because of the increasing amount of entries into the industry
Future Skills and training needs	
"I have no doubt that over the next five-ten years, we will change significantly and that we will have more data analysts than people fixing things" (I-10). "Big data isn't just an important part of the future, it may be the future itself, so our industry will definitely shape the future" (I-16)	The construction industry will change significantly in terms of big data analytics in the next five years
"The changes we will see in next five years for Big Data will not reflect a massive difference as we are going on a slow pace" (I-2) .	Changes are expected, but not so soon as in five years. It will be on a slow pace.

Skills, knowledge, and training needs for Internet of Things (IOT)	
Current Skills and training needs	
Quoted Perception	**Key Dimension of the perception**
"I think being able to convince is the most important skill. From my point of view, being able to make that case, to my boss, in particularly why we should invest money in IOT. It is to make the case and convince people. People need to have the basic understanding of the principles. I do not think you have to have the technical knowledge. The thing about facility management is, it is such a broad area that a facility manager does not have a deepened understanding of every area he is responsible for. You get specialist cleaners, specialist securities, and specialist maintenance and it is the same. I would bring in the consultant basically. I need to know how to identify the best consultants. I think that's the skill I need have" (I-2). *"Probably what they need to do is, start with getting people onboard. At senior management level, advising employees to spread awareness is important. Training for specialist skills can then be done"(I-16)*	Being able to convince the value of IOT for the employees is far important than having specialist skills
"BIM managers do not necessarily need to have knowledge about asset information. What they need to have is knowledge around engineering and project management to be able to use asset information and to manipulate assets at functional information level. BIM workflow and asset information comes in fragmented silos. Therefore, we need to bridge this gap. This can only be done by cross-discipline training" (I-14)	Cross discipline skills and knowledge is important
"One of the biggest challenges that we have identified is how to upskill the professions within our company to cater the technology demand. We must start this as early as undergraduate level. We cannot just rely on the traditional method of teaching the technical skills" (I-9).	There are quite serious challenges with regards to IOT upskilling we need to overcome as an industry.
"There is a big barrier to training the leaders especially for big data and IOT. Because BIM has now become business as usual and people get the basic BIM training. But the problem is for BDA and IOT. In digital education, you got to bribe or scare the staff in getting good at these things by either grants or things like the 2011 BIM mandate. However, apprenticeships can play a role in bringing industry and academia closer together, this must start now. Therefore, quite a lot of improvement needed in BDA and IOT sides. If we spent	Barriers to IOT training

a bit more time trying to make the apprenticeships work rather than using it as a cash cow to fund part-time degree courses, it could help bring these digital skills into the industry" (I-7) *Lot of current CPD events encourage understanding of these IOT, BDA techniques rather than an application of them to the real world. It is about an application of the process, not just reiterating what the standard says. Again, vocational training needs more push. More standardised accreditation of that certification I think would make it more useful for things like IOT and Big Data". (I-7)*	
"We have a range of training sessions running in collaboration with a standard development institute. This training covers all dimensions of the application of the Internet of Things in an organisation: Business models, Technical aspects, Organisational concerns, Budget impact and Security issues. We give this training to many roles regardless of their daily task involvement to IOT." (I-8)	We have a range of different IOT training methods, and they are for all levels of managers.
"I don't think having a special IOT programme would be beneficial for any company. We have on-going training for smart technology at our head offices. But not very focused on the specific issues of IOT. We have invested in training and development through our talent management programmes to realise the potential of our people across all areas of the business, but not for IOT- that is not yet in the priority list (I-4)	Do not see an urgent need for training
*"We have training but still they require more support"(I-14); "*The existing training is not sufficient. We require more training around IOT"(I-11); "Our company certainly need more training on these areas"(I-12)	We have some training programmes but still, we need more training because of their inadequacy
"We do not have training policy specifically for IOT. There is nothing like formal route for training. If you had an interest in IOT and you want to do a training course, they would support you. But there is no such a thing like IOT academy or something like that. I think that is something we need to pay attention to implement"(I-18); *"Not yet but it will be coming in a way. I think it is important to address the fundamentals in the here and now and try to get that consistently progressing. I clearly see there is an urgent training need for IOT but, unfortunately we still haven't got that" (I-20)*	We have not established a formal IOT training programme yet.
"Because we are a company moving to a data driven future, we have started lot of training programmes targeting above areas on digitalisation. We have a scheme that we give sponsorship/ scholarship for certain employees to go and obtain relevant certificates in the field" (I-19).	We give sufficient support for IoT training

"We have a good training process for the IoT skills. We have a strong side in terms of IOT as we started with our home security systems and now that we have exploited the smart security systems" (I-10)	
"I'm actually going to write a strategy for IOT training, and I will find some money in the budget to support that. But that is not going to be to the extent that I would love it to be. It should be central, if I were the director of the company, it should be our central plan and policy of what we would all moving towards, because that is the future. But I am in a low voice now. So, unfortunately I don't know how far my strategy will go"(I-2)	Sees the need for training but not in a position to implement it. It must be initiated by senior management
"A quite big chunk of funding has been allocated for construction sector digitalisation by UK Government to be able to invest in a range of projects and this will fund up to 70% of the total value of the project. So, the industry has more opportunities available for upskilling. We must use them for our benefit. If we look at the company level, still we require training to a greater extent. We need to make use of the opportunities offered by the government" (I-9)	Government is lending their hand; we are not making beneficial use out of it
Future Skills and training needs	
"There will be a huge difference. Within our company, IOT is definitely an area that we'll take lot more serious in the future" (I-18) *"Definitely in next five years, there would be exponentially growth in the skill requirement as well as training requirements"(I-20).*	There will be a huge difference in the skills and training for IOT in construction in next five years
"I do not think in construction industry, there will be a very big advance in the skills of IOT. We are one of the leaders in IOT and smart security. So, there are a lot to reach that level as well"(I-10)	*There will not be a very big advance in the skills of IOT in construction in the next five years*
"There may be a difference in how we manage our data and what system we use to make payment, but I don't believe they'll be a massive change in how we turn off the light"(I-4) *"There will be a change. But I think it is going to be a slightly longer journey. And it will take much longer to get there, where the other sectors are now. It is like any industry that has not been through a revolution. It will take longer"(i-16)* *"Drone technology, smart City development, remote access control will be the key skills for future. But all these will not happen within next five years. It will take some time. I am however pretty sure that construction industry will begin to implement all of these in a certain extent" (I-25)*	There may be some advances, but not a noticeable difference. It is going to be a slow and long journey.

Appendix F2: Further insights for BIM, BDA and IOT Skills/ knowledge from Qualitative data

	SKILL/KNOWLEDGE DIMENSION FOR BIM			
	KEY DIMENSIONS	**SUB-DIMENSIONS (CURRENT)**	**SUB-DIMENSIONS (FUTURE)**	**NEED FOR TRAINING**
1	**Leadership** (i.e. leading and guiding others through the overall process of implementing/exploiting BIM systems and workflows)	***1.1 Leadership in digitalisation*** ***1.2 Empowering others*** ***1.3 Managing people and culture*** ***1.4 Teaching and coaching***	***1.1 Rapid prototyping*** ***1.2 Immersive learning***	*Skills for leadership disciplines are in increasing demand. Ability to create quick early versions of changes (innovation), with the expectation that later success will require early failures. Helps to fail early, often, and cheaply which eventually helps getting into flawless results. When coupled with 'digital leadership', executives and managers across clients, contractors, consultants, and the supply chain are giving their lead to resourcing and delivering their projects digitally.*
2	**Communication- oral/written** (i.e. communicating overall managerial goals of BIM systems and workflows)	***2.1 Maintaining the effectiveness of communication*** ***2.2 Listening to subordinates*** ***2.3 Ability to explain complex situations***	***2.1 Ability to communicate with shared sense of meaning***	*Ability to create, engage with and nurture a sense of common purposefulness or social change networks through intelligent use of electronic or other media. Among a range of media options, choosing the best medium for each communication challenge.*

3	**Negotiation** (i.e. negotiating with business partners/ clients/ supply chain members for maximizing the delivery value as well as for business development)	***3.1 Negotiate for a better value*** ***3.2 Conflict management***	***3.1 Negotiate towards a Win-Win outcome*** ***3.2 Conflict management***	*Delicate balance between ownership of one's principles and the ability to compromise. Create an environment in which conflict is a rare occurrence and joint decision making is favoured.*
4	**Motivation** (i.e. encouraging employees to use and share BIM tools and processes productively and effectively)	***4.1 Creativity*** ***4.2 Forward thinking*** ***4.3 Willingness to change things*** ***4.4 Willingness to learn*** ***4.5 Willingness to want to engage***	***4.6 Emotional Intelligence***	*The need for training in motivation skills is a part of the entire construction process.*
5	**Teamwork** (i.e. managing collaborative teams involved in the delivery of BIM projects, including BIM steering committee recruitment and delegation of authority according to each individual's competencies)	***5.1 Cross discipline collaboration*** ***5.2 Team building***	***5.1 Cross discipline collaboration***	*Team building will improve a group's motivation. It enables individuals to work effectively across teams to plan and to communicate and deliver digitally enabled Smart Construction projects*
6	**Decision Making** (i.e. making the right decisions to achieve organisational or managerial objectives)	***6.1 problem solving*** ***6.2 Dispute resolution*** ***6.3 logical thinking***	***6.1 Dispute resolution*** ***6.2 Problem solving***	*Better training in decision-making avoids disputes as they arise*
7	**Strategic Planning** (i.e. Identify strategic objectives and implement strategies)	***7.1 Business Justification*** ***7.2 Business value of BIM*** ***7.3 Managing the future with a strategic vision*** ***7.4 Project initiation***	***7.1 Business case for BIM*** ***7.2 Macro level target achievement***	*Skills around strategy building will remain in demand as they already face skills shortages, and they are essential in maintaining and extending the existing built environment.*

8	**Partnership and Alliancing** (i.e. initiating partnerships and alliances with other organisations based on BIM deliverables for business development)	***8.1 Agreeing to collaborate across businesses***	***8.1 When businesses agree to collaborate without giving up their independent status***	*Industry must follow the lead of other sectors (e.g. medical) and develop collaborative relationships with technology, software, and equipment providers to enable fully integrated technical solutions to be developed and minimised sector fragmentation.*
9	**Finance Accounting and Budgeting** (planning, allocating, monitoring, and controlling the costs associated with BIM implementation/ exploitation)	***9.1 Whole life costing for BIM process*** ***9.2 Value management for BIM process***	***9.1 Cost Planning*** ***9.2 Value management***	*Helps identifying all costs associated with the BIM system including hidden costs.*
10	**Marketing** (i.e. promoting organisation's BIM capability to its clients and business partners, carry out research on the market position, absorptive capacity, and appetite for BIM deliverables)	***10.2 Promoting BIM implemented projects***	***10.1 Product innovation***	*Marketing firms to reach their target audience in an authentic and helpful way.*
11	**Tendering and Procurement** (i.e. facilitating and steering the procurement of BIM products and services including managing the contractual obligations underlying collaborative BIM Projects and workflows)	***11.1 Use of BIM visualisation in scheduling and reduce the risk of misunderstanding between parties*** ***11.2 fast quantity take-offs through BIM*** ***11.3 Resources allocation***	***11.1 Presentational skills are crucial*** ***11.2 fast quantity take-offs through BIM higher maturity levels- fully integration***	*Training in tendering and estimating helps getting the strategies to achieve best price that will win the contract in a competitive bidding situation, while ensuring that the contract can be carried out profitably.*
12	**Risk Management** (i.e. managing the risks associated with using BIM tools and collaborative workflows)	***12.1 Security*** ***12.2 Use of BIM in minimising the risks***	***12.1 Use of BIM in minimising the risks***	*Risk management helps to plan, monitor, and control those measures needed to prevent exposure to risk.*

13	**Quality Management** (i.e. establishing, managing, and controlling the quality of BIM models, and other project Deliverables)	***13.1 Quality assurance (QA)*** ***13.2 Quality control (QC)***	***13.1 Value Engineering*** ***13.2 Design for Excellence***	*A management system used by construction companies to ensure delivery of high quality products to their customers and client* *Inspecting, Checking and confirming that the work or product that is produced meets the set standards or is correct- technical integrity of the model, the content of the model as well as the verification of the information contained in the model.*
14	**Performance Management** (i.e. evaluating the organisational BIM capability/ maturity against a benchmark)	***14.1 Asset management process*** ***14.2 Employer's information requirements (EIR)*** ***14.3 Interoperability*** ***14.4 Convergence of BIM with other cyber-physical systems*** ***14.5 Integrated project delivery*** ***14.6 Creation of a fully integrated knowledge base/ solutions*** ***14.7 Plan and Quality in project delivery*** ***14.8 Post occupancy evaluations and Asset information model.*** ***14.9 Productivity improvements*** ***14.10 Operational delivery***	***14.1 Design optimisation*** ***14.2 digital asset management*** ***14.3 Integrated project delivery*** ***14.4 Energy Efficiency***	*Productivity improvements within the sector. Training in improving BIM performance helps to unlock the full potential of the BIM technology, especially in sectors like AEC which contains projects involve huge investments of capital, there is limited room for errors; works must be performed correctly and fast in order to maximise efficiency, hence profit.*

15	**Operational Management** (i.e. general modelling, capturing, representing, simulating, quantifying, monitoring, controlling, linking and extending the BIM model with model-based collaboration)	***15.1 BIM awareness- What is BIM*** ***15.2 Understanding of the benefits of BIM*** ***Knowledge of construction nomenclature (Technology literature) and techniques (means and methods)*** ***15.3 Understanding of the Common language for BIM*** ***15.4 BIM capabilities- Ability to use digital technology*** ***15.5 technical knowledge of BIM*** ***15.6 BIM standard and outline specifications*** ***15.7 Protocols required to leverage BIM*** ***15.8 BIM technological maturity*** ***15.9 BIM visualisation and virtual reality*** ***15.10 use of Common data environment*** ***15.11 Design optimisation*** ***15.12 industry Foundation classes (IFC)*** ***15.13 Automation of building design*** ***15.14 Augmented Reality*** ***15.15 internet of things*** ***15.16 understanding of design and document coordination***	***15.1 Automation and digital technology*** ***15.2 Augmented Reality and virtual reality*** ***15.3 Automation of building design*** ***15.4 BIM Level-2*** ***15.5 BIM Soft landing*** ***15.6 internet of things*** ***15.7 Measurement system analysis (MSA)*** ***15.8 Robotics Engineering*** ***15.9 Game based simulation*** ***15.10 Assembly technology***	*Principles of Building Information Modelling. Including its application to the whole-of-life design, construction, management, and operation.*

16	**Technological infrastructure** (i.e. installing, managing, and maintaining general IT infrastructure, including network support with specific software and hardware equipment requirements)Management	***16.1 facilities management*** ***16.2 Cloud computing*** ***16.3 Convergence of BIM with other cyber-physical systems*** ***16.4 Software handling*** ***16.5 Background knowledge around construction technology*** ***16.6 Up-to-date BIM knowledge***	***16.1 Facility management*** ***16.2 Cloud computing*** ***16.3 Convergence of BIM with other cyber-physical systems*** ***16.4 installation and assembly*** ***16.5 Modern methods of construction (MMC)*** ***16.6 Up-to-date software applications*** ***16.7 Systems integration***	*Technical skills to enable deployment of Smart Construction methods during all stages of a project's lifecycle: project initiation, design delivery and operation.* *Staying up to date to government requirements, making a significant contribution individual continued professional development.*
17	**Legislation Management** (i.e. understanding the legal requirements of BIM tools and workflows- policies, regulations and procedures for BIM standards and specifications)	***17.1 Awareness of the government and the industry*** ***17.2 Contractual terms and conditions***	***Contractual terms*** ***Up-to-date policies and protocols***	*Helps, construction claim management*
18	**Innovation Management (i.e. support and facilitate experimenting new beneficial uses of the innovation processes for continuous improvement and change management)**	***18.1 Change management*** ***18.2 Digital transformation from traditional***	***18.1 Change management*** ***18.2 Creativity*** ***18.3 Adaptability*** ***18.4 Agility***	*Allows to take in to account the opportunities that different phases of construction create for innovation and nurture innovations by understanding the behaviour of innovation.*
19	**Supply Chain Management** (i.e. design, plan, execute, control, and monitor supply chain activities related to BIM processes to provide best value)	***19.1 Effective, efficient delivery from aligned systems and procedures*** ***19.2 Compliance with supply chain requirement*** ***19.3 Independent verification of capability for supply chain***	***19.1 Steering supply chain***	*BIM training has simplified and clarified procurement process in the supply chain*

20	**Information Management** (i.e. acquisition of information from varied sources in varied formats to storing, processing and distribution of them)	***20.1 COBie data structure*** ***20.2 Data science*** ***20.3 Algorithms*** ***20.4 Blockchain*** ***20.5 Coding*** ***20.6 Machine learning*** ***20.7 Real-time data analytics*** ***20.8 Project information model and Asset Information Model***	***20.1 Real-time Data Analytics towards insightful information*** ***20.2 Data science*** ***20.3 Algorithms*** ***20.4 Artificial intelligent processes*** ***20.5 Blockchain*** ***20.6 Building Information Optimization*** ***20.7 Coding*** ***20.8 Machine learning***	*Organisations are under increasing pressure to handle the increasing amount of information responsibly and ethically. Information management training ensures data is securely hosted, accessible, traceable, and not just for the current use, but for the lifetime that it may be required.*

	SKILL/KNOWLEDGE DIMENSION FOR BDA			
	KEY DIMENSIONS	**SUB-DIMENSIONS (CURRENT)**	**SUB-DIMENSIONS (FUTURE)**	**NEED FOR TRAINING**
1	***Leadership*** (i.e. leading and guiding others through the overall process of implementing/exploiting Big Data systems)	***1.1 Strategic leadership*** ***1.2 Planning and implementation of Big Data process flow***	***1.1 Social sciences background***	*Training in different leadership aspects allows improved Business Decision-Making and thereby improved Operational Performance.* *Training in social sciences could help looking at the social impact of data as well within the built environment.*

2	***Communication oral/written*** (i.e. communicating overall managerial goals of Big Data systems)	***2.1 Communicating results***	***2.1 Creating interactive visualisations (i.e. for dashboards)***	*presenting what have been found in a manner that people are willing to trust, believe and take actions is a key.*
3	***Negotiation*** (i.e. negotiating with business partners/ clients/ supply chain members for maximizing the delivery value as well as for business development)	***3.1 Trust building in B2B relationships***	***3.1 Ability to utilising data in deal-making***	*Negotiation skills with industry experts will expose yourself to relevant opportunities based on their business expertise. Ability to utilise data in deal-making will be a more desirable skill for future construction professionals than the ability to negotiate face-to-face.*
4	***Motivation*** (i.e. encouraging employees to use and share Big Data tools and processes productively and effectively)	***4.1 Human resources management*** ***4.2 Organisational culture management***	***4.1 Courage building*** ***4.2 Improving data process transparency*** ***4.3 Work ethics*** ***4.4 Human behavioural science***	*Understanding the benefits of big data analytics offer some degree of motivation to managers to use big data.*
5	***Teamwork*** (i.e. managing collaborative teams involved in the delivery of Big Data projects, including Data analysing steering committee recruitment and delegation of authority according to everyone's competencies)	***5.1 Making meaningful interactions with the team***	***5.1 holistic overviewing by ingesting data from many sources***	*Creating a team that can deliver value out of big data rather than silos that work in isolation is crucial.* *Making meaningful interactions with all members of an organization's hierarchy helps taking the industry knowledge to recommend ideas that can be applied right away.*

6	***Decision Making*** (i.e. making the right decisions to achieve organisational or managerial objectives)	***6.1 Problem solving*** ***6.2 Research*** ***6.3 Reaching conclusions***	***6.1 Horizon-scanning*** ***6.2 Anticipatory and proactive decision making***	*Employees trained for decision making could help better understand customers form data analytics and make more informed business decisions and meet their needs,*
7	***Strategic Planning*** (i.e. Identify strategic objectives and implement strategies)	***7.1 Value proposition of big data*** ***7.2 Exploitation of data*** ***7.3 Business case of big data*** ***7.4 Business improvement*** ***7.5 Competitor analysis*** ***7.6 Metrics (KPI) development for business goals***	***7.1 Business case of big data*** ***7.2 Capability assessment*** ***7.3 Plan and implement a big data strategy***	*Raising awareness of the value of data for businesses identify the benefits of it.* *Exploitation of data can help constructors add value to their service delivery offering. Parties involved need to know what they have built and to be able to hand over data to the employer to support their asset.*
8	***Partnership and Alliancing*** (i.e. initiating partnerships and alliances with other organisations based on Big Data inputs and outputs for business development)	***8.1 Networking*** ***8.2 Community engagement***	***8.1 Partnering***	*Networking and get to know the main players in the community to make essential connections as it allows moving towards partnering and shared outcomes.* *Growing dependence upon digital partners that can handle a world where machines are being replaced by bits and bytes that emulate them encourages to build more partnerships and therefore partnering skill is crucial.* *Construction organisations need the partnered support from IT professionals hence the need for training in partnering is in high demand*

9	***Finance Accounting and Budgeting*** (i.e. planning, allocating, monitoring, and controlling the costs associated with BDA implementation/ exploitation)	***9.1 Finance for big data analytics*** ***9.2 Estimating and cost planning*** ***9.3 Life cycle costing***	***9.1 Life cycle costing*** ***9.2 Cost- benefit analysis of BDA***	*Training employees to handle big data for financial purposes could help firms determine the most profitable projects to pursue and how to manage cashflow efficiently. To that end, skill knowledge around costing, pricing and finance is important.*
10	***Marketing*** (i.e. promoting organisation's BDA capability to its clients and business partners, carry out research on the market position, absorptive capacity, and appetite for Data-centric deliverables)	***10.1 Customer-centric marketing***	***10.1 sales and marketing*** ***10.2 Brand sentiment analysis***	*Valuable insights that the data provides for making marketing decisions about the project/ product offers the ability to make faster and more informed business decisions.*
11	***Tendering and Procurement*** (i.e. facilitating and steering the procurement of Big Data products and services including managing the contractual obligations underlying collaborative Big Data Projects	***11. Data driven bidding strategy***	***11. Data driven bidding strategy***	*To stay competitive, businesses need to seize the full value of big data and operate in a data-driven way- making decisions based on the evidence presented by big data.*

12	***Risk Management*** (i.e. managing the risks associated with using Big Data tools/ techniques and collaborative workflows)	***12.1 ability to assess the level of risk posed by the incursion of big data***	***12.1 Experimenting***	*New technologies are, by their nature, untested as they come online. There will be some risk involved in testing them and firms will have to manage that risk by remaining cautious and be prepared to experiment more.* *When data is combined with high powered analysis, root causes of failures, issues, threats and defects in near-real time can be determined. It helps businesses to take steps to spot patterns and the probability of risk so that they can apply preventative measures in new projects.*
13	***Quality Management*** (i.e. establishing, managing, and controlling the quality of Big Data analytical techniques as well as outputs)	***13.1 Data quality***	***13.1 Data quality***	*In order to discover potential issues ahead of time, quality monitoring flow that generates insights for the data quality regularly is important. Maintaining a desired quality in the data process improves efficiency, potentially reduce costs and improve safety and security.*

14	***Performance Management*** (i.e. evaluating the organisational BDA capability against a benchmark and business intelligence to derive insights through presented big data)	***14.1 Outcome management*** ***14.2 Deriving knowledge and wisdom through Big Data*** ***14.3 Productivity management*** ***14.4 Testing innovations for better business decisions*** ***14.5 Statistical and behavioural modelling***	***14.1 Performance measurement for big data analytics (through KPIs)*** ***14.2 Whole life performance***	*Managing the performance through data analytics helps buildings or estates to be more efficient and sustainable.* *Statistical and behavioural modelling help predict the construction performance.* *Harnessing big data to improve performance could be a stepping stone towards promoting another tier high for companies.*

15	***Operational Management*** (i.e. understanding of data structures, types, formats, platforms, data analytical techniques like data mining, machine learning, data warehousing, data engineering and visualisation techniques)	***15.1 Big Data awareness*** ***15.2 Data interpretation and Visualisation*** ***15.3 Integration of every element to produce desired outcome*** ***15.4 Data analytics (quantitative analysis, data mining, machine learning, trend analysis, statistical analysis)*** ***15.5 Numerical/ mathematics skills*** ***15.6 Programming*** ***15.7 Artificial Intelligence (AI)*** ***15.8 Algorithms*** ***15.9 Transparency and visibility of data*** ***15.10 Modern data modelling techniques***	***15.1 Data analytics (predictive analytics)*** ***15.2 Trouble shooting*** ***15.3 Inventory levels management*** ***15.4 Geo-location data management*** ***15.5 Security events and pattern identification*** ***15.6 Social channel data management*** ***15.7 Global network traffic identification*** ***15.8 Asset/ resource tracking*** ***15.9 Computer Controlled Craftsmanship*** ***15.10 Algorithmic modelling*** ***15.11 CNC (Computer Numerical Control)*** ***15.12 Neural network analysis***	*Data analytics helps an assessment of market conditions based on a specific project. To be able to analyse the data and allows getting intelligence on specialised areas* *Data visualisation help in understanding the analysis performed by the analytics tools.*

16	***Technological infrastructure Management*** (i.e. installing, managing, and maintaining general IT infrastructure, including network support with specific software and hardware equipment requirements)	***16.1 Software engineering*** ***16.2 Hardware engineering*** ***16.2 Background knowledge around construction technology*** ***16.3 Project Management in construction*** ***16.4 Project Management in design*** ***17.5 Use of quantitative and qualitative data analysis software***	***16.1 Software sharing*** ***16.2 5G connectivity*** ***16.3 Machine-to-machine communication*** ***16.4 Virtual network log management***	*It is vital that managers keep themselves up to date with the latest tools and technologies because of the ability to cloud host which creates the need for certifications. This has recently been in high demand as many of the big data specialised skill sets often require certifications for career growth.*
17	***Legislation Management*** (i.e. understanding the legal requirements of Big Data protocols-regulations, data ethics, privacy, ownership, security)	***17.1 Contractual implications of big data analytics***	***17.1 Digital (or data) compliances***	*Increasing reliance on virtual technologies will require more training in the digital legislations*

18	***Innovation Management*** (i.e. support and facilitate experimenting new beneficial uses of the innovation processes for continuous improvement and change management)	***18.1 Change Management*** ***18.2 Creativity*** ***18.3 Passion for learning*** ***18.4 Curiosity*** ***18.5 Ingenuity*** ***18.6 Open-mindedness***	***18.1 Changing the approach of working*** ***18.2 Research and development*** ***18.3 Ability to be innovative (looking for new ways to build competitive strengths and enable the development of new products and services)*** ***18.4 Creativity*** ***18.5 Adaptability*** ***18.6 Risk-taking***	*Introducing Big Data as an innovation and managing its transition helps all individuals regardless of their hierarchical level to move from a reactive to a pro-active approach to maintaining building systems, processes and managing construction sites.* *Training people to establish research centres on digital tech use enables design and construction integration such as VR and parametric decision making through advanced modelling.*
19	***Supply Chain Management*** (i.e. design, plan, execute, control, and monitor supply chain activities related to Big Data processes to provide best value)	***19.1 Detecting fraudulent behaviour in supply chain*** ***20.1 Analysing supply chain dynamics***	***19.1 Supply chain anomaly detection and resolution***	*Analysing supply chain information and discovering hidden trends leads to cost reductions, time reductions, new product development and optimized offerings, and smart decision making. Moreover, where there are areas of repetition, knowledge/skills around supply chain dynamics would be much useful to harness big data*

20	***Information Management*** (i.e. acquisition of information from varied sources in varied formats to storing, processing and distribution of them)	***20.1 Access to data*** ***20.2 Data capturing*** ***20.3 Data structuring*** ***20.4 Data Engineering*** ***20.5 Data collection*** ***20.6 Agile Data warehousing*** ***20.7 Data transformation to information*** ***20.8 Data integration*** ***20.9 Data measurement*** ***20.10 Data Hygiene*** ***20.11 Understanding of different information requirements (OIR, AIR and EIR)***	***20.1 Data discovery*** ***20.2 Data compression*** ***20.3 Data integration*** ***20.4 Data migration*** ***20.5 Data protection, security*** ***20.6 Data synchronisation*** ***20.6 Information/ data simplification*** ***20.7 High frequency data management***	*Managing large volumes of information will help the systems become far more agile and responsive to changing conditions and be much better at optimising the results. Better the information management is safer the working practices is. There are data feature sets, that contain far too much complexity that people do not actually use. Simplifying these data. High frequency data management communicate changes to data rather than sending entire files.*

	SKILL/KNOWLEDGE DIMENSION FOR IOT			
	KEY DIMENSIONS	**SUB-DIMENSIONS (CURRENT)**	**SUB-DIMENSIONS (FUTURE)**	**NEED FOR TRAINING**

1	***Leadership*** (i.e. leading and guiding others through the overall process of implementing/exploiting interconnected IOT systems)	***1.1 Digital Leadership*** ***1.2 Mentoring*** ***1.3 Project management*** ***1.4 Logical Questioning*** ***1.5 Locate available knowledge bases and leverage them***	***1.1 Talent search*** ***1.2 Intelligence Recruitment of employees*** ***1.3 Decentralised control management***	*Through a combination of learning experiences and vocational guidance for leadership training, companies help their employees to make informed decisions about their future – while providing an exciting insight into the many different careers our industry has to offer.*
2	***Communication oral/written*** (i.e. communicating overall managerial goals of IOT systems)	***2.1 Presenting and dissemination of results***	***2.1 Creating interactive visualisations (i.e. for dashboards)***	*What is discovered in data must be communicated to relevant parties via any available communication method.*
3	***Negotiation*** (i.e. negotiating with business partners/ clients/ supply chain members for maximizing the delivery value as well as for business development)	***3.1 Identify and pitch the most appropriate consultants***	***3.1 Ability of utilising data in deal-making***	*Building a network of talented IT consultants/ vendors or contractors helps the development of required skills, manage, and execute the IoT projects. The process would need strong negotiation skills.*
4	***Motivation*** (i.e. encouraging employees to use and share IOT tools and processes productively and effectively)	***4.1 Improve awareness and wipe away the fear of people*** ***4.2 Being able to convince the benefit of IOT***	***4.1 Work ethics*** ***4.2 Emotional Intelligence***	*The greatest motivation is with getting people in and at senior management level to advice employees to spread awareness and wipe away their fear towards IOT. And then start train the people thereafter.*
5	***Teamwork*** (i.e. managing collaborative teams involved in the delivery of IOT projects including steering committee recruitment and delegation of authority according to everyone's competencies)	***5.1 Collaborative work ethics***	***1.2 Recruitment of employees from different industries to allow cross-industry collaboration***	*The objective as well as the need for training in cross discipline collaboration/ or teamwork is to allow the alignment of all the departments of a company, so that the major opportunities given by IOT can be considered in a strategic and coordinated way.*

6	***Decision Making*** (i.e. making the right decisions to achieve organisational or managerial objectives)	***6.1 Proactive problem solving*** ***6.2 Process Mapping*** ***6.3 Cognitive ability***	***6.1 Decision support systems*** ***6.2 Problem solving***	*After analysing IOT data, to provide useful information, make predictions or take actions the skills/knowledge in decision making is vital.*
7	***Strategic Planning*** (i.e. Identify strategic objectives and implement strategies)	***7.1 Improving reliability of IOT systems*** ***7.2 Understanding the value propositions and potential revenue streams of IOT*** ***7.3 knowledge/ skills to research on Businesses outside one's own industry to be informed of new tricks.*** ***7.4 Time frame, scheduling, timing*** ***7.5 Development of IOT business case*** ***7.6 Entrepreneurship***	***7.1 Strategy development*** ***7.2 Business development***	*Increasing use automation will mean that the industry becomes more productive in the long run, creating new roles for skilled workers in most advanced areas, while reducing the need for those undertaking repetitive, manual tasks, lessening long term health risks. To that end knowledge around strategic planning is crucial.*

8	***Partnership and Alliancing*** (i.e. initiating partnerships and alliances with other organisations based on IOT deliverables for business development)	***8.1 Building mutual partnerships with other industry businesses to gain their expertise.*** ***8.2 Building a network of alliances with higher education universities is for collaborative research & development and teaching.***	***8.1 Integration of disparate enterprise systems***	*Building a network of alliances with higher education universities is a very important aspect. Through partnerships with a teaching and research competent University helps development of unique courses and training programmes. This could make open to applicants from across the world, the programmes seek to develop the next generation of industry innovators, challenging candidates to rethink current practices.*
9	***Finance Accounting and Budgeting*** (i.e. planning, allocating, monitoring, and controlling the costs associated with IOT implementation/ exploitation)	***9.1 Cost-benefit analysis***	***9.1 Design estimating*** ***9.2 Streamline Financing and Payments***	*This will allow evaluation of the likely costs for the whole concept of the Internet of Things which is based on continuous data acquisition and analysis.*
10	***Marketing*** (i.e. promoting organisation's IOT capability to its clients and business partners, carry out research on the market position, absorptive capacity, and appetite for IOT deliverables)	***10.1 Competitor analysis*** ***10.2 Creating competitive advantages*** ***10.3 Marketing research***	***10.1 Data-driven marketing*** ***10.2 Real-time customer data management for service***	*A good marketing strategy could attract public engagement to learn more about the project, the people behind it and the benefits it has brought to the local community. It is a very transparent process. Keeping the community informed.*

11	***Tendering and Procurement*** (i.e. facilitating and steering the procurement of IOT products and services including managing the contractual obligations underlying collaborative IOT Projects)	***11.1 Regulations for private and public procurement***	***11.1 Blockchain technology***	*Before implementing digital procurement, strategy which aims to create synergies by connecting virtual information and supply chain partners, the domain knowledge about tendering and procurement is a must. The transformation can only be applied when the basics are followed.*
12	***Risk Management*** (i.e. managing the risks associated with using IOT tools and interconnected systems)	***12.1 Issues Generation and Analysis***	***12.1 Experimenting***	*The significant growth of the Internet of Things (IoT) has dramatically increased the number of risk management and security challenges businesses face. Therefore, structured way of managing risks is in high demand.*
13	***Quality Management*** (i.e. establishing, managing, and controlling the quality of IOT systems)	***13.1 knowledge around accuracy- physical observation***	***13.1 Proactive quality management*** ***13.2 Prescriptive quality control***	*IOT helps predicting construction quality problems before they occur. The new quality management procedures ensure checking for likely errors, identify and remedy previously unknown problems.*
14	***Performance Management*** (i.e. evaluating the organisational IOT capability against a benchmark and Business Intelligence to gain insights though monitored IOT data)	***14.1 Asset performance management*** ***14.2 Digital asset lifecycle management*** ***14.3 Productivity gains*** ***14.4 Preventive Maintenance***	***14.1 Function analysis*** ***14.2 Digital Asset Management*** ***14.3 Quantified KPIs***	*Work with in-house people to help build the skills and mindsets our industry will need to meet future engineering challenges profitably and sustainably. The training and development of in-house employees remains one of our most significant areas of investment.*

15	***Operational Management*** (i.e. wireless protocols like Bluetooth/3G/4G low energy connections and automation of IoT hardware devices with sensor systems and intelligence software- automated room control systems, smart building)	***15.1 Ability to use digital tools*** ***15.2 UI/UX design (User Interface and User experience design)*** ***15.3 Remote control Development for IOT devices*** ***15.4 Sensor technology*** ***15.6 Prototyping IOT apps and tools*** ***15.7 Troubleshooting*** ***15.8 Programming*** ***15.7 Real time Data analytics*** ***15.9 Engineering physics*** ***15.10 Mobile application*** ***15.11 Augmented Reality*** ***15.12 Virtual Reality*** ***15.13 Application of design*** ***15.14 Intelligent analysis*** ***15.15 The technologies for CPPS (cyber-physical production systems)***	***15.1 Ability to use digital tools*** ***15.2 Sensor technology*** ***15.3 Algorithms*** ***15.4 real-time Big data analytics*** ***15.5 Artificial Intelligence (AI)*** ***15.6 Augmented Reality*** ***15.7 Virtual Reality*** ***15.8 Building Information Modelling (BIM)*** ***15.9 Robotics*** ***15.10 Smart infrastructure development (smart city)*** ***15.11 Drone technology*** ***15.12 Remote access control development*** ***15.13 3D printing*** ***15.14 Object awareness for remote access control*** ***15.15 Photogrammetry.***	*IOT operational training offers exciting career paths that combine project-based experience with formal academic qualifications which leads to attractive alternatives.*

16	***Technological infrastructure Management*** (i.e. installing, managing, and maintaining general IT infrastructure, including cloud platform connectivity with specific software and hardware equipment requirements)	***16.1 Networking*** ***16.2 Hardware engineering*** ***16.3 Software engineering*** ***16.4 Basic IOT infrastructure*** ***16.5 Cloud computing*** ***16.6 Wireless technology*** ***16.7 Facility Management*** ***16.8 IOT device power consumption***	***16.1 Modern methods of construction (MMC)*** ***16.2 Building sustainability*** ***16.3 Offsite construction***	*Training in technological infrastructure helps change outdated perceptions of the industry, enabling attraction of a more diverse, skilled labour force.*
17	***Legislation Management*** (i.e. understanding the legal requirements of IOT protocols-regulations, privacy, security, and copyright of IoT data)	***17.1 Standardisation of competency requirements*** ***18.1 Regulatory requirements***	***17.1 Development of Smart Contracts*** ***17.2 Simplification of lengthy contracts*** ***17.3 Additional standards for offsite runs***	*Increasing reliance on virtual technologies will require more training in the digital legislations*
18	***Innovation Management*** (i.e. support and facilitate experimenting new beneficial uses of the innovation processes for continuous improvement and change management)	***18.1 Business Intelligence*** ***18.2 Ability to train people's mind for a change*** ***18.3 Open-mindedness*** ***18.4 Innovative lateral thinking*** ***18.5 Function Analysis System Technique (FAST)*** ***18.6 Pareto Analysis*** ***18.7 driving transformational change within the business*** ***18.8 Innovation implementation*** ***18.9 Innovation exploitation***	***18.1 Embrace new ways of delivering built assets*** ***18.2 Adaptability*** ***18.3 Change management***	*With the increasing move toward more high-tech methods of delivery, programmes as such innovation training will become vital in creating the multi-skilled workforce, we need to sustain the industry well into the future.*

19	***Supply Chain Management*** (i.e. design, plan, execute, control, and monitor supply chain activities related to IOT processes to provide best value)	***19.1 Connected supply chain technology*** ***19.2 Business process automation***	***19.1 Supply chain collaboration*** ***19.2 Early defect/ issue identification of supply chain***	*With skills and knowledge around supply chain collaboration, the Location of Goods can be authenticated at Any Time, speed of movement can be tracked, When Goods Will Arrive can be determined.* *Early identification of issues with goods getting lost or delayed.*
20	***Information Management*** (i.e. acquisition of information from varied sources in varied formats to storing, processing and distribution of them)	***20.1 Data Security/ protection*** ***20.2 Data integration*** ***20.3 Actionable information creation*** ***20.4 Artificial Intelligence*** ***20.5 Data synthesising*** ***20.6 Data collecting*** ***20.7 Data privacy*** ***20.8 Data interoperability***	***20.1 Provenance and Traceability of information***	*Professionals with in-depth knowledge of their information business domains will be needed to assess data sensitivity and regulations with which they must comply. They will be key to weighing in on issues of security and privacy.*