Optimising the adoption of Building Information Modelling (BIM) in Facilities Management (FM): a model for value enhancement

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"We should treat our problem as a new problem,
and approach it, so far as possible, with innocent minds."

Ralph Barton Perry, 1914

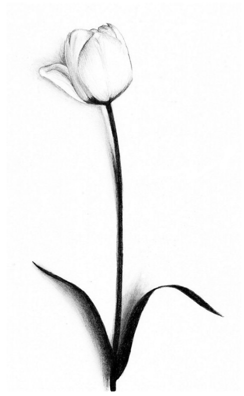
Abstract

Facilities Management (FM) and Building Information Modelling (BIM) are comparatively new concepts emerged in late 20th and early 21st centuries therefore, limited in theoretical knowledge. Knowledge generation in such immature subject areas have constantly faced with the lack of theoretical groundings hence, proposals and suggestions made for efficient and effective applications are being superseded in a fast phase. In identifying this gap in knowledge, this research makes a significant contribution to the theory in Building Information Modelling and Facilities Management by studying the implications on each other by taking a multi-disciplinary perspective.

There is a complex information flow in FM. The late involvement of facility managers has made this complexity more exposed. An effective information management system is considered as a significant driver for FM to enhance the capabilities of built environments in long run. However, this leaves with lack of understanding over FM needs for an information system. On the other hand, BIM is a novel method, recently introduced to the construction industry as a means of providing rich information. A growing demand for through-life BIM application in construction is identified. Although, the application of BIM in design and construction phases is commonly seen, its application in FM is seemingly poor. Multiple reasons for this situation are being suggested by the existing research however, the gap in theoretical grounding leave it vulnerable to interpretation. Therefore, this study aims to bridge the gap by developing a BIM value model for FM to present the theoretical groundings between two concepts. A qualitative multi methodology is being followed to explain the social phenomenon based on critical realist ontological and epistemological assumptions. The study is structured under three phases; the first phase is focused on a deeper understanding of the problem, the second phase – is the development of the solution and final phase is dedicated to the verification of the research output. Two rounds of interviews and focus groups were used as data collection methods while data was analysed using Constant Comparative Method staying true to the Grounded Theory research strategy.

The research brings together scholarly work on FM and BIM while interrogating different value theories to develop a unique understanding on BIM acceptance in FM. Value as the main dependent variable in social science brought rich understanding of the phenomenon. The findings reveal how value is represented through barriers and benefits and possibilities of value enhancement through adopting BIM in FM. This leads to a new perspective by identifying barriers of adopting BIM as unfulfilled expectations of users therefore, act as recommendations for improvements required in BIM to help promote the best practice. Finally, the research contributes to the knowledge with a value model which represents relationships discovered during the study and a value principle abstracting the findings. This will guide the client and contractors on identifying BIM requirements and match the competencies of the supply chain to bring the best outcome.

Keywords: Building Information Modelling (BIM), Construction information, Facilities Management (FM), Value in-use, Behavioural economics



Dedication

To those who understood…

Acknowledgement

The work (CITE) presented in this thesis is an effort of many who contributed with or without being conscious about their part in play. I thank Liverpool John Moores University for providing me the opportunity for further studies and generous contribution with the scholarship and for maintaining a welcoming atmosphere for international students and an excellent study environment with immense help whenever I wanted to go an extra mile. This includes the Department of Built Environment, Doctoral Academy and Avril Roberts Library with its rich collection of books, resources and staff which became home to this thesis day and night.

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Sincere gratitude to Liverpool City Region (LCR) Future Energy Project for giving me access into a different perspective of living which in return made a massive contribution to this thesis through personal maturity gained as a researcher. The opportunity I had through the project is priceless and I am more than thankful for the project team, partners, SMEs for the opportunities and challenges and for LJMU for the leap of trust invested in me from the beginning. Also, to LCR Eco Innovatory Project for their continuous support and encouragement. Constructing Excellence Liverpool City Region for welcoming me as a student among a team of extremely successful professional, providing me space to grow and giving a hand during data collection of this research.

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Last but not least, my honour and gratitude for my beloved parents for being the reason to keep going the thousand times I wanted to give up. My heartiest thanks for my brother, sister, friends and all others who stood around me taking up different roles to colour my life story. Finally, I am profoundly grateful for this process of PhD for maturing me to understand a sentence which I have been mumbling for 14 years without not knowing what it really means. So I say it now with its fullest depth;

"Glory be to God alone"

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List of Abbreviations

AEC	Architecture Engineering and Construction
BIM	Building Information Modelling
BRE	Building Research Establishment
CAD	Computer Aided Drawings
CDA	Critical Discourse Analysis
COBie	Construction Operation Building Information Exchange
CR	Critical Realism
DOI	Diffusion of Innovation
EIR	Employer Information Requirement
FIM	Facilities Information Management
FM	Facilities Management
GT	Grounded Theory
HM	Her Majesty
IES	Integrated Environment Solution
IFC	Industry Foundation Classes
ISO	International Standards Organisation
IT	Information Technology
LC	Lean Construction
MMR	Mixed Method Research
PAS	Publicly Available Standards
QUAL	Qualitative
QUAN	Quantitative
RIBA	Royal Institute of British Architects
ROI	Return on Investment
TAM	Technology Acceptance Model
TMSA	Transformational Model of Social Activity
TRA	Theory of Reasoned Action
UK	United Kingdom

Chapter 1

Introduction to the research

1.1 Introduction

The fragmented nature and the complexities of the end products and services account for many inefficiencies in the construction industry. As a solution, Building Information Modelling (BIM) was introduced in 2011 and later under the Construction 2025 strategy to create, use and manage information effectively and efficiently while promoting collaboration and integration among stakeholders. It has retain the attention within the field of Construction Management over the years. Especially, in the UK due to Government influence to promote the best practices in the industry with the aim of taking the global leadership in digital construction. By discussing the current motives of the UK construction industry, this introductory chapter sets the background to the research, highlighting the rationale and existing gaps in the current knowledge related to BIM adoption in facilities management. As key contributions, the chapter introduces the research aim, objectives, an overview of the adopted methodology and work undertaken within the specified scope and the limitations of the research.

1.2 Background and rational

The construction industry is a significant contributor to the UK economy as well as to the society (Government, 2013). In numbers, it contributed £96.8 billion to the UK economy in 2017 which is 6.1% of the GDP (ONS, 2018). These numbers include the value of construction assets (e.g. buildings and infrastructure) however, exclude the construction related consultancy services (e.g. Quantity Surveying, Architecture) and construction product manufacturing (e.g. brick, cement, heating equipment). Therefore, overall contribution of the construction industry is estimated to be even larger. On the other hand, literature reveals that 40% of the world construction market will be residential buildings (Saxon, 2013) confirming the continuous growth of the industry with the rising population. Therefore, creating knowledge to improve the performance of the industry is a must for a sustainable growth.

The construction industry is complex with its uncertainties and interdependence and well known for inefficiencies in operation (Dubois and Gadde, 2002). Construction products are heterogeneous and designed for long lifespans. Therefore, collaboration among project partners are identified as a key factor to minimise these inefficiencies (Dulaimi, Akintoye, and Main, 2007). On a positive note, these features of the construction industry suggest that Information Technology (IT) has great potential for improving efficiency (Ahmad, Russell, and Abou-Zeid, 1995) especially in the UK, as the industry is highly dependent on sub-contracting (Government, 2013). Taking a technology based approach raise the need to consider technology acceptance mechanisms to gain a successful dissemination.Further, Human-technology interaction and understanding the human value becomes vital for a smooth transition of the industry practices and achieving Government goals.

Building Information Modelling (BIM) is an approach which promotes collaboration and integration among project stakeholders. Due to visualization, collaboration and information management features, BIM has been identified as a successful solution to increase the efficiency of the construction industry (Underwood, 2009). Inspired by these promising benefits of BIM, Construction Strategy 2025 (Government, 2013) promotes Smart Construction and Digital Design through adoption of Level-2 BIM for construction projects in effect from April 2016. This is an initial step to bring the industry in line with the digital economy by embracing BIM Level-3 by 2025. The successful achievement of this target will enhance the level of collaboration among the project stakeholders. In fact, working towards construction strategy will not only result in achieving government targets but also provides win-win solutions to the wider society by bringing resource efficiency, sustainability and employment. Although the current trend is to adopt BIM in public construction projects (Demian and Walters, 2014), BIM awareness level is increasing and organisations are getting involved in BIM more frequently (NBS, 2014).

Interestingly, positive image of BIM in the literature has been challenged in practice questioning whether the full potential of BIM is being utilised as expected (Liu et al., 2016). Although BIM is designed to provide benefits throughout the building life cycle, current literature has been unbalanced in focusing on the application of BIM in post-construction stages (Codinhoto et al., 2013). Also from the practitioners' perspective, the primary attention of project stakeholders is mainly on the constructed facility rather its operation and maintenance (Becerik-Gerber et al., 2012). The empirical research has explained that the existing buildings represent approximately 99% of the UK building stock, with new construction at a rate of less than 1% of the total stock per year (Commission et al., 2005). This ensures the majority of buildings are in their in-use phase and adoption of BIM at the Facilities Management (FM) stage provides enormous benefits to the entire building stock in the UK. Nevertheless, current attention has been paid to explore the BIM execution at the early stages of buildings rather the later. Therefore, this research is aimed at exploring the current status quo of BIM adoption within the Facilities Management phase (in-use) of built assets while creating opportunities to promote BIM adoption in FM. A summary of the research is presented with specific aims and objectives in next section.

1.3 Research aim and objectives

With the knowledge and experience in current BIM practices in facilities management, this study was initiated by the research question;

why BIM is not adopted in FM as anticipated?

The ultimate goal of this research is to develop a model to explore the reasons behind the slow adoption of BIM in FM and inter alia will expose wide range of tentative theoretical solutions. This is to work along with the existing BIM standards and guidelines supporting the wider application of BIM beyond construction and to create an extra support when come across a bottleneck applying formal standards and guidelines. This is done through, identifying human values and customising the BIM adoption by making it personal experience. In a word, the aim of the research is to;

Develop a value model for BIM in Facilities Management that is to act as a decision support model applicable along with existing BIM standards and guidelines and promoting BIM in FM.

The objectives formed to achieve the research aim are presented below (Table 1.1).

TABLE 1.1: Research objectives

Current practice	1.To identify the drivers of BIM in facilities management that are adopted within the built environment facilities
Issue	2. To understand the factors affecting slow adoption of BIM in facilities management
Solution	3. To determine the value of BIM for facilities management
	4. To develop a BIM value model for facilities management
Validate	5. To validate the model for its usability within the built environment facilities.

As presented in the Table 1.1, the research objectives are mapped along the broad themes which are in interest of this research. The first objective is focused On understanding the current applications of BIM in construction and maintenance of built assets. The second objective identifies the key issues behind the slow adoption of BIM in FM. The third and fourth objectives provide possible solutions for those issues through a development of a model. The practical applications and validity of the model is tested in the fifth objective. The achievement of each objective through each chapter of the thesis is illustrated in a later section (See topic 1.7).

1.4 Overview of research methodology

Based on critical realism philosophical foundations the research is designed to follow a Grounded Theory research strategy taking a qualitative multi methods approach (Figure 1.1). As a result, a cross sectional study was conducted using interviews and focus group discussions for data collection while data were analysed deploying constant comparison influenced by a Grounded Theory research strategy.

As illustrated in Figure 1.1, the study is structured under three phases. The research began with a background study, which involved a detailed literature review in key subject areas namely; Building Information Modelling (BIM), Facilities Management (FM) and construction information management. The purpose of conducting a background study was to identify the current gap in the knowledge and formulate the research question. Also the broader understanding of the research question helped setting the research aim and objectives focusing on novelty and contribution to knowledge. Influenced by Grounded Theory, the second part of the literature review is conducted later in the research after the first round of data collection to maintain a value free, objective process.

Formulating the aim and objectives made a clear path ahead by defining the key milestones. The first objective of the research was to understand BIM in construction industry, Facilities Management (FM) and the potential uses of BIM in FM. This demanded knowledge on information management practices both in construction industry and FM; highlighting the possibilities of embracing these two subject areas for mutual benefit. On the other hand, validity of research heavily depends on the adopted research methodology. As a result, other aspects of the research which required exploring existing knowledge was identified. Therefore, the background study was extended into a detailed literature review on BIM, FM, value and research methodologies staying within the construction management discipline.

As a result of the detailed literature review, the existing gap in the current knowledge related to lack of application of BIM in FM was identified.This initiated the phase one data collection using semi-structured interviews with convenience sampling to understand the current practices of information exchange during FM and construction phases along with the reasons for acceptance and rejection of BIM. The concepts emerged from the initial data directed the phase two to carry on further investigations to identify and confirm the reasons for the problem. This involved continuing data collection through interviews as well as conducting a focus group to clarify contradictory concepts which emerged during the initial round of data collection. In parallel to the extensive primary data collection, further study on theories related to value concept was carried out to derive meaning from the data. As a result, a multi-disciplinary perspective was taken by studying literature related to value in-use from economics and psychology. Due to the lack of existing knowledge on defining value in Facilities Management; primary data gathered were used to establish the meaning of value with the support of existing theories. Once the theoretical basis was established, the value model was developed to explain the substantive theory generated through the research. The value model communicates the three main elements of BIM and allows clients and facilities managers to assess their BIM expectations. Finally, the model was validated for its applicability through a focus group. Appropriate justifications for the selected methods and reasons for rejecting other alternative methods are discussed in the Research Methodology Chapter (see Chapter 4).

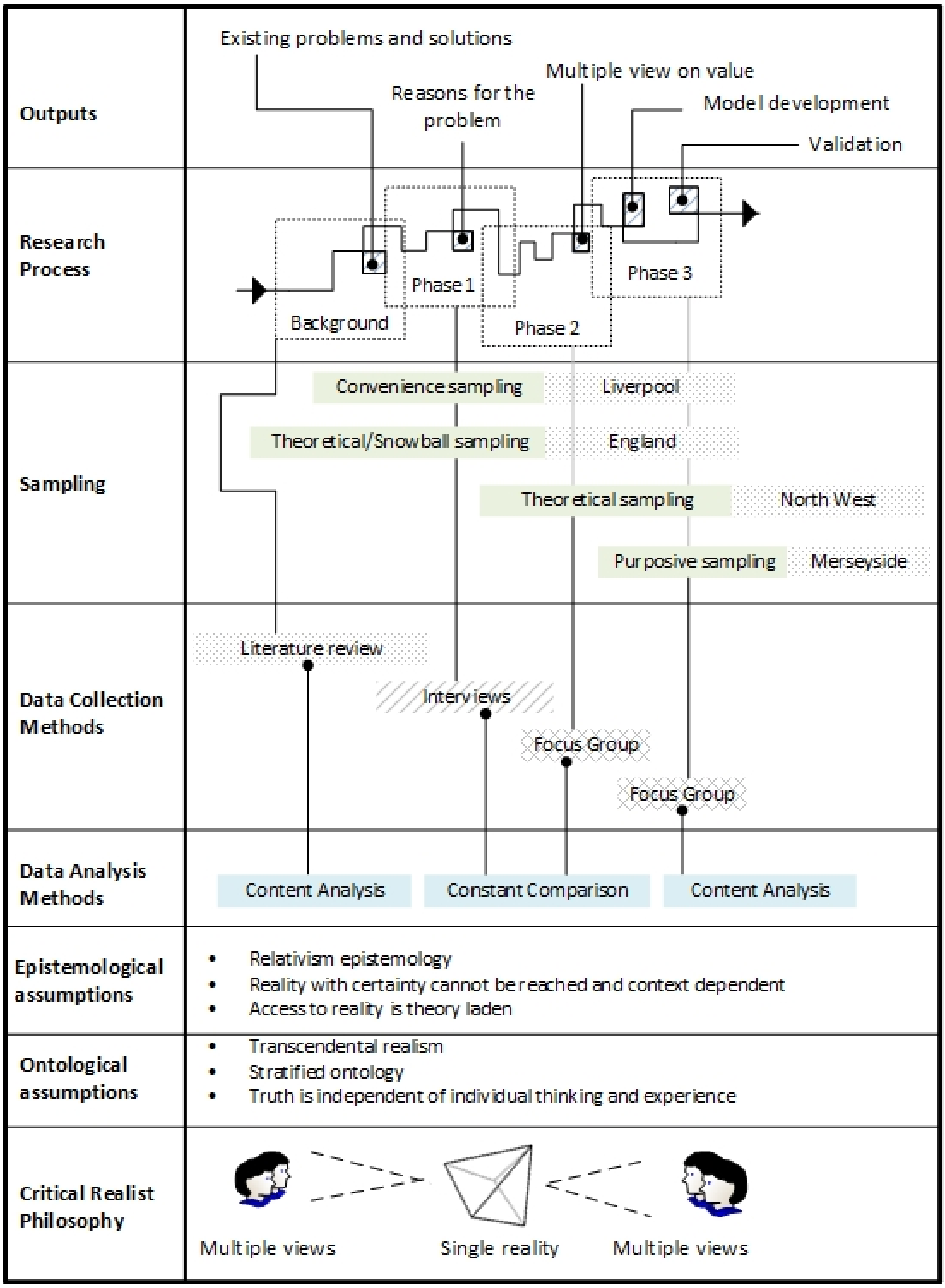


FIGURE 1.1: Snapshot of research method

1.5 Contribution to knowledge

The significance of facilities information management was identified through the review of seminal literature. However, current practices of facilities information management vaguely provide a robust solution for effective information management as many of them do not consider the human value underpinnings in the process. Therefore, often fail to have a long term impact. Having considered the capabilities of BIM as an 'information rich tool' this study aimed to develop a model to communicate user expectations of facilities information management of built environment assets to enhance the value of BIM in FM. The key contribution of this research is the identification of the user (facilities manager) expected value of BIM where the existing information models have not paid their attention to date. This leads into providing a new meaning to barriers of BIM.

In simple terms, this research explains what BIM should provide to achieve facilities management needs rather than listing the benefits of BIM, so FM could fit in. This creates new knowledge in exploring and introducing the application of basic human value theory in construction, which reveals the causal mechanisms of choices made on facility information requirement identification and management. A detail elaboration on knowledge contribution from different perspectives is given in Chapter 8 (see topic 8.3).

1.6 Scope and limitations

This study is conducted giving priority to higher educational facilities in the UK, to produce a guiding tool for understanding BIM requirements of the facilities management stage for new built projects. The large estates managed by the higher education, amount of facilities management expenditure and multi stakeholder involvement proves it to be an ideal case study. The proposed model is based on both experienced and expected values of BIM in the building operations stage. The information value concept is limited to understanding value as an abstract concept rather providing a concrete benchmark through converting value into monetary figures. Also, the research is conducted within the limits of qualitative methods although, this has not compromise the validity of the findings. Further discussion on limitations of the study is presented in Chapter 8 (see section 8.4).

1.7 Dissemination

The findings of the research were disseminated through several publications, presentations and posters. This includes refereed journals and conferences held locally and internationally. All the conference papers were presented at the conferences to obtain opinions from the interested parties on the subject matter. The initial work of the research is also published in a well-recognised journal - Engineering, Construction and Architectural Management (ECAM) in the field of Architecture, Engineering and Construction (AEC). The reference list of the publications is compiled at the end of the thesis.

1.8 Structure of the thesis

Figure 1.2 illustrates the structure of the thesis. Accordingly, each chapter is designed to achieve a specific purpose and the thesis provides a blue print of evidence for accomplishing the research aim. Although, the thesis has followed a standard structure, the arrows indicated the sequence that the chapters evolved through the journey of the research project. An important character of this thesis emphasised through the positioning of Chapter 5, which is a review of theories in Technology acceptance and human values after the methodology chapter. This is a conscious decision to maintain the authenticity as a thesis following Grounded Theory research strategy.

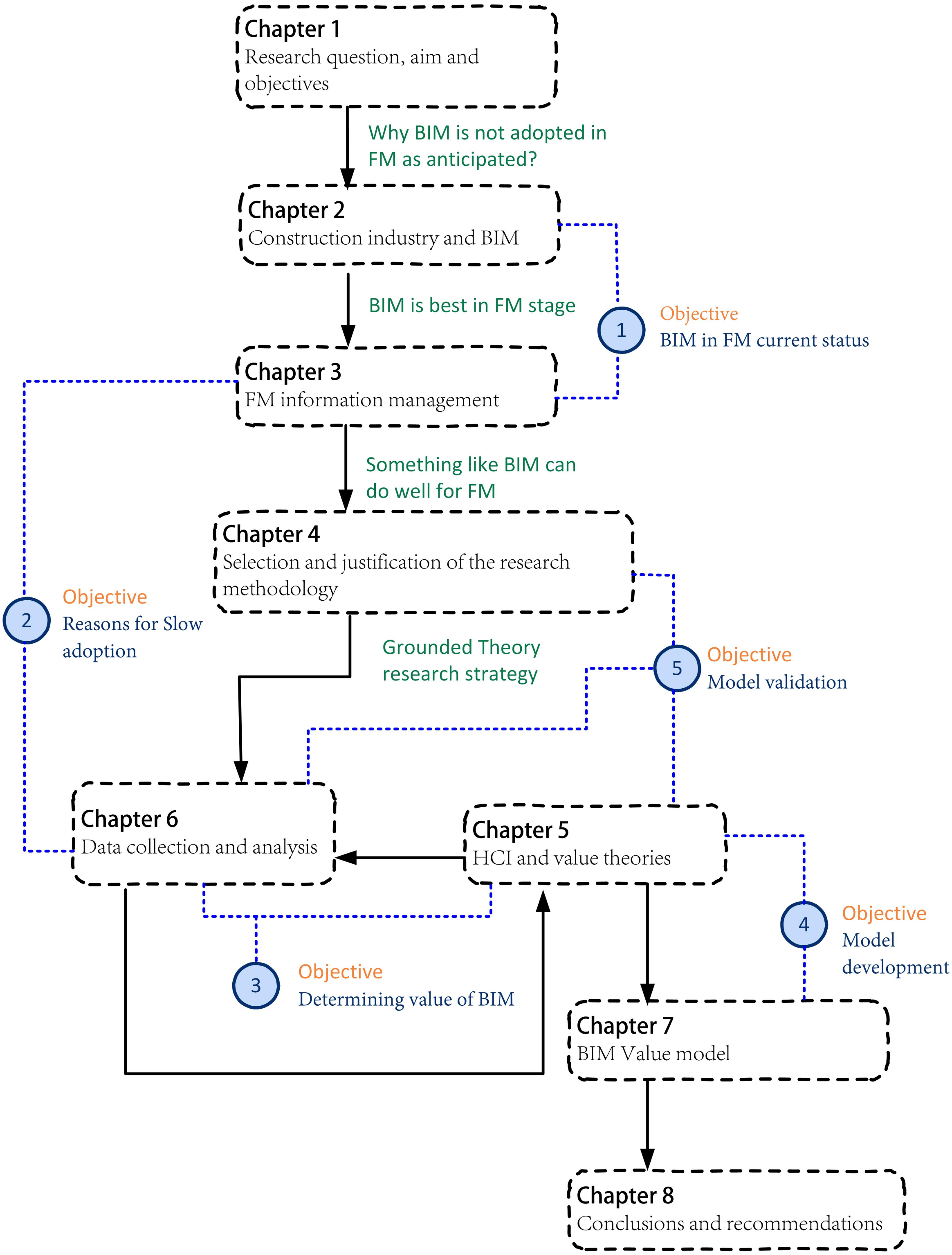


FIGURE 1.2: Thesis structure

Chapter 2

Building Information Modelling (BIM) in construction

2.1 Introduction

Having set the research background in the previous chapter, it is apparent that the thesis brings together three key subject areas namely; Building Information Modelling (BIM), Facilities Management (FM) and value. This chapter explains the application of BIM in construction while understanding the environment in which BIM is being used, stakeholders involved and the way it functions. Therefore, it commences by introducing the nature of the built environment in support of understanding BIM, FM and value in this context. This leads to a discussion on 21^{st} century construction practices by introducing upcoming trends such as Modern Methods of Construction (MMC) and use of information in construction. The discussion on construction information highlights the issues in information management and lack of concern towards in-use phase at the beginning of a project. Having explained the characteristics of the construction industry, it gradually introduces BIM as the most up to date information management system. The chapter continues to review the current literature pertaining to principles and practices of BIM and its contribution for effective facilities information management during the building's in-use phase. This also gives priority in discussing the recognition and methods of understanding value in construction industry develop the link to the upcoming chapters (i.e. Chapter 5). Lean construction, value management and value engineering are taken into consideration to understand value in construction. The knowledge on existing value theories in construction provides strengths and weaknesses in effective use of value in construction sector therefore, a starting point in developing value of BIM in FM. Due to the nature of the research - i.e. curiosity over the matter under a critical realist perspective, the literature review chapters takes a descriptive nature, looking for fundamentals of the phenomena which is in contrast with a positivist or positivist philosophical perspective which would follow a deductive approach.

2.2 Anthropology and nature of built environment

The ultimate purpose of this study is to bring new insight into the existing knowledge pool to improve creation and operation of the built environment. This section builds up the background of the subject area by exploring what it is meant by "built environment", how it is evolved and nature of the 21st century built environment. This understanding is acknowledged to be vital to recognise the underpinning assumptions behind construction, FM, BIM and value management especially, under critical realist ontological assumptions.

2.2.1 Anthropology of built environment

The simplicity in early construction activities help in seeing through a noise free image to recognise the fundamentals of the construction industry. There is a remarkable difference between early constructions that was identified as an ancient human activity of creating shelter and what is now constructed in the first century of the third millennium. The need for studying this difference is in the interest of understanding the decay of core values interacted between humans, natural environment and built environment. The research on the anthropology of the built environment holds witness to how construction of space has moved from shelter to representations of the social order (Lawrence and Low, 1990; Ashworth, 2011). Access to water became the key attraction at the beginning. However, the development of human needs demanded for a change of ways in accommodating them. Skills, knowledge and technology reversed the cycle of man moving towards the resources (e.g. water) into bringing what a man needs towards its user. This contributed to the complexity of the construction industry and opened up the opportunity for a wider service industry.

Moving further in civilisations shows that the built environment is not only accommodating functional requirements but perceived value (Ashworth, 2011). Therefore, development of the built environment was also influenced by the pull demand beyond the market push through what it can offer with material and technology advancement. This is in contrast of the belief that the development of the built environment is purely based on material and technology advancement. In support, (Gieryn, 2002) provided an interesting discussion on how buildings forms and dissolve social structure through an example of a science lab building project.

The modern construction of the built environment is being pushed forward with the technology advancements, lack of resources and complex designs giving less regard towards core human concerns. Since the broader spectrum of complex human needs are narrowed down to quantifiable measurements of cost, quality and time in today's construction industry, it is a question whether the stakeholders understand the underpinning human needs communicated through the iron triangle – i.e. cost, quality and time (Atkinson, 1999). Rapoport, 1982 presents a seminal study on meanings of built environment defined by different user groups. One of the examples it presents is the findings of a survey done in France on preference for living in small-detached houses. It holds evidence on how building user expresses the meaning of space around the house through "clean air". Revisiting the house spacing over the time shows how knowledge and technology has influenced the decision

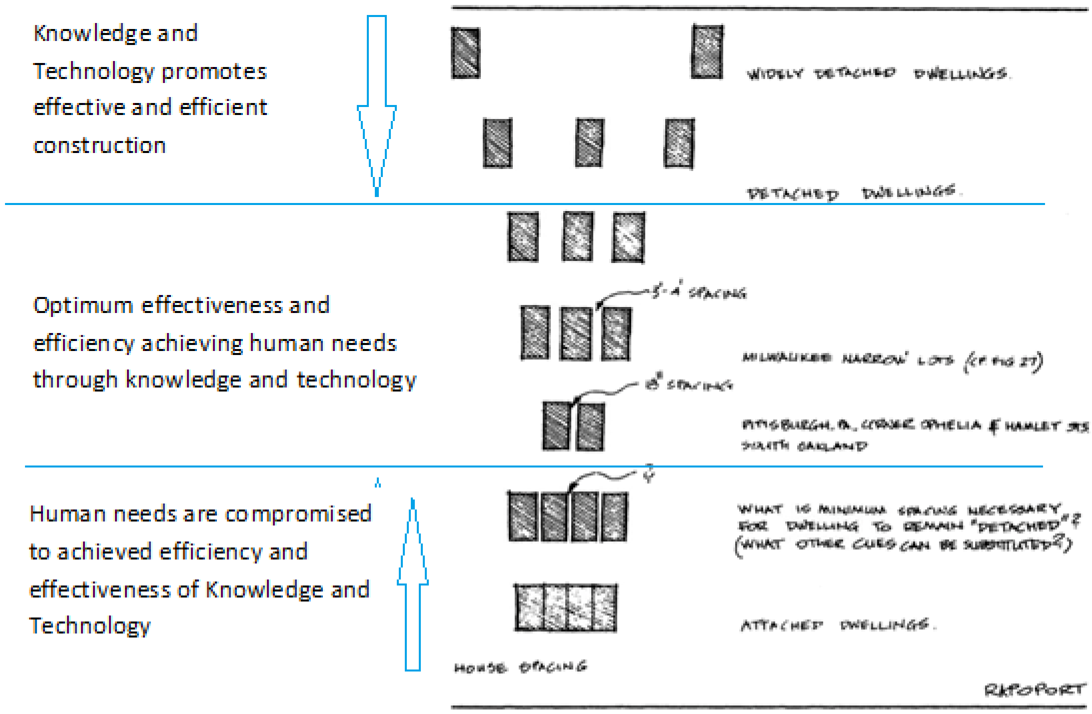


FIGURE 2.1: Space necessary for meaning of 'Detached' (Source: Wijekoon, Manewa and Ross (2018))

but, with the uncertainty of whether technology achieved ease of implementation at the expense of compromised human needs. Analysing the work of Rapoport, 1982 and explaining the findings through the lens of human needs, Wijekoon, Manewa, and Ross, 2018 reproduce Figure 2.1.

2.2.2 Definition of built environment

The history of construction took the discussion back to the earliest endeavours of creation of shelters with the single purpose of fulfilling the functional need of a controlled environment to restrain the effects of weather. With the development of construction materials, tools and techniques, the construction industry in the 21st century has reversed the process of people creating the built environment into the human behaviour being influenced by the built environment (Lawrence and Low, 1990). In a broad sense, built environment refers to any form of man-made alteration to the natural environment (Lawrence and Low, 1990). This is the same explanation Aristotle gave in identifying technology (Franssen, Lokhorst, and Poel, 2018). This hints the inconsistency in theoretical understanding about construction.

As Lawrence and Low, 1990 highlight, built environment includes forms of buildings such as dwellings, commercial buildings, theatres that are enclosed spaces; and roads, parks or plaza that are defined spaces but not necessarily enclosed. However, it is important to acknowledge that the built environment is not only the physical object one could see as a building or road but also includes services which support the functioning of that physical object (i.e. water and waste management in a building). Saxon, 2013 has acknowledged this

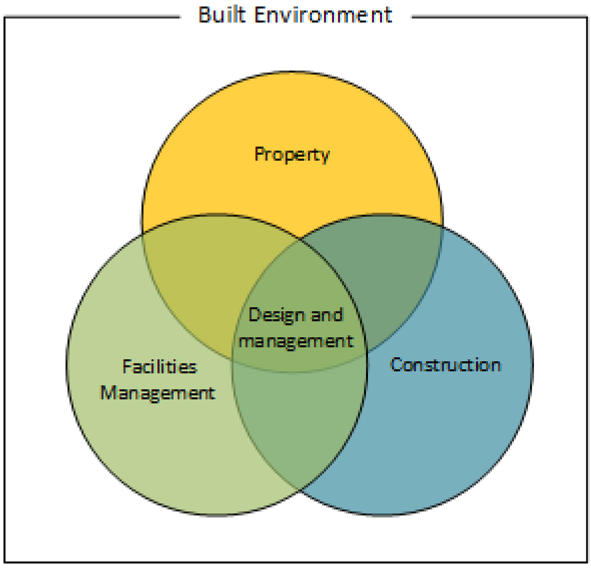


FIGURE 2.2: Sectors of built environment (Source: Saxon (2013))

by emphasising that facilities management has an equal proportion in the built environment (Figure 2.2).

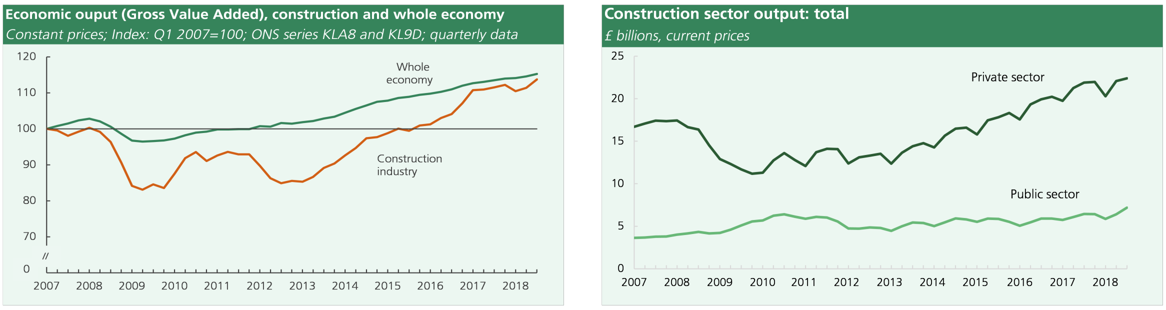
As shown in Figure 2.2 the modern built environment is recognised as a combination of three sub industries (Saxon, 2013). The recognition of facilities management (FM) as a key component of the built environment is a success factor in modern construction since a building spends its longest time in the facilities management stage with its complexities. The changing definition of buildings from shelter to creation of an interplay between "physical, spatial and social values" is now heading for interactive buildings by 2030 (Alavi et al., 2016b). On the other hand, built environment is the facilitator of a core business, enabling the function and performance (Saxon, 2013). Therefore, development in built environment will not be limited within property, construction and FM but will have a wider benefit in business performance and specifically in achieving emission targets.

Including evidence from building anthropology to analysis of different explanations given to describe the built environment takes us through the revelation that the essence of this industry is closely related with human beings although, modern innovations and technology have taken the attention. Giving priority to understand the human element of the built environment, the next section explains key elements of today's construction industry. This broader view of the construction industry will be then narrowed down to the means of creation and use of information in the built environment to focus on the element of the study (BIM). The next section focuses on the specifics of the UK construction industry related to its current and future trends.

2.3 Construction industry

The construction is the largest industry in the world with highly fragmented organisations (Becerik-Gerber and Rice, 2010). In 2017, the construction industry contributed £113 billion

(6%) to the UK economy making a significant recovery from the economic recession in 2009 and downfall experienced again in 2012 (Figure 2.3a). This contribution is made through creating 2.4 million employments and continue with the positive contribution towards the society by uplifting human lives with the supply of housing, infrastructure and an environment in which to function and prosper (Rhodes, 2018). Private sector orders continued to grow claiming 75% of the construction work in 2017 (Figure 2.3b). This helps to understand why BIM is not seen in practice as much as it is seen in academia.



(A) Economic output

(B) Construction sector output

FIGURE 2.3: Economic and construction sector output

As identified by the Standard Industrial Classification (SIC), construction sector includes the work of civil and engineering projects, residential and non-residential buildings and special construction activities such as plumbing and electrical installation. In 2017, total contribution of UK construction industry was made up with 25% housing, 12% infrastructure, 34% repaired and maintenance and other 29% (Rhodes, 2018). In summary, construction is identified as a service which brings together the services of different participants (Hu and Zhou, 2009). RIBA Plan of Work (Figure 2.4) represents the key phases of a construction project lifecycle and stakeholder involvement in each phase.

Accordingly, a typical construction project follows 7 key stages. These projects can be procured under different procurement methods such as traditional (design-bid-built), design and built, management contract or public and private sector partnerships such as Private Finance Initiative (PFI). Ashworth and Perera, 2018 provide a comprehensive review on construction project procurement including factors influencing the selection of contract forms. Different forms of contracts adopted in the UK construction industry is noted in Appendix A. Integrated Project Delivery is a modern form of project delivery introduced as a solution to the traditional construction and to promote collaborative construction (El Asmar, Hanna, and Loh, 2013).

Multiple government publications made since 1994, focusing the construction industry highlights the industry's impact on the economy and commitment of the UK Government for its improvement. Marsh (2017, pp.16-20) provides a summary of Government commissioned reports dedicated to the development of construction industry from 1944-2016. The most prominent Government policies related to construction are explained in Construction Strategy 2025 (Government, 2013) and Construction Sector Deal (Government, 2018). Digital Built Britain Level 3 strategy (Government, 2015) is a dedicated piece of work to develop

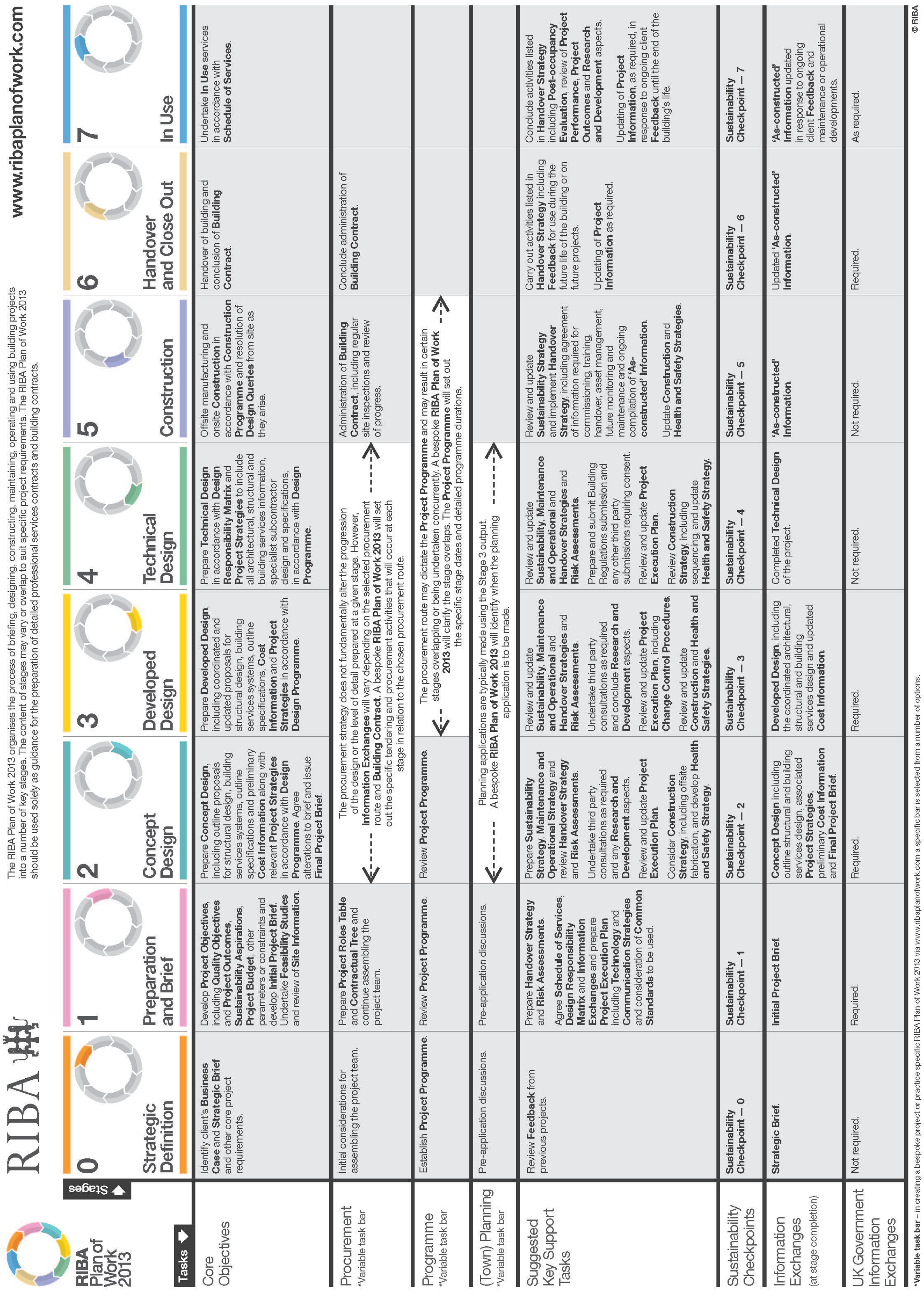


FIGURE 2.4: RIBA Plan of Work

a computerised construction sector. All of these influential Government strategies are sector level implementations of Government Construction Strategy 2011 (Government, 2011).

Construction 2025 considers number of strategic ambitions for the construction sector. Rhodes, 2018 summarises the goals of Construction 2025 strategy as follows;

- 33% reduction in both the initial cost of construction and the whole life cost of assets (from 2010/09 levels).
- 50% reduction in the overall time from inception to completion for new build and refurbished assets (based on industry standards in 2013).
- 50% reduction in greenhouse gas emissions in the built environment (compared to 1990).
- 50% reduction in the trade gap between total exports and total imports for construction products and materials.

It is evident from these targets that Construction 2025 is concerned on achieving sustainability through waste reduction and improved efficiency. Introducing BIM through digital construction initiative, BIM Level 2 mandate for government procurement (i.e. public sector procurement) is one of the achievements reached under this strategy. However, when referring to the proportion of public and private sector orders placed in construction industry (see Figure 2.3b) it is evident why BIM level 2 mandate set by Construction 2025 strategy is not obviously apparent in the daily life of the construction sector.

Superseding Construction 2020 Strategy, the Construction Sector Deal is a part of the Industrial Strategy which brings ambitious partnerships between industry and government (Rhodes, 2018). The initiations of Construction Sector Deal have found the Construction Leadership Council; a forum consist of both public and private sector key roles in construction with the aim of driving industry improvement to achieve the targets set in Construction 2025 (Government, 2018). Further, Construction Sector Deal has initiated several Challenged Fund to transform the construction practices through research and development. As part of committing to Construction 2025, the UK government has committed to adopt and promote modern methods of construction supporting offsite construction 2019 onwards (Rhodes, 2018). It has identified that offsite construction has the capacity to make construction industry more productive and competitive by producing high quality products in shorter time.

2.3.1 Modern Methods of Construction

Methods of Construction (MMC) is getting attention and being promoted by the UK government due to its promising outputs with efficiency, quality and sustainability. This trend in the construction industry reinforce the need to move into digital construction more than ever before and gather whole life information about building performance and usage for better design and manufacturing. Therefore, different types of MMC is reviewed to support that through life use of information through BIM is not only a value addition to facilities management but also to the stakeholders involved in design and construction phases.

To begin with, the history of MMC in Britain goes back to the 11^{th} century indicating the applications of prefabrication techniques (O'Neill and Organ, 2016). The need for alternative methods of construction was formed post war with the immediate need raised for housing construction and refurbishment. The early methods of MMC were found to have evolved from the introduction of the cruck frame in 1066 (O'Neill and Organ, 2016) making a supportive case for its immediate replication with Light Gauge Steel (LGS) frames in present. This brief overview on the history of MMC itself brings evidence that principles of MMC have been there in the industry for a long time questioning how modern these methods are. Development of technology, influence of building regulations and focus on sustainability has continuously improved the use of basic principles with innovative solutions.

There is no trace of an exact or commonly recognised explanation for MMC. As the earliest reference to the term MMC, Ross, 2005 recognised in his BRE Trust publication on MMC that all construction methods evolved from mid 1990s are considered as MMC and pre 1990s as traditional methods of construction. MMC is an umbrella term covering a number of construction methods therefore, sometimes identified as prefabrication, industrialised construction and modular construction. The UK Housing Corporation classified MMC by form of construction and they are broadly separated as offsite and onsite methods (Riley and Cotgrave, 2013). Majority of the MMC widely used are offsite methods. Offsite construction includes the subtypes of volumetric (Goh and Goh, 2019), panellised (Ariyanayagam and Mahendran, 2019), hybrid (Lawson and Ogden, 2008) and sub-assemblies. Literature on housing construction often discusses applications of onsite and offsite construction forms of MMC (Veljkovic and Johansson, 2006; Malik, Ahmad, and Al-Hussein, 2019) however, Riley and Cotgrave, 2013 argues that existing techniques of onsite MMC have not made a favourable case for housing.

The above discussed methods are well established in construction to the date and more pronounced changes are expected as an extension for these MMC. On the other hand, use of robotics in modular manufacturing is new but an increasingly growing practice. Most of the applications of robotics are within the range of work performed in factory premises (i.e. enclosed and fixed location). Taking a step forward from the standard application of robotics, Factory-in-a-box is a concept of mobile manufacturing facility (Stillström and Jackson, 2007). With standard manufacturing modules robotics are transported close to the customer (e.g. offshore welding) and even globally to explore new markets. Moreover, the same terminology is used in construction sector on a newly experimented method to develop a "kit factory" to adopt click and connect building concept (e.g. Ikea furniture) in construction. The aim is to deliver a shipping container with all elements that a layperson can build a house (Offsite: The building built by Ghurkas, 2016). In summary, information management in construction has a significant influence over development and success of these upcoming trends in construction. Therefore, nature of construction information is discussed in next section.

2.3.2 Construction information

Construction activities are "shrouded in information" therefore, create and store considerable amount of real-time information (Craig, 2006) in silos. The process of construction and maintenance of the product itself generates huge amounts of data throughout its lifecycle. These data flows (in – out) are frequent and are critical to support the management of a facility as information is the blue print of the changes took place over the time. However, the use of information for its best potentials is questionable.

The nature of construction industry is not naturally supportive for information management systems. The information flows of construction projects are enormously complex, scattered and multi-dimensional (Hu and Zhou, 2009). This is mainly caused by the heterogeneous end products and fragmentation of the industry. The construction industry produces one-off products, many of which have longer life-cycles (30 to 60 years). On the other hand, the construction industry is highly dependent on sub-contracting (Government, 2013) therefore, the information related to the built asset is expected to be more scattered among many parties involved in individual phases (Hu and Zhou, 2009). Because of the fragmentation industry takes little effort to make improvements. The need for integration in the construction industry has been constantly emphasised since early 1980's (Alshawi and Underwood, 1996). Among them, supply chain integration through the information systems has been identified as one of prominent considerations for effective delivery of construction products and processes (Ahmad, Russell, and Abou-Zeid, 1995; Alshawi and Underwood, 1996).

The process of multiple individuals involved in different phases holding responsibility and performing information management tasks has constantly failed when performed by its own (Craig, 2006). Although this was identified as a source for the cost overrun at the construction as well as during operation and maintenance of the building; it remained behind many other immediate concerns over the physical product. However, digital developments have pushed construction industry to react (Fairhead, 2015). With the introduction of BIM, the interest towards information use and management in the construction industry has gained its due attention and support.

It is the formal practice to use RIBA Plan of Work (See Figure 2.4) to explain construction projects although it is heavily architect centred. Highlighting the rising attention and need for use and management of information in construction, RIBA provides an information exchange guide mapped along the Plan of Work (Fairhead, 2015). It is a successful attempt in explaining the purpose of project information, how they can be used and what for. Accordingly, construction information is used to identify the project requirements and responsibilities, to assess the project outcomes and learn for future projects from the feedback from in-use stage. Following the stages of RIBA Plan of Work, Table 2.1 presents the information output at each stage along with a discussion on the role of facility manager in construction information exchange process. This is in support of highlighting the importance and contribution of early involved facility managers for efficient and effective use of construction information.

TABLE 2.1: Facilities Facility managers' role in construction information

RIBA stages and information exchange	**Purpose for FM**
Stage 0 **Strategic brief**	FM involvement at high level to check existing asset and BIM strategy (articulate and describe the organisation information requirements (OIR) and asset information requirements (AIR)). BS 8536 should be read and consideration given to the information needed at handover and if the principles of government soft landings (GSL) are to be followed. Consideration should be given to what asset data will be needed (e.g., asset lifespan, costs, recycling, replacement etc.) BIM standards should be referred to and questions asked to allow the start of drafting the EIR template. This phase is critical as it sets the tone for the project in terms of ensuring engagement between all the stakeholders to deliver real value from the BIM process
Stage 1 **Initial project brief**	FM/client to structure information for project tender documentation. FM to assist with the project brief which should be completed in line with guidance in RIBA PoW 2013. Another useful document at stages (0, 1 and 2) is RIBA's Client conversations: insights into successful project outcomes. This describes development from the initial to the final status. The project brief is critically important and should not only be derived from the client's aspirations but as a result of questions asked of them. Ideally, the client should articulate what they need from the building in terms of performance, sustainability, environment (working), ease of use, replacement/demolition strategy, reporting needs etc. The answers to these project specific questions will then form part of the tender questions as opposed to using a generic question set. FM should identify known CAFM/IWMS/other enterprise management systems to be used at stage 7. Check if existing systems are capable of accepting data using COBie. Where no such tool(s) exist or a new one is to be provided, the facility manager should clarify the system as early as possible and establish how this is to be funded and what training will be provided to necessary FM staff. Thought should be given to using a common data environment (CDE) for the project and how this will be managed during the project and after handover. FM should consider the

RIBA stages and information exchange	Purpose for FM
	requirements of the CAFM/IWMS and other systems to communicate with access control, BMS, CCTV, alarms and control systems and other relevant systems. FM should assist capex approval of the outline business case.
Stage 2 **Final project brief, concept design, project strategies and cost information**	FM to work with design team to give FM input on design concepts through the CDE. This is mainly a reviewing role – e.g., asking questions such as "What if?", "How will we?", "What does the client/FM need/expect?" etc.
Stage 3 **Developed design and updated cost information**	FM to work with design team to give FM input on developed design through the CDE. FM should also develop the process on behalf of the client for working with the contractor (and CAFM/IWMS suppliers) to plan the data transfer into nominated system/s.
Stage 4 **Technical design**	FM to check the design's fitness for purpose and cost efficiency from a Whole Life Cost (WLC) perspective. This may include fabrication, manufacturing details, verification of systems and elements including commissioning, operation and maintenance information etc.
Stage 5 **As constructed information**	FM to check construction progress and compliance of updated production information and to ensure contractor provides correct information for commissioning and handover procedures. The process of implementing the CAFM/IWMS should be considered as the building is being constructed and assets are put in place as this is when the history of the building starts. As such, data can be captured and maintained from this point forward. Pre-completion commissioning and the testing programme should be considered. Note information and data will be required well ahead of the planned completion and handover. BIM model clash recording and resolution as well as snagging and incident reporting should be included in the records of the building. As operations and maintenance (O&M) requirements are compiled, confirmed and validated they

RIBA stages and information exchange	Purpose for FM
	should be incorporated into the CAFM rather than being a separate, disjointed entity. At this stage, the level of definition (LOD) is sufficiently detailed and appropriately formatted to be pushed into the relevant data management systems. This stage should be equivalent to a sign off of data that will be used to manage the remainder of the lifecycle.
Stage 6	
Updated as constructed information	From a FM perspective, this stage should be seen as the "in inspection" of the "as-built information"- i.e., accepting the building/facility/asset into service. There should not be any questions at this stage, but simply confirmation and verification. FM should ensure the handover process has already validated and transferred relevant data into CAFM/IWMS or other enterprise management system as defined in the EIR. The handover process should allow for CAFM/IWMS integration with other systems as required. All O&Ms should be completed and signed off with the client and FM team within the CDE - or appropriate sign of system. FM should also test that they can access all BIM models passed to them. Handover should be considered as a handover of a completed project, with the solutions implemented, tested, validated by the client and, after staff training, signed off as completed. As an example of the detail to be considered: when door schedules are finalised, and at a time required by the programme (the planning of such detail should be started early in the process), 2D DWG drawings with all doors (requiring client supplied locks) numbered and scheduled shall be supplied for lock ordering purposes.
Stage 7	
Feedback and asset information	FM should test CAFM/IWMS systems to ensure all data can be used to optimise the assets. There may be updates to the practical completion data drop as required during the defect liability period and/or GSL (if applicable). This period is where the FM should focus on refining the CAFM/IWMS system and data quality. BIM as a process must include FM all the way through to ensure the operational teams receive the high quality and accurate data they need to succeed.

Adopted from: Fairhead (2015); Ashworth and Tucker (2017, pp.9-10)

Table 2.1 draws the information link between each stage in construction project with the in-use phase (Fairhead, 2015; Ashworth and Tucker, 2017). As a result, when the project develops over the later stages, more information is generated which are relevant for building operation and maintenance. Learning from the other industries and novel trends such as Big Data emphasise the necessity for separating the information needed from vast amount of information available. The term Big Data itself is implying the capability of creating enormous size of the datasets with unintentional data recording activities such as web browsing. Value is a criteria for both information sorting and system design. On the other hand, recent publications on guidance for innovation and research in the construction industry have emphasised the importance of user value (Haugbølle and Boyd, 2013). This underlines the need for more rigorous studies on user value in built environment as an emerging trend to improve efficiency and effectiveness of the construction industry. In next section, the different value concepts practiced in the construction industry are discussed.

2.4 Value in Construction

Value in construction has come across range of debates. There are well articulated values presented in websites and annual reports of construction companies; however, lack of understanding of value as a separate concept is noted in both practice and research (Mills et al., 2009). On the other hand, value is not a new concept in construction but definitely a misused one (Salvatierra-Garrido, 2011a). The increased availability of information through accessibility and reliability of technology continuously reminds the importance of understanding value in terms of system design as well as criteria to measure success. RIBA Plan of Work 2013 Guide on information exchange provides a list of different types of value emerge as project outputs (Table 2.2). This work of Fairhead, 2015 guides construction projects to explore overall value of a project to gain the true benefit rather limiting to exchange value, especially in an age of information.

As many other theories, value was also welcomed into construction after its successful application in manufacturing. Value methodology which was introduced in 1947 in manufacturing to improve the efficiency without compromising the quality was taken into design and construction in mid 1960s marking the first involvement of value in construction (Kelly, Graham and Male, 2014). The ease of identification of customer and end user in manufacturing setting and complexity in customer and end user roles in real estate industry makes the difference in direct application of value theories as it is in manufacturing to construction (Haddadi et al., 2016; Salem et al., 2006). However, Modern Methods of Construction (MMC) help reducing this gap between manufacturing and construction.

TABLE 2.2: Value as construction project outcome

Type of value	What does it mean	How is it measured
Exchange value	The building as a commodity to be traded, whose commercial value is measure by the price that the market is willing to pay. For the owner, this is the book value, for the developer the return on capital and profitability. Also covers issues such as ease of letting and disposability.	Book value, Return on capital,Rental, Yield
Use value	Contribution of a building to organisational outcomes: productivity, profitability, competitiveness and repeat business, and arises from a working environment that is safe in use, that promotes staff health, well-being and job satisfaction, that encourages flexible working, teamwork and communication and enhances recruitment and retention while reducing absenteeism.	Measured associated with occupancy such as satisfaction, motivation, teamwork, measures of productivity and profitability, such as healthcare recovery rates, retail footfall, educational exam results, occupant satisfaction
Image value	Contribution of the development to corporate identity, prestige, vision and reputation, demonstrating commitment to design, excellence or to innovation to openness, or as part of a brand image.	Public relations opportunities, brand awareness and prestige. The recognition and 'wow' factors
Social value	Developments that make connections between people, creating or enhancing opportunities for positive social interaction, reinforcing social identity and civic pride, encouraging social inclusion and contributing to improved social health, prosperity, morale, goodwill, neighbourly behaviour, safety and security, while reducing vandalism and crime.	Place making Sense of community, civic pride and neighbourly behaviour, Reduced crime and vandalism

Environmental value	The added value arising from a concern for inter generational equity, the protection of biodiversity and the precautionary principle in relation to consumption of finite resources and climate change. The principles include adaptability and flexibility, robustness and low maintenance, and the application of a whole life cost approach. The immediate benefits are to local health and pollution.	Environmental impact, Whole-life value, Ecological footprint
Cultural value	Culture makes us what we are. This is a measure of a development's contribution to the rich tapestry of a town or city, how it relates to its local and context, and also to broader patterns of historical development and a sense of place, cultural value may include consideration of highly intangible issues like symbolism, inspiration and aesthetics.	Critical opinion and reviews, professional press coverage, Lay press coverage

Source: from Fairhead (2015, p.16)

The next question is how well construction industry understand the value concept. When early 19th century work highly concentrate on quantifying value in time, cost, quality (Atkinson, 1999), 21st century scholarly works attempts embrace the subjective nature of the concept. In support, there are number of doctoral research project conducted in value in construction claiming its role in build environment practices (Koskela, 2000; Varangu, 2006; Mills, 2013; Salvatierra-Garrido, 2011a). All these scholarly works bring a detail discussion on value from its origins from the times of Aristotle to the 21st century construction industry practices. However, they are limited to understanding and claiming value in design stage and in some cases committing to single theory such as basic human value theory (Mills, 2013) or Lean construction (Salvatierra-Garrido, 2011a). Laursen and Svejvig, 2016 provide an interesting discussion based on a literature review to summarise what construction industry know about value to the date. This is done in the light of project value management. Acknowledging the work of Laursen and Svejvig, 2016 yet entering into the discussion from a different view Green and Sergeeva, 2019 explain the value creation process in construction projects taking a social constructivism standpoint. Leading from the qualitative notion of the value in construction, commonly used value principles in construction are revisited.

2.4.1 Lean Construction

Lean Construction (LC) is a philosophy developed upon Toyota Production System placing its roots in manufacturing industry. In simple terms, LC is gaining customer value by reduction of waste. Toyota Production System which is branded as 'The Toyota Way' is a combination of methods to achieve 'cost reduction, quality assurance and respect for humanity to ensure sustainable growth' (Forbes, 2011). This is achieved by practicing Just in Time (JIT) stock management principles, automation of the work flow, creating workforce flexibility and promoting creative thinking. Giving Toyota Production System a universal application beyond automotive industry, Womack and Jones coined the term 'Lean' in 1990s.

Laurie Koskela, an influential scholar in LC has constantly noted the weaknesses in Lean Thinking when it is applied in construction as it still focuses on manufacturing setting which is repetitive production of the same product in a factory setting (Bertelsen and Koskela, 2004; Koskela, 2004). In 1992, Laurie Koskela introduced Lean philosophy into construction, later extended with the Transformation- Flow-Value (TFV) theory and 'value generation model' which he later developed as a part of his doctoral research (Koskela, 2000). In a study on value in construction, Salvatierra-Garrido (2011) provides a favourable review of TFV from a third point of view. However, application of Lean Construction is beyond the TFV production theory.

Current research claim that it is the Lean concept which pave the way for unique transformation of value in construction (Salvatierra-Garrido, 2011). Value is at the heart of lean philosophy. It is through the understanding of value which makes it possible to distinguish waste from the process (Emuze and Saurin, 2015). The fact of identifying Lean a as a philosophy provides the freedom to explore different methods in implementing this theory. As a result, integration of Lean Construction and BIM incline to bring promising advantages to improve efficiency in construction workflows (Coates, 2013; Dave et al., 2013; Sacks et al., 2010). Coates, 2013 applies Lean principles to identify the BIM benefits. On the other hand, research summarising multiple scholarly work in lean in construction emphasis that use of multiple principles such as JIT, Kaizen, Last Planner System, etc. are being recognised as Lean Construction practice. Keeping the aim of waste reduction without limiting to TVF production theory. Further, (Jørgensen and Emmitt, 2008) emphasise that Lean Construction is "lost in transition" from manufacturing to construction arguing on inconsistency in definitions and lack of publications in peer reviewed journals.

Accordingly, existing literature on LC provides mixed views on the theory discussing both its pros and cons. The precise focus on waste minimisation as a means of value management has been the winner and the core of the concept. However, this same fact has been the limitation as it restricts what is defined as value. Therefore, there is a gap in holistic approach to understand value in construction.

2.4.2 Value Engineering and Value Management

Value Engineering (VE) is another approach used in construction sector (Salvatierra-Garrido, 2011) which again has early roots in manufacturing. VE is identified as a subset of Value Management (VM) (Kelly, Graham, and Male, 2014; Lester, 2017). Kelly, Graham and Male (2014) provides an extensive history on VM discussing the beginning of the Value Analysis as a solution for the material shortage during World War II. Later, Value Analysis was recognised as Value Engineering because of the involvement of engineers in the process of cost reduction in manufacturing through redesigning. As Kelly, Graham and Male (2014) explain, VM is introduced as an extension to VE practices since VE's ultimate focus is to redesign for cost reduction when VM is a "customer focused design procedure". Looking from a different angle Green and Sergeeva (2019) distinguish VE from VM as hard-VM and soft-VM. On the other hand, Lester (2017) argues VM is concerned with "what" to be done to enhance performance, when VE is focused on "how". Therefore, what is recognised as VE and VM tend to be different.

From a VE and VM perspective, Lester (2017) defines value as the ration of function and cost. In simple terms, the aim of VE and VM is to increase the usefulness of a product or service while reducing cost. With this Lester (2017) emphasises that VM and VE are essential because of this constant search to reduce costs across organisation without compromising quality. However, this statement is found to be contradictory since being a quality product or in other terms not being broken after using twice is part of the "usefulness". Although, VE and VM are commonly used concepts in construction and they have continued to support to enhance the project value, what is recognised as value is not a stable.

By means of all these different concepts it is evident that construction industry acknowledges the importance of understanding and enhancing value. However, since the introduction of these concepts to construction industry the focus has always been on identifying and measuring the value of the process of the construction to the third party. For instance, construction project value is assessed in reference to the organisation, client, economy or society. To the knowledge of the researcher, there is no effort being made on identifying the value of a construction activity to the individuals involved in the process. On the other hand, number of literature on value in construction has constantly emphasised the need of understanding both subjective and objective nature of value in construction rather limiting to existing value theories (i.e. value management and value engineering) which predominantly consider objective value measures (Thomson et al., 2003; Thomson and Austin, 2006; Thomson et al., 2013; Mills, Austin, and Thomson, 2009; Salvatierra-Garrido, 2011a). With this finding, it is predicted in the thesis that this knowledge gap has constructed an artificial value which ultimately provides a large numerical value to the investor, society and economy which does not reflects at the individual level of the project participants. Therefore, face a continuous struggle in terms of introducing change. This is precisely why that the same person who is ready to change the mobile phone every two years and the motor vehicle in every 5 years but not the way one does the job in construction. This questions whether it is the resistance to change is the real issue.

2.5 Building Information Modelling

Building Information Modelling (BIM) is a global concept, creating a universal construction platform for organisations to work beyond geographical boundaries and the UK stands among the few countries taking the BIM leadership (Figure 2.5). The term BIM was introduced to the British construction industry in 2011 to expand the working methods in construction and as a first step forward to smart cities and artificial intelligence (Saxon, 2013). Since then, the UK construction industry has made a slow progression towards digital construction through BIM. However, UK stands ahead in European countries due to government influence and only being second to United States in the global league (Schober, Hoff, and Lecat, 2017).

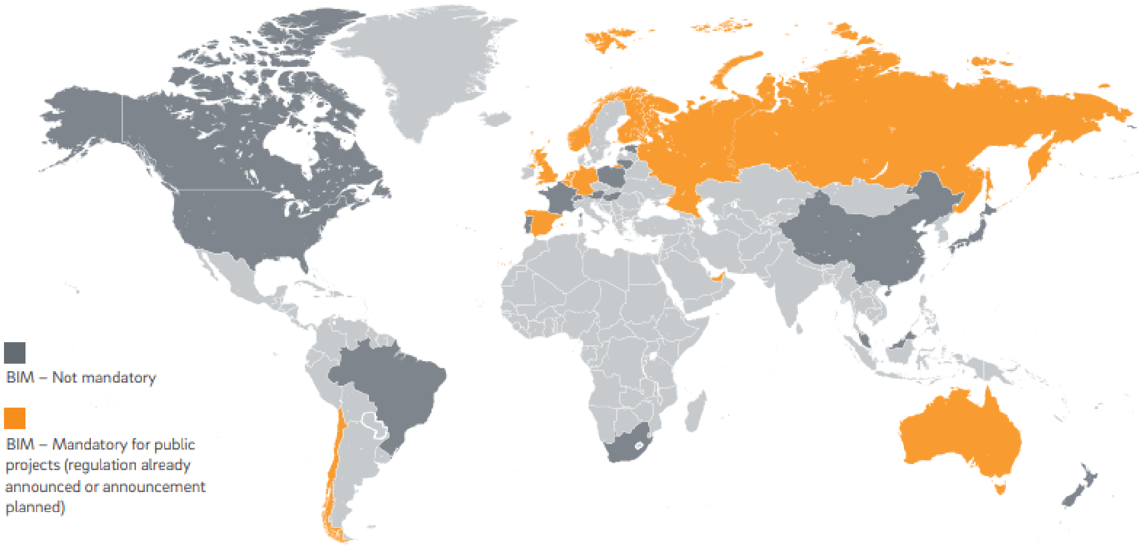


FIGURE 2.5: Global snapshot of BIM (Source: Schober et al. (2017))

BIM is becoming popular as a project management solution however, in a scattered form (Jallow, 2011). On the other hand, it is a digitised approach supports through life application of building information with the information exchange and interoperability capacity (Eastman, 2011). BIM is identified as the facilitator of collaboration, integration and interoperation expected in the construction industry (Vanlande, Nicolle and Cruz, 2008). Although there are many ways to explain what BIM is, the common aspect in most of them is placing BIM in the boundaries of information technology and Computer Aided Design (CAD). Existing knowledge about BIM favours its positive contribution towards the construction industry and economy while highlighting few short-term barriers. Both barriers and benefits of BIM are discussed in detail under following sections. Regardless of the counterweight of BIM benefits with barriers; by moving towards BIM, the construction industry will only catch up with modern manufacturing industries that have been practising product life cycle management over two decades (Saxon, 2013).

2.5.1 BIM as information, technology and process

Scholars and industry practitioners have described BIM in many ways. It is commonly identified as a digital representation of the physical building (Underwood, 2009) or three-dimensional (3D) description of the building (Construction-Innovation, 2007). In contrast, some define BIM as a process rather than a tool covering variety of functions and tools as BIM (IWFM, 2012). Interestingly, Vanlande, Nicolle and Cruz (2008) defined BIM in terms of what it does with the information. Accordingly, BIM is the process of creating, storing, managing and sharing building information in an interoperable and reusable manner. It is evident that most of these definitions are built around the main feature of BIM – i.e. 3D model.

Taking a step further from the idea that BIM is a software; Azhar, Malik, and Tayyab, 2012 identify BIM as a combination of technology and process. They consider information is received as an output of using BIM technology and process. Looking from a facilities management perspective, Aziz, Nawawi, and Ariff, 2016b identify BIM as an Information Communication System, emphasising the information and technology aspects of BIM. Acknowledging this widespread inconsistency in BIM definitions, recent scholarly work present an extensive review of different BIM definitions (Dakhil, 2017; Marsh, 2017).

In this study, Building Information Modelling (BIM) is identified as an information system which includes information technology and processes for creating, storing, processing and managing digital built asset. With this definition it is emphasised that this thesis acknowledge the equal roles played by information, technology and process. Accordingly, by an organisation adopting BIM it will introduce an information system which will not only limited to maintenance department but influence the core business functioning. Therefore, implementing BIM at the in-use phase required to understand the relationship between built asset and its users.

2.5.2 Barriers and benefits of BIM

BIM made its way into the Architectural, Engineering and Construction (AEC) sector because of the advance capabilities it carries (McGraw-Hill, 2009). It is mostly used in design stage to manage and validate the building design (Vanlande, Nicolle and Cruz, 2008). However, since buildings are recognised as facilitators to many industries; the contribution of BIM will enable the performance of economic activities beyond design and construction (Saxon, 2013). Therefore, its long term contribution and existence in the construction industry is no doubt regardless of its slow adoption. Starting from the definition itself BIM is a complicated concept as it continues expanding from a software to an asset management information system (Love et al., 2013). Therefore, in short term both in practice and academia find befits as well as barriers of BIM. Here, BIM barriers and benefits are identified in general and they are analysed referring in related to FM context.

Starting from the positives, BIM provides a number of advantages to project stakeholders through apposite coordination, waste reduction, informed decision making and also contributing correct information at the correct time (Love et al., 2013). Figure 7.3 illustrates the findings from the literature on BIM benefits. It is evident that BIM offers a strong way forward especially with the Smart Cities agenda by creating a digital and intelligent built environment. Research suggests that BIM should not be seen only as a mere technology for designing and construction but also its life-cycle implications as an information tool for operation and maintenance of built asset (Love et al., 2013).

In terms of barriers to implement BIM in FM; lack of tangible benefits, knowledge on implementation, technological issues with interoperability and skill shortage are highlighted (Kassem et al., 2015). Generational differences, steep learning curve and pull and push

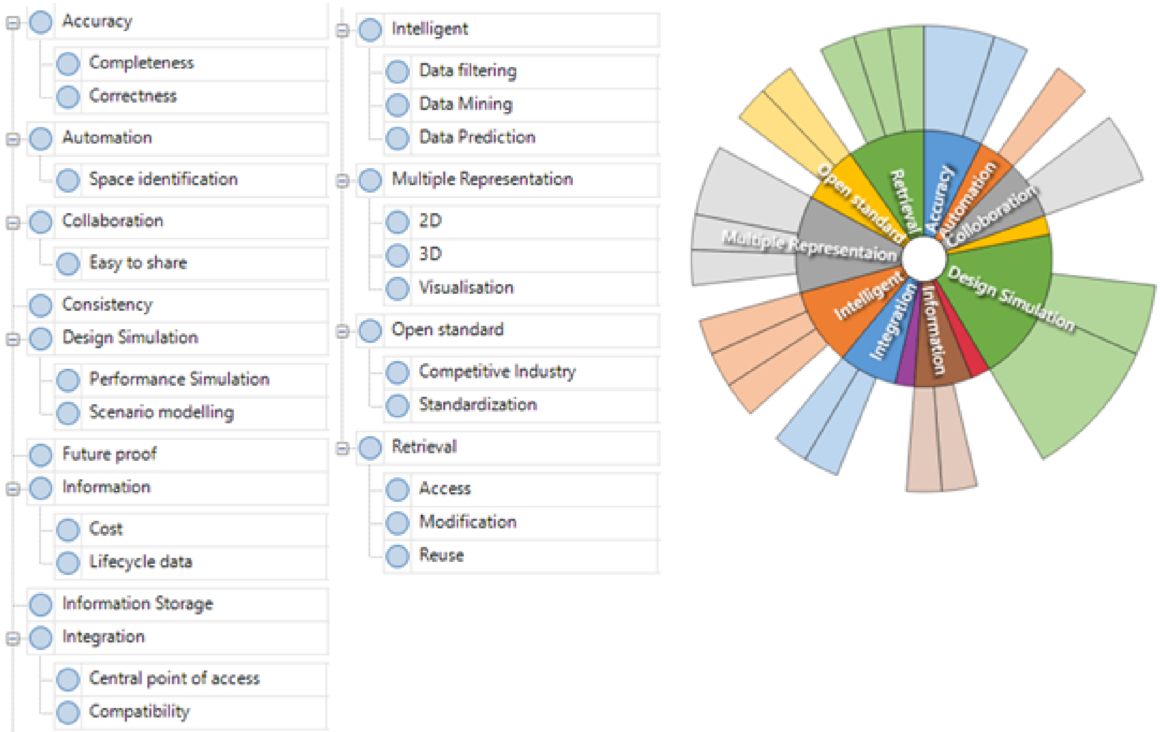


FIGURE 2.6: Literature analysis summary

between those who are ready to adopt and not, have also been identified as barriers to implementation of BIM in general (Becerik-Gerber and Rice, 2010). Another barrier is that scattered form of use of this integration tool (Jallow, 2011). Everyone in the building life cycle tend to develop their own BIM. This becomes the problem at the handover and in-use face to integrate fragmented data. To be an effective tool at the facilities management (in-use) stage of a building, BIM should contain FM information (NBS, 2014). BIM has undeveloped capabilities of addressing FM issues such as process management and visualization (Becerik-Gerber et al., 2012). NBS, 2014 noted the importance of collaboration between FM, BIM and Government Soft Landing.

Although the study included majority of FM related BIM literature (Construction-Innovation, 2007; Aziz, Nawawi, and Ariff, 2016a; Kassem et al., 2015; Gerrish et al., 2017); each of them discusses on how to use BIM in ways that offers benefits to FM rather attempting to understand what FM expects from BIM. With this regard, Parn, Edwards, and Sing, 2017 provide a critical review of the BIM benefits related to FM. However, Demian and Walters, 2014 noted that necessary precautions should be taken when generalising benefits of BIM as an information management tool. On the other hand, overall benefit of BIM is not completely identified and construction project stakeholders are still struggling to make decisions on possibilities for adopting BIM within their project execution plan (Barlish and Sullivan, 2012).

BIM facilitates initial data for FM which enhances the potentials of FM (Becerik-Gerber et al., 2012). FM is dealing with large amount of building information; acquiring, updating and analysing (Wang et al., 2013). BIM as a platform coming from the early stages of a building is a perfect solution for FM data management. What is more important is, BIM allows to

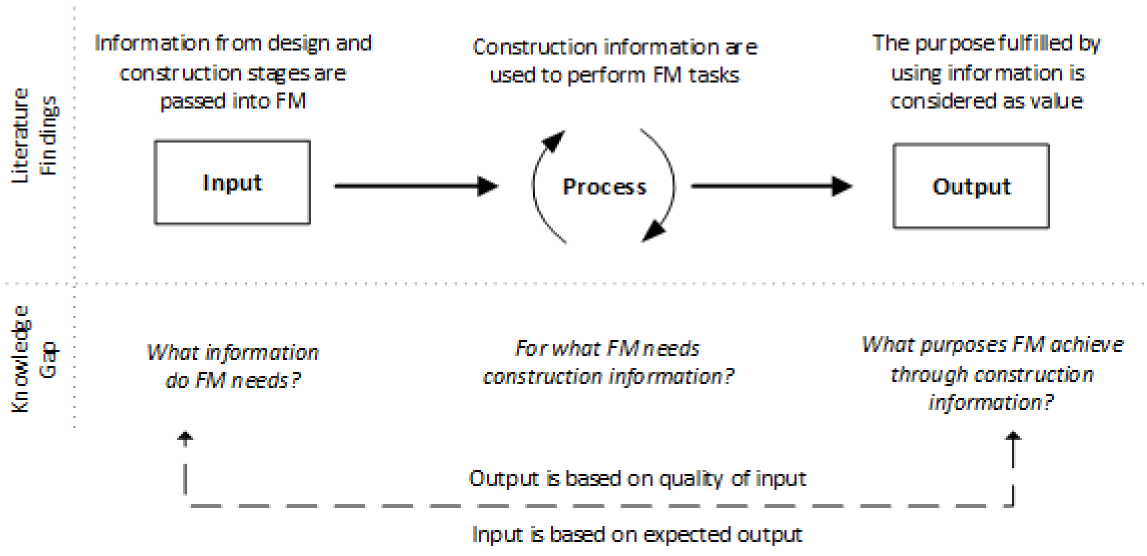


FIGURE 2.7: Information Value Process

communicate FM needs in early stages (IWFM, 2012). The positive contribution of adopting BIM in facilities information management is identified as a significant value addition associates with BIM (Gu and London, 2010). Eadie et al., 2013 highlight that facilities managers and client benefit the most out of BIM implementation. From client's perspective, a considerable effort should be given to define client's FM needs at the early construction stages (Becerik-Gerber et al., 2012). However, majority of construction projects do not hand over the 3D model and the developed datasets (e.g.COBie) at the commissioning phase, which prevents the grasping of BIM advantages to the FM (Eadie et al., 2013).

In concern of this research BIM is adopted as a vehicle for data acquiring, storing, integrating and updating (all-inclusive management) through the building life cycle along with a graphical model. BIM is capable of gathering data of a built asset. Identifying the value of information is a mechanism to filter necessary information (Zhao et al., 2008). However, information overloading and poor understanding on information needs for FM, and level of details of those information drive towards the low implementation of BIM in FM (Parsanezhad and Dimyadi, 2014). The potentials of BIM are widening with its recent developments in different sectors. Literature highlights the benefits and capabilities of BIM and 'information management' as one of important capabilities integrated within it. However, many features of BIM are not fully practiced within construction projects, more specifically during the facilities management stage and existing knowledge has constantly neglected to understand the FM needs regards to BIM (Figure 2.7). In next section, BIM related standards and guideline are explored to defend the available support for BIM adoption in FM.

2.6 BIM standard and guidelines

COBie and IFC (Industry Foundation Classes) are the commonly used data exchange formats in BIM. COBie is the UK government accepted information exchange format (British

Standards Institute, 2014), which allows data exchange in a structured manner for commissioning, operation and maintenance of an asset (British Standards Institute, 2012) . IFC is one of several approved formats of COBie (i.e. spreadsheets) which is a platform neutral data model to facilitate interoperability in construction, operations and maintenance stages of a built asset (International Standard Organisation, 2013). IFC by itself does not give a detailed explanation to decide what information is required by any specific task under the given scope (William East, Nisbet, and Liebich, 2012).

Standards and guidelines are the most common and quickest way to understand the information needs at the early stages of a building. Having identified the potential of BIM and its long-term benefits, the number of standards developed during the last decade is identified from the literature. The summary of the available standards reveals that the majority of the issues related to BIM implementation are addressed to the date and continuous developments have taken place to improve these standards and guidelines to overcome their loopholes. Although the governing bodies have made all efforts to promote and streamline the BIM application in the facilities industry, the practical application has not expanded as much as the theoretical developments. Table 2.3 summarises the standards and guidelines related to construction information management through BIM. However, they do not provide a complete solution in specific to FM information requirements (Patacas, Dawood, and Kassem, 2015).

TABLE 2.3: FM information related BIM standards

Standard/guideline	Relevant facts for information management
BS 8587:2012 Guide to Facility Information Management	• Information management strategy, policy and procedure • FM handbook containing legal, commercial, financial, technical and managerial information about the facility • Recommends COBie • Asset registry
ISO 19650 – 1 (PAS 1192 – 2) Organisation of information on construction works. Information management using building information modelling - Part 1: Concepts and principles	• Relevant standards for BIM and information management • Relationship between documents used for information management • Information delivery cycle and responsible parties for each stage • Content areas of EIR • Information classification – Uniclass Information Exchange - COBie

Standard/guideline	Relevant facts for information management
ISO 19650 – 2 (PAS 1192 – 3) Organisation of information on construction works. Information management using building information modelling - Part 2: Delivery phase of assets	• Summary of relevant asset information standards • Information management plan • Asset information process • Content of the Asset Information Model (AIM) • Link between AIM and enterprise system • Need of a data manager to enhance accuracy of data
BS 1192 – 4:2014 Collaborative production of information Part 4: Fulfilling employers information exchange requirements using COBie	• Assist information demand side • The role of employer, design/contractor lead and subcontractors/manufactures in information exchange • Purposes of required facility information
CIC BIM Protocol Standard Protocol for use in projects using Building Information Models (Construction Industry Council, 2013)	• Need of an information manager • A form to be attached with the contract documents explaining BIM model needs specifically with data drops at different project stages, types of software and version to be used
Uniclass 2015 A universal classification system for the construction industry	• A classification system for building elements and products
ISO 16739:2013 Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries (British Standards Institute, 2013)	• A standard format for data exchange • Provide categories and coding system for building elements and assets
BS 8536-1:2015 Briefing for design and construction. Code of practice for facilities management (Buildings infrastructure)	• Early involvement of the FM for information requirement identification • Transfer of information from Project Information Model to Asset Information Model • Specified after care period to extend the service of the project team after the handover of the facility

Standard/guideline	Relevant facts for information management
Digital Plan of Work	• Web-based free tool to guide the information responsibilities and delivery at each stage of the construction project • Defines information requirements

2.7 Application of BIM in AEC/FM Environments

Building information modelling had a immediate effect on the Architecture, Engineering and Construction (AEC) sectors because of its visualisation ability (Volk, Stengel, and Schultmann, 2014). It was then extended to the FM industry and visualisation has made a major impact on adopting BIM in AEC/FM environments. It is a key requirement at the design phase to communicate the ideas of the project team to the client to win the project. In that sense, moving from a 2D platform to the BIM environment was a great value addition to the architects. Moving forward, this is also recognised as a relevant feature for facilities management functions in the iconic Sydney Opera House FM Exemplar project (Construction-Innovation, 2007). Visualisation through 3D modelling has been popular in daily operations and management as well as to understand the root causes of the problems in FM (Patacas, Dawood, and Kassem, 2015). One such example is scenario planning for refurbishment projects with least disturbance to the existing structure (Kassem et al., 2015) and locating building components for maintenance and repair (Korpela et al., 2015). Accordingly, scenario planning is one of the common application of visualisation feature of BIM in FM and therefore, a motivation for whole-life BIM adoption. However, the frequency of this application in day to day maintenance and demand of time and skills to perform the scenario modelling is to be noted.

Collaboration is another attractive feature in BIM. It solves many issues evolving from the fragmented nature of the construction industry (Eadie et al., 2013). In other words, it brings all stakeholders together into a single platform taking them out from the silo environments. This feature has the highest positive financial contribution to BIM projects during design and construction stages (Eadie et al., 2013). The savings were made not only through money but also with time. Yet, there is hardly any evidence on application of this feature related to FM tasks. Cost modelling is another such use of BIM which is benefited from, at the early stages of a construction project (Eadie et al., 2015) yet no straightforward application beyond construction.

Clash detection is a similar impressive feature in BIM where at some occasions solely identified as a synonym to BIM. As a part of BIM, Navisworks provides this feature by reviewing different drawings produced by different professionals and diagnoses the physical clashes in the complete model. This feature is a value addition of BIM and it is well recognised for the savings made by detecting potential variations/rework before starting the actual construction work (Eadie et al., 2013). However, there is no considerable contribution to the FM tasks with this feature other than the potential small-scale refurbishments which could take place at some point.

Straightforward benefits of BIM for FM have been identified as the significant time savings at the transfer of as-built information to the CAFM systems and efficient handover process (Korpela et al., 2015). Delivering handover information in digital form reduces much time and rework in data transferring at the facilities management stage (Akcamete, Akinci, and Garrett, 2010). Although digital information is not a unique feature of BIM still it is considered as a value addition. This digitised aspect also adds value in design and construction stages by being able to alter design drawings over and over again with little effort. Another important feature is the intelligence. The BIM model identifies the space and objects for what they are rather than symbolising (Ding, Zhou, and Akinci, 2014). Application of this feature could be seen on different occasions throughout the life cycle.

It is evident through these key applications of BIM that most of its high-end features are directly providing solutions to critical issues in design and construction stages. In contrast, FM is trying hard to make some use out of the given BIM features. Summarising the literature findings on BIM features and FM requirements through relevant standards and guidelines, Figure 2.8 represents a map of BIM features with FM expectations. For instance, visualisation through 3D modelling is a key feature in BIM and it is utilised in FM for scenario modelling, presentation and management purposes. Therefore, visualisation is a feature which promotes the investment in BIM in FM. Another such well recognised beneficial feature is clash detection. It has proven to be beneficial in design and construction stages more often. However, this not an attractive concern to promote BIM in FM. Likewise many established features are dedicated to improve the efficiency and effectiveness in design and construction stages rather than in FM. On the other hand, most of the FM related BIM features are merely seen on paper to exaggerate the potential contribution of BIM for FM.

The skeleton of BIM is the information. It is information which makes all the above features possible (Arayici, Onyenobi, and Egbu, 2012; Antón and Díaz, 2014) and it is the key value addition to FM through BIM. Therefore, it is essential that the necessary information is there in the BIM model without information overloading (Parsanezhad and Dimyadi, 2014). Referring to the above features it is clear that most of the exciting features are mainly for design and construction purposes and not many have an impressive contribution for facilities management. However, beyond the unique features, information carried through BIM has a greater potential in FM (Eadie et al., 2013).

Therefore, it is critical to understand the facilities management information requirements to make the best use of BIM. Conversely, it is the lack of experience and knowledge related to information requirements that is a key reason for the poor adoption of BIM in FM (Giel and Issa, 2015). Therefore, the successful adoption of BIM in FM will depend on the understanding of value of information for facilities management and having this information on BIM models. Identifying value of information is knowing what you need (Zhao et al., 2008) indeed is a filtering mechanism to separate what is needed from what is available.

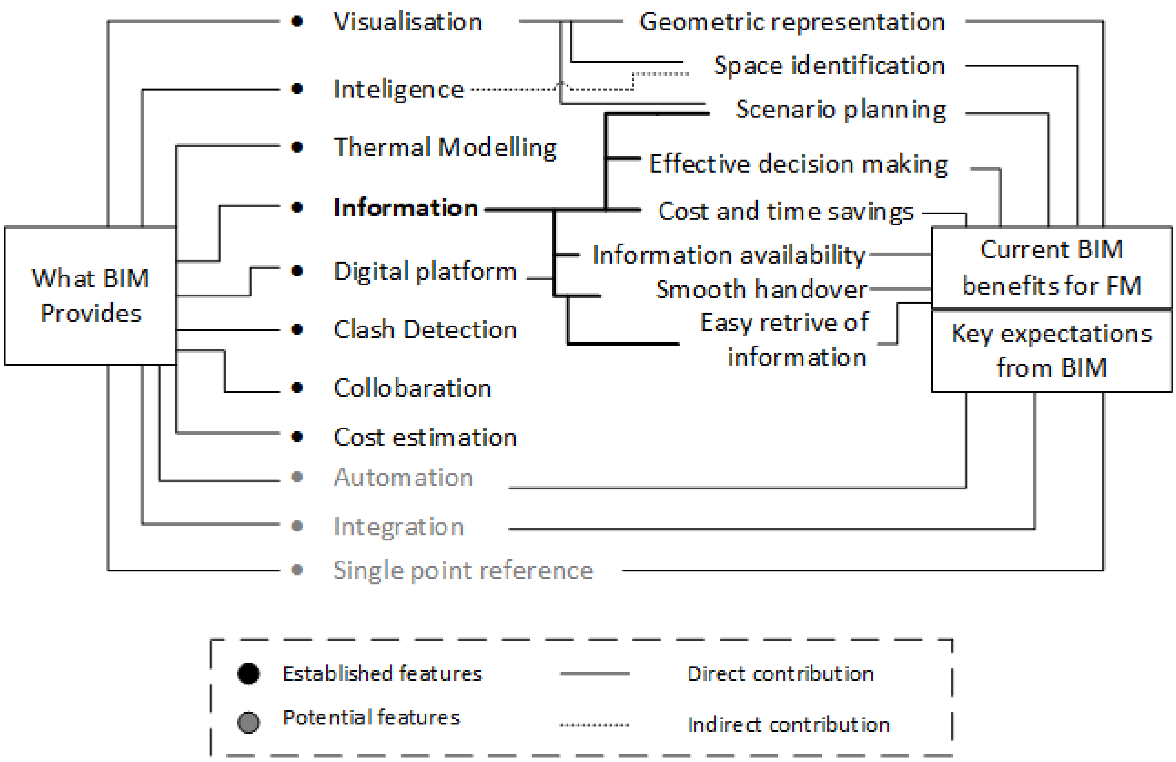


FIGURE 2.8: Mapping BIM features with FM expectations with FM expectations

In engineering systems' terms, "every design is a response to a motivation" (Benavides, 2012). When applying this notion within the research immediately raise the question whether BIM is the response for FM's motivation? Finding answers to this question is in interest of this thesis as it will reveal an unexplored area of BIM and guide towards the reasons behind the slow adoption of BIM in FM. In support, recent studies claim that design science methodology is an appropriate way forward to understand BIM (Kehily and Underwood, 2015).

2.8 Chapter Summary

This chapter brings a complete narrative of the construction industry from its early practices to 21st century expectations in terms of value and information management, leading to the discussions on Building Information modelling (BIM). The anthropology of the built environment supported the value play and role of human interaction in the construction industry that have been neglected in most construction innovations. Further review on value management practices through Lean Construction, value engineering and value management emphasised the lack of theoretical knowledge related to value management in construction sector. Further discussions on value theories and previous attempts on integrating human value into construction industry is presented later in the thesis (Chapter 5).

It is evident since 2011 that the UK Government is committed to development of construction industry and determined to hold the global leadership in the sector. Using digital construction to promote sustainability is one of the key events in this agenda which was released to the public through multiple initiatives such as Digital Built Britain, Construction Strategy 2025 and Construction Sector Deal. Promoted by these Government initiatives, BIM is identified as the rising information management system in construction. A substantial support in promoting best practices is identified along with fundamental weaknesses in the construction industry. Accordingly, following summarise the key findings of the chapter;

- For being a practical and labour intensive industry with a focus on physical output (i.e. the building), information is recognised as a secondary output giving less of concern
- However, living in the age of information makes it impossible for the construction industry to isolate from information systems and the social interaction
- BIM has gained its reputation as the way forward for digital construction
- The ability of BIM to fulfil facility management needs are minimum in current context

These key findings informs the necessity of understanding the nature of information requirements and management during facilities management. With this regards, next chapter is dedicated to explore facilities management and through life information management of built assets.

Chapter 3

Through-life information management of built environment facilities

3.1 Introduction

The previous chapter identified Building Information Modelling (BIM) as an effective and efficient digital approach to manage construction information. However, its application is not limited to the design and construction stages. The purpose of this chapter is to build the case from the facilities management perspective on the usability of BIM. Therefore, the chapter begins with introducing FM by bringing forward different definitions presented by leading professional bodies followed by information management practices at the FM stage. The later part of the chapter discusses the issues faced by facilities managers along with their lack of collaboration with early stages of building lifecycle. Finally, the future of facilities management built upon technological advancements is discussed to prove the necessity of adopting BIM beyond construction.

3.2 Facilities Management

Rising operational costs of buildings, increasing regulations on health, safety, environment and amplification of complexity of buildings by the use of technology than ever before has brought organisations to be conscious about facilities management (Alexander, 2013). For a business to be successful it is vital to understand the impact of rising costs on building occupancy, services and workplace management throughout the business life cycle (Codinhoto and Kiviniemi, 2014).

As a comparatively modern discipline in the construction industry, facilities management is defined by many, bringing different insights on to the table. The IWFM, 2015 define Facilities Management (FM) as the centre point of responsibility which ensures services of an organisation perform up to the agreed standards to support the core business performance to achieve business objectives. Having a similar view, the European Standard for Facilities Management describes FM as the integration of processes within an organisation to maintain and develop the agreed services which support and improve the effectiveness of its primary activities (Standasization, 2007). Some other identifies FM as a process focuses on managing the complexities of a built facility to smooth functioning of its physical structure and support services to enhance the core business performance (Kincaid, 1994).

FM is a multi-disciplinary profession, which has a vast information requirement (Becerik-Gerber et al., 2012). In daily basis FM deals with an enormous amount of asset information; including acquiring, updating and analysing it (Wang et al., 2013). In order to be successful in continuously growing, complex built environments, FM requires to manage the information produced by different stakeholders throughout building life cycle (Pittet, Cruz, and Nicolle, 2014). Capturing and storing information related to the building is the initial success factor for a well-planned facility management (Akcamete, Akinci, and Garrett, 2010).

However, previous research holds evidence for the current inefficiency through poor information management in FM and in particularly facility managers waste vast amount of time in non-value added activities such as searching for required information (Jylhä and Suvanto, 2015). BIM as a platform evolving from the early stages of a building is a perfect solution for FM information management. BIM allows the communication of FM needs at the early stages of projects (IWFM, 2012). The positive contributions of BIM for facilities information management (FIM) is identified as a significant value addition to FM (Gu and London, 2010). Eadie et al., 2013 explain facilities managers and clients benefit the most out of BIM implementation. Howver, Becerik-Gerber et al., 2012 argues that a considerable effort should be given to define a client's FM needs at the project briefing stage. Moreover, the majority of BIM enabled projects are reluctant to handover the complete 3D model and Construction Operations Building Information Exchange (COBie) data at the commissioning stage, which prevents BIM adoption in FM (Eadie et al., 2013).

Managing design and construction information has become much more complex due to increasing volume, continuous changes and variety of parties interested or using the same information (Zhao et al., 2008). As a solution, Wang et al., 2013 explain the potential of FM engagement in the early construction stages of a built asset through BIM and its positive impact on reduced operational cost. Out of several ways of transferring construction information into in-use stage, the most frequently practised method is to get information on paper and later updating and retrieving on software interfaces (William East, Nisbet, and Liebich, 2012). Therefore, data stored in BIM at the construction stage are beneficial for most of the FM tasks (Becerik-Gerber et al., 2012) as it produces a better information management platform. RIBA Plan of work (RIBA, 2013) is a popular framework, which explains the development of asset information through the asset life cycle (Manning, 2014). Accordingly, information is being created throughout these stages in different capacities. This information is managed through PAS 1192-2 (Manning, 2014).

From the earliest stages in building construction, the need for communication within the project team can be identified as a basic and an important requirement (Gelder et al., 2013). For many centuries industry adopted 2D paper based drawings (Czmoch and Pękala, 2014) and there are many inefficiencies in this traditional practice (Khosrowshahi and Arayici, 2012). Initially, Computer Aided Design (CAD) change this process (Czmoch and Pękala, 2014) yet, technology by itself could not make a complete difference (Khosrowshahi and

Arayici, 2012). Therefore, industry is growing fast from CAD to information rich Building Information Modelling (Malsane et al., 2015), which facilitated information management throughout the project lifecycle. Knowing the value of information is knowing what you want (Zhao et al., 2008) and robust information is generated when the information provider is aware of the immense value of information to its users (Xue et al., 2011).

In terms of project information management, (i.e. create, store and use of information), BIM is identified as one of the best and fastest growing solutions for construction. Volk, Stengel and Schultmann (2014) explain how BIM can be useful to move into automated cost estimation and acquiring robust construction information. BIM has become a solution for adhering to the compliance making it much easier by promoting automated compliance checking (Malsane et al., 2015). BIM promotes early creation of critical information related to design, coordination and logistics which brings significant progress on later phases (Demian and Walters, 2014). This feature is much beneficial at the construction stage. Further, even the asset information management standards are extending to align with BIM (Pocock et al., 2014). The construction industry is shifting towards sustainable practices and BIM is becoming as a powerful tool which assists sustainability in construction projects (Antón and Díaz, 2014).

A frequent adoption of BIM during design and construction phases is identified (Eadie et al., 2013), and if use of BIM continues until the end of life of the facility (demolition), a lot more benefits can be expected such as reduced maintenance cost, sustainable building operations and maintenance and valuable feedback from operational stage to develop effective modular construction. It is a widely accepted fact that information captured through BIM is capable of resolving most common issues in facilities management, for example a smooth handover process (Kassem et al., 2015; Cavka, Staub-French, and Poirier, 2017). Although the application of BIM is dominant in the early stages of a building, owners and facilities managers have higher potential in achieving benefits from through-life BIM adoption (Howard and Björk, 2008; Eadie et al., 2013). However, it is important to note that most of the potential benefits of BIM are based on the information it carries and information passed through to the facilities managers and owner may depend on the clear specification of the employer information requirement (EIR) at the early stages.

3.3 Facilities information management

The success of construction asset management relies on the information management practices during an asset's construction (Manning, 2015). BIM Task Group together with Royal Institute of British Architects (RIBA) have identified the key stages of an asset's life (Manning, 2014) to emphasise the importance of whole life information management. Asset information is generated at each phase and this information is necessary for continuous operation and maintenance of a built asset.

Facilities Management (FM) refers to managing the complexities of a built facility to conduct smooth functioning including its physical structure and support services (Kincaid, 1994) to enhance the core business performance. The reason for revisiting the definition of

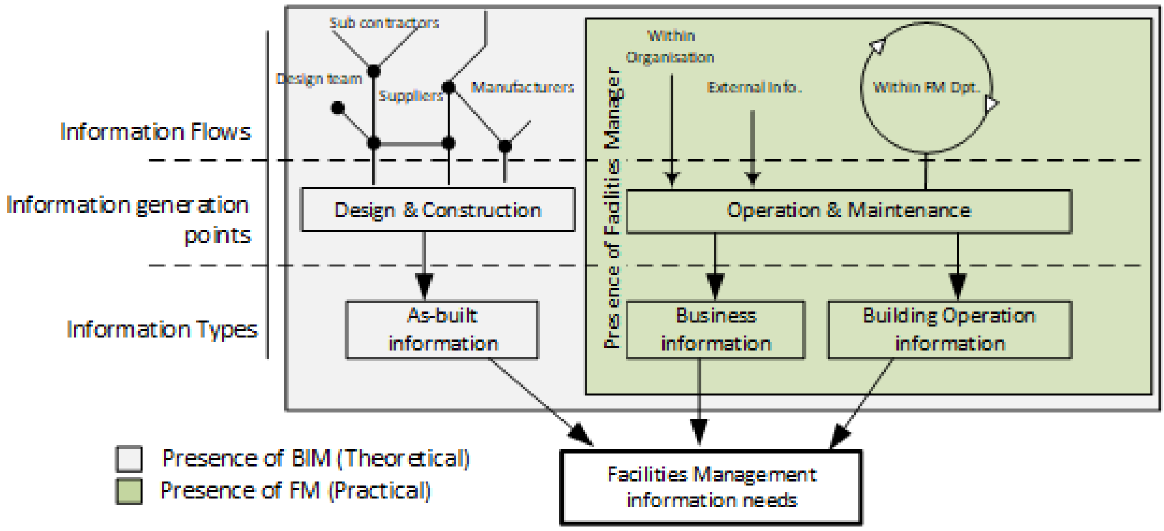


FIGURE 3.1: Facilities information flow

the facilities management is that definition itself provides the intensity of the amount of information involved in the process. Moreover, the growing interest on BIM in construction has drawn the attention towards FM information. Therefore, much of the recent literature written on facilities information management analyse the applications of information technology for information management (Becerik-Gerber et al., 2012; Codinhoto and Kiviniemi, 2014; Aziz, Nawawi, and Ariff, 2016b; Aziz, Nawawi, and Ariff, 2016a; Araszkiewicz, 2017) and explain how information management in FM stage enhance the quality of life (Aziz, Nawawi, and Ariff, 2016a).

Types of facilities management information and their inbound complexities in terms of information flows are identified in Figure 3.1. Information use for FM purposes is being broadly categorised into three namely; as-built information, business information and building operation information. In general, as-built information refers to the final versions of construction information which is generated during design and modified during construction of a facility (Craig, 2006). However, from FM's perspective it is the information which is produced to the building owner/facility manager by the project manager at the project handover (Clayton, Johnson, and Song, 1999) which includes the as-built information (e.g. as-built drawings) and excludes a large amount of other construction information such as design variations, clash detections. This raise the need for a filtering mechanism to separate as-built FM information from the as-built construction information. As-built information is generated by a number of project stakeholders who have different level of interests and influence towards the project targets (Figure 3.1). This information takes a complex flow due to the fragmented nature of the construction industry (Bouchlaghem, Kimmance, and Anumba, 2004).

It is evident that information required for a smooth FM is scattered throughout the building life cycle. Although a must needed early engagement of a facilities manager is recommended in the theory as a solution for minimise many errors including inefficiencies in information management occur due to mistakes made in early stages, it is not common in the practice (Eastman, 2011). Due to late involvement of a facility manager and complexities in construction information flows create several difficulties for facilities managers in acquiring construction information (Clayton, Johnson, and Song, 1999; Anderson et al., 2012; Wang et al., 2013). Therefore, most critical and frequent facility information management issues are based on construction information (Clayton, Johnson, and Song, 1999; Bröchner, 2008).

Information management in FM has always being in the interest intertwined with the usage of information and communication technology (Becerik-Gerber et al., 2012; Aziz, Nawawi, and Ariff, 2016b; Aziz, Nawawi, and Ariff, 2016b). The early work such as Svensson, 1998 provides an elaborated review of FM information concluding the need of BIM in FM. Aziz, Nawawi, and Ariff, 2016b evaluate different information and communication technology been used in FM and its evolution over the time (Figure 3.2). It concludes naming BIM as the latest information management system in FM. Exploring pathways to best use BIM in FM; Future capabilities – through life management report (Harris et al., 2019) explore aerospace and automotive industries to gain cross industry learnings for digital asset management. Acknowledging the contribution of information systems in FM Ebbesen and Jensen, 2017 model the added value of information systems contributing in conceptualising value in FM.

However, reviewing existing literature on the subject matter reveals that all attempts on knowledge generation have succeeded towards bringing pragmatic but temporary explanations and solutions to increase information management efficiency therefore, discredit its value under new publications. This alarms the lack of theoretical knowledge on the subject both in academia and practice. Only few attempts have been made in theory building in FM such as doctoral work of Amaratunga, 2001. Driven by the industry needs to be pragmatic and useful in practice, academic contribution tends to be development of models and frameworks which are rarely being used neither by academics nor industry. Therefore, critical need for theoretical explanations on facilities information management is identified especially in a digitally transforming era.

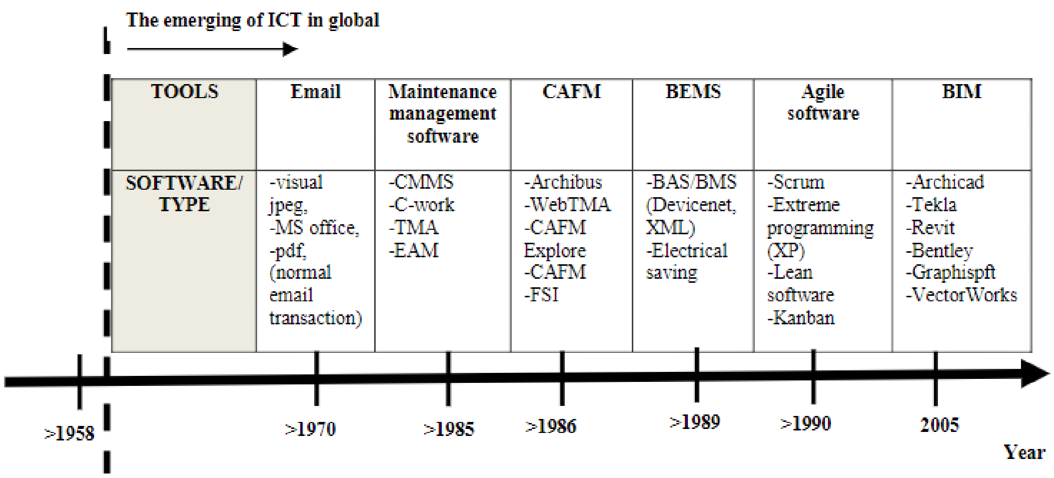


FIGURE 3.2: Evolution of Information Technology in FM (Source; Aziz, Nawawi, and Ariff, 2016b)

On the other hand BIM as a concept initiating digital information management from early stages of a built facility has become a partial solution to the problems faced in design and construction in related to gathering information from number of stakeholders (Grilo and Jardim-Goncalves, 2010). Above that, it carries a greater potential in information management during facilities management (Giel and Issa, 2016). However, the potential benefits of BIM in facilities management is promised over the information availability at the facility handover (Anderson et al., 2012). Therefore, it is necessary to identify facilities management information requirements at the early stages of a built facility. Due to the large number of information generated during design and construction and variety of needs in building operation and maintenance, it is essential to accompany a filtering mechanism to recognise the information with an economical consideration. In this regard, identifying value of information is considered as an accepted concept to create a hierarchy of order to identify most important information (Neal and Strauss, 2008). On the other hand, Zadeh et al., 2017 discuss number of errors in information in current BIM output produce at the handover such as; incompleteness, inaccuracy, redundancy, weaknesses in information format and ability to understand.

3.4 Facilities Management information requirements

The FM process focuses on managing the complexities of a built facility to smooth the functioning of its physical structure and support services to enhance the core business performance (Kincaid, 1994). The information flows during the FM stage is significant to achieve such targets. In a typical construction project, information exchange is frequent and the information providers/users range from design team, builders, suppliers, regulatory bodies, funders, end-users etc. Involvement of these roles on information exchange depends on the selected procurement route and the conditions of the contract (RIBA, 2013). Therefore, information flows and the timing of them varies and is crucial to operate a facility with minimum disruptions. Having identified such variables, Information considered within this thesis has been narrowed down to as-built information of projects procured through a design and build arrangement. Also, it determines the 'information value' in terms of fit for purpose rather than monetary value due to several reasons such as lack of experience in whole life application of BIM, unmeasured and indirect contribution of as-built information to facilities management and poor consideration of facilities management needs at the early stages of construction. However, it is evident that a successful Facilities Information Management clearly considers the 'type of information' (WHAT), 'timing of them' (WHEN), 'uses/functions' (WHY), 'flows' (HOW) and the 'users and providers' (WHO). Therefore, it is vital to have a complete understanding beforehand, without being specific to the area of study.

Types of information - (WHAT)

Based on existing knowledge, information which is used to complete FM functions comes in three main domains, namely 'Construction information', 'Business information' and 'Facility operation information'. Construction information refers to the information which is generated and in-use during the design and construction phases of a facility (Craig, 2006). Facilities Managers identify construction information as the one which is exchanged between project manager and the owner/facility manager specifically to particular assets at the project handover stage (Clayton, Johnson, and Song, 1999). For example, asset information, space allocations and maintenance schedules etc.

Business or market driven information support running the business, while maintaining the competitive advantage. For example, functional requirements related to the space being used, expected occupancy and other business functional information that influences facility operations are considered within this category. Usually, such information is fed into the FM system internally or externally (Chotipanich, 2004). The need is to have the right information at the right time for the business to prosper.

Facility operational information refers to the information which is directly related to the operation and maintenance of the facility in current and future environments. Examples of such information are energy consumption, maintenance records, facility operation staff information etc. (Whitaker, 1995). Whitaker, 1995 further noted the need for a proactive role of facility managers towards managing the operational information efficiently and productively.

Timing of information (WHEN)

Information needed for FM is generated and released in different phases of a project life cycle. For example, client information requirements are produced at preliminary stages of the facility through an EIR, and they are continuously amended and improved during the design and construction stages. Although such information is generated during the inception phase; it may be released to the facilities manager along with the physical output of the project. Subsequently, asset operation and maintenance information such as post occupancy evaluations, breakdown records, energy consumption, etc. are added continuously during the FM phase. Information flows during the facility operations and maintenance stages include details of the built asset as well as the business operations. This continues up to the disposal of the facility at the end of its economic, physical or functional life cycles, including information related to refurbishment or end of use.

Uses/Functions (WHY)

As mentioned above different types of information feeds into facilities management systems at different times. A variety of information is gathered to serve the multiple needs of FM. Information from the early stages of a facility up to the construction phase is used to learn about the building and its nature, spatial plan, etc. On the other hand, business operations related information such as occupancy rate, business functional needs and market information are gathered to perform daily FM activities to support the current business and secure the future potential business opportunities. This information assists to maintain a flexible built environment, capable of adapting to changing business needs. Moreover, operational and maintenance information are used to upkeep a sustainable built environment.

Users and Providers (WHO)

The FM related information flows from a variety of sources. Construction information is provided by supply chain/stakeholders who are in the project team ranging from clients/end-users, architects, engineers, to service providers and manufacturers. Similarly, business operations information flows into the FM division from various departments within the organisation such as finance, marketing and administration as well as from external sources such as government, funders, standardization bodies and competitors. Operations and maintenance information is mostly generated within the FM division. The users of FM information vary amongst different professional roles, and the level of the detail of the information used varies with the user and the project objectives.

Flows (HOW)

Business and facility operation information maintains a direct flow, as it is generated during the operation and maintenance of the facility over which FM have much more control. However, the construction information flows vary with the type of procurement arrangement. For example, in a design and build procurement approach, the responsibility for information handover is vested with the main contractor/architect creating a more centralized approach. In the traditional procurement method (i.e. design- bid-build) it consists of a complex array of information flows due to the engagement of a number of parties and dispersed involvement in the construction phase.

Having studied what, when, why, who and how questions it is evident that information required for a continuous FM is scattered throughout the facility life cycle. Although an early engagement of FM is recommended in theory, it is not frequent and visible in current practice (Eastman, 2011). The late involvement of facility managers in construction projects and the complexities in information flows create multiple difficulties for facilities managers when absorbing appropriate construction information (Clayton, Johnson, and Song, 1999; Anderson et al., 2012; Wang et al., 2013). Hence, the information exchange between construction and FM stages is not coordinated. Literature further confirms that the root cause for most of the FIM issues are due to drawbacks arising from information generated and handed over from the construction phase (Clayton, Johnson, and Song, 1999; Bröchner, 2008). Therefore, it is necessary to study the value of construction information for facilities management to understand the value of BIM in facilities information management (FIM).

Moreover, the adoption of BIM in FM is beyond overcoming current inefficiencies but as a preparation to fit into the near future. The future expected for FM involves working with artificial intelligence and getting paid through cryptocurrency. With the increased use and possibilities of information, built environment is no longer a separate entity but a part of interactive and connected network. New research trends in human building interaction provides evidence that the future buildings will be interactive therefore, open to wider range of stakeholders creating opportunities as well as undiscovered risks. A glance at near future FM emphasise the tremendous changes lined up. It is obvious that the main focus of all these changes are technology related. Therefore, making use of human values to develop future proof solutions for current issues is a novel addition to knowledge.

3.5 Chapter Summary

Facility managers under take the responsibility of through life information management of buildings. Using the advantage of information to optimise the daily operations and maintenance of buildings is becoming the standard way of FM operations pushed by both technology developments and manufacturing industry. In summary, following key points can be drawn from the content of this chapter;

- Multi-disciplinary nature of facility management with the involvement both soft and hard FM functions has a created a complex information flow spanning throughout the building life cycle.
- Most common information related inefficiencies take place within FM is due to incomplete information handover from the construction stage to in-use stage.
- Promising benefits are being experienced by Information Technology solutions provided for FM since early 90S and BIM is recognised as the most beneficial application at the present
- However, from the technical perspective BIM needs to incorporate FM specific features and from a strategic perspective there is a lack of knowledge of FM information requirements.

Therefore, identification of FM information requirements from the beginning of the project saves both money and time while bringing competitive advantages. Although, there is a continuous growth in industry guidelines and scholarly work published addressing this matter, lack of integration between information management, technology development and human nature is emphasised. Having recognised the multi–disciplinary nature of the matter, the next chapter investigates and justify the suitable methodology to understand the phenomenon.

Chapter 4

Research methodology

4.1 Introduction

The previous chapters sets the background to the research through a study of the construction information and facilities management. With a sound knowledge of key subject areas of the study (BIM, FM and value), this chapter presents the road map of the research project. The research methodology, as the backbone of the study, explains the philosophical position and research method accompanied within the investigation. As the research is based on a pure qualitative multi method choice, theoretical assumptions based within the selected research methods and justifications given for them hold evidence for validity of the research findings. Therefore, this chapter provides a thorough analysis of available methods under each step of the methodology in detail while justifying the choices made.

The chapter begins with an overview of the research methodology explaining its importance to research and later sections brings in-depth discussion on each step. Starting with an inquiry into the purpose of the research, a comparison between natural and social science research is made to set the background for the validity of the methodology. Taking a thorough look at social science research, the discussion is directed towards different research paradigms adopted within construction management research. The second section explains different research approaches followed by research strategies. Finally, data collection and analysis methods along with justifications for the selected methods and the reasons for rejecting other appropriate methods.

An overview of the selected methods are presented in Figure 4.1. It illustrate the logical sequence of research question, philosophy, approach, research strategy and selected data collection and analysis tools. Accordingly, it explains original assumptions under each concept and when they were accepted and rejected in order to create a methodology which to reveals the complexities in phenomena under study. Existing scholarly work carried out under similar methodological assumptions have been provided when the selected methods are against the conventional applications.

4.2 Research Methodology

Research method and methodology are quite often used interchangeably in construction research. In this chapter, research methodology and methods are discussed in two different

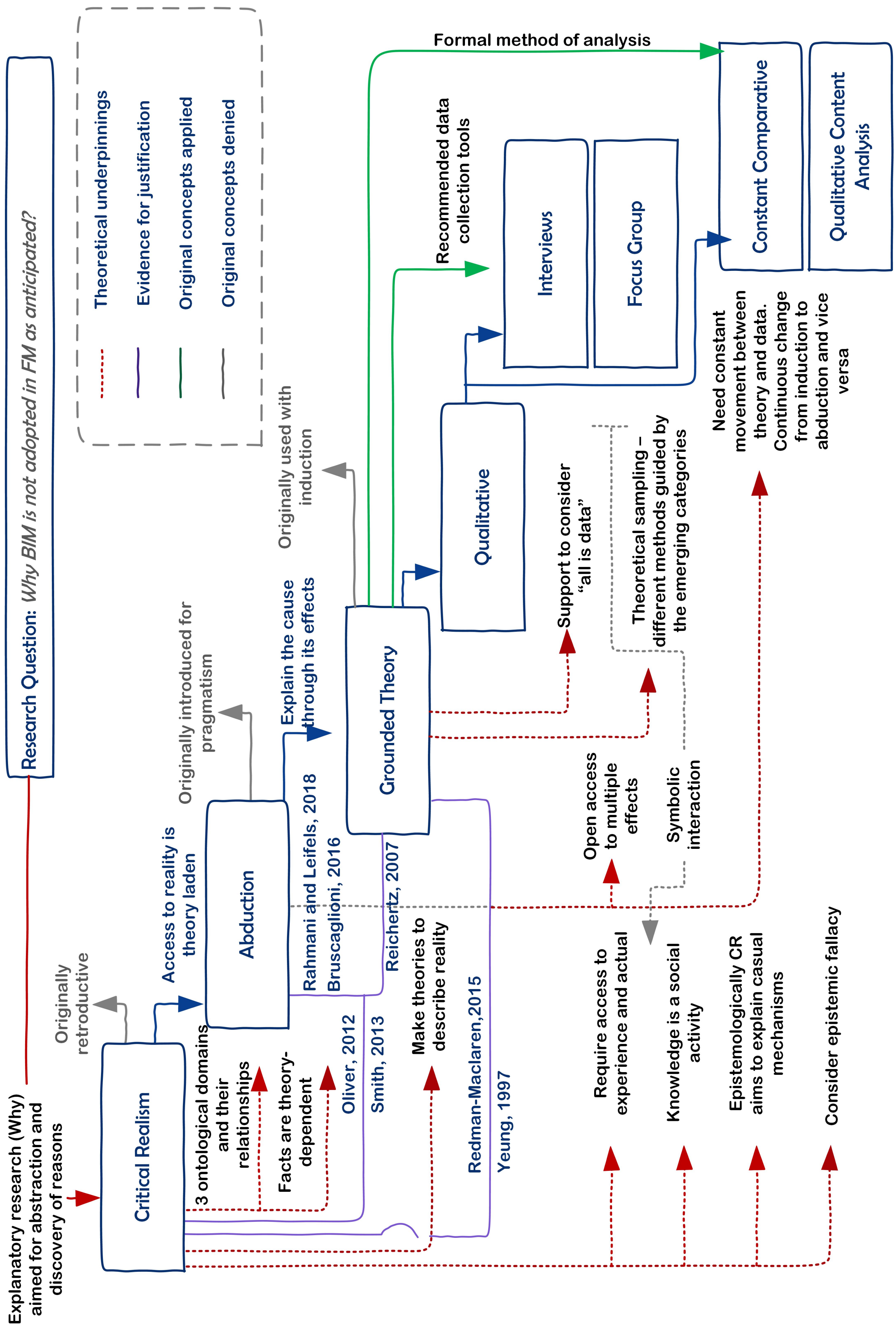


FIGURE 4.1: Theoretical underpinnings of the methodology

sections explaining the philosophical and scientific base of the research referred to as research methodology and the way that research is being conducted using different tools and techniques which emphasis the research method. In other words, research methodology is positioning how the researcher makes judgements about the research (Mills and Birks, 2014). It is the step of describing, evaluating and understanding research methods. Discussion of methodology will help understanding the justifications for the selected method (Creswell, 2018). On the other hand, construction management research, which includes both natural, and social science aspects is rich with methodological pluralism (Knight and Ruddock, 2009). Therefore, this section is dedicated to laying out the scientific aspect of the research and setting the background for the philosophy discussed in following section.

In order to understand "how" to do research first concentrate on "what" is research. Human beings with a special ability of thinking and intellectual capacity, constantly raise questions even about day to day life such as: Why there is an unusual level of traffic today? Or where can I get lunch from? Formal research is an extended version of these daily inquiries (Stringer, 2007). The purpose of research is to understand the truth or in other terms the search for knowledge (Newman and Benz, 1998). When the ultimate purpose of research is to create knowledge then it becomes vital to understand what is identified as knowledge. This immediately create a compulsion to reflect on what one could know, or at least think that one knows, to ascertain common features or patterns of knowledge. At a glance, it is obvious that everyone is familiar with, and has some knowledge regardless of, his or her intellectual capabilities. To clarify this stance Pritchard, 2014 explains knowledge in two kinds; ability knowledge and propositional knowledge. Ability knowledge refers to things' living beings' or objects' know-how. As an example; a toddler knows how to walk and a tiger knows how to hunt. However, this know-how does not explain how one does something. Propositional knowledge understands and makes statements (propositions) about things such as water boils at 100C. Propositional knowledge is unique to humans at least up to this date (in the absence of Artificial Intelligence) and it is the knowledge that understands and explains the reality. Therefore, this research endeavours to generate propositional knowledge precisely in understanding the relationship between BIM technology and its users in the focus of promoting BIM adoption in facilities management through value enhancement.

With this understanding of the key expectation of the research, the next step is to explore how to generate knowledge. A proposition that is a justifiable true belief is accepted as knowledge (Pritchard, 2014). The commonly given example for such is looking at a clock and telling the time. However, creating knowledge through empirical studies is more complex. Gettier issue to be considered that proposition has not used fallible justifications and/or made out of luck. If considered with the previous example, the clock might have stopped working at 9 p.m. last night but when the proposition was made at 8.50a.m. next day, looking at the broken clock it was a justifiable true belief that the time is correct and no reason to doubt that the clock has stopped working. Hence, Gettier issue underlines the importance of methods used to reach knowledge.

In early years, even before being conscious about the Gettier issue, scholars showed an equal interest towards understanding how one came into a new finding as much as they appreciated the new knowledge (Fann, 1970). As a result, research had much validity when knowledge creation was built upon empirical methods (Newman and Benz, 1998). The debate was then followed into what is recognised as an empirical method creating a friction between quantitative and qualitative research methods. In a broader sense, this was in question of what is "science" or more precisely the question was: Is sociology is a science? Science became the main source of knowledge between the eighteenth and nineteenth centuries replacing the church in the western world. In a broader sense, science is an "endeavour in understanding, explaining and theorising the world using distinctive methods" (Boutellier et al., 2011). Accordingly, the methodology followed to understand the subject matter is a crucial factor in science. However, this has to be justified with other methods of understanding and predicting the world such as astrology and religion which are also identified as branches of science (Boutellier et al., 2011).

Qualitative methods which came in with social science inquiries are often questioned for their credibility due to subjective claims made during the study. On the other hand, quantitative methods which came along with natural science have an advantage as a scientific method claiming its use of objective procedure to reach knowledge and ability of reproduction of the same answers. However, the key which distinguishes natural from social science is the entity of study; dependent and independent variables in nature (Boutellier et al., 2011). Not the method of enquiry. This demonstrates that both natural and social science could benefit from subjective and objective data collection and analysis methods and none of these methods is restricted to only one of them. On the other hand, subject areas such as construction management, which draws from both natural and social science have the privilege to benefit from both qualitative and quantitative methods (Love, Holt, and Li, 2002; Knight and Ruddock, 2009).

Indeed, both natural and social science are socially defined but, the difference is natural science objects are naturally produced though socially defined, while social science objects are socially produced as well as socially defined (Danermark, 2002). Therefore, it is difficult to distinguish the object from its producer in social science. The other key difference is that social science objects under study are capable of thinking while natural science objects are not (Love, Holt, and Li, 2002). However, it was a fair question to ask whether social science is really a science given examples such as; is a study on history science where complete exclusion of value at one study and value inclusion in another social phenomena and freedom to use of different methods (Van De Walle, 1932). Yet, answering the first question of what is an empirical method, Van De Walle, 1932 concludes "every possible combination of belief has its representative, and no combination more than one". After many years of arguments over the subject, both qualitative and quantitative methods were identified as empirical research methods. This paradigm war specifically among construction management research took place in late 19th century (Raftery, McGeorge, and Walters, 1997; Runeson, 1997; Seymour, Crook, and Rooke, 1997; Seymour, Crook, and Rooke, 1998). Moreover, using a combination of the two methods was given more credibility as one method could overcome the weaknesses in the other and create a counterbalance (Love, Holt, and Li, 2002). This is identified as triangulation and different ways of triangulation are discussed later in this chapter.

The selection of an appropriate research method for a specific enquiry is informed by the research question and research philosophy. The research onion (Figure 4.2) introduced by Saunders, Lewis and Thornhill (2012) is a commonly used and simplified illustration of this logical relationship starting from research philosophy to selection of data collection and analysis. The first layer of the research onion is to determine the research philosophy. Understanding research philosophy reveals the underpinning assumptions of the research (Saunders, Lewis and Thornhill, 2012).

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FIGURE 4.2: The research "onion" (Source: Saunders, Lewis and Thornhill (2012))

As a brief overview, research philosophy consists of ontology, epistemology and axiology. Ontology is an enquiry into what is real and epistemology enquires into how one can know about what is real. One could hold different opinions over each of these elements on a personal level as well as based on the subject matter under study. Research paradigms explains different combination of opinions on ontology and epistemology. For instance, positivist ontology states that reality exists separate from the human mind while constructivist ontology states that reality is created by the human mind. The recognition of an individual's ontological and epistemological assumptions informed by the research question will lead to the selection of an appropriate research paradigm. On the other hand, one could only identify a research problem through the person's own worldview. For instance, an individual who is a constructivist rarely finds a positivist research question interesting or takes a positivist approach to solving a question.

Positivism, post-positivism, pragmatism and constructivism are a few of the commonly used research paradigms in construction management research. A detailed appraisal of each of the suitable research paradigms is discussed in the next section. For effortless understanding on how each decision informed its successor; this chapter is structured following the layers of the Research Onion.

4.3 Research Philosophy

Philosophy has become a word which is loosely used in terms of organisational philosophy or personal philosophy to communicate fundamental principles (Brinkmann, 2017). In a general sense, research philosophy communicates the fundamental assumptions underpinning all aspects of the research. Which is in contrast to other topics discussed in this chapter. The choice of the methods will be logically chosen as appropriate to the given circumstances while research philosophy is the sense of what research really means in depth rather a choice (James, 2010). It refers to the systems followed and assumptions made discovering new knowledge (Saunders, Lewis and Thornhill, 2012). The exact translation of the word is "love (philo) of knowledge (sophia)" (Brinkmann, 2017). In other words, philosophy is concerned with what and how knowledge is possible. This is an important question when making a scientific inquiry as philosophy will act as a mirror revealing why certain actions are taken and more importantly how things are being understood. Every attempt at knowledge creation is based on a number of assumptions; about what one can know (epistemological assumptions), what is identified as real in the study (ontological assumptions) and how individual values influence (axiological assumptions) in giving meaning and making decisions (Saunders, Lewis, and Thornhill, 2012). Although, it is possible to make these assumptions even with no awareness of research philosophy; acknowledging these assumptions is paramount to convey the validity and generalise the findings.

The overall goal of this research is to create knowledge and knowledge is described as a justifiable true belief (Steup, 2009). Hence, what is truth? Alternatively, the most commonly given description "what is the nature of being", which is ontology is needed to be identified before discovery of new knowledge. In this thesis, it is a concern of what is the nature of social reality. What kind of things exist and their relationships. Secondly, epistemology as a branch of philosophy of knowledge raises another question – how one can know what the truth is? Ontology and epistemology always come along hand in hand and informs the philosophical view of the research (Creswell, 2013). Although constructivists identify a close relationship between ontology and epistemology, critical realists see a distinct difference between them. In short, what is real and what one knows as real are two different things (Figure 4.3) for critical realists. In contrast, constructivists acknowledge that what is real is created in human minds so it only could be understood through their interpretation. Positivism, constructivism and critical realism are some of the commonly discussed research paradigms in social science research. Each research paradigm represents different combinations of ontological and epistemological assumptions while some make relatively close assumptions and others make contradictions between paradigms.

4.3.1 Realism and Idealism ontology

As mentioned above, philosophy of knowledge consists of three main branches; ontology, epistemology and axiology. This section brings in a brief introduction on what is ontology and introduces the ontology of the research. Ontology is a branch of philosophy coming under metaphysics (that is looking at the nature of reality, relationship of mind and matter, possibility and actuality, etc.) and acts as the core of the knowledge as it specifies the nature of being. It is an important aspect of research because, ontology defines the empirical phenomenon being studied through specifying its characteristic (Goertz and Mahoney, 2012). One of the characteristics of reality is that it is not transparent (Danermark, 2002). Therefore, specifying this underlying invisible layer of research supports the defence of the construct validity. In terms of this thesis; it attempts to clarify what is real in the social reality of facility managers' value in BIM. A discussion on commonly identified realities is taken as a starting point of discovering ontology of the research.

In answering the question of what is the social reality of BIM value, two controversial views on ontology are taken into consideration; realism and idealism. Realists claim that there is a reality independent of the human mind. For example, the internet exists as a different object from the human mind. On the other hand, idealists agree with the realists that there is a reality however, they do not settle with the fact that reality is independent of the human mind but, argue that what is real is experiential immediately by consciousness. In other words, ideas are what exist. Referring to the same example given before, an idealist would interpret that the internet was an idea which gave birth to its materialistic existence. Therefore, what is really the internet is the idea of the internet.

The two extremes of the ontology are drawn consider whether reality is objective - has a separate existence from the human mind or subjective - the being is constructed by human minds. Communicating the same phenomena, the two opposite views of ontology can be identified under different labels such as realism vs idealism, objectivism vs constructivism (Bryman, 2016), objectivism vs subjectivism (Saunders, Lewis and Thornhill, 2012). Within these two extremes there are many other ontological views. For instance, supporting a realist view, naturalists argue that the thought of internet is created by mind and mind is something evolved through matter, discarding the possibility of a reality created through mind. Furthermore, materialists believe that everything in reality is a matter of identifying even the mental status as a physical status of mind (Landesman, 1997). What materialists point out is that what is real is matter and the characteristics of material objectives, people, etc. will bring the knowledge on reality (Benton, 2001). From these ontological assumptions, taking a realist ontological view, post-positivism is the most widely used paradigm in construction and social science research. Naturalism and materialism are identified as extremes of realism (Landesman, 1997). On the other hand, the critical realism paradigm which takes a transcendental realism ontology is identified to bring a middle point of view from positivism and interpretivism (Zachariadis, Scott, and Barrett, 2013). Figure 4.3 presents the three ontological domains in critical realism making a visual representation of the hidden reality and visible empirical level. As it is represented through the iceberg metaphor, transcendental realism claims that reality exists separate from human experience or knowledge about it (Mingers, 2006; Denzin and Lincoln, 2011). Bringing an interesting point of view to debate, idealists claim that what is certainly real is what is going on in human minds and everything external is a result of the thought process.

In other terms, reality exists independent of experiencing it through human sensors (Pritchard, 2014) agreeing partially with transcendental realism. However, it means knowledge gained through sensors is constructed by an individual's perceptions which is declined by transcendental realism. These two contradicting beliefs (realism and idealism) can be drawn as the two ends of the ontology spectrum (Figure 4.4). To bring a snapshot of the overview of research philosophy, all the research paradigms can be placed in between these two ends. However, different authors draw different labels for the spectrum of ontology and epistemology to communicate the same principal differences. One such common alteration

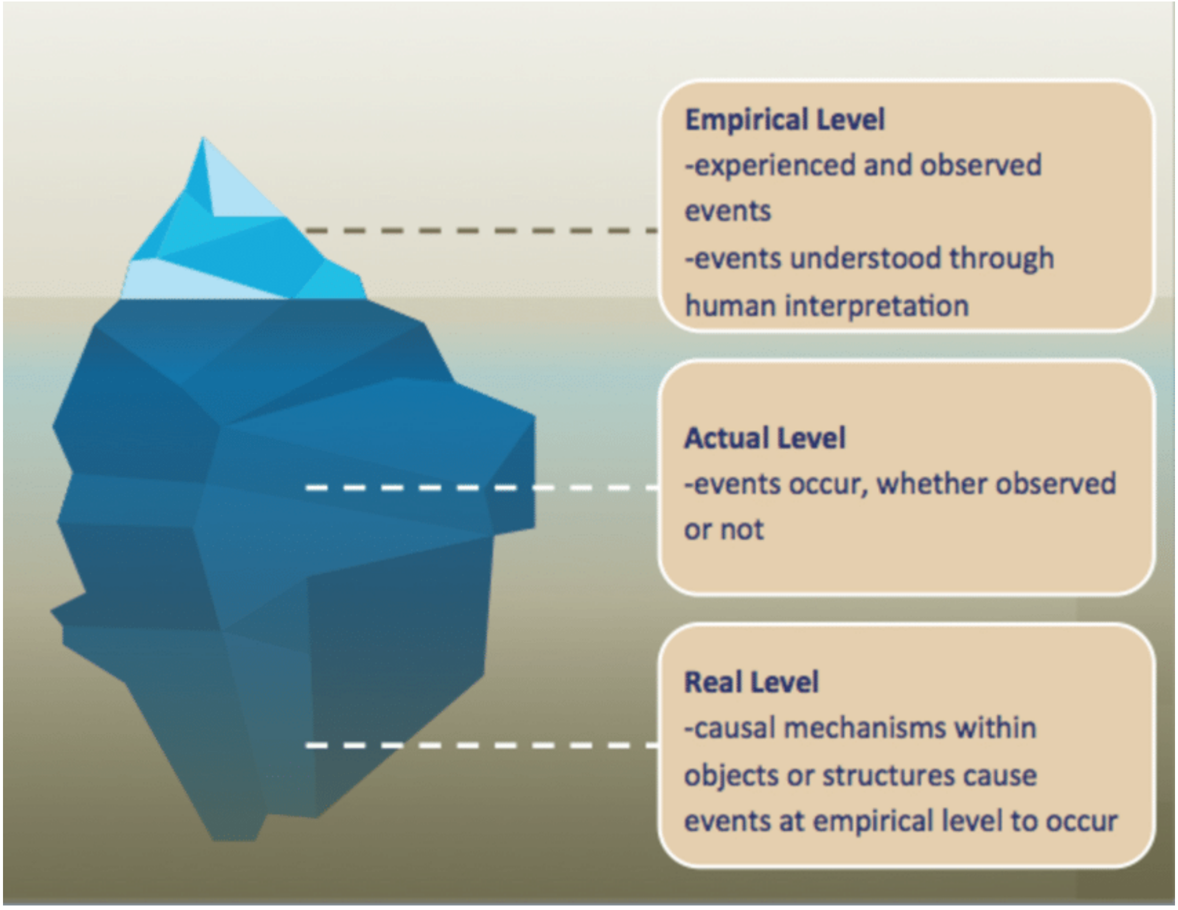

FIGURE 4.3: An iceberg metaphor for critical realism ontology (Source: Fletcher, 2017)

is identifying objectivism and subjectivism ontology along with positivism and interpretivism epistemology (Bryman, 2012).

This explanation is not being followed in this study to avoid potential confusion, since positivism is also commonly identified as a paradigm which stands for a unique combination of ontology epistemology and axiology, rather than a pure epistemological theory. Some authors take other approaches to acknowledge this difference by making a distinction between positivist and positivism (Kulatunga, Amaratunga, and Haigh, 2007). Due to these conflicts in multiple interpretation many doctoral research studies conducted in construction management discipline avoid this detail discussion. However, Figure 4.4 is drawn bringing together ontology, epistemology and axiology while distinguishing among them to support the critical realist view. The two ends of the epistemology spectrum have been labelled as empiricism and realism (Knight and Ruddock, 2009). This critical step is taken as a mode of validity by being transparent about the fundamental principles which demonstrate the skeleton of the data analysis.

In summary, this research takes a transcendental realist ontological position in support of the critical realist (CR) philosophy. Detailed discussion of critical realist philosophy can be found later in this section. The ontological position of CR is better understood in comparison

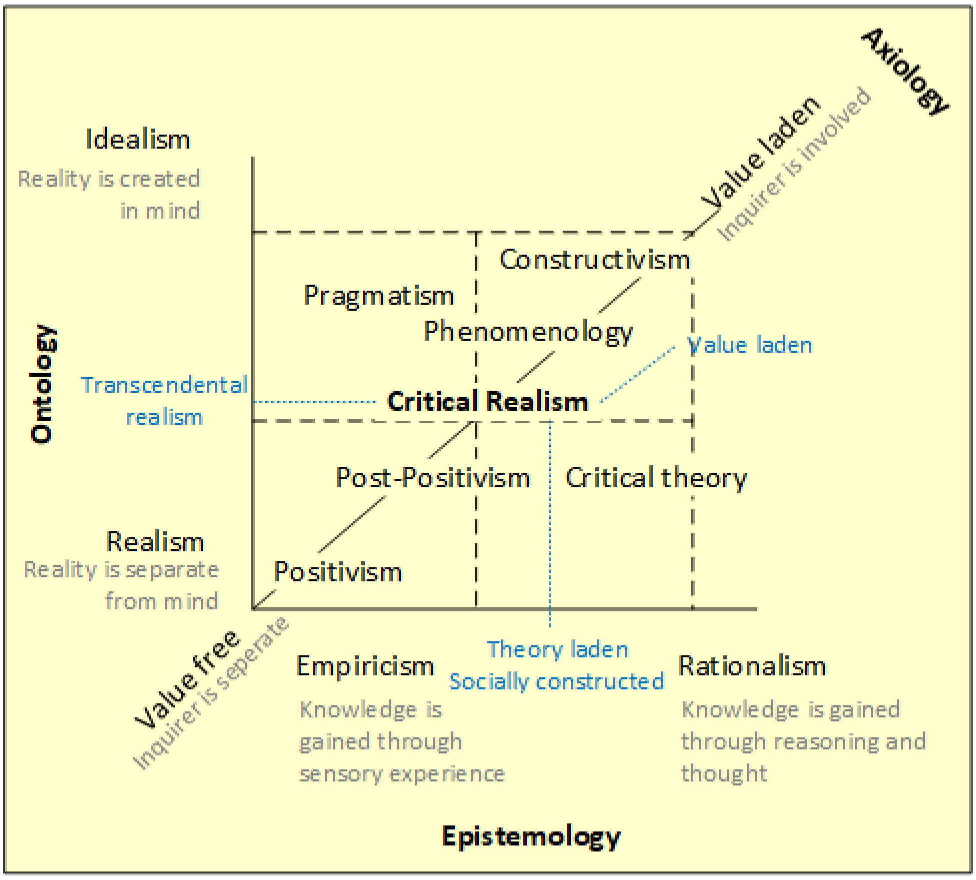

FIGURE 4.4: Ontology, epistemology and axiology

to transcendental idealism. Transcendental idealism, introduced by Immanuel Kant (1724-1804), is based on assumptions in both realist and idealist ontology (Pritchard, 2014). The difference between transcendental realism and transcendental idealism is that the former accept that objects in time and space exist independent of human experience or knowledge of them, while the latter denies this (Stang, 2018). Critical realism is built on this ontological foundation and placed in the middle point of the two ontological extremes (Zachariadis, Scott, and Barrett, 2013). Accordingly, Critical realism holds onto a reality independent of the human mind taking a realist view. With this underpinning, the value of BIM is seen separate from what one thinks about it and allows the value of BIM to be quantified through financial accounts. In contrast, reality is however also beyond human experience and knowledge about the mind independent reality is gained through reasoning. Accordingly, the CR view is that what is experienced by living is raised through the reality but not limited to the experience. It is well known to study the theory- practice inconsistencies (Smith, 2006). Particularly, this research is focused on understanding why the benefits of BIM identified in theory are not reflected in the current construction practices. Smith, 2006 points out that theory-practice inconsistency is a common issue in the information systems field and argues on the appropriateness of critical realism to study the problem mainly due to its explanatory power.

4.3.2 Empiricist and rationalist epistemology

Logically, ontology guides the epistemology and epistemology informs the methodology (Sutrisna, 2009). Epistemology is the branch of philosophy which examines the "possibility, limits, structure, methods and validity of knowledge" (Delanty and Strydom, 2003). The word epistemology comes from Greek origins giving a direct English translation of "theory of knowledge". Discussions on what is knowledge, different types of knowledge and Gattier issue at the beginning of this chapter (see topic 4.2) are the first questions raised under epistemology. As discussed earlier, knowledge is identified as a justifiable true belief. Further questioning coming under epistemology enquire into the qualities of a belief when one claims it as knowledge; whether reasoning is more important than to be true or vice versa making the extremes of scepticism and externalism (Morton, 1997). Scepticism basically serves a methodological function questioning the possibility that the current experience is a perceptual illusion and it is not possible to know that one is being fundamentally deceived therefore unable to have knowledge about the world (Pritchard, 2016). This also could be because of the mistakes in the reasoning; a hypothesis being reasoned to be true is not true (Morton, 1997). In both circumstances, scepticism challenges the ability of knowing based on reasoning. On a different note externalists acknowledge a true belief from a reliable method as knowledge, that is by depending on cognitive ability, when internalists acknowledge only a justified belief as knowledge, that is by having supportive evidence (Pritchard, 2014). Referring to the former definition of knowledge, both truth and justification are qualities of knowledge. However, they are fundamentally opposite attributes of knowledge and both can lead to sceptical conclusions (Morton, 1997).

Therefore, epistemology looks at potential and valid ways to gaining knowledge (Sutrisna, 2009). The fundamental question here is how knowledge is possible? In other terms, the methodology of gaining knowledge. Therefore, it acts as the foundation of the knowledge generated through the research and requires specifying the epistemological theory of the research in order to defends its validity (Ohnson and Duberley, 2000). This is why research methodology is given an equal place and upcoming topics under this chapter peals each layer of the methodology by discussing their depths to support the epistemological groundings of the research. In short, the purpose of the methodology chapter is to answer how knowledge claimed through the thesis is possible.

A recurring pattern of two strongly accepted but contradictory views on each branch of philosophy (ontology, epistemology and axiology) is noted. The strong acceptance of each view speaks for the truth in it and having room for a second view speaks of the incompleteness of the considered paradigm. Another observation is that the first understanding of a phenomenon is quantitative. Once this quantified objective knowledge is captured, it reveals the qualitative attributes in it bringing the full picture on to the table. When both objective and subjective claims are found to be true, then the debates were taken to the next level to inquire what matters after all. Starting the conversation among philosophy and engineering. It is a question of what is important. To know the fundamentals with right and wrong or to have something functioning and applicable. This is an underlying problem and the reason for the lack of pure qualitative research in the built environment. This sector is more concerned with practical outcomes of research which has resulted in an enormous number of frameworks and guidelines claimed to have a practical application but barely being used. On the other hand, fundamental underpinning of these works which were mainly focused on concrete outcomes is questionable.

One of the tasks of epistemology is to define the relationship between knower and known (Lincoln and Guba., 1984) that is the relationship between researcher and participant (Teddlie and Tashakkori, 2009). One way to describe this is that the relationship is objective, that the knower and known are separable. This is the epistemological claim of positivists. On the other hand, constructivists claim a subjective relationship explaining that researcher and participant together co-create social realities (ibid). These extreme contradictions take place because they are influenced by different disciplines. Positivists were referring to their lab research on rats (human vs non-human) and constructivists were referring to a study of human interactions with another human. Therefore, the general positivist claim in social science is post-positivism which is based on positivist assumptions but moderated to fit the social reality and this is where triangulation (see topic 4.5.3) comes in, to fix the unaccepted assumptions in studying social realities in a positivist view. On the other hand, critical realists acknowledge the subjectivity and value play in knowledge creation and would only demand to choose the best method and be transparent about such involvements rather than fixing it because fixing it will only lead the findings to be much vulnerable under basic philosophical assumptions.

When continuing the debate on the role value plays in the process of knowledge generation, one would soon become acquainted with Axiology - the third angle of the philosophy of knowledge/science (Figure 4.4). The term axiology is derived from two Greek words axio (worth) and logos (reasoning). Although value was considered for a long time, the term "Axiology" came into use as a philosophical aspect in the 19th century (Lincoln and Guba., 1984). Axiology refers to the ethical, aesthetic and religious foundations in a paradigm (Denzin and Lincoln, 2011). Accordingly, these values are being imposed onto a research through many ways such as choice of the research problem, choice of paradigm, data collection and analytical tools, theoretical framework and context of study. Ethics debates on what is right and wrong, obligation and duty. Aesthetics argues on what is beautiful and ugly. Religion looks into the ultimate purpose or meaning of life. The first discussions on axiology go back to the time of Aristotle and the debate is still ongoing even to agree on a universal definition. Further discussion in this regard is found later in the thesis (See Chapter 5).

With the brief knowledge on these foundations, the discussion takes a turn to paradigms. A paradigm is a representation of the essence of how one sees the world and formulation of this essential meaning one inherits cannot be proved (Lincoln and Guba., 1984). This definition itself speaks for its utmost importance on explicitly clarifying the paradigm behind a research – unproven fundamental logic which forms the entire intellectual discussion. The term paradigm came to the attention with the work of Thomas Kuhn published through his book "The structure of scientific revolution – 1962" to distinguish "normal science" from "mature science". Accordingly, paradigm is a common pattern of thinking which is shared by a community with a similar mindset and open to discussion or with the flexibility to adopt (Kuhn, 2012). A scientific inquiry fails without a paradigm due to lack of "orientation and criteria for choice" because, all research questions, data collection and analysis techniques are equally valid (Corbetta, 2003). Application of a particular set of research tools under a specific paradigm makes them superior to others.

There are a number of philosophical paradigms introduced by different philosophers explaining their worldview on knowledge and how it is possible. Saunders, Lewis and Thornhill (2012) noted Positivism, Realism, interpretivism and pragmatism as the most commonly used research philosophies in management research. In general, paradigms could also be known as epistemological theories (Bryman, 2016). Each of the paradigms stands for a unique pattern of knowledge creation. Positivists claim that knowledge is only possible through observations. Therefore, theoretical elements which do not agree with direct observation are not considered as scientific – e.g. ability of human being to make decisions.

Positivists and post positivists take a very much similar approach towards knowledge creation. Post-positivism is often recognised as the positivist approach in social science. Both paradigms in support of objective ontology argues that there is a single reality independent from the human mind. However, post-positivists acknowledge that complete realisation of reality is impossible. This is an important element to clarify because, to understand how knowledge is possible, it is necessary to understand the nature of what is existing. In contrasts to positivist ontology, critical realists argue that there are unobservable mechanisms in reality that can only be experienced indirectly through their cause. Roy Bhaskar claims this as transcendental realist ontology (Bhaskar, 1979) claiming to be different from Immanuel Kant's transcendental idealism. Accordingly, there are three ontological domains; Empirical – what one can experience, often known as data in science and what is called reality under positivism. Actual – things which happen regardless of human experience. This stratum of reality is acknowledged by the constructivists by allowing individuals to interpret. Real – mechanisms that produce the events (Figure 4.3). This is the ontological stance taken in this thesis.

Positivists assume that absolute truth exists, and it is independent from those who undertake the inquiry (Fossey et al., 2002). Post-positivist assumptions are that absolute truth exists independent of those who undertake the inquiry, but it cannot be fully discovered (Levers, 2013). Due to the objective nature of the access to knowledge both of these paradigms follow a value free methodology. These paradigms are well accepted to form the foundation for scientific research however, the truth behind value free and complete objectivity is highly questionable (Lincoln and Guba., 1984) referring to early explanations on how value interplays in the knowledge creation process. Therefore, application of these paradigms especially in social science research comes along with a portion of constructed reality or in other words, objective reality is rooted in constructed phenomena. As a result, the choice of such a paradigm will not allow the study of the complex nature of the social world as well as giving no guarantee on objectivity or internal validity.

As a paradigm stands in favour of studying social science phenomena, constructivism acknowledges people create or recreate what is true by themselves (Perkins, 1999). Another similar paradigm is constructionism; often considered the same as constructivism.

Both paradigms acknowledge that people construct and interpret reality however, the epistemological difference is that constructivism is focused on activity of interpretation and construction of reality in individuals' mind while constructionism is focused on the social act of "collective generation and transmission of meaning" (Patton, 2015). Since both paradigms are very much similar both are being referred as constructivism in this thesis. Constructivism is an extension of symbolic interaction. Studying an abstract concept such as value under constructivism allows us to access individual contribution towards value creation however, that leaves us much more vulnerable to lead the research into a dead end due to the possibility of the existence of multiple realities. Therefore, it is necessary to study such a delicate subject staying within the middle ground rather taking extreme positions (positivism or constructivism). Pragmatism is a philosophical solution brought in to resolve the empiricism and optimism debate by introducing "tough minded" and "soft minded" (Legg and Hookway, 2019). Giving away rigid commitment to any extreme, and opportunity to benefit from both, by being value neutral. Pragmatism argues that knowledge is based on personal experience which can be considered as a branch of empiricism (Legg and Hookway, 2019). Due to the involvement of the individuals in the knowledge creation process and flexibility to work with both qualitative and quantitative methods, this paradigm is in favour of understanding personal value towards BIM, however the limited application of BIM within FM functions restricts the full potentials of pragmatism.

As a research project, studying an entity of the society and social behaviour of decision making, this study aims to understand people's perspective towards value of information in facilities management. The need for close involvement of individuals in order to understand the value of BIM for FM demands paradigms capable of preserving the richness of value laden methodology. Rejecting pragmatism opens doors to phenomenology. Another rich paradigm to study lived experience, to understand how people make sense through experience. However, lack of experience in the subject study weakens the application of the paradigm to achieve a plausible result. Phenomenology and hermeneutics are widely known paradigms to study how people make sense of the world. Taking a hermeneutic view will engage one in a deep study of what people mean by the value of BIM bringing an interesting perspective however, such in-depth study will need to involve studying a selected group of people and studying them against their history and context. BIM as a phenomenon dealing with the future of the construction industry will not benefit as much as anticipated by taking a hermeneutic view unless studying a similar transformation in the construction industry in the past (e.g. acceptance of CAD) and learning ways of promoting BIM through that. A summary of the comparison of different paradigms is presented in Table 4.1.

The same person can value the same thing differently in different situations therefore, it is context dependent. Value evolves over time; the value of something before it is possessed and the value of something when it is possessed and value of the same thing when one no longer has it, is different. Therefore, at a glance constructivism overrides the other paradigms to study the phenomena.

TABLE 4.1: Philosophical Comparison of Research Paradigms

Paradigm	**Nature of reality**	**Access to reality**	**Suitability**
Positivism	Single and external reality. Complete knowledge of reality is possible	By observing and sensory experience without interacting who or what is being studied	BIM is an emerging concept in construction industry. Therefore, theories about FM and BIM are yet to be developed placing deductive approaches in an unfair position. On the other hand, one of the key objectives of the research is to identify the value of BIM in FM. Studying value in quantified measures commonly limits to monetary value. Yet, the purpose of the research is to define the value as it is identified in BIM in FM context. Therefore, epistemologically much open methodology is suitable.
Post positivism	Single and external reality but probabilistically reachable		
Critical realism	Reality is separate from being perceived about the reality. Probabilistically reachable single reality (objective ontology)	Access to reality is theory laden (subjective epistemology)	Critical realism (CR) stands in a positive position as this study is looking at an abstract concept of value that needs to take a critical position when dealing with the subjective nature of the topic. In the meantime, CR accepts the possibility of accessing the reality through personal experience. Moreover, it stands in line with the researcher's fundamental views.
Phenomenology	Reality is sensory appearances	Knowledge gained through lived experience	Phenomenology is one of frequently adopted philosophies in social science studies with practical aspect such as clinical research. However, this has been rejected within this investigation due to lack of lived experience of total BIM and time limitations.

Paradigm	Nature of reality	Nature of reality	Suitability
Pragmatism	Reality is practical consequences of an idea. What is true is what is working at the given moment		Pragmatism is a suitable philosophy to study construction industry due its practical nature however, accessing knowledge under pragmatism will limit the knowledge contribution due to lack of experience and practical application of BIM current context. Therefore, creating knowledge depend on practical consequences will not be suitable.
Constructivism	Multiple and relative reality created by human mind	Meanings are created through the interaction of inquirer and inquired	Subjective value considered in the research is constructed by individuals involved in the subject matter. Therefore, there is a constructivist influence on the research. However, studying an abstract concept such as value in under constructivist assumptions may lead to fallible conclusions due to multiple realities.

Nevertheless, considering the abstract nature of the subject value and studying this concept based on constructivist assumptions will widen the vulnerability of the study and limit its ability to generalise. On the other hand, being people oriented and the practical nature of the construction industry leads to a mentally constructed reality in a pragmatic world which counts on practical consequences.

The literature also holds evidence and confirms the suitability of the pragmatic stance to architecture, engineering, construction and facilities management research (Wing, Raftery and Walker, 1998). However, the application of pragmatism will limit the understanding the truth due to limited application of whole life cycle BIM. Taking the middle ground, the critical realist paradigm is identified as a strong position to study the deep roots of the subjective notion of value with the help of existing theory to support the validity and be value neutral. Being positioned between positivism and constructivism helps not to be drowned in the subjectivity but to be sensitive. The next section introduces the selected paradigm and its suitability within this research enquiry.

4.3.3 Critical Realism

Critical realism (CR) is a philosophy of science for social science (Yeung, 1997) bringing scientific aspects into social enquiries. It provides an alternative explanation to the traditional contradiction between positivism and interpretivism by looking at the reality in stratified form (Walliman, 2006). Accordingly, reality (real) has two sub-layers actual and empirical (see figure 4.3). Each layer is informed by its previous which is acting as the foundation and cause of greater complexity. The richness of this paradigm is supported by the multiple theories it's built on by carrying components of empiricism, relativism and hermeneutics (Danermark, 2002).

With reference to Roy Bhaskar, the founder of CR, science is a social activity engaged in production of knowledge independent of existing and active things (Archer et al., 2013). Therefore, demands that scientific work must look beyond regularities and understand the structure, processes and mechanisms cause the patterns observed (Denzin and Lincoln, 2011). As previously discussed, it takes a transcendental realist ontology which identifies reality in three levels (empirical, actual and real). From an epistemological perspective CR is taking a theory led epistemology. That is: acquisition of knowledge is supported by theories. This is a commonly accepted view in qualitative research taken after Thomas Kuhn (Given, 2008). The way people make sense of a phenomenon is guided by one of range of theories. In other words, theories shape the way of seeing. As a result a certain theory could be more or less useful to understand a particular phenomenon distinguishing from the hypothesis which will be accepted or rejected at the end of the study (Silverman, 2013).

Critical realism as its name indicates is being "critical" and rejects the methodological individualism of realism and claims to universal truth (Denzin and Lincoln, 2011). Therefore, it is open to accommodate both qualitative and quantitative methods where appropriate. When Bhaskar introduced CR in 1970s it was defended as a strong philosophical framework because of this characteristic; it was not being limited to a set of methods (Fletcher, 2017). However, some identify this as a limitation of CR obstructing the widespread application of this rich philosophy (Oliver, 2012) by not specifying how to practice CR. Under the CR philosophical view it is accepted that knowledge is socially constructed (Walliman, 2006; Denzin and Lincoln, 2011) which stands it in positive stead as regards this thesis, as it is a requirement in order to access the value of BIM as seen by FMs and wider stakeholders. To be precise, CR rejects the notion that natural order is understood only by observation but the underpinning order is understood through interpretation (Walliman, 2006). As a result, this paradigm acknowledges the necessity of qualitative methods such as interviews and observations to understand causal mechanisms in social science. This will justify the methodological choices made later in this chapter.

There are both critics (Denzin and Lincoln, 2011) and enthusiasts of CR in social science. CR and positivism agrees that there is a single reality, a natural order in social science and it is separate from knowing it (Walliman, 2006). The key difference between CR and positivism is that CR acknowledges that people co-create realities at the experience level and interpret them differently. This difference is the same fact that CR and constructivism agree on. Still CR is different from constructivism because of the fact it agrees with positivism. That deeper causal mechanisms are common, they are not constructed by people therefore, does not trapped in a person or group of people. Since the reality is same regardless of the way it is being interpreted this thesis has not looked into the philosophical perspectives of the individuals (unit of analysis/interviewees) who contribute to discovering the empirical level truth.

Finally, this research was driven by a research question which highlights the knowledge gap between theory and practice. Building Information Modelling (BIM) as described in literature is a highly beneficial application for facilities management (FM) and clients however, this was not correctly reflected in current practice. Therefore, the research raises a "why" question to understand the causal mechanisms of BIM practices in facilities management (see section 1.3). On the other hand, critical realism is a philosophical framework focused on studying the nature of social reality (Faulkner and Runde, 2013). Rather than understanding what is happening; critical realists are interested in understanding why something is happening. Its ability to identify causal mechanisms and explanatory power helps researchers to make recommendations for social problems (Fletcher, 2017). Therefore, CR has earned its credentials to study "why" research questions. Secondly, neither BIM nor FM has a substantial theoretical background already established to generate empirical knowledge taking a deductive approach following positivist or post-positivist philosophical assumptions. In favour of the subject under study, CR proves its suitability as a philosophy of social science often identified as a metatheory due to its use of theory to understand the reality.

4.4 Research Approach

The term "research approach" is being used to explain different elements of research by different scholars. Some use the term to explain the methodological choice of quantitative, qualitative and mixed methods (Amaratunga et al., 2002) and others refer to the logic of reasoning (Hyde, 2000). Fann, 1970 identifies that classifying inference as a key task of logic and presents Peirce's classification of inference (Figure 4.5). Peirce's classification of inference was found interesting as it included a novel approach (abduction) along with the traditional induction and deduction (Burks, 1946). "Explicative inference" follow the from the premise that if a premise is true, the result is true (Fann, 1970). Conclusions made through "Ampliative inference" adds into the premises rather than explain (ibid).

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FIGURE 4.5: Classification of Inference (Source: Fann, 1970 p.7)

In the nineteenth century it was a key concern in philosophy of science to understand whether there is a logic in inference and the nature of the reasoning (Fann, 1970). It was of interest to know how one came to discover something as much as to know about the new discoveries. Therefore, three main reasoning logics (deductive, inductive and abductive) were taken into debate to select the most appropriate approach for the research. Table 4.2 (see page 66) presents a comparison of the three approaches summarising the key features.

4.4.1 Deductive reasoning

Deductive reasoning is the logic of theory testing (Hyde, 2000). The reasoning process begins with a pre-established theory (general theory) and applies it to a specific context (deduce) to test its applicability. A study based on deductive reasoning will end with an observation confirming the general rule or falsification of it (Timmermans and Tavory, 2012). The result can either confirm the theory or modify it - where theory generation happens through deduction logic. Deductive reasoning is dominant in the natural science research because, existing natural laws lay the foundation for explanations in natural science therefore, making it possible to predict and anticipate a phenomenon and also to control it (Saunders, Lewis, and Thornhill, 2012). Saunders, Lewis, and Thornhill, 2012 emphasise three characteristics which form deductive reasoning;

- **Explain causal relationships** – The key strength of deductive reasoning is its capacity to determine relationship between a concept and its variables. The deductive logic (Figure 4.6) is designed to achieve this primary goal. The process begins with theories related to the concepts being studied to identify variables. Then, the relationship between key variables and concept will draw in the hypothesis for testing. This feature of deductive reasoning becomes a constraint to research areas which aren't theoretically established.

- **Structured methodology** – The conclusions of a research project are made following a rigid structure of data collection and analysis so that the subject is reduced to measurable components and replication of the output is made possible to enhance the reliability of the output. High intellectual contribution is demanded in identifying the causal relationships and designing a method to capture and analyse the identified relationships. Therefore, research under deductive reasoning invests more time and effort on designing data collection and analysis techniques while inductive research spends more time in collection and analysing of data.

- **Generalisation** – Although it is induction reasoning which is widely known for its generalisation ability, a research study can produce generalizable output under deduction inference. However, this requires a careful selection of the sample to justify the generalisability. This emphasises the sufficient sample size especially when taking a deductive approach in social science research. Therefore, a larger number of sample size is recommended for questionnaire surveys and the size of the sample is decided in proportion with the population size. However, there is often the problem of knowing the actual size of the population and reaching the total required sample in social science research.

As illustrated in Figure 4.6, a research project conducted under deductive reasoning begins with a broader view and ends with specialising in a specific subject. Most of the research on BIM which has taken a deductive approach begins with the wider scope of BIM and information technology however, extensive study is conducted on specific areas of BIM such as 3D model, thermal modelling, information, etc. This type of logical reasoning does not bring new knowledge but truth-conveying (Reichertz, 2007). It only confirms or denies the pre-established theory and is often used in quantitative research. This approach is very much in line with what Kuhn, 2012 refers as "normal science" research which is a study based on past scientific achievements (theory).

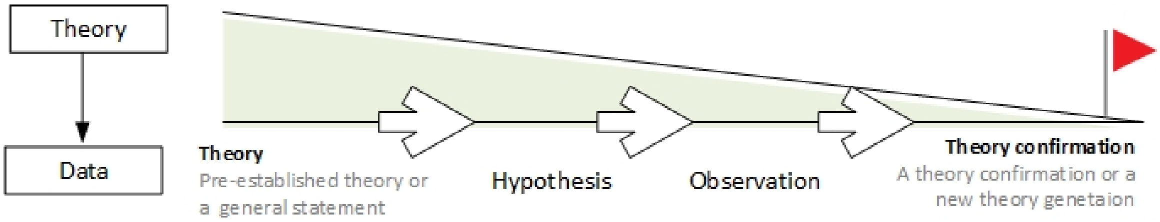

FIGURE 4.6: Deductive Logic

4.4.2 Inductive reasoning

Inductive reasoning is the process of theory building; starting from observations of a specific subject matter (Figure 4.7) and to end with an universal statement about the matter under investigation (Hyde, 2000). Due to the absence of specific theories on the value of BIM, inductive inference stands in favour of the subject under study allowing us to begin with observations. The Inductive approach enables the researcher to develop theories through data collection and analysis (Engward, 2013). The identification of patterns in collective observations will lead to theory generation under inductive reasoning (Timmermans and Tavory, 2012). This has become possible under the key principle of induction - "nature is uniform" (Johnson and Duberley, 2000).

Karl Popper in 1934 stood against the claim of universal statement and argued that no matter how many similar objects or incidents have been observed, the conclusions made will be singular (not universal) (Danermark, 2002; Delanty and Strydom, 2003). This argument is recognised as the problem of induction and further supported by explaining that the universal statements are made true on several occasions only by reducing them to a singular statement. For example, one can observe 1,000 swans and conclude that all swans are white. Then this universal statement becomes true on some other occasions when one comes across a swan and it is white. However, when viewed under the problem of induction the universal statement becoming true on other occasions only makes it true in those singular experiences. Therefore, this becomes a central issue if applied to gain knowledge on a developing concept such as BIM. For instance, it might lead to the common error to conclude that BIM is a 3D model because that is how many practitioners see BIM and accept it to remain as a 3D model in the future. Nevertheless, with its own positive and negative features, inductive reasoning has served empirical researchers for many decades, for after all, there is nothing exciting about proving what is already known (deductive reasoning).

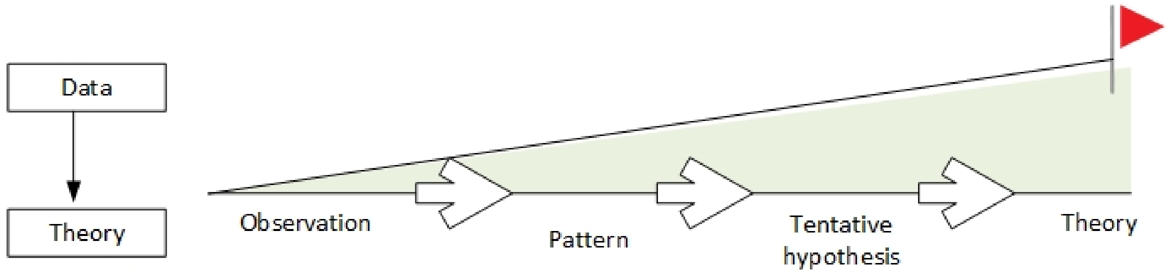

FIGURE 4.7: Inductive Logic

4.4.3 Abductive reasoning

Abductive reasoning which is also known as "inference to the best explanation" (Pritchard, 2014) gained its reputation with its introduction as the logical reasoning of pragmatism by Charles Sanders Peirce (Fann, 1970). However, the history of abduction goes back to the Aristotelian time (Reichertz, 2007). At the beginning Peirce termed this logical reasoning which is "inference of a cause from its effects" as "Hypothesis" taking after Aristotle and Immanuel Kant (Niiniluoto, 1999). Therefore, early publications of abduction refer to this logical reasoning as Hypothesis and later identified it as Abduction. Comparing the deductive logic (Figure 4.6) and abductive logic (Figure 4.8) it is evident that abduction begins with a specific observation making a clear difference from deduction inference which begins with a general theory. Since there is an element of induction as shown in Figure 4.8 at a glance abduction may not be distinguished from induction (Bryman, 2012). Therefore, it is critical to define what is known as abduction to take its place as another type of logical inference to sustain among those who doubt abduction as a type of logical reasoning (Fann, 1970).

Peirce distinguished induction as the logical reasoning for theory discovery while abduction as the inference for "discovering causes" (Niiniluoto, 1999). On the other hand, when inductive reasoning is focused on answering "what" questions; deductive and abductive reasoning are interested in "why" (Blaikie, 2009). Therefore, abduction is not an inference to discard induction nor deduction but a third type of inference with a specific task.

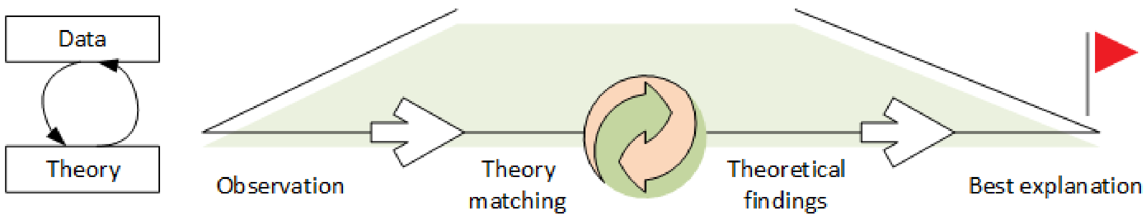

FIGURE 4.8: Abductive Logic

Abduction is a reasoning process based on interpretation (mental process) of collected data to make discoveries when there is no rule or explanation in the existing knowledge store (Reichertz, 2007). Therefore, it starts from a known quantity which is the result (known through observation) and proceeds to the unknown case and rule through the intellectual act (Burks, 1946; Reichertz, 2007). Often, this first observation at the starting point is an unexpected (surprising) phenomenon and the researcher will look for causes for the event creating a potential hypothesis (Teddlie and Tashakkori, 2009). The creation of hypothesis is theory laden. Abduction leads the researcher from a "problematic situation to a tentative solution" (Burks, 1946). Miller and Brewer (2003) explain abduction as the "creative inspiration during which the researcher conceives of a hypothetical explanation for some empirical fact". The way that abduction logic is presented in this thesis (Figure 4.8) agrees with Miller and Brewer's (2003, p.3) graphical example on the process of abduction which presents that it starts and ends with a specific fact which is different both the other logical inferences.

The most popular Peirce's example "all the beans from this bag are white" which is followed by many authors explaining the difference between induction, deduction and abduction through Rule, Case and Result (Fann, 1970; Danermark, 2002) is somewhat confusing with Peirce's own writings about the differences between the three logical inferences. The abduction inference used in this research begins with the known which is the "Result" agreeing with Reichertz, 2007. Both induction and deduction were introduced under natural science yet induction with both qualitative and quantitative applications. The methodological conflict between natural and social sciences occurs due to the core differences of the subject matter; i.e. objects under study in natural sciences are not capable of bringing meaning to the events or their environment while people do. Therefore, it is important to treat the social science objects (people) as subjects capable of making their own reflections of the social world. In support, abduction predominantly supports qualitative methods (Blaikie, 2009). Abductive reasoning is distinguished from inductive reasoning for its efforts to understand the world from the participant's point of view (Bryman, 2012).

Abduction is the only inference which brings new ideas by establishing an explanatory hypothesis to be explicated by deduction through identification of consequences and testing and induction is to establish the hypothesis with the use of frequency or probability (Burks, 1946). Therefore it is accepted that the function of abduction is to discover a hypothesis rather than justification.

TABLE 4.2: Three modes of inference

	Deuction	**Induction**	**Abduction**
Fundamental structure/thought operations	To derive logically valid conclusions from given premises. To derive knowledge of individual phenomena from universal laws.	From number of observations to draw universally valid conclusions about a whole population. To see similarities in a number of observations and draw the conclusion that these similarities also apply to non-studies cases. From observed co-variants to draw conclusions about the law-like relations.	To interpret and recontextualize individual phenomena within a conceptual framework or a set of ideas. To be able to understand something in a new way by observing and interpreting this something in a new conceptual framework
Formal logic	Yes	Yes	Yes and No
Strict logic inference	Yes	No	No
Central issue	What are the logical conclusions of the premises?	What is the element common for a number of observed entities and is it true also of a larger population?	What meaning is given to something interpreted within a particular conceptual framework?
Strength	Provides and rules and guidance for logical derivations and investigations of the logical validity in all argument.	Provides guidance in connection with empirical generalisations and possibilities to calculate, in part, the precision of such generalisation	Provides guidance for the interpretative processes by which we ascribe meaning to events in relation to a larger context

	Deuction	Induction	Abduction
Limitations	Deduction does not say anything new about reality beyond what is already in the premises. It is strictly analytical.	Internal limitations of induction Inductive inference can never be either analytically or empirically certain External limitation of induction Induction is restricted to conclusions at the empirical level.	There is no fixed criteria from which it is possible to assess in a definite way the validity of an abductive conclusion.
Important quality on the part of the researcher	Logical reasoning ability	Ability to master statistical analysis	Creativity and imagination
Example	Rule: All beans from this sack are white Case: These beans are from this sack Result: These beans are white	Case: These beans are from this sack Result: These beans are white Rule: All beans from this sack are white	Result: These beans are white Rule: All beans from this sack are white Case: These beans from this sack

Source: Adopted from Danermark (2002)

Retroduction is another term which comes along sometimes under the topic of logical inferences. It is a form of logical inference identified by some scholars (Danermark, 2002; Fletcher, 2017) while some see it as the analytical framework which came along with critical realism (Bunt, 2018) and others as a similar logical inference to abduction (Fann, 1970) and another as the real way that actually research is taking place – i.e. going back and forth between different inferences (Miller and Brewer, 2003). The term "retroduction" has become popular among researchers with its use under critical realism by Roy Bhaskar. The focus of retroductive inference is to explain observed regularities and discover underlying mechanisms (Blaikie, 2009). This explanation of retroduction summarises the essence of critical realism therefore very much more suitable for studying the phenomena under investigation. However, this much is as far as it goes. The limited amount of literature available on retroduction as a research approach and the problem of not having a defined way of discovering the underlying mechanisms (Blaikie, 2009) have led to the rejection of the application of retroductive inference in this thesis.

4.5 Research Method

Previous sections laid the ground work of the research methodology by revealing the researcher's world view and logical reasoning behind the study compared to other existing alternatives. Although, these are some of the key pillars which inform the research method, they often stay invisible in the process. In general, the research methodology is visible from this point – research method. Therefore, it is often misinterpreted with methodology. There are two distinctive research methods namely; qualitative and quantitative. Sometimes, the combination of these two methods (mixed methods) is also identified as a separate method (Creswell, 2018). However, there is no single method appropriate for AEC/FM research (Wing, Raftery and Walker, 1998). Thus, a detailed analysis of each type is discussed in the coming sections. The choice of research method is made based on the philosophical view of the research (Creswell, 2014). As explained in the above section, this research is conducted with a critical realist (CR) philosophical view. Previous scholarly work conducted based on CR supports the application of both qualitative and quantitative research methods equally within CR (Mills, 2013). In contrast, the ontological and epistemological differences between the research choices have created a long known debate between quantitative and qualitative choices (Newman and Benz, 1998) which is even taken to the extent that the two choices are not compatible together (Firestone, 1987). Therefore, it is crucial to keep in mind the research method followed to achieve the research aim is embedded with certain assumptions which come along with the philosophical stance (Creswell, 2014). While being conscious about the research methodology, different tools (which are recognised as research methods) could be used to achieve the aims and objectives of the scientific investigation (Sutrisna, 2009). Therefore, each research method consists of selection of options for data collection and analysis while some are unique to the addressed research methods and others are flexible to use with any. Qualitative methods are designed to see the depth of a phenomenon while quantitative methods are structured in a way to cover the breadth, hence, one needs to trade off one for the other (Patton, 2015).

4.5.1 Qualitative methods

Qualitative methods is an umbrella term for tools most useful for exploring and developing concepts distinguishing them from their counterparts (quantitative methods) which require pre-conceptualisation (Dey, 1993). Qualitative methods represent the combination of data collection and analysis techniques used for research to bring meaning from qualitative data such as text, images, and recordings. Any research method that does not quantify data statistically or by any other means falls under qualitative methods (Strauss and Corbin, 1998). However, Strauss and Corbin (1998) point out the difficulty of maintaining this definition since some researchers collect data through observations or interviews (qualitatively) and code the data in a manner that supports a statistical analysis. With a different view Bryman (2012) identified data analysis such as frequency of occurrence as acceptable in qualitative research. Therefore, the application of the qualitative and quantitative methods differs from one study to another although there are many authors who point out the obvious difference between qualitative and quantitative methods (Bryman, 2012, p.408).

Qualitative methods always face the criticism, at least in the built environment community, due to their subjectivity in comparison to quantitative methods especially because built environment research has an equal possibility of using qualitative or quantitative or even mixed methods.

The history of qualitative research comes from studies in sociology, anthropology and humanities (Creswell, 2018). Therefore, qualitative research is soon recognised for its capabilities to study complex situations, especially with phenomena involving human subjects (Sutrisna, 2009). In general they represents an "individual phenomenological perspective" compared to quantitative research which focuses on a common objective reality (Newman and Benz, 1998). Qualitative methods are primarily introduced to work under inductive inference introduced from natural science practices but, abduction inference is also qualified to work with qualitative methods. When a research adopts qualitative methods it is often influenced by the interpretivist epistemological position since the researcher is making sense of the reality as its subjects interpret them (Saunders, Lewis and Thornhill, 2012). Therefore, highly abstract principles of the researcher on what is ontology, epistemology (i.e. philosophy) and methodology play a key role in shaping the research (Denzin and Lincoln, 2011). As a result, it is accepted that the researcher is an instrument in qualitative research, capable of collecting as well as generating data (Mills and Birks, 2014). Hence, value neutrality is an important aspect of social science research. It is the responsibility of the sociologist to be impartial and overcome personal influence as they conduct the research. There are other challenges made especially in comparison to quantitative methods such as generalisability, transparency, replicability and subjectivity (Bryman, 2016).

In general qualitative research avoids early hypothesis (Silverman, 2013). In other words, qualitative research is much more appropriate for research questions with no solid hypothesis to begin with. The advantage of qualitative methods is their capacity to study the reality as it is rather than creating a controlled environment as in other methods (Saunders, Lewis and Thornhill, 2012). The usual negative characteristics of the built environment, such as being labour intensive, practical and with scattered multi stakeholders, tend to blend well with the qualitative methods to reveal the unknown of the complex situations. Therefore, qualitative research has gained its recognition and popularity in built environment research (Sutrisna, 2009). The wide range of data collection and analysis techniques coming under qualitative methods, especially favourable for built environment research, are discussed in section 5.6. The selection of the data collection and analysis techniques for research are often guided by the research aim and objectives. Different focusses and questions raised at given points of time in the research spiral may demand the use of different data collection tools (Crabtree et al., 1993). The use of a combination of data collection and/or analysis tools provides the possibility of taking a multimethod approach. On the other hand, the selection of a certain research strategy based on the research aim and objectives will guide the selection of data collection and analysis tools by narrowing down to the most logical combinations suitable to answer the research question. Since qualitative research uses a different approach to justify the validity and rigour, the theory behind the data collection and analysis tools is paramount to justify the findings. Silverman (2013) However, qualitative methods in general are favoured for social science subject matters as they have the flexibility to adjust according to the situation.

4.5.2 Quantitative methods

In qualitative research reality is conceptualised as variables to reduce into measurable components (Punch, 2003). Quantitative methods represent the combination of data collection and analysis techniques used in such research to reveal knowledge broadly through numerical data. The function of quantitative methods is to determine the relationship between independent and dependent variables in a given context (Sutrisna, 2009). The primary focus is to understand the relationships between variables rather than explain them. These variables are measured using instruments and statistically analysed (Creswell, 2018). Therefore, the data gathered through quantitative methods are either numerical, categorical or specifically in social science it even could be along a continuum such as low to high.

Qualitative methods are an objective way of theory testing (Creswell, 2018) based under deductive reasoning. This research method has been the dominant and traditional way of researching in social science for a considerable time (Newman and Benz, 1998) due to characteristics coming from deductive inference. Quantitative research is commonly carried out as experiments or surveys. In the 1960's quantitative survey was the method of 90% of social science research (Silverman, 1985). Often, logical empiricism is the metatheory behind quantitative methods (Danermark, 2002) which engage in systematic deduction of metaphysics into logical and mathematical components. So that what can be verified is identified as meaningful.

In general, quantitative research is motivated to reach a common reality that every person agrees with, regardless of the theoretical differences (Newman and Benz, 1998). Its assumptions are primarily influenced by the positivist paradigm by accepting that reality can be explained through objective facts (Firestone, 1987). Therefore, the choice of quantitative research method favour towards research strategies such as survey, experiment, quasi-experiment and pre-test-post-test designs (Newman and Benz, 1998). In comparison to qualitative methods; there are only a few strategies for data collection in quantitative methods but they have variety of analysis tools, where only a few are available for qualitative studies. Following a quantitative method requires the researcher to decide on data analysis techniques before embarking on data collection (Saunders, Lewis and Thornhill, 2012) because data should be collected in a manner suitable for the selected analysis. Therefore, it requires pre-established knowledge on the subject matter to proceed with quantitative methods. Moreover, quantitative methods are limited with theory testing and incapable of following an inductive approach. Both facilities management and Building Information Modelling (BIM), being comparatively new subject areas as individual subjects, as well as having a lack of pre-established interdisciplinary theories are not conducive to using quantitative methods as the primary research method. However, qualitative methods are useful for triangulation purposes when the research subject and question are in favour of qualitative methodology.

4.5.3 Triangulation

The methods discussed above have their own strengths and limitations. Therefore, the use of a combination of methods is advised to overcome the limitations of one by using the other. Within these two contradicting research methods (i.e. qualitative and quantitative) there are many variations to select from when designing the research framework. Saunders, Lewis and Thornhill (2012) illustrates different methodological choices a research could take (Figure 4.9).

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FIGURE 4.9: Methodological Choices (Source; Saunders, Lewis and Thornhill (2012, p.165)

Mono methods were discussed under previous headings introducing use of qualitative (QUAL) and quantitative (QUAN) methods separately. Only one type of data collection and analysis method will be employed under mono method research. If two or more types of data collection and/or analysis methods were used within the QUAL or QUAN choices then these are referred to as multimethod research. For instance, the work in hand was carried out using interviews and focus groups for data collection and constant comparative method and content analysis for data analysis staying within the QUAN discipline but taking the multimethod research design. The last type of methodological choices - mixed method, this is to be done by combining QUAL and QUAN methods. When the combination of two types of methods is done at different phases of a research such is identified as mixed method research. When QUAL and QUAN methods are combined within or across stages of a research then it is referred as mixed model research (Johnson, 2004).Methodological triangulation is only one out of many types of triangulation. However, it is important to note that triangulation is not about using many different methods, but understanding the strengths and weaknesses of each method and using a counterbalance to make a strong case. The terminology of triangulation comes from navigational and land surveying showing how accurately one can locate a place at the intersection of directions given from two landmarks compared to directions from a single landmark (Patton, 2015). Also, metaphorically triangular being the strongest geometric shape. Therefore, it is a technique of making a strong case for the knowledge presented by approaching the phenomenon with a variety of methods and/or theories.

The notion of triangulation is strongly associated with social science research and its initial reference can be found in the book "Unobtrusive Measures" first published in 1966, written by Eugene Webb, Donald Campbell, Richard Schwartz, and Lee Sechrest (Webb et al., 2000; Lee, 2015).

"Once a proposition has been confirmed by two or more independent processes, the uncertainty of its interpretation is greatly reduced. The most persuasive evidence comes through triangulation of measurement process." (Webb et al, 1966, p.3).

Unobtrusive measures was introduced mainly with two purposes; firstly, to promote use of multiple methods to study a phenomenon in order to avoid bias in social science research and secondly, to promote creativity, imagination and innovation to design non-reactive measures (Lee, 2015). Under this concept, most of the social science measures are identified as reactive measures; that is when a questionnaire is given to a participant explaining its aim for example; identifying consumer behaviour it is natural to expect an inclination (Sechrest and Hill, 2001). Therefore, many creative and alternative ways are supported under unobtrusive measures such as understanding the visitor flow by studying the museum floor tiles (Lee, 2015). However, Webb et al., 2000 skip through the weaknesses in unobtrusive measures especially with relation to ethics.

Triangulation gained its popularity through the work of sociologist Norman Denzin in 1970 (Lewis-Beck, 2004; Lee, 2015). Similar to the classification (see Figure 4.9) of Saunders, Lewis and Thornhill (2012), Denzin (1989) distinguished between the "within method" and the "between method" introducing the possibility of within method triangulation with a variety of uses of the same method (e.g. different scales in questionnaires) and use of different methods to study the same phenomenon (e.g. questionnaires and observations) as between method triangulation. More importantly, Denzin extended these existing discussions of triangulation and introduced four different possibilities of achieving triangulation (Patton, 2015).

- **Data triangulation**
  This refers to the use of different sources of data which is different from methodological triangulation. Data triangulation allows us to make the maximum use of a single method by "studying the same phenomenon at different times, different locations or with different people" (Flick, 2007). In this thesis, data triangulation is achieved through approaching some of the selected interviewees at different times and in different contexts. Moreover, Denzin compared data triangulation as something similar to theoretical sampling discussed by Glaser and Strauss (1967) since both methods are purposefully selecting and integrating the people and cases (Flick, 2007). Therefore, use of theoretical sampling within the study also stands in support of the validity of the thesis.

- **Investigator triangulation**
  This method of triangulation places its emphasis on employing different observers or interviewees to enhance the reliability by minimising the bias that could occur from

a single observer (i.e. single viewpoint) (Flick, 2007). Within this thesis, it has been difficult to employ this method to a great extent as the work carried out is a partial fulfilment of an academic qualification however, a third party view was absorbed into the research through continuous and long term involvement of two academic supervisors, and comments received through peer reviewed publications.

- **Theory triangulation**
  Theory triangulation is about accessing data with multiple viewpoints. These could be multiple theories or hypotheses. This brings the possibility of using data to confirm or reject an existing theory or the most plausible theory or even to create a new one. However, the most important point of theory triangulation is that one considers all possible alternatives rather being limited to the preliminary assumptions or ignoring alternative explanations by choosing one (Flick, 2014). The collection and analysis of data in this thesis are supported by multiple theories such as philosophical and methodological underpinnings, basic human value theory and economic theory (see Figure 6.11 on pg. 170).

- **Methodological triangulation**
  As Webb et al. (2000) explains "no research method is without bias" therefore, one method should be accompanied by another with "different methodological weaknesses". Methodological triangulation is the widely used method of triangulation practised by conducting mixed method research (MMR). However, methodological triangulation involves both within-method and between-methods triangulation (Flick, 2007). Methodological triangulation is achieved within this thesis using both within-method (continuous update of the interview protocol) and between-method techniques (i.e. use of interviews and focus groups). Observations were taken into account where permission was granted during some site visits. In support, use of both in-depth interviews and focus groups makes a strong case for triangulation in qualitative research (Carter et al., 2014).

Often triangulation refers to the use of both qualitative and quantitative methods in a single study. However, differences between methodological triangulation, mixed methods and conducting research with pragmatism assumptions is necessary to draw separately in order to achieve true methodological triangulation. For instance, applying a combination of qualitative and quantitative methods should be guided by the research question therefore, mixed method is not suitable for every research project (Tashakkori, 2009).

From its introduction, the purpose of triangulation was to look beyond traditional data collection methods which were interviews and questionnaires in the 1960s and enhance the validity of the social research (Lee, 2015). Therefore, qualitative research can achieve triangulation by combining interviews with observation, employing different non-probability sampling techniques, using different theories or theoretical perspectives at the analysis (Patton, 2015). As a result, methodological triangulation or more specifically combining QUAL and QUAN methods are not the only way to prove the validity of social science research.

However, the most common way of triangulation in general is using mixed methods in terms of qualitative and quantitative. If one looks deep into this notion this is combining hypothetic-deductive and holistic-inductive approaches (Denzin and Lincoln, 2011; Patton, 2015). Which is already done in this research by taking an abductive approach which includes an uninterrupted inductive and deductive inference. Often MMR defends this cyclical approach in the context of justification rather under the logic of discovery (Denzin and Lincoln, 2011). As a research project with the main focus on discovery rather justification, this thesis is not identified as an MMR.

The common argument against MMR is that there is an epistemological inconsistency with QUAL and QUAN methods (Denzin and Lincoln, 2011). Pragmatism is the main paradigm which supports combining QUAL and QUAN through creating a suitable philosophical background (Johnson, 2004). However, this argument is not valid for the work in hand as it is built on critical realism philosophical assumptions with its support of both QUAL and QUAN or in other terms not limited to any method unlike other conventional paradigms.

On the other hand, MMR are time consuming which is a key issue for doctoral students and expensive in general (Denzin and Lincoln, 2011, p.295). If none of these are problems for a researcher, then the question would be why not select a larger sample to bring more credibility to the research since these are the same reasons for sampling in the first place. On the other hand, managing construction of questionnaires and interview protocols and analysing quantitative and qualitative data takes time, effort and requires long training as they operate under different logics (Brinkmann and Kvale, 2015). Therefore, if not done right, they will only lead to more bias rather than stronger inference. The common use of mixed methods is to cover the breadth through quantitative methods and use qualitative methods to see deep into a phenomenon. The combination of focus group and in-depth interviews covers the breadth and depth of a phenomenon (Morgan, 1993).

Moreover, the primary logic behind triangulation is to overcome the limitations of one from the other. However, popularity and emphasis on mixed method is often coming from a post-positivism paradigm where the limitation of pure QUAN methods is accepted. From the QUAN perspective, one should select the research method which is best to answer the research question. If the research has already used the most appropriate method (for example QUAL) then the argument for overcoming the limitations using a previously rejected method (as per the example given - QUAN) is a fragile notion. Therefore, the true application of mixed method is only supported under a pragmatism philosophical stance which forms the middle ground questions which require using both QUAL and QUAN in answering them (Teddlie and Tashakkori, 2009; Biesta, 2010). Although critical realism supports both QUAL and QUAN applications it is primarily in favour of QUAN with its subjective epistemology.

On the other hand, the logic of mixed methods will truly work if the same question was posed using QUAL and QUAN methods and making a comparison in between the answers. In practice this is not what is happening when one calls a research mixed method. In support, research undertaking with post-positivist roots often in favour of survey research strategy. As a good practice of survey research strategy, QUAL methods such as interviews or focus groups are conducted as a preparatory step for the main survey. This is a step taken to limit the weaknesses in survey as a data collection tool, yet mixed method scholars overlook the weakness and argue for increased credibility for employing both QUAL and QUAN. Even with such precautionary steps, it can only partially defend the measurement validity and fails in internal validity (Bryman, 2016, p.53).

However, this is not an attempt to discard use of mixed methods but, to emphasise the need for its use where appropriate rather than as a standard rule of validation. Accordingly, Denzin and Lincoln (2011) present eight characteristics of research in favour of mixed methods (Table 4.3). In summary, social science research questions with the ability to use mixed methods are at an advantage to bring logical justifications for the validity of its findings by overcoming the reactiveness of one method by another however, the findings are more concrete therefore limited to a specific case. On the other hand, social science research questions specifically in the focus of this thesis, are in favour of qualitative methods and at a disadvantage with time bound limitations to justify their findings with the use of quantitative methods as a separate theory testing phase. However, the findings are abstract hence, have a broader application with a solid contribution to knowledge.

TABLE 4.3: Characteristics of Mixed Method Research

Characteristic	**Explanation**
Methodological eclecticism	Rejection of paradigms which are incompatible with using both QUAL and QUAN in a single study. Therefore, designing the research based on paradigms such as pragmatism which fundamentally accept the application of both QUAL and QUAN is one of the characteristics of choosing mixed method.
Paradigm pluralism	Studies based on multiple paradigms and in return both QUAL and QUAN are supported by individual paradigms epistemologically in favour of each method.
Emphasis on diversity at all levels of the research enterprise	When the research has multiple components with different questions ranging from confirmatory to exploratory each level could be studied under a methods most suitable giving freedom to choose between QUAL and QUAN

Characteristic	Explanation
Emphasis on continua rather than a set of dichotomies	Mixed methods are a solution when the primary research design (data collection and analysis), research question or the quality of inference is in question when choosing between options such as exploratory or explanatory, statics of thematic analysis.
Iterative, cyclical approach research	One of the fundamentals of MMR is cyclical approach of including inductive and deductive logic in the same research. Therefore, in some form all research are MMR.
Focus on the research question in determining the methods	When the research question is in favour of MMR, research to be conducted under mixed method design. Often MMR is directed by an "umbrella" question followed by sub-questions.
Set of basic signature research designs and analytical process	When two separate strands (QUAL and QUAN) are required to answer different aspects of the same question (parallel MMR) or when the requirement of an alternative strand is emerged from the first (signature MMR).
Tendency towards balance and compromise that implicit within	MMR is suitable when the researcher and the research requires a middle ground from philosophical dualism and excess of QUAL and QUAN.

Adopted from: Denzin and Lincoln (2011)

4.6 Research Strategy

Within the choice of qualitative, quantitative or mixed method, the researcher has to select a type of enquiry which is identified as research strategy or design (Creswell, 2018). As all the above discussed layers of the research onion, choice of research strategy is also governed by the research philosophy, aim and objectives. Confirming this fact, Kelly, 2004 draws the attention to how individual choice of research philosophy frames the research strategy (Figure 8.1). The horizontal (x) axis with positivist and constructivist metatheories placed at the two ends represents the assumptions in ontology and epistemology while vertical (y) axis explain the axiological grounding under the norm that more the researcher is involved in the study, the output will be value laden.

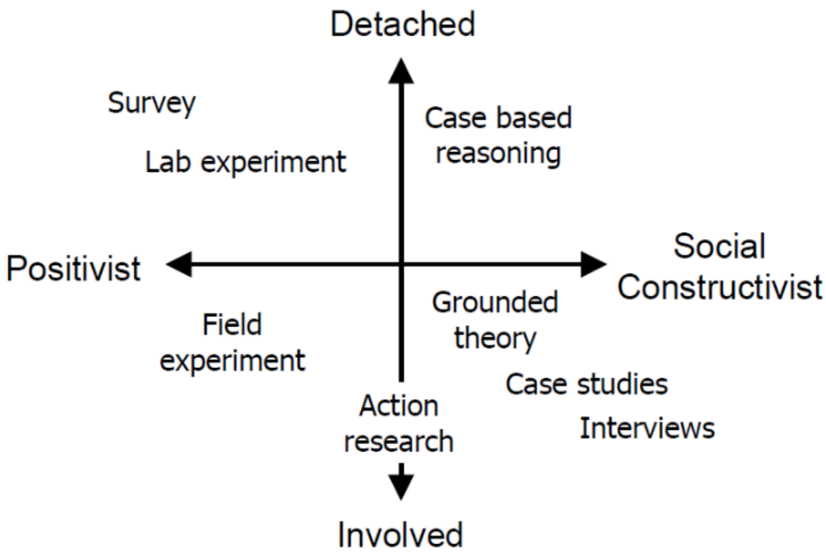

FIGURE 4.10: Research method based on the approach (Source: Kelly (2004))

Case study, ethnography, surveys, experiments, archival research and grounded theory are some of the widely used social science research strategies (Yin, 2003). Therefore, further discussion is made based on these strategies with the addition of action research which is another social science research strategy predominantly for practitioner-researchers. Surveys and experiments are the commonly used quantitative research strategies invoked from positivist/post-positivist philosophical underpinnings (Creswell, 2018). While other methods are mostly based on interpretivism. Looking to the depths of these strategies reveals that most of them are rooted in a specific data collection tool. Taking an unusual formation, grounded theory is rooted in a specific data sampling (theoretical sampling) and analysis technique (constant comparative analysis).

The aim of this research is to develop a model to emphasis the value of BIM at the in-use phase of a facility. Grounded Theory is widely known as a successful strategy to reveal the relationships. Based on a critical realist philosophical view, researcher will observe the world to understand the actual and causal mechanisms causing the adoption of BIM in facilities management while being a part (involved) of the observed world. Therefore, this research can be located in the lower left corner area on the Figure 8.1, representing the researcher's involvement with data with continuous interaction and interest in experience of this social activity as interpreted by its actors. However, each research strategy has its own advantages and disadvantages and clear application of these elements will help to understand and justify the selected strategy (Yin, 2003).

4.6.1 Experiment

Experiment is a natural science dominant research strategy although it is used in psychology and other social science research (Saunders, Lewis, and Thornhill, 2012)). The classic experimental research (laboratory experiments) is the first and valid form of research identified by natural science disciplines with a strong positivist background (Tanner, 2018). On the other hand, common experimental strategies (field experiments) used in social science research align with post-positivist philosophy (ibid). However, most of the psychological experiments are laboratory based therefore, overall experiments are considered as a potential research strategy for both natural and social science research. Especially when built environment research includes both natural and social science subjects. Experiment research act as the bench mark for defining the validity of scientific research apart from its lack of use in social science research. Therefore, an introductory knowledge on experiments research strategy is necessary even at the absence of its use in a particular research (Bryman, 2016).

The experimental research strategy is designed to study the relationships among cause and effect of defined variables therefore, it is the prominent research strategy to be employed for research aiming at discovering causal relationships (Saunders, Lewis, and Thornhill, 2012; Tanner, 2018). This research strategy is often directed by a hypothesis rather than a research question (Saunders, Lewis, and Thornhill, 2012). Validity of causal relationship inference is predominantly true for laboratory experiments due to high control over the other variables and random selection of subjects. On the other hand, conducting the experiment in a natural setting under field experiment design may bring the possibility of independent variables, related to the dependent variable, out of control of the researcher.

Following experiment as the research strategy also involves choosing and designing the experiment to be used in the data collection (Saunders, Lewis, and Thornhill, 2012). At a basic level, experiment strategy consists of observation, control through experimental treatment and a time framework (Bryman, 2016). Although observation as a data collection tool is commonly identified along with ethnography as a qualitative data collection method its application under experimental research converts observations into a quantitative data collection method. The difference is that experiment research strategy employs structured observations. This is one of the key situations emphasising the necessity of defining the methodological underpinnings of a research. Further discussions on types of observations and experiments (lab, field and quasi experiments) as a data collection tool are presented later in this chapter (see topic 4.6.1). However, the lack of interest towards cause and effect of the phenomena and absence of knowledge related to the value of BIM in order to draw the independent and dependent variables have resulted in the rejection of the application of this research strategy for this thesis.

4.6.2 Survey

Survey as a strategy of enquiry is often misunderstood with the survey as a data collection technique. Similar to any other research strategy, choice of surveys is decided based on the research question and aim. Research question, aim and objectives will define the variables that are the interest of study under this research strategy (Punch, 2003) following a deductive research approach (Saunders, Lewis, and Thornhill, 2012) under post-positivist philosophical assumptions. This requires pre-established theory or knowledge to verify and quantify the variables and therefore, is limited to subject areas with sound existing knowledge. However, it is a successful strategy when the aim of the research is to generalise a solution.

The function of survey as a research strategy is to identify the variables to study, selection of data collection and analysis tools and sampling strategies standing in favour of survey techniques (Punch, 2003). In other words, this strategy predominantly guides a researcher on how to successfully conduct a survey. Therefore, it is necessary that selection of this research strategy is principally informed by the research question and aim beforehand. This will be of help in achieving the purpose of the research rather than conducting an accurate and valid survey. The key elements of the survey research strategy are sampling for variation, simultaneous data collection, quantification and causality (Bryman, 2016). That is the survey strategy looks for samples of different cases to represent variations in variables and as a result promotes larger samples. In comparison to experiment strategy which includes different data collection rounds (pre experiment, during experiment and post experiment) survey research strategy focuses on a single point of time data collection. For example, within a time of a month 100 will respond to the survey, each at a single point of time. Finally, to examine the relationships between variables, data are collected and arranged in a standardised manner which demands quantification of data to maintain the consistency and benefit from statistical analysis for relationships identification.

Surveys can be done using a questionnaire with closed or open ended questions as well as structured interviews (using closed ended interview questions) (Bryman, 2016). Both are self-report systems in which the participant itself asses themselves. However, questionnaires require a level literacy from the participants. For instance, using questionnaires with lower level labourers might not be effective due to lack of reading and writing capabilities and knowledge on the subject to understand certain terminology. Survey research strategy predominantly serves the quantitative research which is in interest of understanding relationships between variables (Punch, 2003), therefore, not much of a use in understanding the nature of variables and describing them. A detailed discussion of how to conduct surveys is presented later in this chapter (see topic 4.6.1.).

4.6.3 Action Research

The nature of the action research has attempted for many years to bring together academia and industry as well as rigour and relevance into research (Denzin and Lincoln, 2011). Unless like in other research strategies scholars describe about action research standing close to the generic idea of research rather than a theoretical stance because of its very nature of practicality. However, action research is different from traditional research from what is studied (what researcher practice and claims to know about), why it is studied (to make personal/social situational improvements comparative to explaining or testing in traditional research) and where the researcher is in the research (practitioner-researcher is part of the field compared to researcher is an outsider, separate from the observed in traditional research) (McNiff, 2009). The purpose of action research is to provide means to carry out a systematic enquiry, create an appropriate method to achieve a goal and evaluate its effectiveness (Stringer, 2007), and as a result to provide practical knowledge for everyday life. Unit of analysis or subjects referred by other research strategies becomes participants in action research, who are actively and directly engage in the research (Stringer, 2007). Action research produces a valuable experience to those who are involved (Saunders, Lewis, and Thornhill, 2012) that is both the researcher and the participants gain propositional and/or experiential knowledge.

Figure 4.11 is a graphical representation of the process of action research. Kurt Lewin is the first to introduce the term action research along with the action research spiral (Williamson, 2018). Look, think, act routine is one of the many forms in which action research is visualised. Another form of description for this spiral of actions is plan, act, observe, reflect (Costello and Costello, 2011). The initial work of Lewin identified the steps as identify a problem, plan and take action (Williamson, 2018). However, all these different forms of descriptions underline the same principles of actions and their recurring nature.

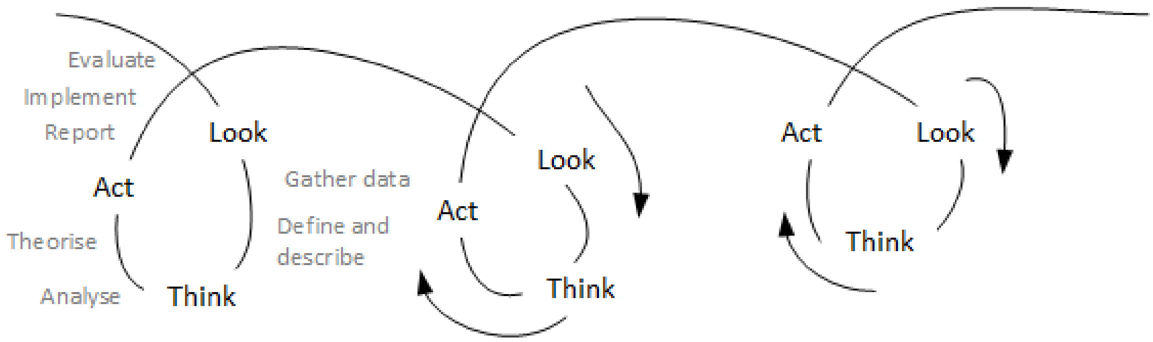

FIGURE 4.11: Action research spiral Adopted from Stringer (2007)

Unlike in experiments or surveys which are focused on generalisation of the research findings, the intention of action research is to generate localised solutions to the specific situation (Stringer, 2007). Therefore, these multiple cycles of look, think and act will take place within the same setting with the same people without considering for similar or negative cases but, changing the practice of the selected case with the focus of achieving improvement. This model uplifts the capacity of action research for both theory testing and generation (Williamson, 2018). However, its predominant focus is to find a local solution in one way or other.

Following Stringer, 2007 form of action research spiral, Look is the first step which involves finding information about the case therefore, collecting data. Similar to other predominantly qualitative research strategies such as case study, ethnography and grounded theory, data collection in action research is open to utilising interviews, focus groups, documents, literature, surveys and observations. Precisely observations under ethnographic foundations i.e. by allowing the observer to develop the story of those who are being observed rather observing specifics. The second step – Think represents the analysis of collected data. This includes general aspects of primarily qualitative analysis such as coding, categorising and explaining. Analysis will inform the third stage – Action. Sometimes it is the immediate actions for improvements and in other times provide direction for more exploration to understand the problem and theorising. The only special concern is, if it is a community-based action research, when analysing and reporting the research, the voice of the group should be emphasised rather the researcher's perspective (Stringer, 2007).

In the spiral of action research which repeats the key steps over time, the first few cycles are dedicated to understand the problem and later to focus on the improvements of practice (Stringer, 2007). This is a well suited research strategy especially because of pragmatic nature of the construction industry. However, the project-based nature of the work carried out limits the efficient and effective application of action research strategy due to the short time period and changing working groups. On the other hand, this can be helpful to implement BIM in a specific project from the client's perspective for instance if the improved handing over of the project is the expectation. Conversely, this will limit the study to a specific application of BIM rather understanding its long term capabilities in the facilities management stage. With this strategic level limitation along with other practical barriers such as full-time access to a project, time commitment and dependency on other practitioners as participants, action research is being rejected as an effective research strategy for the work in hand.

4.6.4 Archival Research

Archival research is predominantly a qualitative research method however, with the quantitative analysis tools used it is capable of delivering mixed method research (Hargittai, 2009). It is a strategy of answering research questions about the incidents which have already taken place (i.e. in the past) by the use of administrating records (Saunders, Lewis and Thornhill, 2012). Although, this provides a simple introduction to archival research and distinguishes it from other research strategies, it is necessary to highlight that archival research is not limited to historians but has a wider application in many social science fields such as communication and media, psychology and geography (Hargittai, 2009). Archival data is the celebrating feature of this strategy and Das, Jain, and Mishra, 2018 explain archival data as "data which are gathered and stored prior to the commencement of the research, intended for later use". Archival data are different from secondary data since secondary data were originally recorded as a part of day to day activities and later used to achieve the purpose of the research. When the same records are treated as archival data, they are "part of the reality being studied" (Saunders, Lewis and Thornhill, 2012). Since archives related to revealing the reality of BIM is limited in terms of existence and access, more importantly it is the aim of the study to provide a solution for the near future rather than understanding existing reality, and so this strategy is not considered in detail. However, a brief overview is presented to understand the alternative uses of the strategy. The alternative uses of this research strategy have been made possible as it is mainly focused on using archival data. There are other instances such as ethnography and case study research strategies that make use of archival data.

4.6.5 Case Study

In some ways it is possible to say that all social science research projects are case studies as there is a unit of analysis (individual or an event), and collection and analysis of data in relation to the unit of analysis. Case study research strategy is identified as an appropriate way to study construction management related research questions due to the project-based nature of activities that take place and multi organisation involvement (Knight and Ruddock, 2009). However, this does not mean that case studies are limited to particular types of studies, data collection or analysis methods but a research strategy just like experiments and ethnography; which can accommodate both qualitative and quantitative methods (Yin, 1981). Yin define case study as follows;

> *"An empirical inquiry that investigates a contemporary phenomenon (the "case") in depth and within its real-world context. Especially when the boundaries between phenomenon and context may not be clearly evident." (2014, p.16)*

This definition indicates two criteria about case studies; investigation of life as it is and a separation between subject of study and its context cannot be clearly defined. Therefore, this demands case studies to define the boundaries of the unit of study and conducting an intensive investigation within the defined boundaries (Denzin and Lincoln, 2011). Case studies are known for their capacity to study live experiences as they are making a clear distinction from experiment research strategy which harshly disconnects the unit of analysis from its context (Yin, 1981).

Case study is a strategy appropriate to answer "why" and "how" research questions (Yin, 2014). That is when the requirement of the research is to investigate the phenomena in depth (vertical) rather reaching a wider spread (horizontal). Depending how deep an investigation is needed to be conducted, case studies also have the flexibility to be used as explanatory, exploratory and descriptive investigations (Yin, 2014). When case study is the primary research strategy it is often used as an explanatory study of the phenomenon; looking at the causal mechanisms. Also, case studies are used at early stages of survey research in an exploratory or descriptive manner to have a clear understanding of the phenomenon before stepping into the main data collection process. The richness of this strategy is that within a case study the investigation could be qualitative, quantitative or mixed method (Yin, 1981; Denzin and Lincoln, 2011). Therefore, it could use multiple data collection tools such as interviews, observations and questionnaires. However, Yin (2014) discuss the problem of case study research strategy highlighting its lack of specific analytical tools.

Due to multiple possibilities of applications, design of a case study is a key step. As Yin (2014) points out, case study design helps to make a stronger case to defend its validity and reliability. Accordingly, he suggests two dimensions in designing case studies; holistic verses embedded and single case versus multiple case designs (Figure 4.12). As the name implies the difference between single and multiple case study designs is the number of cases used for data collection and analysis. The difference between holistic and embedded design is that multiple units of analysis are chosen to be studied within a single case under embedded design and holistic design considers the "global nature" of the case as the unit of analysis. In other words, natural characteristics and boundaries of the organisation are considered as the characteristics and limits of the unit of analysis under holistic design. The choice of holistic or embedded will be driven by the research question and the phenomenon under study.

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FIGURE 4.12: Case study designs (Source: COSMOS Corporation as cited in Yin (2014, p.50)

Considering the drawbacks, case studies are time consuming, added to the lack of generalisability in qualitative studies by limiting the investigation towards specific cases. Single case studies are only acceptable if the case study selected is "critical, revelatory (previously inaccessible), common, unusual or longitudinal" and multiple case studies are recommended in every other occasion (Yin, 2014). On the other hand, there is the risk of conducting a single case study as the case can be different from what it was thought to be at the beginning. It is required to be trained in order to perform a successful case study (Yin, 2014) which was not available during the time of study. More importantly, absence of access to a case study with a whole life use of BIM rejects the capability of this research strategy to achieve the research aim. Although it has many advantages in studying human behaviour, sense making and involvement with the technology studying a subtle topic such as value in an incomplete context will either be limited to the existing experiences or increase its vulnerability to deviate from the subject by going deep into psycho- social aspects.

4.6.6 Ethnography

The justification provided so far for the choices made related to the research methodology equally justify the suitability of ethnography as a credible research strategy to study the phenomena. The literal meaning of the word ethnography is "description of a people" and as a methodology it is looking at societies, community groups conducting a study on a group of people rather individuals (Angrosino, 2007). However, the work in hand is focused on the use of BIM to a particular discipline (facilities management) rather its application for the entire project team as a single community. On the other hand, considering a wider population of the discipline rather than a single community avoids the need for cultural concerns therefore, this research strategy is at disadvantage in fulfilling research aim from the fundamental level. Along with this comes other supportive facts for rejection such as long-time frame in-use stage, nature of use of BIM in FM, etc. However, as a much appropriate research strategy to study human values and how people make meaning, a brief discussion is carried out to be informed about the missed opportunity. This is help make use of the ethnographic principles where appropriate.

As mentioned above "ethnography" is referred to as a methodology of fieldwork as well as the output of such work (written description). The interest of this research is in ethnography as a methodology therefore, further discussions are aimed at discovering this as a method. Silverman, 2011 introduces ethnography as a research strategy with a great history recognised under qualitative methods to study cultures and people. It is a strategy based on observation, where in contrast surveys and interview strategies are rooted on asking questions and listening. Not that ethnography is not involved with listening to participants, asking questions or reading documents relevant to the study but along with all that, the uniqueness of ethnography as a research strategy lies in "active role of observation". Observations, interviews and archival research summarise all the data collection possibilities under ethnography (Angrosino, 2007). Although, these are separate forms of qualitative enquiry; their uniqueness when applied under ethnographic research strategy is that the interactions are made in the context in which they occur (Schensul and LeCompte, 2012). Among these forms of qualitative inquiries, observation is treated as the primary source. There are two types of observation methods based on involvement of the inquirer as a participant or observer. These types are discussed later under data collection methods (see topic 4.6.1). Then there is non-participant ethnography which does not involve field observations such as participants writing or recording their own autobiographies (Angrosino, 2007).

4.6.7 Grounded Theory

Grounded Theory (GT) is a method of systematic development of theory from rigorous data acquiring and analysis (Glaser, 1998). It is a guided process to generate or discover a general explanation shaped by the participants' view on the action, process or an interaction (Creswell, 2013). GT was introduced in the 1960's by Barney Glaser and Anselm Strauss the founders of Grounded Theory, with the studies they published in 1965 – Awareness of Dying, 1967 – The Discovery of Grounded Theory and in 1968 – Time for Dying. However, the birth of GT is commonly identified through The Discovery of Grounded Theory (1967). In this methodological monograph which Glaser and Strauss, 1967 explain the methodology of generating theory under an inductive approach with an emphasis on a theory free start. This theory free start has been challenged later by Strauss and Corbin, 1998 arguing that it is impossible for one to be completely theory free. However, both Strauss and Corbin, 1998 and Glaser and Strauss, 1967 were referring to a similar concept i.e. entering the data collection and analysis without any pre-established assumptions or hypothesis. On a different note, Charmaz, 2006 promotes a continuous acquaintance with literature and pre-established theory to avoid generating a theory which already exists. Although there is a valid point, Charmaz's approach is exposed to a greater risk of seeing what the researcher expects to see rather than what data is communicating. Among the different versions of GT introduced by different authors, a controlled data collection through theoretical sampling and constant comparative method for analysis remained constant. This is done to remain under the GT foundation which allows us to convert experience into knowledge and summarise the essence of it into a theory so that knowledge could be transferred to practice (Turner, 2014).

The second key variation in Grounded Theory is the approach taken; inductive or abductive. Due to theory free start, deductive inference logically falls off the discussion. To be precise, the intention of Glaser and Strauss in introducing GT is to take sociology beyond "theory verification" (Bruscaglioni, 2016). However, being completely theory free is challenged by later versions of GT (Reichertz, 2007). GT is frequently explained with inductive inference although there are different arguments on the logic of inference in GT. As mostly known, GT is applied in empirical research under an inductive approach (Engward, 2013) taking after Glaser and Struss while some bring evidence for more effective use of GT when taken an abduction approach (Reichertz, 2007; Timmermans and Tavory, 2012; Bruscaglioni, 2016; Rahmani and Leifels, 2018). This has become possible because when Glaser and Strauss introduced GT under inductive reasoning, the main reason was to contrast with deductive reasoning (theory verification) which was dominant at the time (Bruscaglioni, 2016) rather than emphasising inductive as the logical reasoning behind GT (Bryant, 2017). Later versions of GT by Strauss and Corbin hold a strong position on the application of GT under abductive inference without any mention of the logical reasoning but taking into account the role of theory in theory development (Reichertz, 2007).

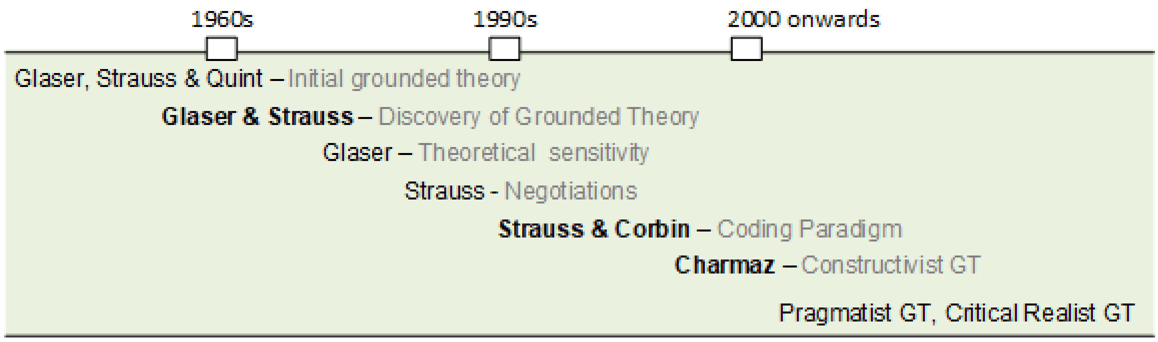

FIGURE 4.13: Canonical basis of Grounded Theory (adopted from Bryant (2017))

Emerging from Glaser and Strauss's GT, a few others contributed by exploring the research strategy under different philosophical views (Figure 4.13). Even Glaser and Strauss took different views on classical GT over time but, only by making this research strategy available to a wider audience. How different eras have contributed to GT has symbolised the ontological and epistemological differences in those societies at the time, and the strength of GT to reflect and represent the changing world (Hallberg, 2006).

Strauss and Corbin (1998) introduced what is known as their own version of GT while making few changes to initial principles introduced by the co-founders. All these versions of GT follow the fundamentals of generating theory by comparative analysis and theoretical sampling. However, each version discusses the constant comparative analysis in detail taking different paths as it wasn't comprehensive in the first publication in which Glaser and Strauss introduced GT. These differences are discussed later under data analysis techniques (see topic 4.6.3). However, this thesis has only looked into a brief overview of these differences as detailed comparison of different versions of GT is already available in the current knowledge pool (Heath and Cowley, 2004; Bryant, 2017; Kelle, 2007).

GT helps researchers to perform the intellectual task of coding and developing/re-developing theories by repeated movement between data collection, coding and memo writing (Reichertz, 2007). The key feature in Grounded Theory methodology is the way that the data collection and analysis is conducted. That is the use of theoretical sampling and constant comparative analysis which will be discussed later in this chapter (see topic 5.6). Grounded theory requires the use of an initial sampling strategy in order to support the use of theoretical sampling. The initial sampling strategy will provide the starting point while theoretical sampling will show where to go from there (Charmaz, 2006). However, the researcher cannot decide the sample of the research at the planning stage (Dey, 2003) like in other research strategies (e.g. Survey, Case Study). Although they might find this inconvenient and uncertain, following the process is vital for discovery of theory grounded in data.

Literature suggests GT as a research strategy supporting qualitative research methods (Coyne, 1997; Strauss and Corbin, 1998; Engward, 2013). It has even been identified as the most influential strategy of enquiry in qualitative research (Denzin and Lincoln, 2011, p.109). However, Grounded Theory is a self-standing research strategy which has the capability of dealing with both qualitative and quantitative data (Glaser, 1998). Therefore, it isn't limited to one method and allows using mixed methods when appropriate. However, it is important that theorizing is the driver of the methodological choice (Strauss and Corbin, 1998). Meaning that, application of both qualitative and quantitative methods under grounded theory does not make it superior to a pure qualitative method when both choices are made with the aim of supporting the emerging theory (Glaser and Strauss, 1967). Although GT does not reject quantitative methods, it stands in favour of qualitative methods because of their capacity for exploration and conceptualisation (Dey, 2003). Therefore, this has been recognised as a limitation of GT (Seale, 1999).

It is noticed that the definition of Grounded Theory - systematic generation of theory from data remains the same although GT has evolved over the years with many influences (Glaser, 1998). This emphasises that theory generation is paramount however, often mislead among researchers with the question of what it is meant by "theory". It is possible to find many definitions to explain the term "theory" yet, the goal of GT is to develop an explanation or understanding of the subject matter (Creswell, 2013). This was a commonly raised question among researchers interested in practising GT and Glaser (1998) answers this question by stressing that theory is not findings but the statement of relationship among conceptual hypotheses.

Under a general notion Saunders, Lewis and Thornhill (2012) talk about three types of theory a research can generate (Figure 4.14). According to them, grand theories have a high generalisability and change the way of current thinking. These are often the output of natural science research (e.g.. Newton's theory of gravity). Middle range theories are useful theories to understand human activities however, they are not strong as grand theories to change the way of thinking. Substantive theories more likely are the outputs of management research. They explain a situation bound by time, setting, population and the addressed problem.

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FIGURE 4.14: Types of theories (Source: Saunders, Lewis and Thornhill, (2012, p.50))

In terms of theory generation under GT, Glaser and Strauss (1967) talk about forming substantive and/or formal theory as a result of constant comparative analysis. Staying in line with the standard definition for substantial theory Glaser and Strauss acknowledge that following GT will enable a researcher to discover a substantive theory specific to an area of study such as "how doctors and nurses give medical attention to dying patients according to the patient's social value" and extending this into a formal theory by omitting substantive phrases. Therefore the formal theory would be "how professional services are distributed according to social value of clients" (1967,p.80).

Both of these outputs of GT (substantive and formal theory) are identified as middle range theories (Glaser and Strauss, 1967, p.32). However, in this thesis to distinguish between the two outputs, only formal theory is referred to as a middle range theory. Although, it is possible to generate both substantive and formal theories within a single study it is advised to have a key focus because the way to reach each is different (Glaser and Strauss, 1967). Therefore, this thesis brings both substantive and formal theory with the key focus on discovering a substantive theory.

After 50 years since introduction of Grounded Theory, successful application of this research strategy can be seen among different research communities such as psychology, sociology and healthcare (Chiovitti and Piran, 2003; Jane, Ann, and Karen, 2006) and even an increasing trend is seen in the construction sector (Macpherson, Kelly, and Webb, 1993; Loosemore, 1999; Rahmani and Leifels, 2018)(Macpherson, Kelly and Webb, 1993; Loosemore, 1999; Rahmani and Leifels, 2018). Rahmani and Leifels, 2018 specially make a case for appropriateness of GT for construction management research when taking an abductive approach. Their study supports the argument to move from inductive to abductive reasoning however, under a pragmatic philosophical view. Conducting GT with a critical realist view is comparatively new in the AEC/FM research nevertheless its fruitful application is found in other social science disciplines (Danermark, 2002; Oliver, 2012) supporting the methodological validity and appropriateness in conducting GT in a critical realist perspective. Moreover, well defended doctoral research conducted in value in the construction industry (Mills, 2013) acts as evidence for the richness of accompanying grounded theory taking an abductive approach under the critical realist view and defends the methodological choice made for the subject under study.

GT is not everyone's strength. It demands for creativity, ability to abstract, sensitivity to words and action and devotion to work process (Strauss and Corbin, 1998). When one gets to the end of the process of GT one realises the depth and beauty of this statement by Strauss and Corbin. The most commonly identified challenge in GT is that the investigator needs to distance him/herself from his/her own theoretical ideas so as to allow a substantive theory to emerge from the data (Creswell, 2013). Glaser (1998) constantly emphasises Trust is paramount because, there is always the chance of misinterpretation by forcing ideas into data rather than identifying the hypothesis grounded in data. In other words, GT works effectively when the investigator does not hold any strong beliefs or pre-judgements about the subject and is open to all possibilities. Since the previous experience of the researcher is based outside the UK and the research is not bound for an organisational agenda (i.e. financial or employment), the common biases that come along with GT could be easily overcome and the maximum benefit Grounded Theory research strategy could be gained in given circumstances. However, this theory-neutral feature of GT has often been challenged as a weakness (Bryman, 2016). Is it possible to be theory free and even so, it will hold the researcher till the very late stage to discover existing theories especially making a difficult situation for research bids. More importantly the risk of reaching a theory as a result.

Along with its strengths and weaknesses, GT as a research strategy is acclaimed for investigating difficulties or situations which people must adapt to (Corbin, 2008) making a prominent case for the phenomenon under study, which is adopting building information modelling; a system, which is new and challenging to the majority of construction industry professionals but mandatory to adopt, makes a perfect case to be studied under GT.

In summary, GT is the most natural way of doing true research, which is knowledge creation. As a research strategy it has closely observed the natural curiosity and thirst for knowledge by the nature of human beings and how they go forth fulfilling these desires as intellectuals. Putting together the key strategies employed on this journey creates the Grounded Theory with its tools of theoretical sampling and constant comparative analysis.

4.7 Research Techniques

Research techniques deal with the pragmatic side of the research and refer to the tools that can be used to capture and make sense of data. Therefore, this section includes data collection and analysis tools as well as sampling techniques for qualitative and quantitative research. There is a good choice of research techniques available for both data collection and data analysis to be selected based on their suitability for the area of study. The free choice of research techniques is one pragmatic occasion to understand the individual's ontological and epistemological position (Mason, 1996). Which means, if one is allowed to freely select research techniques without being restricted to any formal logical deduction procedure, it will give a glimpse of personal philosophical assumptions. Philosophical underpinnings of the choice on research techniques can be recognised as an enabler as well as a constraint (Mason, 1996).

This section may be found to be a repetition of the previous section since most of the research strategies are grounded in a unique data collection tool therefore, previously discussed methods have been kept short. Research techniques - data collection, analysis and sampling techniques can be categorised under qualitative and quantitative methods where some are unique to one type of method while some can be used between both types of methods with some alterations. Most of the qualitative research techniques were introduced for natural science research and later adopted in social science research to prove the possibility of making a scientific enquiry about the social world. As this research is in interest of identifying individual response to information technology systems, further discussions on research techniques are focused on commonly used social science data collection and data analysis tools. Qualitative research techniques have the capability to distinguish the difference between the object of study in natural science and social science while respecting the social objects' (people) complex nature of sense making as well as absorbing meaning from social structures. A number of data collection tools, sampling techniques and analysis tools are discussed below giving priority to techniques suitable for qualitative research as this study is conducted as a multi-method qualitative research project. The research has taken a multi-method research approach by focussing on the specific goals and questions which emerged at given points of time in the research spiral (Morgan, 1993).

4.7.1 Data Collection

Research data are factual material that can be in the form of numbers, words, images, etc. and can generate during the research or validate the original research. Although there are many forms of data, in some way all data are qualitative as it is humans who convert their raw experiences into words or numbers (Miles, 1994). Qualitative data can appear as text, still or moving images (Miles, Huberman, and Saldana, 2013) or basically in any form of human communication – written, video, audio, behaviour, symbolism or cultural artefact (Gibbs, 2007b). However, further discussions will focus on language in the form of extended text. The words (data) in qualitative research known to be acquired by asking, watching, or examining (Miles, 1994). Therefore, data collection tools are required to capture the necessary data in the required form. Interview protocols, focus group guidelines, field notes, questionnaires, experiment designs are some of the commonly used data collection tools. Each tool needs to be used in a specific set-up (i.e. for example; interview protocol in the form of a conversation) to make sense. Each of these elements has an impact on the richness of the data collected therefore the researcher needs to carefully select the appropriate technique considering practicalities and suitability.

Qualitative methods are known for their capability of exploring and concept developing while quantitative methods are limited to pre-conceptualised subject matters (Dey, 1993). Due to lack of conceptualisation related to information systems in facilities management this research is in search of data collection methods in support of concept development therefore qualitative data collection methods are given priority above others.

■ **Interviews**

Interviews are described as conversations with a "structure and purpose" (Brinkmann and Kvale, 2015). It is the most commonly used data collection tool in qualitative research and there are a few different types of interviews such as structured, semi structured, unstructured which are different in their structure (Brinkmann, 2013) and other interviews which are different in their purpose (i.e. journalistic interviews, legal integration, research interviews) (Patton, 2015) and in-depth or exploratory to prepare the way ahead for a large survey. It also can be conducted under a phenomenological position looking at experiences or more of a discourse position with the interest in the use of language (Brinkmann, 2013). The primary purpose of interviews is to allow research on the things which cannot be observed or things which will not make sense through mere observation (Patton, 2015). This thesis would look at interviews as a technique to gather experiences specifically in terms of the use of BIM in FM. It will allow us to reveal how FMs make value out of BIM through studying their perspectives. Interviews as a data collection tool function under the assumption that human perspectives are meaningful, knowable and can be made explicit (Patton, 2015).

Interviews can be used to gather both qualitative and quantitative data and conducting interviews varies in style based on different philosophical underpinnings. A positivist will break the social interaction into smaller components (i.e. age, gender, education) and study the phenomenon asking more precise questions to determine their relationships while maintaining the uniformity (Rubin and Rubin, 1995). These are the structured interviews used in surveys (Bryman, 2016). Using interviews in this manner avoids the opportunity to see complex social interactions which are time and context dependent (Rubin and Rubin, 1995). However, either qualitative or quantitative what makes an interview are the truly open-ended questions (Patton, 2015). With the nature of the study, which includes a complex social interaction among many parties in the construction supply chain supporting the development of BIM and client's side as its users, further discussions are presented on qualitative interviews.

Choosing interviews as a data collection technique in qualitative research has a number of advantages such as flexibility to adopt according to the situation, high response rate compared to written response, opportunity to explain the questions, probes to get more details about an answer, making clarification on the spot about the researcher's understanding of the interviewee's response, confirmation through repeating the response, prompts to encourage answers referring to examples, make connections with previous answers to check the validity and ability to see beyond what is being said (Miller and Brewer, 2003). In qualitative research, interviews are used to understand the world as experienced by its subjects before bringing in the scientific accounts (Brinkmann and Kvale, 2015). Its natural formation as a data collection tool and flexibility to be employed under different research strategies have made interviews popular in qualitative research. For instance, people involved in day to day conversation naturally tend to share information during these casual conversations. However, it is necessary to bear in mind how natural this conversation is when one has a prepared list of questions when the other party does not. Therefore, the interviewer plays a key role in determining the quality of the interview data. It is the interviewer's responsibility to make the interviewee comfortable, ask questions in a way that the interviewee will be open to share and to be conscious that interviewing also involves "two-way observation" (Patton, 2015). The interviewee is also observing the researcher and possibly mirroring the action while the researcher is observing while listening.

However, with the familiarity of every day interviews such as media or job interviews one should not underestimate the uniqueness of research interviews as a data collection technique. Interviews are not suitable for all research, at least to use as the primary data source (Brinkmann and Kvale, 2015). For example, if the study is about predicting behaviour of a larger group such as general election voting, interviews are not practical to reach a large sample nor logical. Another example is studying individuals' interaction behaviour with the environment is much more suitable to study through fieldwork and observation rather using interviews (ibid). Reflexivity is another concern in interviews (Yin, 2014). That is the possibility of unconsciously being influenced by each other's world views during the conversation. Therefore, it is necessary not to impose the interviewers' views through questions. On the other hand, it isn't just talking with someone. It is important to give enough time and effort preparing for the interviews as much as conducting them (Brinkmann, 2013). Brinkmann and Kvale, 2015 presents three fundamental questions to be asked as a preparatory step for interviews;

- Why: *clarify the purpose of the study*
- What: *obtain background knowledge of the subject matter to be investigated*
- How: *become familiar with different theories and techniques of interviewing and data analysis*

Practically, it is possible to start a conversation without any such preparation and that is the mental picture that comes to one's mind with hearing the word interviews. However, it will not lead the way to rich data which is the paramount advantage of conducting interviews. Therefore, research interviews referred to in this thesis are conducted with a solid purpose and continuously upgrade with emerging themes. Interviews with a purpose could be done under three variations; (a) conversational interviews or unstructured interviews (b) standardised or structured interviews and (c) guided interviews or semi-structured interviews.

Patton, 2015 explains the three variations of interviews using the alternative instruments being used at each. Accordingly, conversational interviews follow a structure of natural conversation asking spontaneous questions related to the subject matter. To maintain the natural flow researcher might not even take notes on given responses but leave it till the end of conversation. When following this type of interview, the researcher is often unaware about whom to interview, who is more important, therefore, no predetermined set of questions will be used. However, this unstructured nature is not to be confused as unfocused.

The merit of this method is the flexibility to be spontaneous and deepen the conversation on a specific area when necessary. However, this method is problematic as it will take a greater amount of time to find conversations that took place with similar questions and these differences in questions asked will take a great effort in analysing the data as well.

Standardised or structured interviews will be conducted with the help of a fully specified interview instrument. This will require careful selection of words, for the questions to be easily understood as well as to communicate the right message. There are many advantages in this type of interview such as minimum variation among data, or being easy to compare among respondents or time frames. Apart from its many other benefits, the flexibility to use interviews within different research strategies highlights its richness as a data collection tool. For example, interviews can be used within case studies, ethnography, action research, archival research as well as in grounded theory. In terms of theory building, interviews are a well-accepted and verified data collection technique (Rubin and Rubin, 1995). On the other hand, it is a method known to gather individuals' perspectives regarding a phenomenon (Patton, 2015), concepts which aren't observable, or vulnerable to generate false understanding even if observed. Therefore, interviewing has been chosen as the primary data collection tool.

■ **Focus group**

Focus group (FG) is a rich data collection tool which has the capability of collecting data under realist as well as constructivist ontological and epistemological assumptions without being limited to any distinct paradigm (Barbour, 2014). However, often application of FG is found in qualitative research. Focus group can be the primary source of data collection or the supplementary source when used along with a separate primary data collection method such as survey or even in a mixed method research where one method is not superior to others (Morgan, 1997; Flick, 2014).

In basic terms focus groups are "collective conversation or a group interview" which could be directed or not, and large or small in numbers (Kamberelis and Dimitriadis, 2011). However, the focus group is a special type of group interview although the terms are often used interchangeably. In simple terms, focus group is a form of group interview but with certain characteristics which are unique to FG (Bryman, 2012).

- As the name emphasises, focus group discussions are conducted on a specific (focus) theme compared to interviews where a wide area is possible to be covered through different sections.

- Secondly, focus groups create a discussion between participants rather an interaction with the moderator (researcher). In contrast, group interviews' participants respond to the interviewer (researcher).

With this comes a key difference of focus groups compared to interviews. The researcher has less control over a focus group within the role of moderator; in contrast where he or she has more control as the interviewer in a one-to-one setting (Bryman, 2016). Frey and

Fontana, 1991 finds focus group as a type of group interview along with other types of group interviews such as brainstorming, nominal/Delphi interviews, natural field interviews and formal field interviews. They could be used for exploratory (understand setting and develop hypothesis), pre-test (test questionnaires or try ideas), triangulation or phenomenological (understand structure of complex relationships, meanings) purposes (ibid). Focus groups are often selected as a data collection method because of their unique interactive aspect (Flick, 2014, p.250). Their common applications are seen in marketing and political research and as the pre-test for a large survey (Baker, 1999).

There are number of concerns when designing a focus group. All concerns are formed around determining the participants and formulating the discussion guideline. Recruiting the participants involves thinking about sampling, composition of the group (homogeneous or mixed), number of participants per group. Focus group sampling is purposive rather representative focusing on avoiding bias rather than generalisation (Morgan, 1997). When selecting the participants, it is important to have a balance. Not to have a group of friends since there will be many uncovered areas which will slip through as they will remain implicit within the group (Flick, 2014, p.251). On the other hand, a comfortable environment is essential; participants will feel free to talk among a known group compared to a group of complete strangers (Morgan, 1993; Baker, 1999).

Morgan, 1997 gives a general idea for each aspect of focus group design concerns as a point of departure;

- Group composition of homogeneous strangers
- Relatively structured guideline with high moderator involvement
- 6 to 10 participants per group
- 3 to 5 groups per study

The reason that Morgan (1997) notes this rule of thumb is to clearly emphasise that this is not the standard way of doing focus groups but how it is done mostly. Also, it is important to understand that these guidelines are for when FG is used as a research strategy rather a data collection technique. In this thesis, FG is used as a data collection technique under Grounded Theory research strategy. Therefore, these suggestions are considered only when appropriate. In terms of formulating the discussion guideline it is recommended to clarify the concepts to discuss and keep the questions open-ended so the moderator can make improvising comments within the framework (Morgan, 1993). The questions should be general rather than imposing the researcher's view through questions (Bryman, 2016). The next concern is the role of the moderator. The involvement of the moderator should not be invasive and structured (Bryman, 2016). It should be in a way supporting to identify the participant's perspective towards the phenomenon and keeping them within the subject.

When conducting focus groups, it should have a beginning and end. As Bryman (2016) suggests the moderator should begin by introducing the group, purpose and format of the study, taking consent for recording the session, data protection and general ground instructions (emergency exits, lavatory, etc.). In the end, the moderator is expected to brief the overall discussion output, explain the use of gathered data and thank the participants. this will help to balance the formality of the discussion by also creating an informal environment for participants to speak freely (Flick, 2014).

Like any other, FG comes with its own strengths and weaknesses. Often it is a difficult task selecting a date, time and a venue suitable for multiple people and getting them there on time (Baker, 1999). Focus groups are bound to the usual weakness, in the qualitative research method, of subjectivity. However, it is also known to be less subjective compared to other qualitative methods with the role played by the researcher as a moderator makes less influence on the data. Comparing and sharing features in FG not only informs the researcher what are the participants' opinions on the phenomenon but also why they have that opinion (Morgan and Hoffman, 2018). It brings the opportunity to see how individuals collectively make meanings and also get exposed to other important concerns related to the topic (Bryman, 2016). This tool is also beneficial to gather more data within a short period of time.

In terms of this research, the focus group technique is used on two occasions. FG is known for its capability to bring interactions between parties with power differentials (Morgan, 1993). This feature of FG was taken as an advantage to generate the conversation between information users and information providers focused on information responsibility and BIM initiation on the first occasion. Secondly, FG is also a useful technique for getting participants' comments on results of a previous study (Flick, 2014). With this recommendation from literature, FG was used at the validation phase. Further, successful application of FG under Grounded theory research strategy to study BIM implications provides more evidence for the suitability of FG for the phenomenon under study (Liu, van Nederveen and Hertogh, 2017).

Crabtree et al. (1993) have written a detailed analysis on combining focus group and in-depth interviews. According to them in multimethod research, the combination of interviews and focus group is marked to cover the "breadth and depth" of the study. It brings a time and cost effective solution to gather rich data without limiting to redefined answers. For instance, using interviews will only require 8 to10 least or even 20 in some cases or 3 to 5 focus groups per study when it is the only method of data collection. All in all, the combination of interviews and focus groups created reliable, effective and efficient research.

■ Observations

Observations as a data collection tool is used in both naturalistic (i.e. under experiment research strategy such as clinical observations) and social constructivist settings. The interest of the thesis is regarding the use of observation in the social science setting. Observation is predominantly the data collection method of ethnographic research therefore, most of the descriptions, guidelines and techniques related to observations are written under ethnographic influence. Observation as a data collection technique is defined as an "act of perceiving" the observed surrounding, participants and their relationships through five senses by the researcher (Angrosino, 2007). Therefore, this involves both observation from eyes and participation to engage other senses.

Based on the method and extent of engagement, observation for data collection is carried out in different ways. Saunders, Lewis and Thornhill (2012) broadly categorise them as structured and participant observation. Claiming that participant observation is interested in qualitative data while structured observation gathers quantitative data, counting the actions, events or incidents taking place within the observed territory. Participant observation is the most common in anthropology and sociology research. It involves the researcher actively participating in the activities and becoming a member in the social group studied (Saunders, Lewis and Thornhill, 2012). Since not all social circumstances allow the researcher to be a complete participant in the group, there may be difficulties in access (e.g. time and resources for research to become a complete member) or ethical and legal issues (e.g. becoming a member of drug addicts) the spectrum of participant observation ranges from complete participation, participating as an observer where the researcher will be acknowledged as a member of the group and observing as a participant having limited involvement with the group (Angrosino, 2007).

Observations are a highly effective data collection technique in education and healthcare sectors. The reason for the successful application of observation in these sectors is the repetitive nature of the work and the work is carried out in a predefined limited space. For instance, a teacher will be teaching within a classroom and she will be teaching in school every day and it is basically the sample principle with a nurse working in her allocated ward. Observations are known for their suitability for studying phenomena in a fixed setting such as school, hospital or shopping mall, sequences of activities that are taking place in a specific setting and being particular for a sector of population (Angrosino, 2007). However, the situation in a facilities management department is quite different from any of the given examples. The tasks performed by facilities managers would be different from day to day and this could be done in separate places within the same building or even in different sites especially considering the nature of the LJMU estate department which is managing 3 different campus sites. On the other hand it is advised to work in teams utilising multiple observers to achieve validity (Angrosino, 2007). Making it more difficulty, the use of BIM or handover information is not a regular activity therefore, using observation as a primary data collection tool is identified to be inappropriate to study the given phenomena. However, advantage of principle was taken when and where appropriate during the site visits, interviews and focus group discussions.

■ **Questionnaire survey**

Surveys as a data collection tool can be designed in two ways - questionnaires or structured interviews. The difference of the two modes is the involvement of the researcher which is less of a concern. Questionnaires are often self-administered while interviews are face to face or over the phone. Structured interviews provide the opportunity to explain the questions to the participants when necessary and collect additional data such as gestures and postures which at times provides insights. This is also useful when the participants are of a low literacy level since questionnaire surveys require a certain level of literacy to self-report (Teddlie and Tashakkori, 2009). The significant element in both modes is the structured list of questions (Baker, 1999). However, the most common practice of surveys is carried out as questionnaire surveys hence, further discussions primarily refer to questionnaire surveys.

As previously discussed (See topic 4.3.1) the survey research strategy provides a detailed guidance on how to conduct a successful survey and this involves sample selection, preparation of survey guideline and making decisions on data analysis to produce an effective survey guideline. When considering questionnaire survey as a data collection method, the key focus will be on the survey guideline because self-administered questionnaires (guideline) can be used under other research strategies such as case study and action research. On the other hand, although survey as a research strategy was rejected as an appropriate method to understand the phenomenon under study; it is possible to use questionnaires for data collection under Grounded Theory when applicable.

However, due to the theory free beginning and lack of familiarity with BIM at the time, this technique was rejected at the start of the study to collect primary data. Although, it would have brought in the benefit of data triangulation by using questionnaire survey through validating qualitative findings through quantitative data and the opportunity to reach a wider sample; this was rejected at the validation phase due to the limitation in the questionnaire survey of providing a platform to receive critical and rich comments on an unfamiliar (novel) model. It was the main purpose of the validation phase to bring an opportunity to introduce BIM value model and receive both applausive and critical industry views.

■ **Experiment**

Laboratory experiments and field experiments are the two main types of experiment; as their names imply, laboratory experiments are conducted in controlled environments (laboratories) while field experiments are conducted in real-life settings (in the field) and mostly used in social science research (Bryman, 2016). What is common to both designs is the random allocation of independent variables. Apart from these two key types, quasi-experiment is another variation of experiments especially found in social science research. This is often referred to as a type of field experiment due to the lack of control over the experiment.

4.7.2 Data Sampling

Once the data collection technique is selected, the next question is to how many interviews or questionnaires to be collected. In practice, sampling, data collection and analysis supports the selection of each other. Although it is desirable to study everyone in the population which is identified as the census, it is not practical in all cases. Therefore, a representative and accessible sample from the population is selected to study in detail something greater than the sample itself (population). This will not only give the opportunity for the researcher to select whom to contact or where to look but also save money, time and provide a good response rate (Seale et al., 2004). The logic of sampling is to select a manageable sample from the population to study them to make a statement about the whole population (Punch, 2014). Stepping down from the population to a sample requires it to be representative so that the findings of the sample could be generalised to the population.

In terms of this research, it is to study a group of facilities managers to understand the needs of the wider population of facilities managers (i.e. outside North West or even UK). Therefore, representativeness stands at the centre of sampling (Baker, 1999) when generalisation is a key object of the research (Saunders, Lewis and Thornhill, 2012; Bryman, 2016). For example; if the research question is to identify whether the packaging of a particular product influences the purchase, the response of the sample will be generalised to the population. If 80% of the sample said “No” then it is statistically generalised that it is the answer of 80% of the population. However, if the research was aimed to understand a less developed area, for instance how packaging influences the purchase then the sample selection will be based on those who are aware of the function of packaging. As per to Baker (1999) in response of such, non-probability sample will contribute to accumulate hypothesis or theory which could be then generalise in a separate round. In contrast, Saunders, Lewis and Thornhill (2012) confirm the possibility to generalise in this manner but not statistically.

There are continuous debates for different forms of generalizability between qualitative and quantitative research (Seale et al., 2004, p.405). One such difference is the population that is considered in probability sampling (consequently quantitative research) are concrete (i.e. for example; UK military male pensioners [age 60+] to the date) while non-probability sampling is generalising for an abstract population (e.g. people no longer work) (Salkind, 2010). Nevertheless, whether the requirement of the research is to generalise or not, sampling is still necessary as it needs to select the unit of analysis, case, group of people to be studied (Saunders, Lewis and Thornhill, 2012) due to the time, cost and access constraints in studying the total population.

Samples are used in both natural and social science research as an accepted solution to time, finance and access limitations involved with research projects. However, the selected sample plays an important role in trustworthiness of the research findings therefore, logic of sampling needs to be considered. Often sampling is identified under general laws of statistics and probability however, sampling can be derived by alternative logics (Mason, 1996). Therefore, both probability and non-probability sampling techniques (Figure 4.15) are discussed below to understand the concept of sampling. The choice of sampling technique appropriate for a research project is primarily based on the objectives of the research and research strategy (Baker, 1999; Saunders, Lewis and Thornhill, 2012).

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FIGURE 4.15: Sampling techniques (Source: Saunders et al., 2012, p.261)

4.7.3 Probability Sampling

Probability sampling techniques are built on centuries of applied mathematics work and reasoning conducted under natural science and quantitative social science research (Neuman, 2010). As mentioned earlier, suitable sampling methods differ based on the study emphasising that neither probability nor non-probability sampling techniques are superior over each other. When generalising is a primary objective of the research it often follows a quantitative methodology as it is much easier to gather and analyse large numbers of quantitative data (numbers) rather than qualitative data (text, image, etc.). Although not often, probability sampling may be used in qualitative research, predominantly under interview research strategy when generalizability is a significant purpose of the research or when the research question does not suggest a specific group of people/unit of analysis (Bryman, 2012). In order to generalise the findings from a small portion of data (sample) compared to the size of population, representativeness of the sample stands for its validity. Such a representative sample could be derived by following precise procedures relying on mathematical probability and therefore, these techniques are identified as probability sampling (Neuman, 2010).

However, in order to achieve the accuracy, representativeness and mathematical assurance probability sampling techniques primarily depend on the sampling frame. Sampling frame is an empirical and concrete list of sampling elements, approximately close to the population (Neuman, 2010). Population is an abstract term, therefore it is necessary to define the specifics of the population considered in the research and that specific population is referred to as the target population. In order to define the target population, the research would need to identify the sampling element which is the unit of analysis. This could be an individual (e.g. Facilities Managers), organisation (i.e. higher education institutes, health care), social action (i.e. drug addicts, divorce), country, etc. Once the sampling element is identified then the geographical (e.g. northwest), temporal (e.g. projects starting Sept 2015 - Aug 2016) and any other (e.g. over 5 years' work experience) boundaries need to be specified in order to specify the target population.

Other than these kinds of self-defined sampling frames there are other sampling frames which one could use such as student society member register, voting register, telephone directories, professional memberships (e.g. BIFM, RICS). In summary, a sampling frame is a list of sampling elements that might not cover the entire target population but, provides a close estimate (Neuman, 2010). Sample will be representative as much as the sampling frame and in many cases especially in social science research a sampling frame cannot be established (Baker, 1999). Baker explains through an example of interviewing Disney World visitors for a few days as the sample of the population of Disney World visitors. Although, the visitors interviewed were part of the population there were not selected from the list of visitors because there is no such registry. Which is the same scenario with the Facilities Managers in the UK who intended to adopt BIM. With the Disney World example, even if the researcher had the chance to get the list from the travel agencies it would only be useful to make a quota sample which is a non-probability sampling technique. Apart from the generalisation not being a key objective, this is one of the key reasons for rejecting probability sampling and consequently quantitative methods for the work in hand.

However, once the sampling frame is drawn and the sample size is decided, the next step is to draw the sample out of the sampling frame. The sample size is to be decided considering the level of representativeness required, accepted marginal error, data analysis techniques to be used, expected response rate (Saunders, Lewis and Thornhill, 2012). There are few alternative techniques for selecting the required sample from the sampling frame and a brief introduction is given to each as none of these techniques is employed in this thesis. In a word, all probability sampling techniques are designed for each sampling element to have a "known probability of being selected into the sample" (Baker, 1999).

■ **Simple random sampling**

This technique is the base for all the other probability sampling techniques. It involves selecting a sample from the sample frame either using the random-number table or computer assisted programme to produce random numbers. It is advised to use random sampling without replacement (Neuman, 2010; Saunders, Lewis and Thornhill, 2012). That is when a sample element is selected once to keep it separate rather adding it back to the sampling frame. Simple random sampling is the best choice when the sampling frame is accurate and includes the entire population however, this might not be suitable if the population is geographically distributed as this means traveling long distance for data collection (Saunders, Lewis and Thornhill, 2012). If the sampling frame does not represent the entire population then it is necessary to repeat the sampling and data collection several times to get a sample distribution (Neuman, 2010). The larger the random sample is, the sample distribution will take a bell curve and middle point of the curve will be the parameter of the population (ibid).

■ **Systematic sampling**

Simple random sampling requires the sampling frame preferably to be equal to the population and/or consecutively number the sampling frame. Therefore, its use has been limited (Baker, 1999). Systematic sampling is similar to random sampling from selecting target population, sample frame to sample size other than the numbering the sample framework and selection of random samples. Systematic sampling will select the sample using sampling interval – n (Neuman, 2010). That is selecting the nth sampling element after a random start, till it reaches the required sampling size (Baker, 1999).

$$\text{Sampling Interval} = \frac{\text{total population}}{\text{actual sample size}}$$

FIGURE 4.16: Sampling interval formula

For example, if it is needed to get 300 individuals from 900 population then, 900/300 = 3. Which means every 3rd person from a random start. Random sampling and systematic sampling usually bring the same result however, this is more useful when the sampling elements in the sampling framework are organised in some sort of order (Neuman, 2010). For instance, if the list is made with client, architect and contractor of each project then, selecting every 3rd individual will result in selecting only the contractors.

■ **Stratified sampling**

In both the above techniques when a sample element is drawn it is independent. That is, if the selected sample element is a contractor, it will not inform the next selection to choose a client or an architect. Therefore, the sample will be somewhat different from the population. For example, if the population is 50 clients and 150 contractors but the sample of 20 may have 10 clients and 10 contractors. This technique is useful to reduce the normal sample variation when the characteristics of the population are known (Fowler, 2014) or an interested group of the population is relatively small (Neuman, 2010). Stratified sampling involves dividing the sampling framework into two or more groups (strata) according to the characteristics and selecting sample elements from each stratum to have a representative sample (Fowler, 2014) or even represent its proportion in the population (Baker, 1999; Neuman, 2010).

■ **Multi-stage cluster sampling**

As the name implies multistage sampling involves in sampling at different levels (making samples out of samples). It is the solution when there is no access or existence of a register of the population (Fowler, 2014). The most commonly used multistage sampling is multistage cluster sampling (Baker, 1999; Fowler, 2014). The same technique is sometimes identified under cluster sampling and multistage is one of the ways of doing cluster sampling (Teddlie and Tashakkori, 2009; Neuman, 2010). When a clear sampling frame (e.g. national list of all graduates) is not available this technique identifies naturally occurring groups in the population (e.g. list of universities) and creates a sample group (which is referred as "clusters" in sampling terminology) at the first stage (e.g. randomly selected list of universities). At the second stage, sample elements will be drawn from the clusters (e.g. graduate lists of randomly selected universities). Probability proportionate to size sampling method can be used to select a cluster when necessary (Baker, 1999; Neuman, 2010). Although this technique provides a solution for when sampling frames are unavailable, it still requires a register of sampling elements at the cluster level therefore, does not provide an appropriate solution for the work in hand.

4.7.4 Non-Probability Sampling

All sampling techniques that do not follow the principles of statistical probability fall under non-probability sampling (Bryman, 2016). Therefore, it includes a range of different alternatives. Qualitative researchers often prefer to name this category as purposeful sampling while quantitative researchers call it non-probability sampling (Patton, 2015). To preserve the logical structure of the thesis, this will be referred to as non-probability sampling from here onwards. Non-probability sampling is highly useful in management research often due to the absence of a sampling framework which is a key necessity in accommodating probability sampling (Saunders, Lewis and Thornhill, 2012). Even some research which uses probability sampling benefits from using non-probability sampling at early rounds of the study as a practical solution (Baker, 1999). On the other hand, what is statistically "bias" can become the intended focus of a qualitative research therefore a strength in terms of non-probability sampling (Patton, 2015). The logic of sampling in qualitative research is to "sample aspects/features of the social world" (Neuman, 2010). Accordingly, the purpose of sampling in qualitative research is to have a deeper understanding over the social aspects, and selection of the cases is based on how well they support in answering the research question rather about the representativeness (ibid).

The rationale for applying a type of non-probability sampling is that it's the best sampling technique for the considered study due to the absence of a sampling framework (Baker, 1999) or a choice of a non-probability sampling technique being dominated by the research question, objectives and research strategy (Saunders, Lewis and Thornhill, 2012). As an explanatory study derived from a research question searching for mechanisms causing slow adoption of BIM, which is a very much an under developed area at the time of study, it makes a favourable case for non-probability sampling. Moreover, having selected the Grounded Theory (GT) research method further justifies the suitability of non-probability sampling by accommodating theoretical sampling as a key element of GT. Unlike in quantitative research, sampling strategy influences the overall validity of qualitative research and this is measured through assessing whether sampling strategy stays in line with the research purpose and question under study (Punch, 2014, p.188). Patton (2015) presents an exhaustive list (40) of non-probability sampling strategies (p.266-272). Commonly used non-probability sampling techniques are considered below.

■ Convenience sampling

Convenience sampling is selecting a sample available to the researcher and capable of answers of interest to the study. The most common example is the academics who are researching on teaching or learning practices using their students or colleagues in the institute as their sample merely because they are readily available. A sample selected purely based on convenience sampling (i.e. selecting an easily accessible group of people) is inclined to bias as the researcher has no control over the sample (Saunders, Lewis and Thornhill, 2012). Some of the acceptable uses of convenience sampling are to pilot research instruments and when the chance presented through convenience sampling is "too good to miss" (Bryman, 2016). On the other hand Saunders, Lewis and Thornhill (2012) argue that often when management research defend the use of convenience sampling by including the research aim into the selection criteria which ultimately meet the criteria of purposive sampling. Convenience sampling is recommended to be used as an open sampling method to bring the initial data about the overall process/situation under study (Morse, 2007) yet with a conscious selection. Therefore, the convenience sampling referred to in this research includes the purposeful selection along with the ease of access. In truth, this is what is happening even with a sophisticated sampling plan in which sampling criteria are made to fit the purpose and convenience (time, cost, energy, accessibility). However, the key problem in convenience sampling is that the findings cannot be generalised as it is difficult to judge whether the population selected sample is representative (Bryman, 2016).

In terms of the work in hand, convenience sampling is aimed towards the estate department of Liverpool John Moores University due to easy access and influence. However, the bias involved in using this sample as the main sampling technique is apprehended; such as incapability of a single unit to represent 162 higher educational institutes in UK (Universities-UK, 2017) and no experience in BIM practices even to conduct an in-depth case study. Although there was a major project to be executed under BIM, studying its application in facilities management was not feasible within the time framework of this research. On the other hand considering convenience sampling, it is often advised to use an alternative sampling method if at all possible (Baker, 1999; Saunders, Lewis, and Thornhill, 2012; Bryman, 2016). This is to avoid the greater risk in using a convenience sample as the primary or sole data source (Patton, 2015). Agreeing with Morse's explanation, the starting point provided by the convenience sampling was employed along with purposive and theoretical sampling.

■ **Purposive sampling**

This sampling method could be referred to as purposive (Saunders, Lewis and Thornhill, 2012; Bryman, 2016) or purposeful sampling (Morse, 2010; Creswell, 2013) as two different names to identify the same technique (Patton, 2015). To maintain the uniformity, the name used by Saunders is taken to refer to the technique in this thesis. Purposive sampling involves selecting a sample best fit with the research question and objectives by making a subjective judgement by the researcher (Saunders, Lewis and Thornhill, 2012). What is referred to by the subjective judgement is the enquirer's cognitive process of defining the sample in terms of unit of analysis and number of units, based on its capacity to inform the research question, rather than based on a statistic logic (Creswell, 2013). Commonly used sampling techniques in qualitative research (i.e. snowball and theoretical sampling) are often identified under the umbrella term of purposive sampling (Bryman, 2012, p.418) since all of these sampling techniques have the common element of purposeful selection of the unit of analysis.

Although grounded theory research strategy has its own sampling technique, in order to accommodate theoretical sampling it requires an initial sampling strategy which can bring an effective starting point to theoretical sampling. Therefore, this initial sampling strategy should be capable of making an informed decision about the sampling criteria on people, cases, sites or any other required unit of analysis to cover the research question and objectives (Charmaz, 2006). Purposive sampling is being identified as an effective sampling method to lead on to theoretical sampling under GT (Strauss and Corbin, 1998; Morse, 2010). Therefore, this sampling technique has been employed to move forward after the convenience sampling.

Doing purposive sampling under GT involves selecting people, sites or projects purposefully to maximise variations of the emerging categories (Morse, 2010). Such as if the participant (client) was talking about someone (contractor) or on behalf of someone (maintenance technician) purposive sampling provides the flexibility to cover these variations. Since theoretical sensitivity is often developed with time, purposive sampling can support in providing data till the enquirer is aware of the emerging theory (Strauss and Corbin, 1998).

■ Theoretical sampling

Theoretical sampling is a technique function under the influence of emerging theory while directing the emergence of the theory (Glaser, 1998). This technique is being discussed by authors dedicated to Grounded Theory as well as other general social scientists. For instance the attempt made by Bryman (2012) to explain theoretical sampling could be misleading for a novice researcher as its application does not follow the logic of grounded theory. Therefore, learning about theoretical sampling from its founders or Grounded Theory specialists is noted to be suitable. Glaser and Strauss (1967) explain theoretical sampling as follows;

> *"Theoretical sampling is the process of data collection for generating theory whereby the analyst jointly collects, codes and analyses data and decides what data to collect next and where to find them in order to develop the theory as it emerges" (p.45)*

The above quotation from Glaser and Strauss explains everything about theoretical sampling in a simple sentence. The purpose of theoretical sampling is the saturation of categories (Glaser, 1998). That is to achieve conceptual and theoretical development and does not aim at bringing a representative sample or statistical generalisability (Charmaz, 2006) as required by any probability sampling technique. Moreover, theoretical sampling does not even attempt to be representative like other non-probability sampling techniques (e.g. Quota sampling). It is a sampling technique to develop emerging categories from the first round of data analysis. Therefore it requires another mechanism to guide the initial point of departure for data collection from the research question (Charmaz, 2006). Corbin and Strauss (2008) name this as "open sampling" as it is the sampling at the open coding stage. Purposive and convenience sampling are some of the recommend sampling techniques suitable to lay the path for theoretical sampling (ibid). Theoretical sensitivity is another important ingredient needed for theoretical sampling to work. It involves pausing and thinking through the emerging theory rather than rigorous sample selection.

Theoretical sampling does not look for similar cases, negative cases or a response set, it considers all as data and data collection stops when theoretical completeness is achieved – theoretical saturation (Glaser, 1998). This does not mean that theoretical sampling ignores the similar or negative cases but does not hunt for them, yet integrate them by both emphasising and ignoring outliers (Morse, 2007). In support of this, the adequacy of the theoretical sample is judged on how "widely and diversely" the cases are chosen (Glaser and Strauss, 1967). Usually when other sampling techniques are promoted to gather as much as data possible, theoretical sampling does not focus on the fullest sample (highest number) to support a category, but collects data on a category to develop its "properties and hypotheses" (ibid).

Theoretical sampling is not only guiding where to go next but guides the questions to focus on emerging themes to achieve "theoretical completeness" therefore, demands a constant change in interview questions (Glaser, 1998, pp.157-158). Also, it is not in favour of any particular type of data or data collection tool therefore, is open to use unlimited data collection tools to be used in any way to collect any form of data in a single study with the sole purpose of achieving theoretical saturation (Glaser and Strauss, 1967). As a research following Grounded Theory research strategy; theoretical sampling has been foundation sampling technique guided the other sampling techniques such as convenience and snowball within the research.

■ **Snowball sampling**

Snowball sampling and Self-selection sampling are the two types of volunteer sampling introduce by Saunders, Lewis and Thornhill (2012). As they explain, seIf-selection sampling involves publicising the research using suitable media and collecting data from those who respond to the advertisement. This technique is rarely discussed by other qualitative research text books. In snowball sampling the researcher selects and contacts a small group of subjects fulfilling the requirements of the sample of the studied population and uses them to find further contacts (Bryman, 2016). This strategy is used when the members of the population studied are difficult to identify (Saunders, Lewis and Thornhill, 2012) or when there is no sampling framework or even if one were created it would be inaccurate (Bryman, 2016). Snowball sampling will continue until no more new contacts are made and/or when the sample at hand is large enough to manage (Saunders, Lewis and Thornhill, 2012). This method of sampling is identified to be more useful even above probability sampling when the research is focused on relationships between people as it opens the possibility to trace connections (Bryman, 2016). On the other hand it has the risk of reaching a homogeneous sample (Saunders, Lewis and Thornhill, 2012).

Overall, this works well along with the purposive (Morse, 2007) and theoretical sampling especially in the given area of study and circumstances where the researcher has limited access to the industry practitioners as an international student. Therefore, expanding the small group of contacts through snowballing, under directions of theoretical sampling, makes a possible case to grasp the advantages of the method while keeping the risks under control. On the other hand, when the purpose of the theoretical sampling is to further develop the emerging concepts, looking further into more similar samples is a requirement to defend the validity of the research findings rather than a weakness in the sampling strategy.

■ **Quota sampling**

Quota sampling is a non-probability sampling having similar characteristics to stratified sampling (which is a kind of probability sampling) often used in social research with structured interviews and questionnaire surveys (Saunders, Lewis and Thornhill, 2012). This method involves creating a matrix of desired characteristics of the subgroups of a population and allocating a quota to each subgroup relative to the proportions represented in the population (Saunders, Lewis and Thornhill, 2012). Baker (1999) provides an example regarding the sample selection for the study looking at preference for a trimester system in a university. The opinions of the change of semester system will vary based on level of the student, school, whether they work or not. Therefore, the quota should be allocated considering all these characteristics and the sample selected based on individuals fulfilling these characteristics to fill the quota rather through a sample framework. Due to the multidisciplinary role played by facilities managers and the wide range of types of buildings, procurement methods, projects, etc. quota sampling is a useful sampling method in some aspects. However, this cannot be used for the primary data collection since grounded theory methodology requires us to conduct the data analysis in parallel to data collection and adjust the sample according to emerging categories. Secondly, apart from the uncertainty of the population size in general, the quota sampling method being restricted to surveys and structured interviews avoids the possibility of getting a full appreciation and criticism on the final research output even if used at the validation phase. On the other hand, this sampling strategy limits the benefits of usual non-probability sampling strategies even at the same expense of generalizability which is a common advantage in probability sampling.

4.7.5 Data Analysis

There are a number of data analysis techniques available for empirical research and they can be broadly categorised into quantitative and qualitative techniques. The choice of the analysis technique is influenced by several factors. The main consideration is the type of data at hand to be analysed. Quantitative analysis techniques are characterised in favour of numerical data while qualitative analysis techniques are for text, images and recordings. Having selected in-depth interviews and focus groups as data collection techniques, qualitative analysis techniques are in favour as they are the most commonly used analysis methods in management research. It is also possible to use inferential analysis techniques such as quantitative content analysis to analyse data gathered through interviews and focus groups however, this requires a careful selection of a sample under probability sampling (Crabtree et al., 1993). Unless otherwise, using statistical analysis methods on a set of data collected under purposeful sampling techniques will lead to an output with a great risk (ibid). Both qualitative and quantitative analysis tools are introduced below, giving priority to qualitative tools.

Qualitative data analysis

Qualitative (QUAL) analysis consists of interpreting, describing and analysing (Wolcott, 1994). Some QUAL analysis techniques may rely on one aspect more than others, however all qualitative analysis techniques are built on the above three aspects. A basic qualitative analysis commences with a set of data in the form of text or any form of human communication and it starts in the field (Gibbs, 2007a). The purpose of qualitative data analysis is to break this text into smaller components to describe what the data is referring to, and to identify the concepts and their relationships (Dey, 1993). For this purpose, coding is an accepted initial data analysis stage in qualitative analysis (Berg and Lune, 2007). Qualitative coding involves defining the meaning of data and tagging them with an abstract name (Charmaz, 2006). A wide range of tools have been introduced for this purpose such as content analysis, thematic analysis (Vaismoradi, Turunen, and Bondas, 2013), pattern coding, cross case analysis (Yin, 2014), open, axial and selective coding (Corbin and Strauss, 2008).

The selection of the analysis technique is as important as any other step in qualitative research. The choice of analysis technique in qualitative research should be driven by the research question and the purpose of data collection (Morgan, 1997). This requires the researcher to be familiar with multiple analysis methods to make the right choice to achieve the research aim. Therefore, a selection of commonly used qualitative analysis techniques in management research are discussed below. Having analysed the merits and demerits of each method, the constant comparison method was adopted as the primary data analysis technique of this investigation as it takes a step by step coding process to identify the emerging theories while supporting the philosophical underpinnings of the research.

■ **Content Analysis**

Content analysis is a common analysis technique for both qualitative and quantitative research. Qualitative content analysis is focused on answering "why" questions to examine perceptions and quantitative content analysis is helpful to study "what" questions (Given, 2008). In common, both qualitative and quantitative content analysis is used to analyse text. In quantitative content analysis; text is coded into predefined categories and uses statistics to explain the phenomenon. Quantitative content analysis is also identified as "quantitative analysis of qualitative data" claiming both techniques are majoring as a qualitative analysis method (Hsiu-Fang, 2005). On the other hand, content analysis can be done with an inductive or deductive approach towards data. In the deductive approach, the text is analysed to identify the predefined categories within the data. Existing theories related to the subject are used to define the categories and criteria (Mayring, 2000). The number of occurrences of the evidence related to the predetermined categories will be counted.

When following an inductive approach, the text will be closely studied for its contextual content (Given, 2008). Defining the categories while staying close to the material under analysis is the paramount part of the inductive approach. Therefore, unlike in the deductive approach, how the categories were made and their definitions are much clearer in the inductive approach. Criteria for the categories will be derived from "theoretical background and research question" and the text is analysed part by part following the developed criteria (Mayring, 2000). Categories created at the beginning are tentative in this process therefore, the part by part analysis of the text allows for revising the categories through a feedback process and reducing to main themes. If the research question requires, the occurrences will be counted at this stage similar to quantitative content analysis. A unique characteristic of the content analysis technique compared to other qualitative analysis techniques is that it is a data reduction method, systematic and flexible (Schreier, 2014). This iterative process in content analysis brings validity and reliability into the results (Given, 2008). It is evident that, fruitfulness of the content analysis heavily depends on the definitions and criteria of categories and the validity and reliability depends on the source. As a result, the immaturity of the theories and personal experience related to BIM adoption and its whole life cycle application have resulted in the rejection of the possibilities of applying either inductive or deductive content analysis as the primary analysis tool for this study. Content analysis is not suitable if working with categories which restrict the phenomena under study (Mayring, 2000).

■ Thematic analysis

Thematic analysis lays the foundation for most of the qualitative analysis techniques (Saunders, Lewis and Thornhill, 2012). Most of the time it is recognised as a general approach to qualitative data analysis while at times it is used as an umbrella term covering most of the qualitative analysis techniques working with themes. Although, this method is rarely discussed as a specific procedure of qualitative data analysis, constant use of the term "Thematic Analysis" is found to be cited in a considerable number of research papers as the method of analysis (Bryman, 2016).

Thematic analysis is free from theoretical underpinnings therefore it is a tool rather than a methodology (Braun and Clarke, 2006). The work of Virginia Braun and Victoria Clarke are often used as the baseline for describing the process of thematic analysis (Vaismoradi, Turunen, and Bondas, 2013; Bryman, 2016). Accordingly, it includes familiarising with data, coding, generating themes by combining codes, evaluating the themes to provide names and higher order, examining the links between themes and subthemes for interpretation and reporting (Vaismoradi, Turunen, and Bondas, 2013). In this thesis, thematic analysis is acknowledged as a foundation skill to perform other qualitative analysis. Studying the process of thematic analysis itself is a repetitive process found in other qualitative analysis techniques. Therefore, detailed discussion on each of the steps involved in thematic analysis is presented by introducing different qualitative analysis techniques. However, Braun and Clarke, 2006 claims that thematic analysis is a separate tool from other qualitative analysis tools as they are theory bounded in their search of codes and themes.

■ Conversation analysis

Conversation analysis (CA) is a technique emerging from the work of Garfinkel related to ethnomethodology in 1967 (Silverman, 2001). It introduces a system to understand how people use language and verbal interactions to construct context and how meaning is conceived in a specific social activity – i.e. talking (Brinkmann and Kvale, 2015). Conversation analysis is not merely looking at talk but the social context in which and through which it occurs. Transcribing using symbols is an important part in this method; it arranges the conversation in such a way to reflect the context of interaction. Therefore it is an approach with many sides; it is a part theory, part data collection method and part data analysis tool (Bryman, 2016).

Conversation analysis is based on three assumptions; (a) talk is structured. It exhibits patterns, that is: they are organised in a certain way and the participants are implicitly aware about the rules generating these structures. Therefore, these patterns are recognised and treated independently from the speaker. (b) Talk is sequential. The speakers' action is revealed in talk and these on-going actions are context dependent. Therefore, talk must be analysed in terms of its predecessor. The next action is exposed in the current action and has a patterned sequence. (c) Analysis grounded in data. The analysist will look for precise details of the above two through fine-grained analysis of transcripts therefore, avoid any prior theoretical orders, and findings must be induced from data (Silverman, 2001; Bryman, 2016).

One of the fundamental ways that structure is achieved in conversation is through turn-taking and individuals use shared codes to indicate the attempt to talk, end of talk etc. which are essential to conduct a smooth conversation (Bryman, 2016). Turn-taking request for listening, understanding and displaying understanding and repair mechanisms are used when turn-taking error happens such as one starts talking before the other speaker has finished (Silverman, 2001). Another basic tool in conversation analysis is adjacent pairs such as a "question is followed by an answer, invitation is followed by a response (accept/decline)" (Bryman, 2016). Summons-answer is the primary adjacent pair that is answering the phone when it rings and there are other types such as non-terminality – action requires further action, conditional relevance - the next action depends on the previous, obligation to answer - question is followed by an answer (Silverman, 2001). Another feature of conversational analysis is looking at how institutional talk (e.g. court room, class room) structure, simplifies or modifies casual conversations to fit into institutional purposes (ibid).

Conversation analysis is a tool designed to analyse natural conversations (Bryman, 2016) such as telephone conversations of marketing campaigns or call centres. Therefore, its application in structured conversations such as interviews in the work in hand should be considered carefully. Conversation analysis carries a detailed analysis of every second of a verbal conversation including words and utterances looking at what is achieved by the verbal interaction rather the intention of the speaker (Brinkmann and Kvale, 2015). On the other hand looking back to the roots of this technique, conversation analysis is coming from ethnomethodology which is a study of methods used in daily life to achieve social order (Bryman, 2016). In simple terms, looking at how accomplishments in social order are achieved through interaction. As this is not the purpose of the thesis, this method of analysis is being rejected as a suitable technique to achieve the research aim.

■ **Analytic induction**

As the name emphasises this is an inductive approach to find a valid explanation to the research question or phenomenon. Therefore, it involves a careful selection of cases for data collection and commencing a theory free examination of the observation data to find categories to bring an explanation for the initial hypothesis (Saunders, Lewis and Thornhill, 2012). Identifying the relationships between categories will help built a valid explanation to the proposition.

From early literature on analytic induction Robinson, 1951 explains, the process of analytic induction begins with defining the subject matter under study and developing a corresponding explanatory hypothesis for it. The hypothesis is then compared with what data and modified accordingly. This modification can be done in two ways. Either to modify the hypothesis to fit in within the new data or the subject matter is redefined to exclude the case which defies the explanation given through the hypothesis. Modifying the hypothesis is widely known through the method of working hypothesis. This welcomes deviant cases in the light of developing a complete explanation. The validity of analytic induction is gained by applying the explanation to a range of diverse cases (Katz, 2001). In contrast, the second type of modification rejects deviant cases and limits the universal application of the explanation. In this way, limitations of the explanation will be clearly lined up. As a result, the researcher will be able to communicate the "presence of the exceptions" in the subject matter (Pascale, 2011). The saturation is achieved when there are no more cases supporting or rejecting the explanation. Based on the process of the analytic induction, it was initially identified as an alternative for statistical sampling (Katz, 2001).

Marking the importance of a basic understanding over analytical induction, the first authors of Grounded Theory commenced explaining its analysis technique (i.e. constant comparison) by explicitly distinguishing it from analytic induction. The two reasons for giving priority to analytical induction within Grounded Theory literature above any other qualitative analysis techniques are; (a) the close similarity in the two methods of analysis. That is constant comparison between data and the constant modification of the hypothesis. In this regard, the difference between Grounded Theory and analytic induction is that in GT the researcher is open to explore many theoretical explanations emerging from the data rather limiting it to a single hypothesis (Pascale, 2011). Secondly, (b) to distinguish from previous work and publications done by Anslem Strauss (co-inventor of GT) and Alfred Lindesmith who was a prominent practitioner in analytic induction (Hammersley, 2010), Glaser and Strauss (1967) explain analytic induction as a tool for theory generating with the key purpose of provisional testing. In contrast, constant comparison uses the process of provisional testing (i.e. coding to prove a proposition) for the function of generating theory (Hammersley, 2010).

Hammersley's (2010) comparison of Glaser and Strauss's grounded theory and analytic induction is presented in Table 4.4 below. The contrast between analytical induction and constant comparison provides the reasons for rejection of this technique. That is the risk of developing a biased explanation from immature industry practices by following a provisional theory testing procedure.

TABLE 4.4: Comparison between Analytic Induction and Grounded Theory

Analytic Induction	Grounded theory
• Both theory development and testing are of concern	• Theory development is the only concern
Focused on developing universally applicable conclusions	• Focused on developing local and specific conclusions
• Aim at developing explanatory theory for a specific question	• Aimed at producing broader theoretical framework
• All exception cases require a revision of theory so that all data matches the theory	• There is no requirement for all or no relation with data and theory therefore, tolerant of frequency differences.

Adopted from Hammersley (2010)

■ Discourse analysis

Discourse analysis is a study of language in terms of text or speech, looking at how language is used to make sense. This is done in close interaction with the context of the phenomenon. As a result, it is capable of revealing how meaning is produced/reproduced out of language in terms of where it is being used (Saunders, Lewis and Thornhill, 2012). It is a package with a methodological foundation rather than a pure analytical tool which is flexible to use freely (Jørgensen and Phillips, 2002). Therefore, a research study has to accept the philosophical premise behind discourse analysis (i.e. social constructionism) in order to apply this technique.

When conducting discourse analysis, the researcher is focused on the use of language in data (i.e. text as forms of documents or interview transcripts). Use of words, grammar and style of making a point. Therefore, what the researcher is looking at is not what is being explained by the participants but how discourse is used to construct the meaning (Willig, 2014). This may be found similar to conversation analysis as it has many common properties, such as talk being the key focus while understanding the construction of meaning through language. However, the difference is that conversation analysis is focused on the social act of talking (turn taking, construction of meaning step by step) while discourse analysis is focused on the use of language (i.e. figure of speech, paired terms) to represent a social act (Wooffitt, 2005). It studies the organisation of the language beyond the sentence. Discourse analysis does not focus on naturally occurring talk like in conversational analysis therefore, interviews as constructed conversations for information gathering are an accepted form of data collection (Bryman, 2016).

Multiple versions of discourse analysis are introduced later in the linguistic research. Critical Discourse Analysis (CDA) particularly related to theories of Norman Foucault is the most widely discussed variation among them. Similar to discourse analysis, CDA is focused on understanding how language acts as a mode of power structure in the society. When discourse analysis is looking at how the meaning of the word is constantly transforming with interaction of other discourses and based on the context in which it is being used, CDA acknowledges the other factors influencing the change and creation of meaning (Jørgensen and Phillips, 2002). Accordingly, CDA focuses on how text is influenced and built on pre-established meanings. This will allow us to discover reproduction of discourse with new elements by a combination of discourses and sometimes reproduction with no new elements.

There is no simple step by step process to conduct a discourse analysis but a time consuming process which requires considerable experience to be familiar with the process (Saunders, Lewis and Thornhill, 2012). Although, discourse analysis is not used as it is for analysing data in this thesis, the principles of discourse analysis have played a role in the selected methods – i.e. Constant Comparison Method. Corbin, 2008 recognise discovering various meanings of words used by respondents as one of the key strategies when theorising from data.

- **Open Coding** – the process of identification and naming categories and discovering their properties
- **Axial Coding** – coding around an axis of a category, generating relationship with subcategories
- **Selective Coding** – the process of relating the categories and refine the theory

On the other hand, Charmaz's entrance to GT with a constructivist perspective stayed close to the original procedure of CCM providing a simplified and thorough description on the method bringing inputs from Strauss and Corbin's coding paradigm where necessary. There are some key features which are common to all these different versions of CCM and they make CCM stand out from other qualitative analysis methods. In CCM, analysis of the data begins from the first interview without separating data collection analysis as two separate steps (Corbin and Strauss, 2008). Parallel data collection and analysis procedure inform the next point of data collection. More precisely, data analysis in CCM begins right at the interview (Glaser, 1998). The researcher is making prompt questions, making adjustments to what is being observed and making notes on what strikes in the moment. The second unique feature in CCM is as the name implies - constant comparison. The researcher will constantly go back and forth between data to revise and categorise their properties and dimensions. During this process, memos will be written to describe the ideas and models are created to visualise the concept. Although CCM is one of the key learnings of the GT, it is even applied outside GT claiming its merits, especially in Action Research (Bryant and Charmaz, 2007). Therefore, its credibility as an analysis technique is well formed among qualitative research.

Quantitative data analysis

Quantitative data analysis refers to a number of statistical analysis techniques used for numerical data interpretation. The common use of quantitative analysis in social science research is practised with surveys. In survey research, a structured questionnaire is provided for the respondents with a preselected set of answers (i.e. response categories) and each of the responses is associated with a numerical label known as a "code". Based on the questions in the questionnaire, answers can be designed under several response categories – i.e.

some are yes or no, and others are asking for actual numbers such as age, years of experience and income. In statistical terms response categories are identified as variables and they are categorised according to the scales of measurement - nominal, ordinal, interval and ratio (Blaikie, 2003).

Nominal scale numbers are the most widely used scale of measure in social science research and they have no value by its own – i.e. 2 is not considered as more valuable than 1 but 2 is the numerical label for the category of women while 1 is the label for category of men (Burton, 2000). On the other hand, ordinal data represent an order or position such as 1,2 and 3 indicates first, second and third preferences however, it does not imply the magnitude – i.e. 2 is twice 1. Interval scales signpost "order of responses and distance between them" however, treating zero as an arbitrary number for the convenience (Fellows and Liu, 2015). For instance, if an interval scale is given from 0-10 to indicate strongly disagree to strongly agree, there is no change even if the numerical scale was given as 30-40 in the second round. Both scales of measure indicate the order and interval. Finally, ratio scales are numerical data with all properties of interval data and an absolute zero. Due to continuous rejection of quantitative methods, quantitative data analysis techniques have not been considered for this research. However, a brief introduction to some broad types of quantitative analysis are discussed for a general understanding.

Saunders, Lewis and Thornhill (2012) explain quantitative analysis methods under three categories; (a) exploratory data analysis with use of simple diagrams such as bar charts, pie charts and tables to understand data and as a guide to choose a rigorous analysis technique suitable for the data at hand. Exploratory analysis will provide a chance to learn new relationships which were not planned at the beginning of the research. As an example, exploratory data analysis will look for totals, specific values, highest and lowest values, trends over time. The other two which are the main classifications of statistics analysis are (b) descriptive analysis and (c) inferential analysis. Under these two general branches, exploratory analysis methods are covered under descriptive statistics analysis (Burton, 2000). As the names provide clues of their function; descriptive statistics are used to describe a data set by communicating its characteristic through central tendency (mean, median, mode) and dispersion (standard deviation, inter-quartile range) while inferential statistics supports the development of statistical generalisations about the phenomena through identifying relationships among different sets of data or between data and theory through bivariate or multivariate statistics (Burton, 2000).

4.7.6 Summary of research techniques employed

In summary, qualitative research methods engage more with words (Creswell, 2013) they examine experience, documents, interactions and communication (Brinkmann and Kvale, 2015). On the other hand, quantitative methods in social science describe the world phenomena by measuring and analysing numerical values (Smith, 2015). Grounded Theory methodology as a theory generation strategy is in favour of qualitative data collection and analysis tools although, it is not completely limited to qualitative research. Therefore, qualitative strategies were used throughout the research are in favour of discovering the substantive theory under Grounded Theory. Table 4.5 outlines the research techniques employed to achieve each research objective.

TABLE 4.5: Proposed research methods

Research objectives	Literature review	Interviews	Focus Group Discussion	Focus Group Workshop
Identify the principles and practices of facilities information management that are adopted within the built environment facilities	X	X		
Investigate the solutions and problems in application of BIM for FM	X	X	X	
Determine the value of BIM based information for facilities management	X	X	X	
Develop a value based strategic management tool to measure and communicate project's BIM value		X		
Test the tool for its validity and usability within built environment facilities				X
Content Analysis	X			X
Constant Comparative Method		X	X	

Validity of scientific findings refers to the accuracy of the outcome while reliability is about replicability of the findings (LeCompte and Goetz, 1982). Validity of research is confirmed by possibility of generating the same result when conducted by another person following the same methodology (Saunders, Lewis and Thornhill, 2012). Standing on this definition there is no argument for the validity of this thesis if each step of the research is precisely followed (including philosophical assumptions) with no time delay. However, validity, reliability, rigour comes from natural science research as they can prove the trustworthiness of research or generated knowledge through objectivity and replicability (Miller and Dingwall, 1997). In social science, reflexivity is a commonly challenged feature because the researcher is a part of the social world being studied. Use of rigorous methods is the realist's answer for reflexivity while naturalists offer a close engagement with the phenomena to minimise reflection of personal values over the society being studied (Hammersley, 2007).

Conversely, objectivity and validity are completely different concepts. Objectivity is formed with a strong theoretical and philosophical rationale defending its acceptance or rejection based on the phenomenon under study (Denzin and Lincoln, 2011). A research study on value can be conducted in a subjective manner for instance looking at human values or objectively considering the market value. Appropriateness of the choice is merely logic. On the other hand, validity cannot be easily ignored or formed into research due to the conflicts of what forms rigorous research (Denzin and Lincoln, 2011). Although validity and reliability are a common concern of any scientific research, proving validity of research through objectivity or possibility of replication of the findings cannot be considered as a fair measure for all research. However, these positivist criteria are helpful for researchers to be sensitive to the potential issues of a research project therefore, alternatives for social science have been suggested (Seale, 1999). The four tests commonly used in social science research to defend its validity are as below (Yin, 2014) however, there are other methods as well, precisely for qualitative (Seale, 1999; Bryman, 2016) and quantitative social science research (Bryman, 2016).

- *Construct validity* – This questions the "operational measures" taken in a research especially, where subjective judgements are involved (Yin, 2014). Similar to external validity this is also focused on generalisability however, specifically on the credibility of generalisation from the process followed, measures or theories one has chosen to develop the concepts created through the research. To discuss construct validity within this thesis is to defend the accuracy of measuring value through needs, benefits and challenges. On the other hand how the research framework helps to identify the true value of BIM. It asks the question how far the concept of "value of BIM" has really studied what it says. The theoretical underpinnings support the construct validity of the research (see Figure 4.1 on pg. 45). This is provided as the summary of Chapter 4 – Research Methodology. Another way of achieving construct validity is collecting data from multiple sources (Yin, 2014). In support to this, data was collected through interviews covering a range of project stakeholders and facilities managers working under different roles within projects and during the operations stage. Also, a review of documents when permitted during site visits enriched the concepts which emerged.

- *Internal validity* – This looks as at the truthfulness and transparency in the analysis. Since the concept of internal validity emerged challenging scientific work under experiment research strategy, the exact questioned asked under internal validity is referring to the confidence in causal relationships determined in the research. In other terms, does one category influence the other and what evidence is there in support of this causal claim (Taylor, 2013).

- *External validity* – This questions how far findings can be applicable to outside the research sample. Using theory is a form of defending external validity (Yin, 2014). Being informed by the Shalom Schwartz theory of basic human values, which is praised for its universal application along with other theoretical underpinnings (philosophy, methodology and economic theories), supports the thesis and speaks for the external validity of the research.

- *Reliability* – This refers to the consistency of the findings if the research is repeated more than once (Tanner, 2018) if the same research process is followed is it possible to repeat the result? Measurement errors are caused by systematic or random errors (Drost, 2011).

It is obvious that these measures are a close translation of positivist measures of validity. In a real sense, scientific objectivity or methodological triangulation does not provide validity or reliability. Just as much as interviews and observations; questionnaires and tests designed by human beings are subject to a researcher's biases by the very questions they ask (Denzin and Lincoln, 2011). Secondly, the logic behind utilising a previously rejected method to study a phenomenon in order to reach methodological triangulation is questionable in terms of its validity (Miller and Dingwall, 1997).These validation mechanisms were necessary to prove the findings are trustworthy when taken a deductive approach to confirm whether the data actually said what they are saying or whether the meaning has been imposed by the theory or the inquirer by his or her pre-concepts. Therefore, this particular concern is absent in this thesis. Discovery of theory is validated through its process of generation (Dey, 2003). On the other hand, when the validation of a hypothesis is the main objective (which is the case in most natural science and post-positivist social science research), the research is designed to quantify validity of the work carried out. In contrast, qualitative research which is mainly aimed at understanding and discovery of social phenomena performs its validity in a different form. It is aimed at following a valid process of understanding the phenomena. Therefore, not having a quantified validation mechanism similar to quantitative research does not imply that qualitative research findings are completely biased. As experts in research, it is paramount to understand that both methods are open to equal levels of bias and they have taken different paths to control it (Denzin and Lincoln, 2011).

The quality of qualitative work is immensely dependent on the enquirer's "methodological training, skills, sensitivity and integrity" (Patton, 2015). Therefore, the enquirer is continuously aware and cautious about his or her involvement. On the other hand, quantitative methods have the space to impose the personal agendas through logic (e.g. framing the questions to enforce) and selecting favourable theories because of their taken-for-granted objectivity. In contrast, one of the reasons for popularity of GT in qualitative research is that it incorporates these quantitative concepts (validity and reliability) in its process by maintaining a balance between objectivity (not to impose on data) and sensitivity (creatively look at data for new ideas) (Denzin and Lincoln, 2011). By following grounded theory one would produce a result grounded in data, not imposed by a pre-established theory or the enquirer's favour towards a particular theory. Confirming the ability of this methodology to claim knowledge, Morton (1997) states that "a belief is qualified as knowledge, if in enquiring it, one had achieved the basic aim in the enquiry that led to it" (p.112).

Therefore, the usual verification mechanisms coming from natural science roots would make no sense in terms of verification of discovered theory. The prime function of research under GT is to discover theory (Strauss and Corbin, 1998). In order to discover theory grounded in data, it is necessary to get closer to data as much as possible (Denzin and Lincoln, 2011) that is through qualitative methods. Testing of the theory is a different approach therefore, if necessary it should be a separate research (Strauss and Corbin, 1998).

In conclusion, as a pure qualitative research it is paramount to stay true to data (Goodyear et al., 2014). That is to acknowledge what the researcher brings into the research. The detailed discussion on philosophy is used to be transparent in this aspect. The questions asked by the concept validity is whether the findings are trustworthy, authentic or more precisely whether the enquirer is at a secure position in making conclusions from the findings. (Denzin and Lincoln, 2011). The straightforward answer to this question is yes; trustworthiness of this thesis is defended by the logical choice of the methodology (by choosing the most appropriate methods to understand the phenomena under given circumstances), being transparent about the philosophical and theoretical assumptions behind the findings (LeCompte and Goetz, 1982) and member validation (Seale, 1999) of the model by taking research findings back to the industry through a focus group. Moreover, input from different viewpoints along the study through three supervisors and peer reviewed publications provide further support for validation (Creswell and Miller, 2000).

4.7.7 Chapter Summary

Chapter 4 sits at the heart of the thesis justifying its theoretical position. As a theory heavy chapter, it begins with a summary of methodology employed in the thesis to provide a background. Later in the chapter discussed the details of the theoretical underpinnings and logic of the reasoning to support the claims made in final chapters of the thesis. Following the structure of the research onion, the Chapter 4 presented an in-depth discussion on each aspect of the research methodology following a logical sequence to present how each layer was informed by its predecessor along with the justifications for the suitability to study the phenomena of concern. Accordingly, further work carried out in the thesis is influenced by the Grounded Theory research strategy. Therefore, next chapter brings in the most important theories to support the knowledge contribution from multi-disciplinary aspects. Theories unfolding with the emerging themes during the data analysis influenced the selection of the technology acceptance and value theories discussed in the next chapter. Although, under a standard thesis structure this is identified as a part of the literature review, it is still being positioned later in the thesis to protect the authenticity of the work as a Grounded Theory research project.

Chapter 5

Technology acceptance and human value

5.1 Introduction

Chapter 5 brings the human value into the research as a means of studying human technology interaction. This is a new area of study which is missing in the existing BIM literature. Although, this is a part of literature review, the relevant theories related to human-computer interaction was referred during the data analysis. When following the Grounded Theory research strategy, both classical and Straussain accounts emphasise a theory free start. Therefore, the literature review on more specific aspects of the research was done later in the study after the initial round of data analysis. The aim of this chapter is to identify and develop an appropriate value definition to bring theoretical support to the research output. Under a standard (deductive) thesis structure this chapter may recognised as a part of the literature review to explore existing knowledge on "value" from the economics perspective to support the understanding of the value of BIM interpretations gathered during data collection. Influenced by the relative nature of value, this exploration leads to knowledge creation in two aspects; identification of BIM as an information system emphasising the technology aspect of the research and explaining values as motivations/expectations of BIM. Therefore, the chapter begins by setting the background for these two key areas and follow into a study of philosophy in technology to understand the value interplay in technology at the stage of technology design and user acceptance.

Secondly, a generic definitions of value in terms of understanding the concept of value, its history and aspects on value in-use and value in exchange are taken into account following different eras in economics. Having provided a broad discussion on two branches of value, the further studies were made on value in-use as it was found to be the appropriate branch of value that provides a holistic picture of the subject matter considered. Subsequently, it leads to analysing different approaches taken specifically in the construction industry to understand value capturing mechanisms. Finally, the chapter evaluates the theory of basic human values to present the deep-rooted relationship between human values and how they are being reflected in daily life of BIM users. With the significant insight provided by the value theories in developing the value model and the value principle, this chapter contributes in bringing the theoretical support for the claims made in the research.

5.2 Background

Building Information Modelling (BIM) is an information creation and management tool within the Architectural, Engineering and Construction sectors (McGraw-Hill, 2009; Underwood, 2009). Wide application of BIM capabilities are seen in the design stage to manage and validate the building design (Vanlande, Nicolle, and Cruz, 2008). Although the application of BIM is dominant in the early stages of a building, owners and facilities managers have good potentials in achieving benefits through whole-life BIM adoption (Howard and Björk, 2008; Eadie et al., 2013). However, whole life benefit of BIM has not yet been completely identified. Being more precise, construction project stakeholders are still struggling to make decisions on possibilities for adopting BIM within their project execution plan (Barlish and Sullivan, 2012). Therefore, a lack of understanding in the value of BIM especially beyond design and construction is noted within literature and during the data collection and analysis processes.

Research in psychology proves that people make choices based on the basis of fulfilling psychological needs (Deci and Ryan, 2000) which are later identified as values in this chapter. Values are the core concept of all social sciences (Rokeach, 1973). In support, recognising construction as an ancient human activity emphasise the sociological aspect of construction. It is a discipline close to human lives and therefore built upon human needs. It was initiated to fulfil the primary need of shelter to protect from changes in climate. Conversely, living in the 21st century, construction is another specialised activity taking place out of everyday life. Therefore this chapter is dedicated to bringing forward the human element of the built environment which is underestimated in time, cost, and quality culture in construction.

This is achieved by staying closed to the aim of the research. Therefore, further discussion are made to bring light to reveal the reasons behind the slow adoption of BIM in the facilities management stage by studying the psychological needs in FM (i.e. humans involved in the processes of FM) concerning BIM. As a result, the discussions are made under three key areas. Firstly, an exploration of philosophy of technology to understand the relationship of human needs and technology. This is an important contribution of the chapter as one of the key pillars of this thesis is BIM, which is recognised as an information technology system. This leads to the discussions of technology acceptance theories making the bridge between humans and technology. The later sections of the chapter are dedicated to refining the knowledge on value in behavioural economics and value in construction industry to lay the foundation for the value taken forward within this thesis to support the BIM value model and value principle.

5.3 Philosophy of technology

Supported by both literature and data gathered in this study, BIM is recognised as an information technology (IT) or Information System (IS) using the two terms as synonyms. Here, it is acknowledged that IT is a sub component of IS. A review of philosophy of technology is carried out in order to understand what it means by referring to BIM as an IT system and how it effects its users. Franssen, Lokhorst, and Poel, 2018 provide a fine starting point bringing philosophical discussions from ancient Greece to modern times. It is interesting to identify early discussions on the philosophy of technology are made in related to construction. Accordingly, Franssen, Lokhorst, and Poel, 2018 put forward four themes in describing the nature of technology. First two themes are in recognising technology; the first, technology learns from nature. The early housing construction, weaving are examples for this. The second theme is on describing the fundamental difference between "natural objects and artefacts.

Referring to the early notes from Aristotle, natural products grow, change and reproduce while artefacts decompose to natural materials if there is no human intervention (Kaplan, 2009). Under this explanation, everything which is man-made is recognised as technology. The understanding on what it is recognised as technology by philosophers have drastically change over time. Kaplan, 2009 presents an extensive review of this change in philosophical views on technology. The early objective view on technology was highly concentrated on scientific aspect on technical problem and technical solution which was identified as a "transcendental perspective". Early positivist approach to knowledge understood technology as a value and disruption free force for betterment of human progress seeing it in a sense of applied science, a means to an end, a tool (Scharff and Dusek, 2014). However, this was changed when further developments of technology started interacting with the society. Modern philosophers from 19 th century identified technology and society in an interdependent relationship. Philosophy of technology was given the opportunity to be reviewed from social constructivism perspective understanding its role in society (Kaplan, 2009). Therefore, description of technology at fundamental level was made in favour of the world view of the philosopher. Bringing in a different perspective, Franssen, Lokhorst, and Poel, 2018 recognise this branch of philosophical study as "humanities philosophy of technology" since it has no interest in standard philosophical discussion on understanding technology for what it is but its impact.

Since the end of World War II technology has been evidently advanced life of the mankind. It is the technology that separate a significant part of a life in a city from a live in village in 20th century living. It has even extend to a level to describe what is to call human in order to distinguish human technology transformation - transhumanism (Kaplan, 2009). The challenge is that technology cause more problems than it solves (Scharff and Dusek, 2014). When technology is seen as a product, marketers do their job right to construct a reality best suit their aim. The intractable problems created by technology are creatively wrapped around its positive contribution to the mankind. When technology development started to rise at the beginning, the positive contribution was easily identified and having spent long enough to see the consequences of some developments it has started to gather knowledge on its negatives. In the modern society it is a very thin line between development and disturbance caused by technology in society. Therefore, it is worth of discover its role in human life and society overall. Fallman, 2007 asks the question "if a website can persuade a customer to become an instant buyer, then is it right for the developer to create it at first place?" This distinction of craft knowledge (i.e. techne) and intellectual knowledge and risk of presence of former at the absence of later is a question raised by Plato (Scharff and Dusek, 2014). This works both ways. The greatest example is the impression over nuclear technology. The tragic experience with the technology cause to reject one (i.e. nuclear power plant) but embrace many other harmful solutions (i.e. coal power plant).

Martin Heidegger, the most prominent philosopher in technology argues that essence of technology is “technological rationality” (Kaplan, 2009). It disposes the existing rationals such as ethics, science and politics and leads to a single criteria for judgement – efficiency. Secondly, the risk of technology to human beings is emphasised through how carefully technology manipulate human mind providing a sense of domination or control. However, in reality technology conceal the knowledge while striving for efficiency with incomplete knowledge. This statement of Martin Heidegger simply reveals why it has become a need to innovate to fix innovation. Therefore, the solution is to understand the contribution of technology for what it is and look beyond so that one become free to accept life has more to offer than efficiency (Kaplan, 2009). The review on philosophy of technology brought the fundamental assumptions about what is investigated in this thesis revealing the risks and opportunity lays behind it. The key learning from philosophy of technology can be summarised as follows;

- Change in technology from objects (e.g. steam boat) to systems - Technology as an object is less interactive but more in control. Technology as a system is more interactive and less in control.
- Two way interaction between technology and human values – in short term technology is inspired by the human values. In long term technology reshape human values.

The success and complexity of technology is entailed with it becoming a system expanding interaction with humans. The majority of the philosophical discussions on technology continuously highlight the unknown risk involved with its development as a system going beyond what was previously known as technology (i.e. a tool). Therefore, ethics in technology is a progressing discussion in 20th century philosophy of technology. From its nature of being, technology is to function for a specific purpose with known impact and any other use may carry unknown consequences (Jacko, 2012). However, this is mostly based on technology as a tool and continuous change of technology as a system is even a challenge for philosophers to define its very nature. These insights are continuous reminders to revisit and understand human values to keep it check what is to be human in transhumanism and make sure that it is humans who dominate. Embedding human values in information systems design was emerged and continue to grow from early 20th century (Friedman, Kahn, and Borning, 2008) acknowledging the underline relationship behind technology and human values. The interest of the thesis is to understand the user acceptance of technology rather development. Therefore, human-technology interaction as a field study specialising in human factor in technology development is discovered in next section to understand and draw support from the existing knowledge to the claims made in this thesis.

5.4 Human-Technology interaction

Human-Technology Interaction in a broader sense and precisely Human-Computer Interaction (HCI) is a field of study which sits within the human factor and ergonomics, information systems, computer science and information science (Jacko, 2012). Recent research on BIM that justify the appropriateness of design science methodology to understand BIM emphasise the theoretical relevance of HCI to narrow down the knowledge gap in BIM acceptance (Kehily and Underwood, 2015). Moreover, influenced by HCI knowledge and the growing application of technology in the built environment has given birth to a new paradigm – Human Building Interaction, acknowledging the changing built environment and the need for understanding the role of human technology interaction within the built environment (Malkawi and Srinivasan, 2005; Alavi et al., 2016a; Alavi et al., 2016b).

Although HCI has been there since the use of the typewriter or punch card, the first remarkable contribution of HCI was the introduction of a ubiquitous graphical interface which allowed the user to manipulate (i.e. select, move, resize) the objects on the screen with the help of a pointing device (Myers, 1998). This was followed by the introduction of computer mouse, Windows interface, and gesture recognition to many modern inventions such as Virtual Reality (VR) and Artificial Intelligence (AI), creating a fundamental difference to computing.

The initial work on HCI knowledge creation was based on lab based experiments following cognitive science principles however, more qualitative methodologies such as ethnography and phenomenology were later introduced to bring a broader understanding of the user experience (Fallman, 2007). This is primarily because, the focus of HCI is to bring the human factor into computer design, and enhance the interactive experience (Jacko, 2012). This ranges from understanding human information processing, mental models, computer user choices, to task loading and stress. Accordingly, technology acceptance is a sub field of HCI specifically focused on integrating human values in computer design. This statement provides a solid support as it confirms the link between the research question (i.e. question on BIM acceptance) and the solution emerging from data (i.e. human value).

The aim of learning human-technology interaction in this thesis is to understand the causal mechanism behind technology acceptance by its users in order to create a baseline to promote BIM among FM. Understanding human motivation is identified to be a front line requirement to develop successful information systems (Davis, 1989). in support, the most widely accepted technology acceptance theories are based on perceived usefulness and ease of use as all information technology begins its development with a predicted use. Research findings have shown that perceived usefulness is 50% more influential than ease of use in terms of user acceptance of technology (Davis, 1993). Therefore, understanding the perception of facilities managers who have not yet adopted BIM brings valuable information to promote BIM beyond construction. On the other hand, Fallman, 2007 argues that user experience has become much important than user performance of technology therefore, creates an accountability on developers to rethink what is considered as "good" raising a philosophical question.

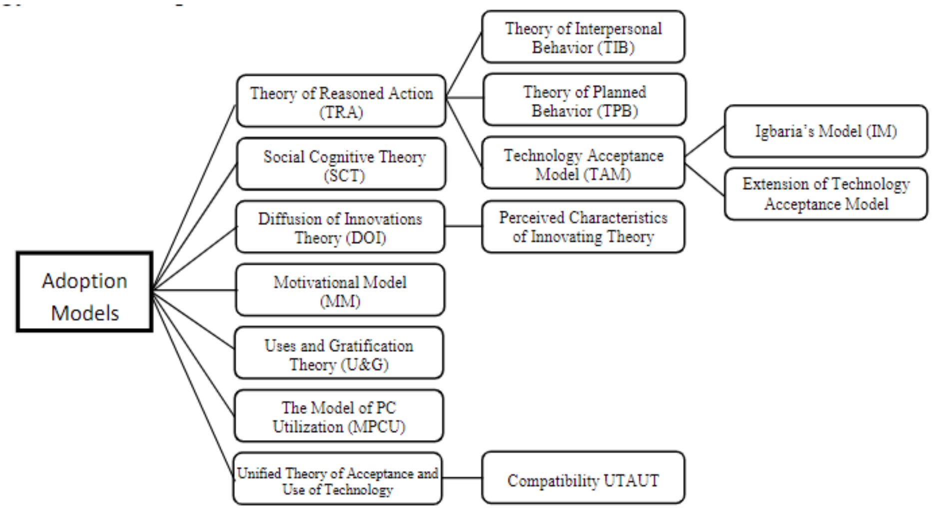

FIGURE 5.1: Summary of technology acceptance theories (Source:Taherdoost, 2018)

There are a number of theories and models in the field of information systems to understand the perceived usefulness and ease of use. Reaching its peak in late 1990s, numerous publications bring together different technology acceptance theories introduced over time. Figure 5.1 presents an overview of the existing theories. Some have presented an in-depth discussion of one or two prominent theories (Davis, 1989; Madden, Ellen, and Ajzen, 1992) while others have presented an overview of a number of widely used theories and models (Venkatesh et al., 2003; Silva and Dias, 2007; Taherdoost, 2018).

The attention towards HCI has continuously grown from in its first successful application in 1963 to the date. The continuous revisits to technology acceptance theories and more recent publications in the subject under built environment (Shibeika and Harty, 2015; Miranda et al., 2016; Buentello, 2017; Zhang, Lu, and Chen, 2018) make the case for the possibility of bringing fruitful insights to understand BIM user acceptance through technology acceptance theories. There are number of research compare and contrast different technology acceptance models (Venkatesh et al., 2003; Ward, 2013; Taherdoost, 2018). Venkatesh et al. (2003) provides an extensive review of eight technology acceptance models. Bringing the essence in these models together they formulate a new model – Unified Theory of Acceptance and Use of Technology (UTAUT). Later, UTAUT-2 was introduced as a unique model to understand consumer technology acceptance introducing hedonic motivation, price value, and habit into original UTAUT (Venkatesh, Thong, and Xu, 2012). The close relationship between technology acceptance models brings the flexibility to mix and match according to the phenomena under consideration. Therefore, in this thesis, multiple models are being considered to bring theoretical support rather committing to a single mode. Taherdoost, 2018 concludes recommending UTAUT, Diffusion Innovations Theory and Technology Acceptance Model (TAM) as the most widely accepted theories in information systems research. A brief introduction to a selection of theories in the field are discussed below.

5.4.1 Theory of reasoned action

The Theory of Reasoned Action (TRA) developed by Martin Fishbein and Icek Ajzen is a well-recognised theory in social psychology to predict human behavioural intentions (Madden, Ellen, and Ajzen, 1992). It is widely used in both technology acceptance and decision-making research. Since it is the interest of the thesis to understand TRA in the sense of technology acceptance, the theory is reviewed based on literature on Information Systems (IS) rather than generic social psychology. Accordingly, Davis, Bagozzi, and Warshaw, 1989 explain TRA as A model that proposes that a "person's performance of specific behaviour is determined by the behavioural intention to perform the behaviour". In other words, the TRA's hypothesis is that performance of a behaviour depends on the strength of intention to perform the specific act. Behavioural intention is triggered by the combination of attitudes and subjective norms (Figure 5.2). Attitude is the negative or positive impression towards the behaviour while, subjective norm refers to the importance of social approval about the behaviour. For example, a person who has a positive impression towards BIM and values the social recognition for taking leadership towards sustainability, may likely adopt BIM in a given time (2011 – 2016).

As claimed by TRA, attitude towards a behaviour is determined by the important beliefs about the consequences of the performance and "implicit evaluative response" (Davis, Bagozzi, and Warshaw, 1989). Evaluative response refers to the idea or feeling of good/bad or like/dislike. Anything external to attitudes and subjective norms is identified to have an impact on forming attitudes and norms rather having a direct impact on the performance of the behaviour (Madden, Ellen and Ajzen, 1992). This is a key learning of the TRA taken forward to information systems research (Davis, Bagozzi, and Warshaw, 1989).

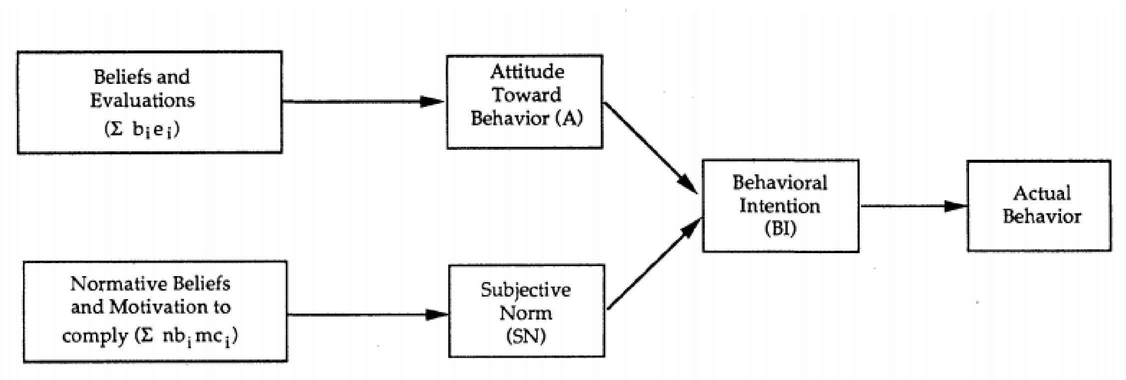

FIGURE 5.2: Model of Theory of Reasoned Action (Source: Davis, Bagozzi and Warshaw, 1989)

TRA is recognised as the foundation theory in user acceptance in technology as it has provided the theoretical base for other successful theories in the field – i.e. Technology Acceptance Model (TAM) (Davis, 1993), Theory of Planned Behaviour (Madden, Ellen and Ajzen, 1992). The influence and similarity of the TRA (Figure 5.2) over TAM (Figure 5.3) is evident through the two theoretical models. TRA has its own limitations as well. It is limited to understanding volitional behaviour – i.e. only the decisions made by choice

(Madden, Ellen and Ajzen, 1992). This not a consideration since adopting BIM is a volitional act. However, TRA does not specify the beliefs significant to the performance leaving the researcher to identify these beliefs although it is a key variable in recognising the attitudes towards the performance. Considering both strengths and weaknesses of TRA, its successful application in behavioural predictions but, its generic nature as a psychosocial theory has influenced developing similar theories yet specifically focused on determinants of computer usage.

5.4.2 Technology Acceptance Model

Technology Acceptance Model (TAM) introduced by Fred Davis in 1986 is an extension of TRA with a specific focus on information systems (Davis, Bagozzi and Warshaw, 1989). Accordingly, TAM can be used to predict as well as to explain the reasons for acceptance or rejection of a computing technology. The primary aim of TAM is to understand how the external factors impact on internal beliefs, attitudes and intentions. As a theory developed upon TRA, the assumption behind TAM is that individual technology acceptance and use can be predicted through those internal variables (i.e. beliefs, attitudes and intentions) (Turner et al., 2010). Accordingly, behavioural intention is the key variable in TAM, taken after TRA.

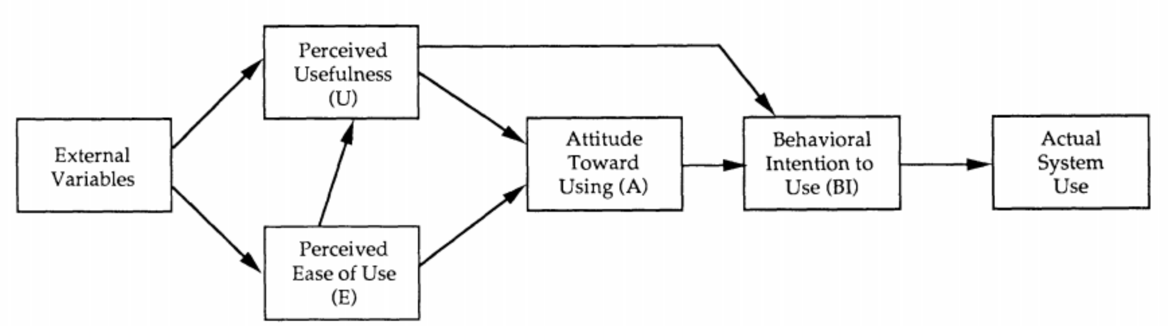

FIGURE 5.3: Technology Acceptance Model (Source: Davis, Bagozzi and Warshaw, 1989)

The unique contribution of TAM is postulating perceived usefulness and ease of use (Davis, 1989). This has been done by adjusting TRA to reflect information system user behaviour. Perceived usefulness refers to the person's belief about how much a particular technology can be helpful to perform a job, although the person may or may not use the technology to fulfil all the expected benefits (Davis, 1989). These expected benefits have a direct influence on the behavioural intention as well as supporting the attitude towards using the technology. Therefore, TAM explains that in an institutional setting, expected usefulness has a stronger influence than the likes or dislikes towards a technology deviating from original TRA assumptions. Further, TAM rejects subjective norms considered in TRA for many reasons such as weaknesses in identifying influence of subjective norms, or indirect influence made on behavioural intention through attitudes. One such example especially in the information systems context is that, in an organisation employees choose a system because that's the preference of the management rather an individual choice (Davis, Bagozzi and Warshaw, 1989).

A second version - TAM2, was introduced by Venkatesh and Davis, 2000 introducing "social influence processes and cognitive instrumental processes" into original TAM. The extension of social influence counts in technology acceptance in voluntary situations – i.e. use of technology is not mandatory or adhering to compliance. This is in acknowledgement of the subjective norm in TRA, which was previously rejected in TAM. Accordingly, TAM2 admit the possibility of acceptance of technology to maintain a favourable image.

The key limitation is that TAM does not guide the precise actions to achieve the objective of technology acceptance. In a nutshell, TAM says that one will accept a technology if it is useful and easy to use but not how to recognise these characteristics. Some other limitations of TAM are discussed in the literature (Turner et al., 2010; Ajibade, 2018). TAM is focused on predicting the acceptance but not understanding the value of technology to an organisation. It was a question whether TAM really considers "actual system use" as it is indicated in the model that the theory of TAM is focused on predicting the usage rather measuring the actual usage (Turner et al., 2010). On the other hand, TAM is successful in understanding individual value over computing technology but limited in its understanding of institutional technology acceptance (Ajibade, 2018). However, none of these key counter arguments stands against the focus of this thesis; it predicts the individual acceptance of BIM in facilities management. Therefore, broadening the understanding over perceived usefulness and ease of use provided the theoretical support to the thesis output.

5.4.3 Diffusion innovation theory

"Innovate or perish" and "Perish as you innovate" are key marketing slogans in 1960 and 1970s respectively (Robertson, 1967). In this era of innovation, Everett Roger introduced Diffusion of Innovation (DOI) theory which was been used since 1960s in variety of disciplines ranging from agriculture to organisational innovation diffusion (Venkatesh et al., 2003). Although, the initial thoughts on DOI was triggered through the agriculture – the most influential study in diffusion of hybrid corn in Iowa, later publications on DOI constantly use innovation and technology as synonyms as the theory has mainly grown into analysing diffusion of technological innovations. While previous theories discussed reveals the complexities behind individual's technology adoption decisions, DOI focus on factors affecting sharing and dissemination of a technology. In contrast to TAM, DOI acknowledge even the innovations with most obvious uses face the difficulty in dissemination. DOI talks through characteristics of an innovation, innovation decision process and the adopter characteristics (Taherdoost, 2018). Each of these sections are systematically discussed in this section following the thoughts of the founder of DOI. As Rogers (2003) describes "Diffusion is the process by which an innovation is communicated through certain channels over time among the members of a social system". This definition of Rogers' gives away the four key elements of DOI.

- Innovation
  Innovation is considered as "an idea, practice or object that is perceived as new". What is important here is the 'newness'. Even if the idea or object was long invented but new

to an individual in terms of knowing it or not having a perception towards it (such as adopting or rejecting), it is an innovation for that individual or organisation. Therefore, 'newness' can be articulated in forms of knowledge about the object, positive or adverse attitude and decision to adopt. Characteristics of innovations helps in understanding why one innovation (i.e. iPhone) is adopted quickly while another (i.e. BIM) takes years. Characteristics of an innovation as identified by Rogers (2003) are as follows;

- *Relative advantage* – the more an individual perceives the advantage of an innovation compared to the idea it replaces, the possibility for adoption of the considered innovation is higher. This includes both objective (such as economic values) and subjective (such as convenience and satisfaction) advantages. Therefore, in dissemination sense, what is important is to have advantages that the indented user group can perceive. This immediately reveals a key reason why BIM is not diffused in FM as predicted.
- *Compatibility* – the degree that an innovation is compatible with existing practice, values and needs of expected users. A compatible innovation adopts faster than an incompatible innovation. On the other hand, adoption of an incompatible innovation first requires an introduction of new value system before adoption of the innovation making it a slower process. Applying this into BIM in FM context highlights the incompatibility of BIM with existing practices such as existing Computer Aided Facilities Management (CAFM) packages.
- *Complexity* – how easy is the innovation to understand and use. This is similar to the "ease of us" in TAM. DOI presents that an innovation which can be understood and used with no extra skills or effort has a higher rate of diffusion.
- *Trialability* – having an opportunity to trial the innovation before fully implementing makes its' diffuse faster by reducing the uncertainty for the individuals who are interested in adopting the innovation. Providing a trial period or an instalment plan are some of the currently used methods. Making BIM trailable under these methods are complicated and currently unavailable. Therefore, BIM is identified as a non-trailable innovation which is expected to have a slow adoption under DOI. On the other hand, it exposes the opportunity to create mechanisms to trial BIM.
- *Observability* – how apparent is the results of the innovation. Easier it is to see the benefits of an innovation, is faster the diffusion. When the results of an innovation are freely visible, it stimulates peer discussions leading to innovation evaluation which helps the adopters to make the decision. Under 'time' and 'social systems' elements of DOI specify that these results of innovation need to be visible in short period of time and be straight forward to identify as a direct outcome of the innovation.

- Communication channels
  The second element of DOI recognise that communication as the essence of the diffusion process. In innovation diffusion, individuals evaluate technology based on subjective measures gained from experience of peers who adopted the technology rather objective evaluations. In most basic level, communication process needs an innovation to talk about, individual with knowledge or experience the innovation, another individual with no knowledge or experience about the innovation and a communication channel. Mass media (Social media, TV, newspaper, etc.) can reach vast number of people to bring awareness about the innovation while interpersonal channels are effective to make an individual accept a new idea. Interactive communication is another channel came into effect with the internet. DOI acknowledge the power behind communication channel. It further, explains that communication between two similar individuals (homophily) are much effective as they both have the same interests and talks the same language compared to technician or an engineer explaining the BIM requirement to the investors (heterophily) who have different interests. The technical language spoken by the engineer may not be understood by the investor.

- Time
  Time as the third element of DOI involved in explaining the innovation decision process from knowing about the innovation to adoption or rejection, innovativeness of an individual compared to others in the social system and innovation's rate of adoption calculated by number of members adopted the innovation over the time. Innovativeness and rate of adoption is discussed later (see Figure 5.4). Innovation decision process is an information seeking and processing activity which includes time-ordered sequence of 6 steps; (1) the knowledge about the existence of the innovation; (2) Persuasion through the favourable/unfavourable attitude developed towards the innovation. Individual will start to use innovation evolution is used at this stage. (3) Decision - engage in actions leads to adoption or rejection of the innovation. (4) Implementation – use the innovation and re-invention if likely (5) Confirmation of the decision supported by the experience of the innovation. BIM in FM can be placed in the persuasion stage of the innovation adoption process.

- Social system
  A social system is a collection of interrelated individuals, informal groups and organisations engaged in to accomplish a common goal. The structure and norms in a social system facilitates the diffusion of innovation. Opination leaders and change agents are two characters influence innovation diffusion. Opinion leaders are self-earned leadership position while change agents are placed by the change agencies to promote or slow down diffusion of innovation. Within these social systems innovation decisions can be optional to reject or adopt by individuals or a collective decision made among the members of the organisation if not, an authority decision which had made by few individuals who have power or expertise. Authority innovation decisions are to have the fastest rate of adoption confirming the reason for BIM adoption in construction so

far. However, the nature of the enforcement has given the opportunity to take it as an optional innovation decision. On the other hand, majority of the construction work does not fall under the BIM Level 2 target as three quarters of the UK construction orders are from the private sector (Rhodes, 2018). Finally, innovations bring consequences to both individuals and social systems. Consequences are the changes made to the social system. Although, change agents expect consequences of innovations to be desirable, direct and as anticipated they also can be dysfunctional, may not bring immediate response and be unintended. This reminds the need to be aware about the possible consequences of BIM in FM to the social system as a part of the innovation diffusion.

The validity of DOI is justified through wider acceptance and application of the theory. DOI is recognised to provide theoretical foundation for innovation diffusion in individual, organisational and global levels (Taherdoost, 2018). Miranda et al., 2016 applied DOI in introducing Enterprise Resource Planning (ERP) system into an organisation. Conducting similar study to this thesis, Buentello, 2017 applies DOI to understand reasons behind poor diffusion of ceramic water filters among residents. On the other hand, comprehensive review on diffusion and sustainability of innovation by Greenhalgh et al., 2007 for UK National Health Service (NHS) to gain the benefit from the existing theories is an immediately translate of a research gap required to be considered in UK construction research. The application of DOI in understanding BIM adoption in FM stage is mainly influenced by the innovation adopter categories over the time (Figure 5.4). Analysing the data received from different groups who had different levels of experiences and beliefs towards BIM adoption clearly complied with the characteristics of the adopter categories described under DOI.

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FIGURE 5.4: Normal adopter distribution and categories (Source; Rogers (2003, p.281)

Rogers (2003) discuss five adopter categories in the social system based on their innovativeness. In other terms motivation towards adopting new technology. First group of people to adopt an innovation is names as Innovators. Their venturesome personality desire for daring and risky challenges. Therefore, using subjective evaluation measures, Innovators tend to adopt an innovation in a short time. The sample group selected in this thesis did not include any participant with innovators' characteristics. Early Adopters - the second group is are localities compared to innovators. They have a "higher degree of opinion leadership" and respected by peers. UK Government and major contractors were identified in this category as the leading bodies in the construction industry promoting BIM. The intention of Early Majority is to adopt an innovation before it becomes an average practice. The have a "deliberate willingness in doping innovation but seldom lead". Most of the BIM case studies published fall into this category. Late Majority has a sceptical and cautious mind towards innovation. They adopt innovation after the average member due to the peer pressure. Most higher education estate departments are found to have similar characteristics to Late Majority. Laggards are traditional and disconnected from the social system. Their decisions are made referred to the past and economical position with limited resource make them precautious in adopting new technology leaving no room for failure.

The time taken to adopt an innovation by each member category will determine the slope of the S-shaped adopter distribution curve but, in average it takes a closer shape to a normal distribution curve (Figure 5.4). The rate of adoption is about the number of members in each of these categories which was no in the interest of this thesis. Therefore, would not further discuss, however, Rogers suggests using statistical tools - mean and standard deviation to divide the five categories.

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5.5 The concept of value

There are certain abstract concepts, which everyone is familiar with, used in daily life and taken for granted. God, after life, love and value are some examples of such concepts. These are easily understood, everyday concepts compared to artificial intelligence or the nature of being. Therefore, the modern literature hesitates to contemplate these concepts due to a lack of excitement and for the uncertainty of arriving at a ground-breaking discovery. In a sense it is similar to philosophical discussions, which no matter how much one questions the concept of value, no one has been able to bring a conclusive definition. Previous inquiries on value in the construction industry points out that value in philosophical perspective is a "seriously under researched area" (Langford, Martinez, and Bititci, 2003). However, this backwardness to accept the challenge does not testify for absence of this core phenomenon in reality. It was interesting to see during data collection how everyone paused for a while facing the question "What do you mean by value?"

A quick answer to this complexity and simplicity of value can be gained through the theory of mind by understanding the three separate levels; (a) level of world, (b) level of thought/concept and (c) level of language. Talbot, 2012 explains these levels through the example of colour – Red. Accordingly, at the first level it is the property of redness which is not a word or the concept of colour. At the second level, it is the concept of the colour red which is the thought of red but not the actual redness or a word. Finally, at the language level, it is the word "red" which has three letters. Neither property of redness nor the concept of red has three letters or letters at all. Reviewing value with an understanding of these three levels reveals the presence of oscillation between simplicity and complexity of the phenomena because of the difficulty of permanent isolation of the "the picture of the picture observed" and "the picture observed".

Since the beginning of social science research, the concept of value attracted the interest among scholars (Schwartz, 2012a). Value was a highly recognised concept in the late 19th century and there are many scholars who argue about it in different ways (Rohan, 2000). Most of the work written on value contributes to capturing the value starting with the assumption that the subject considered is valuable and giving less concern towards what makes something valuable (Bowman and Ambrosini, 2000). This is the same limitation found in BIM research. A continuously growing amount of literature begins and ends with the same notion – i.e. BIM is beneficial. Perry, 1914 places an interesting question in identifying what makes something valuable;

"Now I want you to tell me whether value is one whole, of which virtue and beauty and wealth are parts; or whether all these are only the names of one and the same thing. Are they parts in the same sense in which mouth, nose, and eyes, and ears, are parts of a face; or are they like the parts of gold, which differ from the whole and from one another only in being larger or smaller?"

Definitional inconsistency in value theory is a commonly identified gap in knowledge (Rohan, 2000). Table 5.1 presents a selection of value definitions given by well-known theorists in the subject, focused on answering "what is meant by value?"

From the review of different explanations of value it is evident that concern on value was at the centre of intellectual discussions in 19^{th} century. It was a century that made great effort and contribution towards value concept. This became the central question in early 19^{th} century because of the gradual shift from "intellectualism to voluntarism" (Urban, 1908). Which is the change in philosophical focus on problem of knowledge to problem of voluntary actions. It asks the question why people do certain things with no apparent reason.

Early Greek philosophical discussions on value led in axiological sense, recognising good and bad in ethical, religious and moral context (Hart, 1971). Aristotle's arguments on exchange and user value of goods in terms distributing goods to create justice in society influence both classical and modern economics (Ioan, 2017). Aristotle's stop his discussion on value when he couldn't find a common ground to measure value of different goods. Starting from there, the second uptake on value by economists argued value in terms of a measurement for exchange (value in exchange) and a satisfaction gained by consumption (value in use). At the most fundamental level Gogerty, 2014 explains value as "the human perception of what is important". In this thesis, the concept of value is considered as a status of mind (Ozdilek, 2019), staying in agreement with Gouveia, Milfont, and Guerra, 2014 – this perception express needs. Value as a mental status is likely to rephrase as a physical status under neuroscience and artificial intelligence. However, this will only replicate the mental status in a physical form. On the other hand, understanding on the source of value since each natural substance, product or services has a value embedded and attached to it however, how it is perceived by the users or consumers is an individual experience. What is referred as embedded value of a product or person is its capacity to fulfil users' needs.

The interest of this thesis is the perceived value by the interested party since, what is central is the value acknowledged by people rather the value embodied in a product or service. It can be argued even the embodied value is also at the fundamental level can be abstract as a value given rather value embedded. Due to the nature of the research question value is looked from a passive form – i.e. from the point of receiving end rather a concept that interest-subject is placing on an object. Water-Diamond paradox is a perfect example for this. Water has higher embodied value than perceived value. A different form of example is the new shift in money took place in 2008 with the introduction of cryptocurrency. A digital currency has no founder to hold responsible for or a central governance system but, after 10 years a bitcoin is worth over £10,000. This value is simply created by the collective belief. However, this does not imply that value embodied is neglected but, used as a mechanism to understand the user perceived value. Therefore, value is a relationship between the object and the subject (Hart, 1971). In business sense, the advantage of understanding this mental status is that it gives away competitive advantage by recognising multiple human needs closely related to the considered product or service.

TABLE 5.1: Value Definitions

Theorist	**Definition**
Lewin (1952)	Values influence behaviour but have not the character of a goal (i.e., of a force field). For example, the individual does not try to "reach" the value of fairness, but fairness is "guiding" his behaviour. It is probably correct to say that values determine which types of activity have a positive and which have a negative valence for an individual in a given situation. In other words, values are not force fields, but they "induce" force fields. That means values are constructs that have the same psychological dimension as power fields.
C. K. M. Kluckhohn (1951)	A value is a conception, explicit or implicit, distinctive of an individual or characteristic of a group, of the desirable that influences the selection from available modes, means, and ends of actions.
Heider (1958)	We shall use the term value as meaning the property of an entity (x has values) or as meaning a class of entities (x is a value) with the connotation of being objectively positive in some way.
Rokeach (1973)	A value is an enduring belief that a specific mode of conduct or end-state of existence is personally or socially preferable to an opposite or converse mode of conduct or end-state of existence. I regard values as beliefs about desirable or undesirable ways of behaving or about the desirability or otherwise of general goals.
Keeney (1992)	Values are what we care about. As such, values should be the driving force for our decision making. They should be the basis for the time and effort we spend thinking about decisions
Schwartz (1994)	I define values as desirable trans-situational goals, varying in importance, that serve as guiding principles in the life of a person or other social entity.
Schwartz (1999)	I define values as conceptions of the desirable that guide the way social actors (e.g., organizational leaders, policy-makers, individual persons) select actions, evaluate people and events, and explain their actions and evaluations.

Source: Rohan(2000)

Literature in construction sector constantly distinguish the difference between value and values (Wandahl, 2005; Salvatierra-Garrido, 2011a; Mills, 2013). Although all Mills' value publications emphasise a concern towards value and values only Salvatierra-Garrido (2011) clearly distinguish value from values to explore the necessity of the concept in construction field. Although they are considered as separate concepts, values and value are intimately linked (Thomson and Austin, 2006). Accordingly, values are not the plural of value but the core principles, morals and ideals that individuals live in and shape the societies (Thomson et al., 2003). On the other hand, value is related a product or service and it is objective when expressed and subjective if "internalised within an individual or organisation" (Wandahl, 2005; Salvatierra-Garrido, 2011). Thomson and Austin, 2006 presents a graphical representation of the subjective and objective views on value (Figure 5.5).

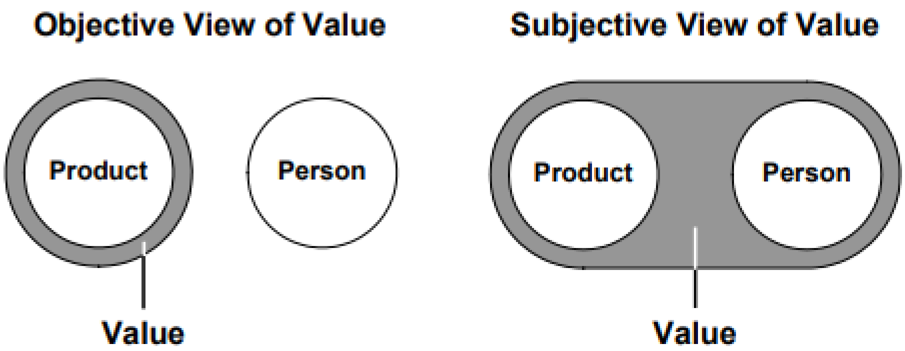


FIGURE 5.5: Subject and objective views on value (Source: Thomson and Austin (2006))

Value has existed since the beginning of the human kind hence, not a novel discovery however, the question is how to know about this complex phenomenon which a feeling at times and a decision-making tool at another was in need to be understood. This is when theorising of value became necessity. Bahm, 1993 claims that access to knowledge on value is through "intuition and inference". That is one can know about values by being conscious to the own feelings and also by logical arguments. Value is a challenging concept as it changes according to the situation. Rokeach, 1973 provides a deep analogy of values by talking through its characteristics. Schwartz's Basic Human Value theory which is discussed later reflects on the Rokeach's analogy. Discussing value in relation to construction industry Wandahl, 2005 lists characteristics of values as subjective, relative, context dependent and dynamic. Value of product for its customer before and after consumption is often different (Woodruff, 1996). The theories describing value and equations which measure are focused on either one. With this regard, the focus of this thesis is value before consumption in order to capture the motivation which drives facility managers to adopt BIM. However, this involves understanding value during consumption in order to propose long term suggestions to support continuation of BIM throughout building life cycle. Learnings from this existing knowledge is applied in the research by including both intended BIM users and existing BIM users in the sample.

From a philosophical point of view Hart, 1971 brings together a collection of research arguments to locate where value settles; in the person (subject) or the product (object). From the intention of understanding the nature of value, some claims that it is man who allocate value to an object rather, man is attracted or repulsed an object because of the value it carries. In contrast, the satisfaction given or gained can be deduced into a physical condition. In agreement that an object is valuable as much as the value given to it; embracing the "rational man" principle from economic theories, it is assumed in this thesis that although man is capable of allocating a value into an object it will not done so unless there is a benefit. Research has concluded reviewing existing knowledge on value in construction that value management has drawn from utility theory, perceived usefulness and concept of function (Jay and Bowen, 2015). Therefore, economic theories in value are taken in to consideration in next section.

5.6 Economics theories of value and decision making

Following the value discussions from the ancient history immediately creates the link into economics. The debates on value has a long history starting from Greek philosophers in 4B.C, followed by the remarking economic theories emerged close to seventeenth century first through wealth and later through production during industrial revolution. Aristotle is the first to explain the existence of value in terms of value-in-use and value in exchange in his interests for creating justice in the society. Later, Wealth of Nations by Adam Smith formally marked the beginning of classical economics while John Stuart Mill's Principles of political economy in 1848 was identified as the last greatest contribution of the classical economics (Kauder, 1965); marking another era of triumphs in understanding the role of value in the society. Making more relevant into the topic discussed in the thesis; the role of economics began to rise during the industrial revolution i.e. from the introduction of steam engine to machinery for cotton industry. In other terms, development of technology caused the rise of economics.

Economics is identified as the scientific study of the production, distribution, and consumption of scarce resources (Ashenfelter, 2001) thus, at one side a study of wealth and more importantly on the other side the study of human behaviour. Modern economics classify the subject matter of economics into two; the work related to politics, industries and whole economy as macroeconomics and studies on individual economic actors under microeconomics. Behavioural economics is a sub field of microeconomics recognised under neoclassical economics, specialising in human behaviour, how people make decisions, why people what they do (Simon, 1959). Slightly deviating from the main economic principles that man is constantly make rational decisions to maximising self-interest. The development of value from the early economic thoughts to the modern economics theories are presented in Figure 5.6.

Value has been in the centre from the early economic thought. Labour theory formally introduced from classical economics and utility theory which demarcate the classical and neoclassical economics are the two main theories of value in economics (Chen, 2018). Although, reference to value, labour value theory (Dooley, 2005) and utility theory can be traced back to

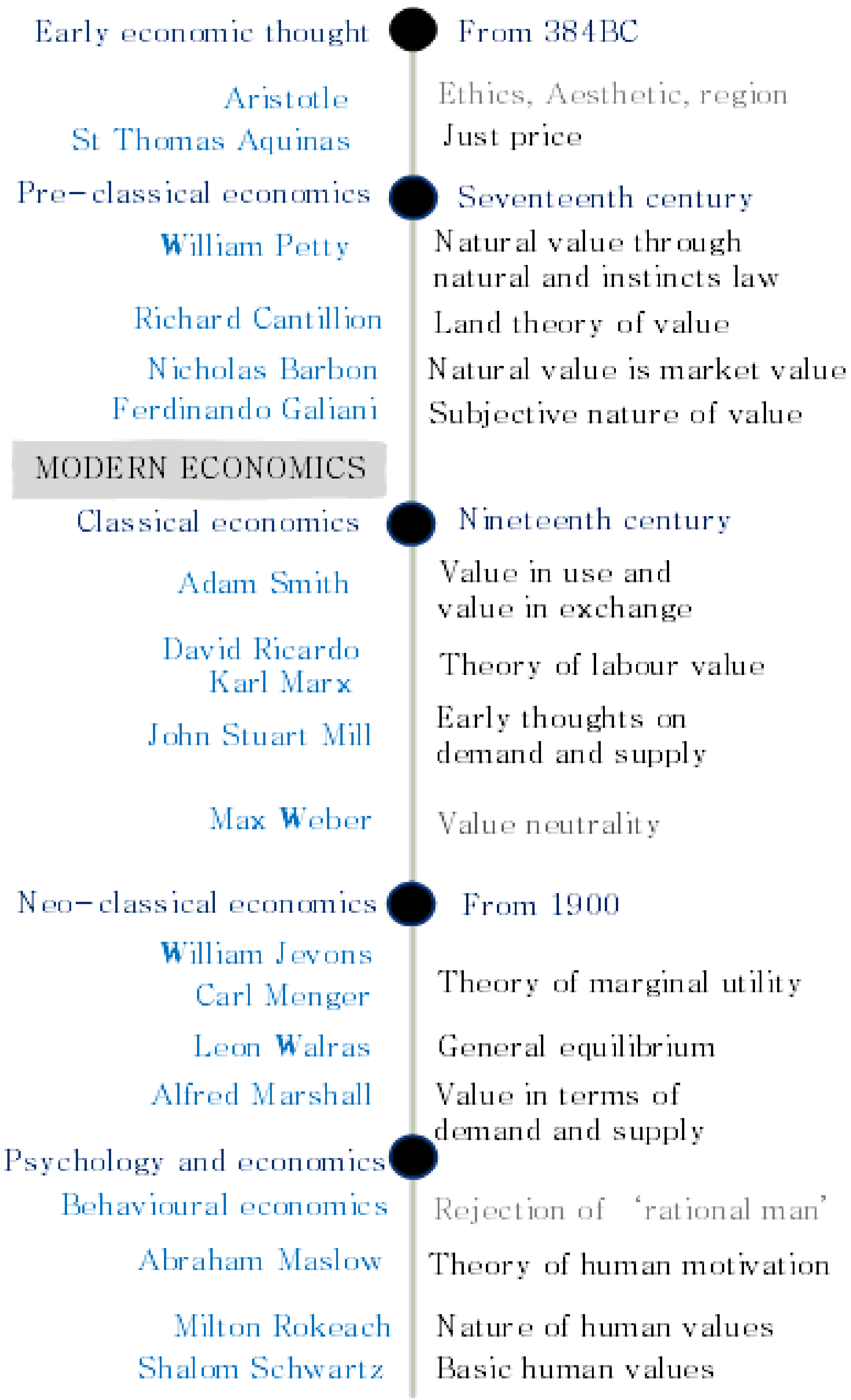


FIGURE 5.6: Development of the economic value

early work of multiple economists (Figure 5.6); here, modern economics theories on labour and marginal utility is taken as the reference. According to Karl Marx's labour theory of value, value of a commodity is determined by both direct and indirect labour value (hours of labour) (Dooley, 2005). Marx identify that labour is the origin of value arguing that even a commodity gains a value-in-use because human labour has created a useful article.

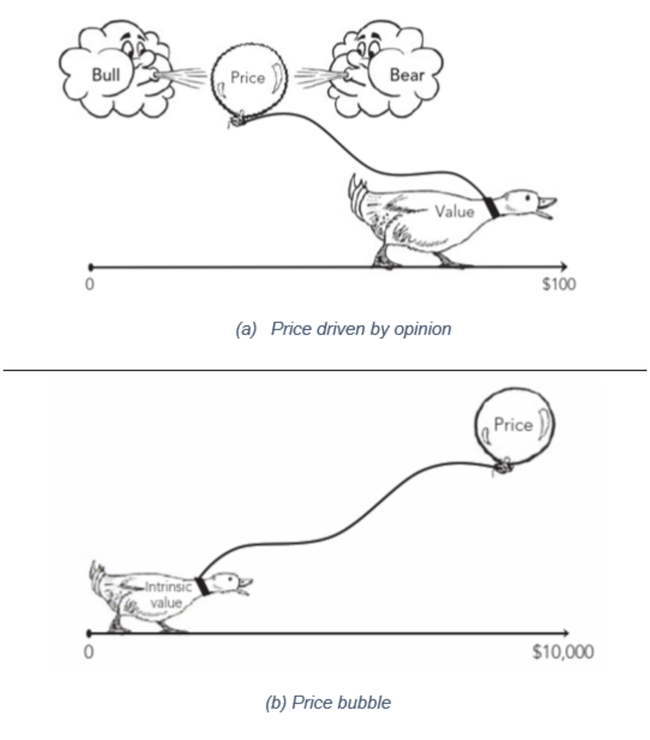
Looking at the background of this theory and Marx's Capitalist view over the society explains why it was a major contribution to knowledge at the time but discredited later when production was not the driving force of the economy. However, studying Marx's work brings a key contribution into the thesis from the perspective that existence of value-in-use is based on what is embodied in the article and rejection of harmony of interests between capitalists and worker under capitalism. In other terms, identifying value through market price will not satisfy both buyer and seller in a given point of time and price. Before, introducing money as the universal measure of value Marx explain what this measure represents. Accordingly, money is an expression of value; both qualitative and quantitative. Therefore, quantifying value in monetary terms itself multiple cycles of translation of true value such as converting Rupees into Dollars to convert to Riyal in order to buy a loaf of bread in Saudi Arabia. When labour theory is a macroeconomic concept for value, marginal utility theory is a micro economic concept. Marginal utility theory argue that value entirely depend on utility claiming that value is a future concept not past production.

Taking from the definition of economics that it is a study of handling scare resources Chen, 2018 introduce a third theory of value 'entropy theory of value'. It is supported by the entropy law in physics and Shannon's theory of information. In short, entropy theory of value claims that scarcity and value have a positively correlated. Scared products are more valuable than widely available. This brings an explanation for the water-diamond paradox thus, at the weakness of assuming that things such as water and air has less or no economic value.

Understanding value theories from economics but applying in construction; narrow it down to often misused concepts; price, cost and value. Multiple attempts are being made previously to consider the best value in construction acknowledging the constant misinterpretation of these concept (Kelly, Graham, and Male, 2014; Kelly, Morledge, and Wilkinson, 2002). However, all of these are written with the aim of value management rather providing a fundamental understanding on value. Others focus on the subjective nature of the value in construction with no reference to economic value (Devine-Wright, Thomson, and Austin, 2003; Thomson et al., 2003; Mills et al., 2009; Salvatierra-Garrido, 2011b).

Literature on the precise matter of price, cost and value emphasise these as close but complete difference concepts (Jacob, 1989; Ozdilek, 2019; Ozdilek, 2010; Gogerty, 2014). Highlighting the problem of day to day practice of value equating price and its impact on market Gogerty, 2014 explains that one who understands the value of a product or firm is at a significant advantage. Gogerty explains the price-value relationship in the market using an example of a Goose (Figure 5.7).

Accordingly, market traders use historical process to value and decide the price and once it is in the market, opinions on the trade prices push or pull the price. Although the price



(a) Price driven by opinion

(b) Price bubble

FIGURE 5.7: Price and value in market (Source; Gogerty (2014))

change, intrinsic value of the firm remains the same in short term. In long term, the true value of the firm brings the price to its right position. This indicates that price reflects the opinion on products' capability to deliver value in future and it is a risky measurement to rely on above its capacity (Gogerty, 2014).

Entering from a microeconomic perspective Ozdilek, 2010 discuss the distinction of cost, price and value in real estate context. Figure 5.8 illustrate an example of property cost, price and value using demand and supply utility theory. Accordingly, a property which cost £100,00 to build is given a price of £110,00 attributing some utility. If assumed the real value of the property is £130,000 then the economic surplus (value – cost) is £30,000 however, in this instance realised surplus is £10,000. As Ozdilek, 2010 the remaining £20,000 of surplus will drive the cost and price until it is recovered. That is optimum market price will be equal to real value.

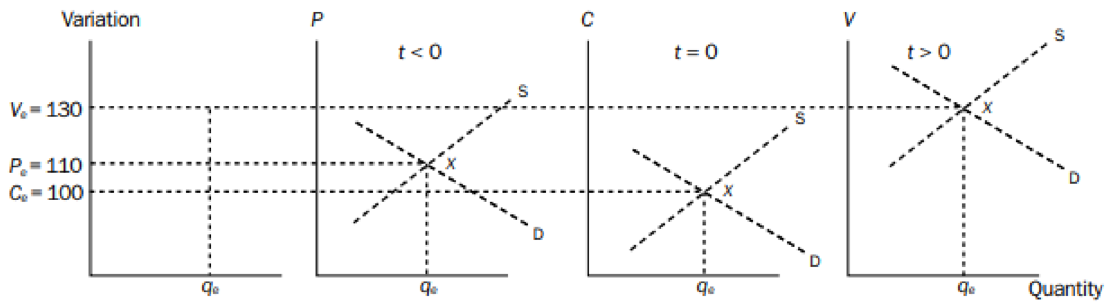


FIGURE 5.8: Variation of cost, price and value (Source; ozdilek (2010))

In summary, both examples illustrated that substituting price for value is a bias. Although, in many cases monetary value has been successfully guiding the value decision, using the same strategy in an undeveloped phenomenon such as BIM experience in FM will not only bring partial evidence but also limits discovering the tremendous possibilities laying ahead in BIM in FM. On the other hand, referring back to the economic theories; labour theory of value is predominantly focused on capturing the production value given the priorities of the 17th and 18th centuries. As a successor of labour theory, marginal utility theorises the understanding of utility from the sales point of view. None of which is eligible as a single theory to support the understanding over BIM in FM. Therefore, holding into value-in-use learnings from economic theories, further alternatives are explored in next two sections by studying different measures of value and physiological aspects of value respectively.

5.7 Measurement of value

For almost the last 50 years, authors have continuously structured value in an objective and rational manner under a positivist's standpoint, providing an equation to measure value (Mills, 2013). Although the concept of value has a long history, measurement of value is a comparatively recent endeavour. The beginning of the value equations goes back to the work of Lawrence D. Miles on value management officially published in 1972 (Mills, 2013; Shen and Ann, 2015). However, Miles' initial work took place in 1952, before emerging as the concept of value engineering beyond the U.S. (Al-Yami and Price, 2005). When referring to the early writings on the concept of value (see Topic 5.4) it is evident that value has a long history before the 1970s and both numerical and qualitative methods were used to describe value. Most common descriptions can be broadly categorised into either value in exchange or value in-use because all the studies on values can be broken down into one of these two basic principles in measuring value. Repo, 1986 provides a detailed explanation for this dual approach "exchange value" and "value in use". Looking at these approaches to understanding the value of information, exchange value refers to the market value of information when it is regarded as a product or service. On the other hand, value-in-use refers to the benefits of information to the users which is not always in monetary terms.

The understanding of concept of value revealed the multifaceted structure of value and it provides different meanings to different stakeholders although there are fundamental level values which are universal. The simplest and most commonly known measurement of value is 'cost' over 'benefits', which represents the worth of the considered matter (Neal and Strauss, 2008). The costs and benefits can be communicated in different ways. As a representation of this variation caused by the individual's world view and matter at consideration, Figure 5.9 presents a collection of value functions from its initiation by Miles in the 1970s. This graphical representation of the value functions provides a snapshot of a timeline. It is evident that interest towards understanding and measuring value increased over time and the major contribution to value literature took place in the 1990s.

The subjective nature of value soon makes the pattern when analysing the development of value functions since its beginning from Miles' work. Although there is a constant pattern

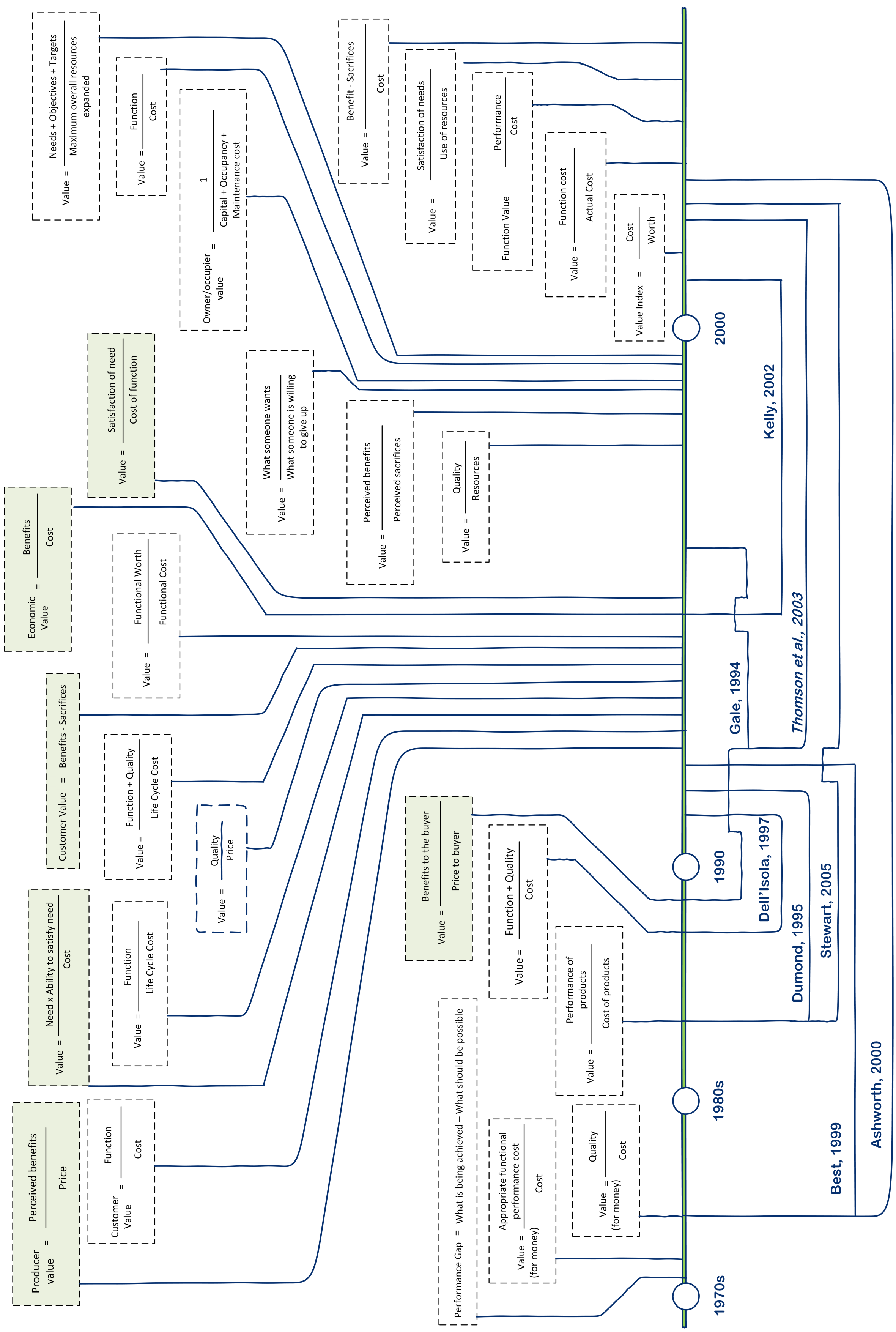


FIGURE 5.9: Value Functions (Adopted from Mills, 2013)

of placing cost as the denominator, the numerator of the equation has persistently changed. It is almost the change in the numerator which brings novelty to each value function. Scholars have used the numerator to indicate subjective variable in value such as quality, benefits and needs. On the other hand, precisely choosing the numerator to place the subjective variable emphasises the weight of subjectivity involved in measuring value. Moreover, accepting subjective methods to measure value has augmented. The interesting fact about the denominator which represents pure quantitative variable is supported by the economic theory. The denominator of the value function has always been represented by cost or price. Considering that cost is the price paid or would have been paid, both price and cost falls under economic pricing. Accordingly, price is an estimation of value. Therefore, at the very fundamental level either the entire value function is subjective or measuring value by value (i.e. price) has unexpressed biases embedded in the work.

In construction, a balance of cost, quality and time is considered as a method to ascertain value (Best and De Valence, 1999). However, the elements associated with each variable (objective or subjective) and the level of influence will differ based on the project. Being more specific, Becerik-Gerber and Rice (2010) present perceived value of BIM through analysing tangible benefits and costs which can be monetised. However, most of the research on value does not gives a precise description what is meant by value. Although the research is set in the Architecture, Construction, Engineering and Facilities Management (AEC/FM) setting, it is necessary to look for the features related to information to define the value of information beyond the project's success. Gallagher, 1974 suggested 3 possible ways to measure the value of information. The first and the best way according to Gallagher is measuring the value after the information is being used and the consequences of the action are known.

Working on the cost benefit following economic theory to capture the value of information, Gavirneni, Kapuscinski and Tayur (1999) developed an equation based on case studies in supply chain information flow. They compare the monetary, performance and lead time improvements made through availability of information. Similarly, by elaborating factors considered as benefits in the value equation Neal and Strauss (2008) introduced a measurement tool to capture the brand value, both of the methods being successful attempts due to the uniform nature of the manufacturing industry and its products. Conversely, this same reason makes them weaker to apply in the construction industry. However, there are key points which can be taken forward to capture the value of construction information for facility management.

One such cross industry lesson to take forward is that of comparing the two situations of performing a task with and without information (Gavirneni, Kapuscinski, and Tayur, 1999). Consequently, the improvements made to the situation when information is available quantify the value addition done through it. This is merged into the research by gathering collective perspectives from both current and potential BIM users and perspectives on before and after BIM experience. Value is something more “adjectival rather than substantive” therefore, it should be found along with the considered object and interest (Perry, 1914). Therefore, data collection was kept in the limits of BIM in construction practices rather than opening up for wider applications such as software or policy developments.

There are two main reasons why cost consideration is not the appropriate view towards value in operational level BIM implementation. Apart from the fact that allocation of a monetary value to a piece of information is almost impractical (Gallagher, 1974), the cost of BIM does not tally with the economic theory as it is not paid by the operational level FM. If the organisation has a budget that fits with the cost of BIM, it becomes possible regardless of FM's preference. On the other hand, high cost of BIM implementation is short term or a matter of time. It will soon be similar to the market price of CAFM, BMS and other similar computer aided building operations and management systems. Love et al. (2013) discuss the failure in using ordinary Return on Investment (ROI) to assess the benefit of adopting BIM in FM. On the other hand Becerik-Gerber and Rice (2010) claims that it is necessary study BIM over 5 to 8 years to quantify the true value in monetary terms. By studying many value functions, the value-in-use is considered to measure value as its concerns fit with the nature of BIM and its application in FM in present time. The next section explores an appropriate theory to understand causal mechanism of value-in-use.

5.8 Basic Human Value Theory

Understanding the human nature is the way to ascertain true value (Hart, 1971). Schwartz's "Basic Human Values" which builds a universal human value structure is one of the most advanced and well proven human value theories in both social science (Cieciuch et al., 2014) and construction research (Mills et al., 2009). Schwartz's initial work is based on Rokech's explanations on values and value systems. Therefore, the roots of the basic human value theory are in psychological research. Basic human value theory is based on the definition "basic values are trans-situational goals, varying in importance, that serve as guiding principles in the life of a person or group" and theorise that basic values of are universal therefore organising them in a logical structure helps in understanding and explaining in individual decion making (Schwartz, 2012b). This structure refers to how values are conflicting and compatible with each other rather considering hierachy of the values (Schwartz, 1992). It is identified that manner that basic values are orderd by indivuals Accordingly, basic human value theory presents 10 basic values (see Table 5.2) which are likely universal and their structure of the circular momentum. Schwartz (2012b) later expanded the original 10 value types instrutuced in 1992 into 19 basic value types by introducing subvalue types to bring a preciese insight. However, this is in repornse to the difficulties faced by the researchers measuring basic value rather than a correction to the theory. Therefore, this thesis identify the basic human value theory for its 10 basic values.

Basic human value theory reveals the complex social realities that come along with procedures and solutions adopted by the construction industry (Mills et al., 2009). One of the key characteristics of values is that there are common features in value as well as distinct differences making the concept of value challenging as well as unique. In Schwartz's theory this is acknowledged as value conflicts and compatible motivations. At the heart of basic value theory is the circular structure of values, where one value motivates the other

(Schwartz, 2012a). Figure 5.10 presents the 10 values arranged in the circular motivational continuum representing the structure.

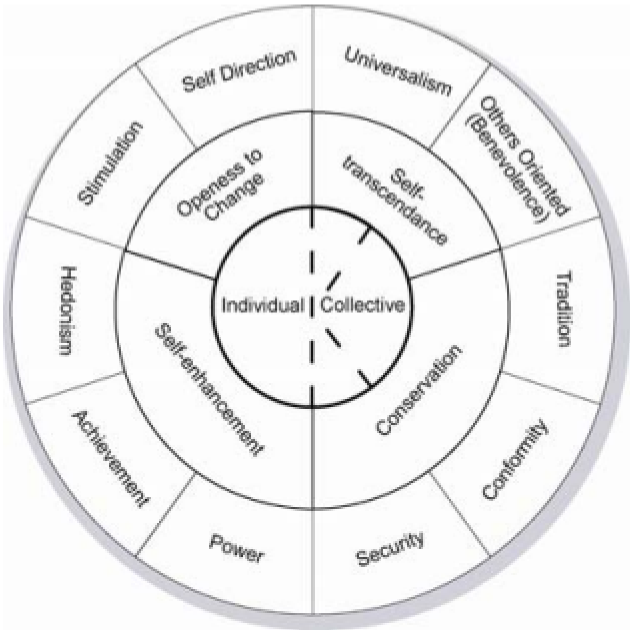


FIGURE 5.10: Circular motivational continuum (Source: Mills, Austin and Thomson (2006))

Although 'value' is an everyday term, this nature of value is what makes it complex to trace down what it means every time when the term value is used in symbolic interaction. Studying similarities of values help defining values. Taken from Rokeach (1973) and expanding through rigorous testing and developments, basic human value theory explains six features common to all values (Schwartz, 2012a);

Values are beliefs: Values are deep rooted with feelings. A person with independence as an important value is delighted when they can enjoy freedom and disturbed when their independence is threatened. This leads to both positive and negative behaviour based on the emotional charge.

Values refer to desirable goals: Values motivate actions. When social acceptance is an important value, one will act and behave to gain social acceptance in all circumstances.

Values transcend specific actions and situations Obedience and honesty may be relevant values in workplace but, these values are not limited to workplace decisions. This is one of the features that distinguish between norms and attitudes which usually refer to specific situations or objects. For example; ones who value lowest cost will make decisions based on price in both personal matters as well as business engagements regardless.

Values serve as standards or criteria: Values guide the people to decide what is good or bad, worth doing or avoiding. However, this logic between values and everyday decisions is rarely conscious. People are only aware about the contribution of values when the judgement to be made has conflicting implications for different values one believes in.

Values are ordered by importance: People prioritise the values based on their character and an ordered system of priorities builds a person's character. These priorities change with the context. Hierarchy is another key feature that distinguishes values from attitudes and norms.

Relative importance of multiple values guides actions: Choices made are typically implications of more than a single value. It could be purely a combination of values gained as well as a combination of values gained at the expense of another. This emphasises the importance of recognising values of FM in order to influence their motivation towards adoption of BIM in FM.

The efforts made to understand the value of BIM in monetary terms have identified that it is too early to determine the tangible value of BIM as it is still in the initial stages (Becerik-Gerber and Rice, 2010; Love et al., 2013). Therefore, understanding the value of BIM through cost savings may not provide the reasons for immediate adoption of BIM in FM. On the other hand, human values are recognised as the core independent variable in studies on behavioural and social attitudes (Rokeach, 1973). Therefore, creating knowledge on how BIM fulfil human needs in the short term is being recognised as a timely solution. Schwartz's theory of basic human values identifies ten basic human values which are empirically proven to be common among cultures (Schwartz, 2012a; Gimenez and Tamajón, 2019). Each basic value type is explained giving example in the context of BIM adoption in Table 5.2.

Schwartz's basic human value theory was initially developed to present the universal aspect in basic human values. However, this has now being applied in different disciplines to identify the human factor in a vast range of subjects such as construction management (Mills, 2013; Mills, Austin, and Thomson, 2006), information technology (Isomursu et al., 2011), circular economy (Piscicelli, Cooper, and Fisher, 2015) and even in ecology studying the influence of values on making sustainable choices (Hicks et al., 2015). Indeed, research conducted applying Schwartz's value theory in the construction industry (Devine-Wright, Thomson, and Austin, 2003; Thomson et al., 2003; Mills et al., 2009) prove the applicability of the theory in understanding the complex social reality in the construction industry. Also, previous research has studied human values to understand the user acceptance of new technology using Schwartz's human value theory similar to the context of application of the same theory to understand the acceptance of BIM by facilities managers.

TABLE 5.2: Schwartz's basic human values

Self-direction:

Independent thought and action which allows to be creative, explore and choose

- This value is motivated in humans as intelligent subjects. It seeks for self-respect, privacy, freedom and promotes creativity. Self-direction is a commonly seen value which influences most of the actions and decisions.
- In BIM terms: It is similar to the general explanation. As an example, adopting BIM because it allows creativity

Simulation: Excitement, novelty and challenge in life • This is derived in relation to self-direction. People make choices to make life exciting and varied. The choices which satisfy this need are valued. This again might be found contradictory with 'Tradition' as people value to commit to what they know. • In BIM terms: Exciting opportunities open up through BIM adoption. For example, being nominated for best practice awards or overseas training opportunity
Hedonism: Pleasure and gratification for oneself • This comes from the person-centred needs. Ability to satisfy one's needs motivated to make choices. • In BIM terms: ability to make user's life easier is a motivational factor to adopt BIM as getting things done instantly is a human need.
Achievement: Personal success gained through demonstrating competence according to social standards • Skills and competences are required for survival and resource generation. Performing to achieve survival and resource generation brings social recognition. Therefore, people act and make choices to gain social recognition. • In BIM terms: Skills and competence gained through BIM is a value and recognition as a BIM expert
Power: Social status and prestige • The simplest explanation of this value is need for dominance over resource and people. In 21st century this is more seen through developing social status. Although this is found similar to the "Achievement" value, "Power" focuses on preserving the social esteem while "Achievement" is towards active engagement to gain social esteem. • In BIM terms: Power held by having undocumented knowledge about the building

Security: Safety, Harmony and stability • This value refers to the individual interest of safety such as being clean as well as wider interest towards national security. • In BIM terms: Stability with current system is valued that unknown BIM
Conformity: Restrain of actions and impulses likely to upset or harm others • This informs the natural tendency to act in a way that violates social expectations. Conformity is a motivational factor to self-discipline and politeness • In BIM terms: This could be defined as honour line manager's non-BIM agenda although that's not one's preference
Tradition Respect, acceptance and commitment of the customs and beliefs according to one's culture/religion • Every person has his own beliefs. Practices and ideas. Common beliefs bring groups together and they express their unique worth. It is a form of subordinating to social expectations in terms of culture and religion rather to persons as it is in "Conformity". • In BIM terms: Generational difference in acceptance of technology
Benevolence Looking after and developing the welfare of those with whom one is in personal contact • Expressed through the voluntary concern towards others' welfare. Primarily within the family and extended society. This value promotes people to be honest, forgiving, responsible and loyal. In 'Conformity', actions such as forgiving and responsible are to avoid negative outcomes. • In BIM terms; adopting BIM purely because of understanding its value as the right thing to do

Universalism
Understanding, appreciation and tolerance of whole universe (people and nature)

- As a survival mechanism to avoid life threatening conflict from people and destruction of the resources from nature. The realization of this value is only perceived with the experience of resource scarcity or encounter with others beyond their group or at a natural disaster. In simple terms this could be paraphrased as appreciation of social justice and world peace. This value contains the subtypes of inner harmony and spiritual life.
- In BIM terms; adopting BIM for recognizing its wider good through universal application and waste reduction

Adopted from Schwartz (2012)

The common use of the basic human value theory is based on the original 10 value types measured through Schwartz Value Survey and Portrait Values Questionnaire (Schwartz, 2012a; Schwartz, 2012b; Mills, 2013). Value types are either translated into everyday life of construction practices to create a hierarchy under quantitative research methods or questions are formed and situations are observed to recognise 10 value types in construction industry settings. However, the application of basic human value theory in this research takes a different approach, discovering an unexplored side of the theory within the construction discipline. It is the value features described under human value theory that is directly translated in to the research rather the value types. 10 value types act as the theoretical lens to see and explore the causal mechanisms causing the output of BIM participant's experience. Further, basic human value theory brings the theoretical evidence and support the substantive theory introduced in this thesis rather the output being reached by using human value theory. Moreover, a breakthrough of basic value theory introduced by Gouveia, Milfont, and Guerra, 2014 explain the function of human values creating the link on how values guide the actions and express human needs.

5.9 Chapter Summary

This chapter builds a vital part of the theoretical support for the claims made in the forthcoming chapters. Accordingly, it is recognised that where there is an attraction or repulsion, there is value. An object is valuable as much as value attached to it by interested-subject. Measuring value in cost benefit sense would deduce true value into a measurable component. Therefore, will only provide a measurable but partial understanding. Focus on value from systems design to human-computer interaction and technology acceptance theories emphasise the necessity of understanding holistic nature of value. Moreover, with the uncertainties in technological developments, revealing the close relationship between basic human needs and technology is in support of sustainable growth. The next chapter presents the multiple rounds of data collection and analysis conducted in order to develop the value model of BIM in FM. The sections in the current chapter is also informed by the themes generated during data collection and analysis.

Chapter 6

Data collection and analysis

6.1 Introduction

The former intricate discussions on research methodology (Chapter 4) answers to the questions of what it is recognised as the being and how the reality is seen through this research. The research aim and investigator's philosophical views have formed the world view of the research. In short, the research aim informed the philosophical base and consequently, research philosophy directed towards the research strategy, data collection and analysis tools. Further, logical reasoning and the relationship between each step narrowed down the theoretically suitable data collection and analysis tools for the subject studied.

This chapter discusses how these selected research techniques were employed in the research. In terms of data collection and analysis, research was divided into three phases for successful achievement of each research objective. Theory which emerged through the analysis of each stage laid the foundation for the next stage until data saturation was achieved. This is one of the key characteristic of a Grounded Theory research. Chapter 6 presents the three stages of data collection and analysis along with a brief explanation of findings leaving space for a detail discussion on the model development in Chapter 7. Being informed by a Critical Realist philosophy the research has taken an Abductive approach. Further, influenced by Grounded Theory research strategy interviews and focus groups data collection tools and constant comparison data analysis tool were employed. The data collection and analysis are explained in detail while discussing how each phase informed its successor when complying with Grounded Theory. In summary, this chapter is the roadmap (Figure 6.1) to development of the BIM based value model for FM.

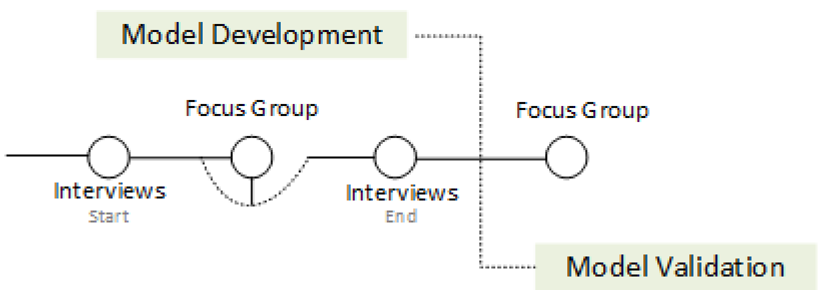


FIGURE 6.1: Data collection timeline

6.2 Phase 1 – Interviews

The first phase of data collection was designed to achieve the second objective of the research which is focused on exploring the reasons behind slow adoption of BIM in FM. Taking the lead from the successful fulfilment of the first objective through the literature synthesis a clear emphasis was found on the importance of seeing information as the key in success to BIM. On the other hand, it was evidenced that there is a bottleneck in moving BIM from construction to in-use onwards and there is a knowledge gap about the formation of this bottleneck as most of the existing knowledge is preoccupied with discussing the positive overall impact and future contribution of BIM. Avoiding making any assumptions from similar scenarios of adopting IT solutions from other industries, the research strategy was influenced by philosophical foundations of the research favoured in investigating the causal mechanisms. Therefore, interviews were selected to gather thoughts about BIM from both clients (information users) and contractors (information suppliers). A detail review of interview as a data collection tool and explanation on theoretical underpinning can be found in Chapter 4 (see section 4.6.1). Initiated by existing knowledge, the first round of questions was formed to identify the information requirement and flows (in / out) in the FM stage and how BIM can be adopted as an effective vehicle to manage the information.

The complexity of the multidisciplinary role played by facilities managers, heterogeneous nature of construction projects and limited application of BIM, created an unfavourable situation to select a sample based on professional discipline, building type or procurement method. Therefore, the study is incompatible with probability sampling techniques. Justifications for the rejection of probability sampling is discussed in detail in the previous chapter (see topic 4.3.2). On the other hand, Grounded Theory research strategy provides freedom to purposefully select the initial sample to conduct theoretical sampling later in the study (Strauss and Corbin, 1998).

Using theoretical sampling method is a fundamental feature in Grounded Theory research strategy. Further, the unique richness of this sampling method to embrace multiple other sampling methods also stands in favour of qualitative research. Therefore, theoretical sampling method was taken as the primary sampling strategy and multiple other methods such as convenience sampling and snowballing technique was used where necessary to trigger theoretical sampling process. There was no predetermined sample size but continued data collection to reach theoretical saturation. This again to comply with the Grounded Theory research strategy and detail discussion on this regards could be found in Chapter 4.

Following convenience sampling, three major scale projects in Liverpool city region that were at inception or design stage in year 2015 and have publicly announced their commitment to BIM were selected for the first round of interviews. Both information users and suppliers of these BIM enabled construction projects were selected to identify the BIM application in FM. Criteria for being interviewed under convenience sampling were;

(a) Currently working on a project intended to deliver with BIM

(b) Minimum 5 years working experience in current role

(c) Working in a role responsible for in-use phase of the building (i.e. facilities manager, estate manager or any other designation given by the organisation for a similar position)

(e) If not (c), working in a role responsible for handover information from the project team's side (i.e. lead architect, contractor).

Five in-depth interviews were selected using convenience sampling to do the ground work to start using theoretical sampling for the rest of the study.

The data collection in all three rounds were given priority to understand the common view on BIM rather focusing on any extreme perspectives. That is not to bring complete focus on successful BIM projects or traditional projects. Therefore, the North West has been the centre point of the sample as it represents the average situation of the construction sector in Great Britain and also provides a higher contribution to the employment in the construction industry (Figure 6.2). This was purposely considered as a necessity since most of the other BIM related publications (e.g. National BIM Survey) were made based on the data from highly concentrated areas (e.g. London) and made a biased view of the overall practice and knowledge on BIM in the construction industry. Apart from these key reasons, convenience in data collection and the requirement of the funder has influenced the sample choice as this study is partly funded through LJMU Estates department and they provided the context for the research study.

Data saturation was not in focus since the aim of the first round of data collection was to inform the thematic sampling for further data collection rounds. Themes which emerged during analysis of the first few interviews immediately emphasised the need of Phase 2 focus group discussion. With continuous influence from the emerging themes (theoretical sampling), the snowball technique was used alongside to continue with interviews and recruit suitable participants until data saturation was achieved. The snowballing method provides the opportunity to gather data from an appropriate population under the theory that those members with a special relevance are familiar with each other in the population (Penrod et al., 2003). A detail discussion on sampling method and justifications for the selection can be found in Chapter 4 (see section 4.6.2). Being guided by the theoretical sampling avoids the weaknesses involved in snowball such as reaching only similar cases. Table 6.1 presents the profiles of the sample.

The true process of Facilities' Information Management consists of several phases (i.e. information requirement identification, communication of these information requirements to project stakeholders, handover and use/reuse of information). Also, as identified in the literature (see Figure 3.1) the information flows are complicated as it flows to and from different parties. Looking from the supply and demand perspectives is one of the ways of studying complex information flows (Bosch, Volker, and Koutamanis, 2015). In this regard, the interview sample was selected to cover both information supply and demand/user sides. Altogether 21 semi-structured interviews were conducted with 6 Facilities Managers (FM1-6), 2 Estate Managers (EM 1-2), 4 Contractors (C1-4), 4 Architects (A1-4), 1 Building Surveyor (BS), 1 BIM Manager (BM), 2 Consultant (Cn) and a CAFM Service Provider (SP).

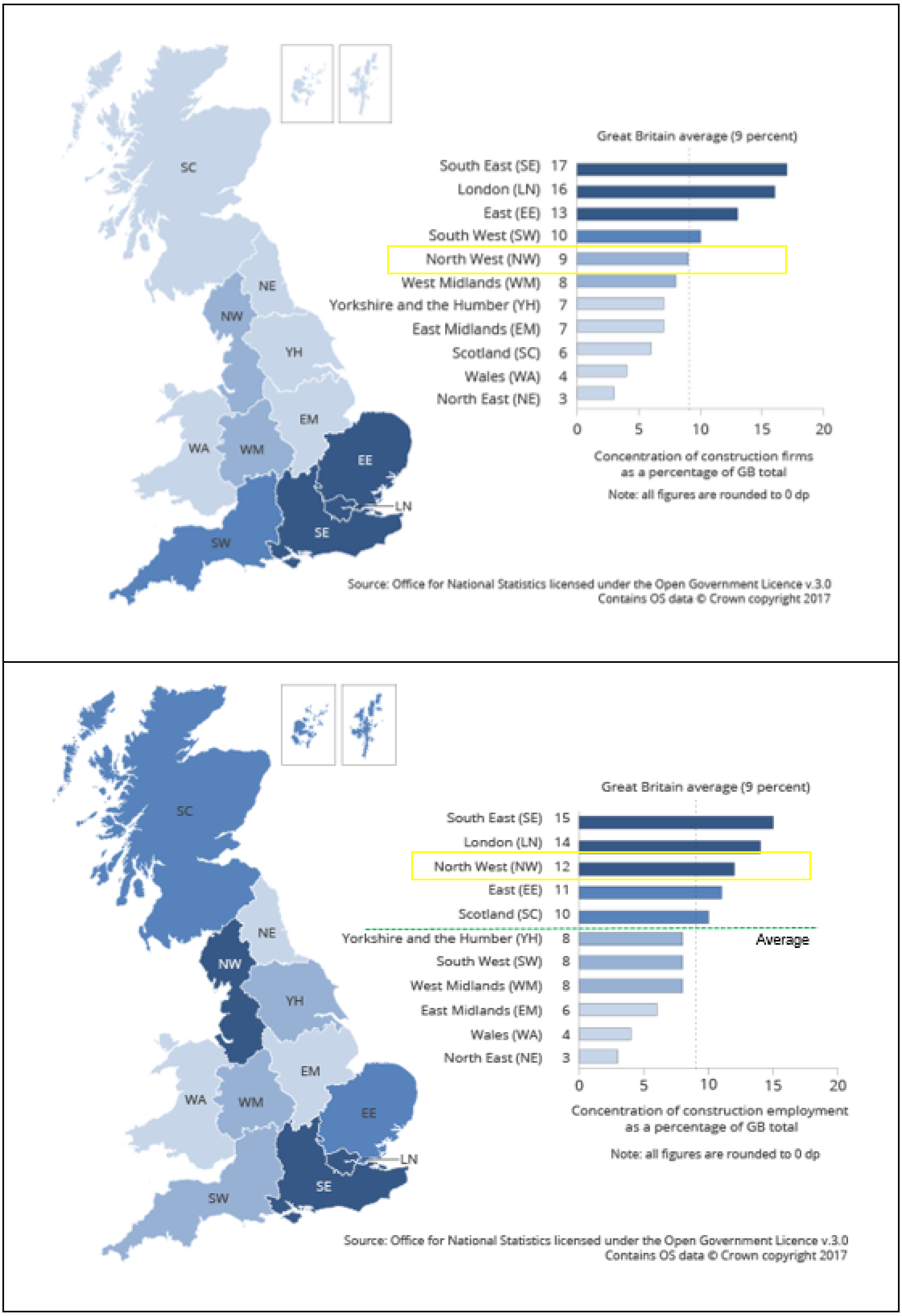


FIGURE 6.2: Concentration of Construction Industry in Great Britain

TABLE 6.1: Interviewee profiles

ID	Role	Industry	BIM Experience	Case
EM-1	Estate Manager	Education	Interested	Base
EM-2	Estate Manager	Education	Novice	Diverse/Similar
EM-3	Estate Manager	Health Care	In progress	Diverse
FM-1	Facilities Manager	Education	Interested	Base
FM-2	Facilities Manager	Health Care	In progress	Diverse
FM-3	Facilities Manager	Commercial/mix	Interested	Diverse
FM-4	Facilities Manager	Education	Interested	Diverse
FM-5	Facilities Manager	Education	Novice	Diverse/Similar
FM-6	Facilities Manager	Facilities Management	Champion	Diverse
BM	BIM manager	Education	Expert	Diverse
BS	Building Surveyor	Estate	Champion	Diverse
Cn-1	Consultant	Construction	Expert	Diverse
Cn-2	Consultant	Construction	Champion	Diverse
A-1	Architect	Construction	Champion	Diverse/Similar
A-2	Architect	Construction	Expert	Diverse/Similar
A-3	Architect	Construction	Champion	Diverse/Similar
A-4	Architect	Construction	Expert	Diverse/Similar
C-1	Contractor	Construction	Expert	Diverse/Similar
C-2	Contractor	Construction	Expert	Diverse/Similar
C-3	Contractor	Construction		Diverse/Similar
C-4	Contractor	Construction		Diverse/Similar

Profiles of the interviewees is given below (see Table 6.1). All the interviewees had a minimum 5 years of professional experience. Priority was given to collecting data from information users (6 facility managers, 2 estate managers, 1 BIM manager and 1 CAFM service provider) due to the limited application of BIM within FM and as required by the themes which emerged. Data collection continued until data saturation was obtained. Often literature on research methods does not suggest an exact number of sample size for qualitative research however, 5-25 in-depth interviews are suggested by Saunders, Lewis, and Thornhill, 2012 as a rule of thumb. Confirming this Glaser, 1998 answers the question reluctantly to put a number but emphasising 20 full interviews are capable of providing ground for a solid theory. On the other hand, especially with the nature of the GT process, too much data is to cause “conceptual blindness” which leads to scanning the data rather going through a “cognitive process” (Morse, 2010). Hence, even with the aid of computer assisted analysis tools, when it comes to qualitative data, analysis will be done by the enquirer (ibid).

The first few interviews were supported by a structured interview guideline. This was designed and piloted for its clarity and readability. Having noted the comments given in the pilot run, a few amendments were made to the interview guideline. The guideline consisted of open ended and multiple-choice questions, and they were structured into four main sections (see Appendix F). The first section was aimed at identifying the generic information of interviewees such as industry experience, type of organisation, roles and responsibilities etc.to pre-qualify the candidates and to identify any patterns based on the background of the respondent. The second section was targeted at identifying current Information management practices (including BIM and non-BIM environments), in FM while the third section considered whether such information was fit for purpose in achieving FM functions. The final section of the interview guideline was used to determine the value considerations of such information in achieving FM tasks and how BIM enhances the value of FIM. Each interview lasted between 40min and 1hour and probing questions were considered where appropriate. Interviews were recorded using a digital recorder and transcribed for analysis when needed. However, this rigid structure of the interview guideline was only used for the first round of the interviews. Structure of the interview guideline was regularly revised based on the themes which emerged during ongoing analysis which took place in parallel to data collection.

6.2.1 Data Analysis

Following Grounded Theory research strategy, Constant Comparative Method (CCM) was used in Phase 1 and 2 analysis following Glaser and Strauss, 1967 in essence, while grasping the advantages of the coding paradigm of Strauss and Corbin, 1998 at the beginning to help start with the process. This section of the Chapter 6 discusses the Phase 1 analysis and how it informed the Phase 2. It is important to note that CCM continues till the theoretical saturation is achieved without making any boundaries between phases. For the presentation purpose, an artificial boundary has been created to maintain the structure of the thesis.

Phase 1 interviews were carried out in two stages. Stage 1 (hereafter referred to as Phase 1.1) consisted of interviews before Phase 2 and Stage 2 (hereafter referred to as Phase 1.2) consisted of interviews conducted after the Phase 2 (see Figure 6.1 on pg. 149). Phase 1.1 focused on handover information and FM practices under the assumption that information is the key driver of BIM as a point of departure. It included interviewees from higher education institutes some with no BIM experience and others with some BIM experience. Also, from a health care organisation which had a major scale ongoing BIM project but had no experience of BIM in FM. As noted, BIM experience and organisational support towards BIM adoption of the interviewees were different. The health care organisation had a more structured protocol for building construction and management where higher educational institutes had a much more flexible system. Another diverse component included in the data was the idea of BIM from outsourced and in-house FM practices. However, there were many similarities within these diverse groups in terms of use of BIM in FM.

Taking off from the assumption that BIM can resolve the information problems faced in the facilities management phase, questions were directed at understanding what information is needed by facilities managers for an effective and efficient in-use phase. From the start of the analysis the incidents that emerged showed an ambiguous connection between information and value (see memo 1) setting the scene for the extended data collection (i.e. Phase 1.2). Agreeing with conventional economic man described in economic theory, information users, or in other terms client representatives, demand “all the information” possible with BIM in order to gain the best value. As presented in Figure 6.3 positive relationship was discovered between information and value.

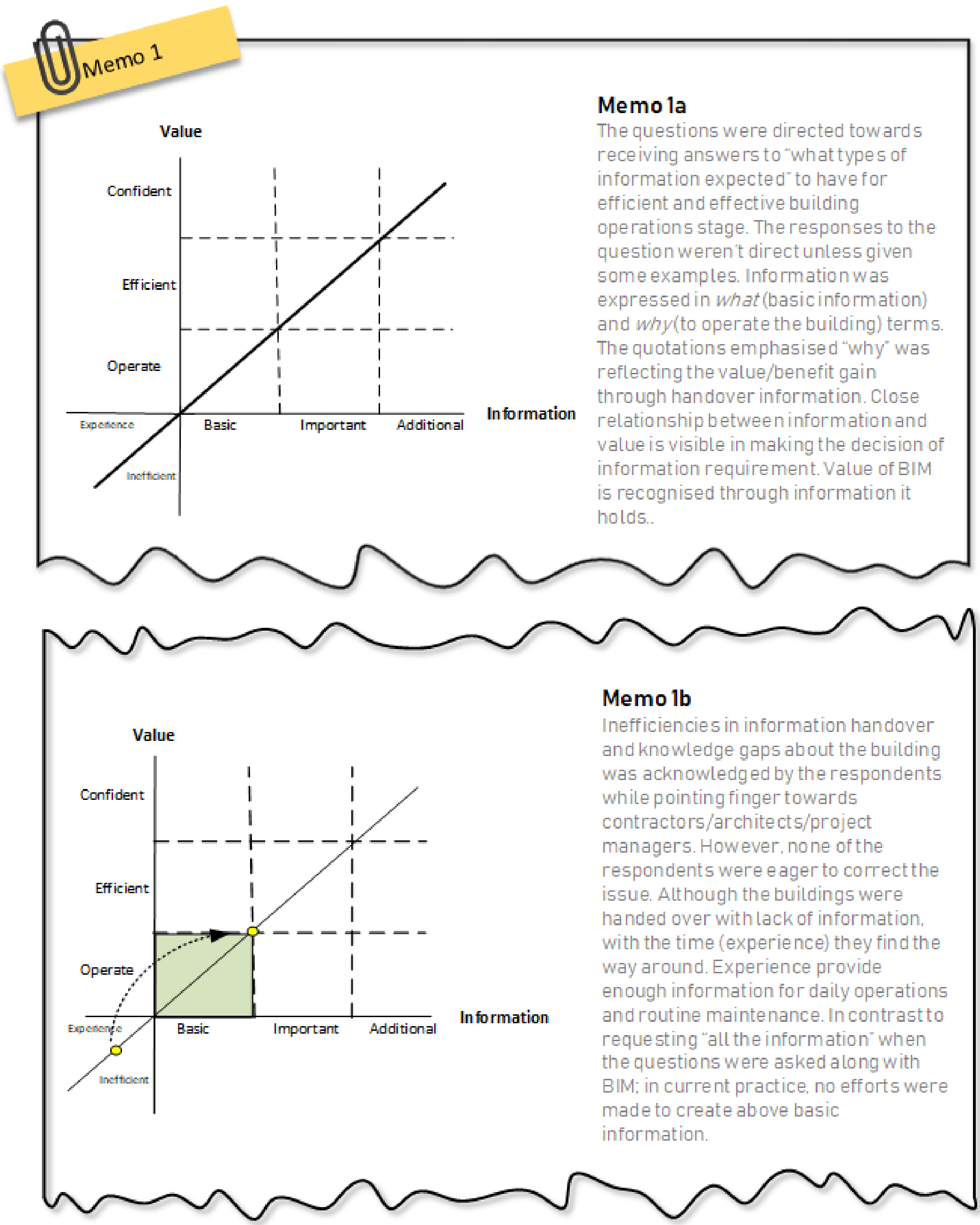


FIGURE 6.3: Memo 1 – Value-information relationship

"We need everything about the building. . . . We have to keep all the information, if not it's not worth to have a BIM system. The problem is how we are going to use this information realistically and that's why CAFM system is there. If fire alarms are fixed in 2005 we can expect all the sprinklers and smoke detectors to fail by 2010. . . . We know if all went in the same time they will fail at the same time. That's me making a decision based on information. We need the information so we can use that to make knowledgeable decisions". (FM4)

Agreeing with the utility theory, information users were found to be more satisfied when they have more information. This is the first instance of revealing the BIM-value relationship. However, none of the interviewees who participated at Phase 1.1 were able to provide a complete list of information which reached their satisfaction. This raised the question whether this is caused by the lack of knowledge on information requirement or this "all the information" is an imaginary mental status. This was soon resolved uncovering the information currently in use and the level of satisfaction.

Memo 1b (Figure 6.3) is a summary of the story of both higher education institutes. Their building portfolio included both modern and Victorian buildings. All of their old buildings were handed over with no as-built information. Building operation and maintenance tasks were performed with the subject knowledge and work experience on building construction and maintenance of skilled employees.

" ..had some information to manage new built without difficulty compared to our old buildings. Didn't receive any information for the Victorian buildings. Had to work with our instinct. Our team created all the drawings and documents we have here, things we learned about the building every day. It took long time to develop the complete drawings but, we know they are accurate" (EM1)

Although, it was an inefficient approach having to work based on mere guesses, this became an effective solution. The maintenance team worked together to document the discovered information about the building. This scenario described strong properties of the developing categories. One is that, this process of information creation, in which the FM team enthusiastically participated, came to an end as soon as they managed to produce the basic information; i.e. basic asset information and updates of as-built drawings. Secondly, information management was efficient, as technicians were continuously referring and updating the information. However, when the team got familiar with the building, they stopped referring to and updating the documents therefore, they aren't up to date any more. Although, functioning with work experience in the absence of information was an advantage, this practice in the long term turned into their own disadvantage.

This analysis also leads to an interesting psychological element. At the start of the conversation both estate managers were satisfied with the way things were but, when the conversation was turned into the contractor's responsibility on handover information; the interviewees become more comfortable in expressing the issues and loopholes in the process. This helped in rephrasing the interview questions to make interviewees feel free to share their true experience.

Continuing the conversation around BIM, all respondents agreed on awareness and positive impact of BIM for the construction industry and FM. Since, awareness on BIM was mostly based on design and construction benefits building professionals involved in the in-use phase were not sure about any tangible benefits of BIM in FM. Individuals were waiting for more examples, case studies and further developments of BIM to convince them of the necessity for BIM adoption. This was due to two reasons; lack of knowledge and examples of actual applications of BIM and the amount of time and effort required to yield the present benefit of BIM in FM is likely to cause more work. In simplest terms as it was summarised by a respondent *"more pain for a smaller gain" (EM2).*

This brought new insight challenging the existing scientific studies on whole life BIM application. Although, the literature continuously argues that the value of BIM is higher in the in-use stage, clearly this is not the case in practice under current circumstances – i.e. BIM as practiced now. Agreeing with the literature, BIM is widely known because of the 3D model therefore, most of its benefits and barriers are seen in relation to the input and output of the 3D model. Under current circumstances, software and training is costly and even if one agrees to bear the cost it is not clear which problems of FM will be directly solved through BIM adoption. Rationally this points out that BIM is not made to function at the in-use phase of a building. However, this will only be a short-term issue with the fast-growing technology developments therefore, this is not taken into further studies. Nevertheless, the key lesson of this incident inspired us to look into FM requirements of BIM and the means of identifying them. This was recognised as an underlying theme at a later stage of the analysis, when the same data was revisited. Before then, the analysis was carried out with the focus on information.

The interview findings further helped to understand different viewpoints of information users (Client, Facilities Managers, Estate Managers, Building Surveyors, BIM Manager, etc.) and providers (Contractors, sub-contractors, etc.) on current facilities information management (FIM) practices. The information users claim:

"We get a mix of information. . . .not all information is accurate a lot of the time" (FM3); "The lead contractor is accountable to provide necessary documents in soft formats at the handover" (EM1).

Accordingly, the information users expect that the providers will provide a complete set of valid information at the handover stage. However, information providers had a different input;

"The client needs to specify his information needs. . . communicate the format they prefer. In most cases this won't happen" (C1).

Although there was a continuous battle between information responsibilities, it was noted that producing an Employee Information Requirements (EIR) as a form of client brief and handing over accurate and complete as-built information are part of existing practice with or without BIM. Therefore, the initial problem of BIM was identified as a problem common to both BIM and conventional construction projects. This redirected the analysis towards information and users' categories and their underlying relationship. New data fed

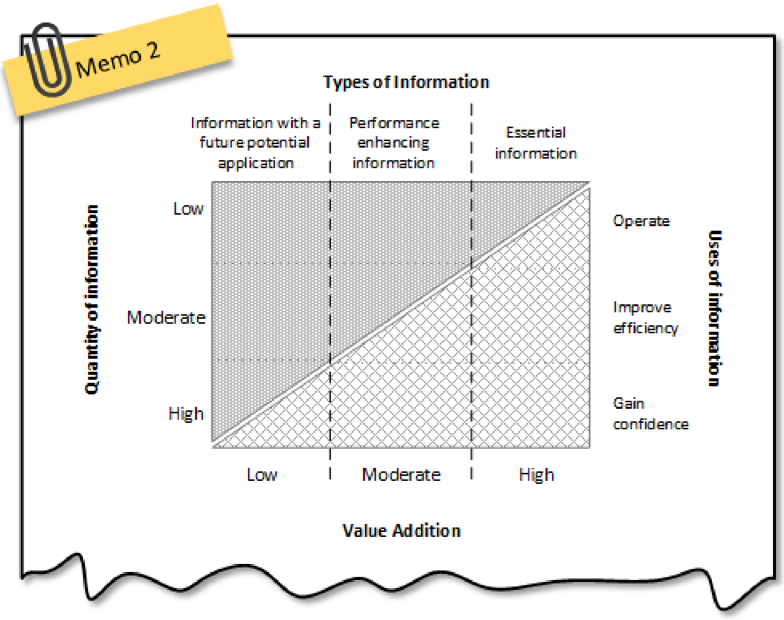


FIGURE 6.4: Memo 2 - Value-information matrix

into the continuing analysis and revisiting the previous data helped to identify a key property (i.e. quantity) of both users and information categories (Figure 6.4). Respondents were naturally categorising information based on their usage.

The kind of information required for building operation and maintenance was explained by the respondents justifying their answers with how information is used and what impact each type of information has over the operations. Although, there were no strict or quantitative boundaries between these information types, the properties of the categories led to identification of a hierarchy within types and uses of information.

Memo 2 (Figure 6.4) was written as an update of the value graph previously created to show the role of experience in the absence of information. Value matrix in Memo 2 was a discussion and demonstration of three dimensions – information, uses and quantities.

Although "all information" was the preference of the majority of information users (i.e. client representatives) none of them had a complete information pool to study its impact. Therefore, the uses of information were identified based on the available information on site for building operation and maintenance during site visits. Handover information is being used to answer two main questions during the in-use phase of a building. At the very beginning of the building operations, handover information assists in understanding the facility including the background details, features and potential capabilities of a particular facility such as occupancy capacity, weatherproof qualities, heat load etc. Secondly, it guides the user on how to operate the facility including the equipment handling, maintenance requirements and possible precautions to be taken for any failure. Facility managers value this contribution of the as-built information and cluster information based on its contribution through different functions. Accordingly, as-built information is clustered into three classes namely; essential information, performance information and additional information. This classification was based on the three levels of uses - operation, efficient and confidence.

Among the uses of information, facilities managers retain most value by having buildings operated with a zero downtime. They tend to make every possible effort to gather information which supports the operation. Next, they value the information which helps to improve efficiency and finally the confidence. The hierarchy was judged based on the functions fulfilled by handover information.

For example, the highest value addition of handover information is supporting the operations of a building to meet the required standards. This can be achieved by having an essential set of information which includes drawings, safety manuals and other information which are necessary to gain approval and maintain compliance requirements. Value matrix on memo 2 graphically indicates this relationship showing that the essential information which contains the least information brings in the highest value addition. Accordingly, this information is used to operate, improve efficiency and bring confidence to the information users by knowing the most critical facts about the building. Essential information is the minimum level of information required for facility management and this will ensure that services will be available, and the building is live for the business. However, this level is more towards adhering to the statutory requirements.

Stepping ahead from the minimum operational level, information has the capability to bring efficient performance. It is the second use of information on the value matrix. In order to perform FM tasks efficiently, it requires some important information along with the basic operational information (i.e. Essential Information). This additional set of performance enhancement information such as energy performance of the building, or location of the assets will avoid extra time and effort spent on facilities management tasks. As an example, given by a Facilities Manager with BIM experience illustrates;

"..If a technician can refer to the information and identify the type of light bulb in the room which the maintenance request was made on, then he could take the right bulb and necessary equipment to fix it at one go rather physically examining for all these details and going back to stores to collect what is needed... We are talking about two days' work here." (FM6)

Finally, information gives confidence. Facility managers do prefer to have more information although they do not fully use them to sustain their businesses. Information users demand for this to gain confidence by knowing all information about the facility. To a certain level, availability of additional information creates the opportunity to identify unrevealed applications of the information to the current system and to make them efficient. However, at the time of request of this additional information they would not increase any efficiency or provide support to operation and maintenance tasks but bring a psychological comfort by giving confidence of knowing.

Therefore, value addition done through information matches with diminishing marginal utility theory. It is right to say that the majority of the information in a fully complete BIM model, as expected by information users at the in-use phase of a building, contains more additional information which brings the least value addition by merely giving confidence to the users. Therefore, it was important to filter the necessary information to capture more basic and performance enhancement information which will ultimately create a highly valued information base.

Nodes

Name	Sources	References
Facility information requirement	0	0
Influences on information requirement	0	0
software requirements and features	4	4
Standards, guidelines and regulations	4	5
Quality of information	0	0
Accuracy	4	6
Completeness	4	6
Format	5	7
Sources of information	2	3
Types	0	0
Enhance performance	3	4
Essential tasks	4	10
Future potentials	4	5

FIGURE 6.5: Fit for purpose of the construction information in achieving FM functions

At this stage, identification of information requirements was considered as one of the mandatory requirements to adopt BIM and for continuous Facilities Information Management (FIM). Therefore, diverse cases were added into the data collection process to bring a holistic view. The results brought in new angles explaining that influence (standards, technology, policies etc.), quality (accuracy, usability, availability, completeness, format etc.), sources (external, internal etc.), types (essential, performance enhance, future potential use) of information were key requirements of facilities information management. To ensure a better use of BIM in FIM, these considerations were necessary to be taken into account in advance. Any advancement in these areas would be a positive contribution to promote whole life cycle BIM practices. The nodes generated through interview analysis are illustrated in Figure 6.5.

As identified at this stage, the value of information is a multifaceted construct. Handover information is used to ensure the certainty, performance and/or commercial attributes of products/processes during its facility management phase. As a result, the value of facilities information contained three levels, namely "certainty value", "performance value" and/or "commercial value". Certainty value of information ensures the perfect knowledge that has total security from error. The information, which helps to enhance the performance of product/process during its FM stage is considered under "performance value" (e.g. improving efficiency, productivity and reducing waste etc.) and the commercial value of information is used to analyse market behaviour in terms of strengths, weaknesses, opportunities and threats.

Revisiting earlier data from conventional projects, it was evident these categories were perfectly in line with all information users regardless of their BIM experience. Information was categorised based on their uses however, the decision on which information was to

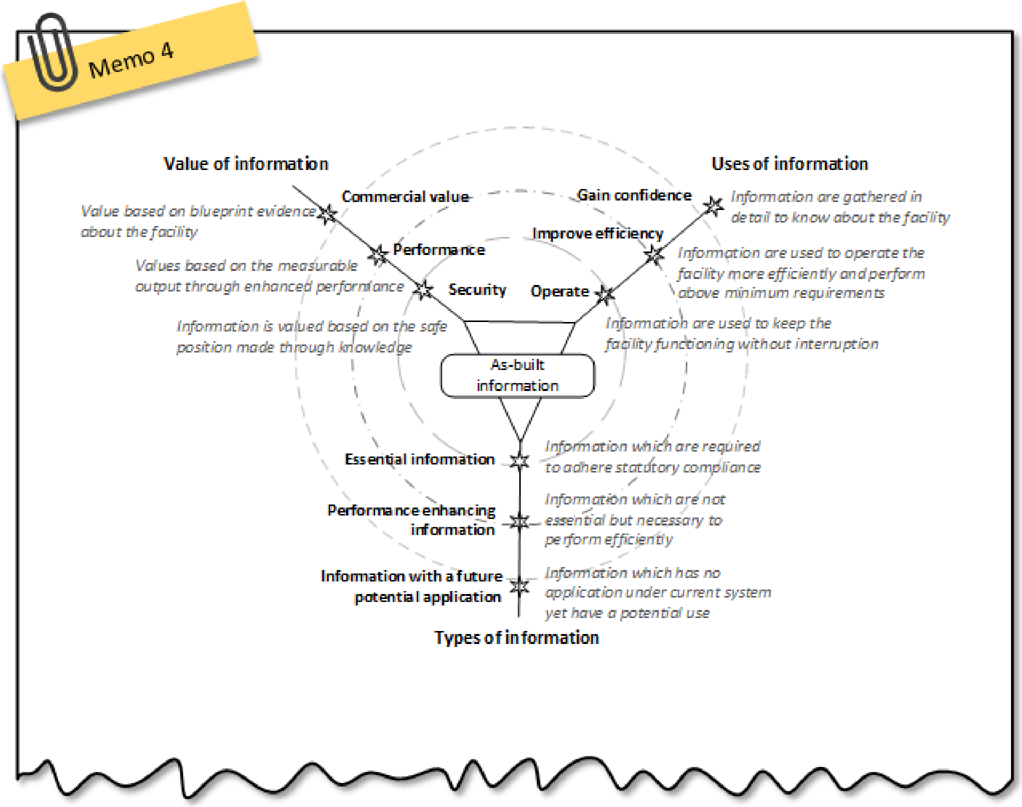


FIGURE 6.6: Fit for purpose of the construction information in achieving FM functions

be selected was a gamble. This simply solved the initial question of requesting "all information". Since information is valuable anyway, people tend to demand more information. However, BIM is not a request or supply of information but, an interplay between information, technology and process. The process of the information emerged at the very beginning of the data analysis with the conflict between information users and providers while technology came into the discussion from the focus group and interview data from diverse cases. Memo 5 (Figure 6.7) was written with this discovery bringing technology and process in equal with information and considering the value of BIM as a combination of all three elements.

A later review on Memo 4 (Figure 6.6) brought insight into how each key category i.e. value of information, uses of information and types of information are explained by respondents, but still do not provide any standard, quantified or rigid explanations but attempt to explain something common among all diverse cases. Revisiting the data after a break helps to conceptualise rather entailing on descriptive data (Corbin and Strauss, 2008). At this instance, the analysis was focused on the overlapping nature of these categories. As a result, the overlapping nature of the categories gave away the underlying mechanisms of these experiences. The breakthrough was made when it soon became apparent that all these incidents were attempts at translations of human needs which take place at the causal mechanisms' strata. The theory of basic human values was identified when going back

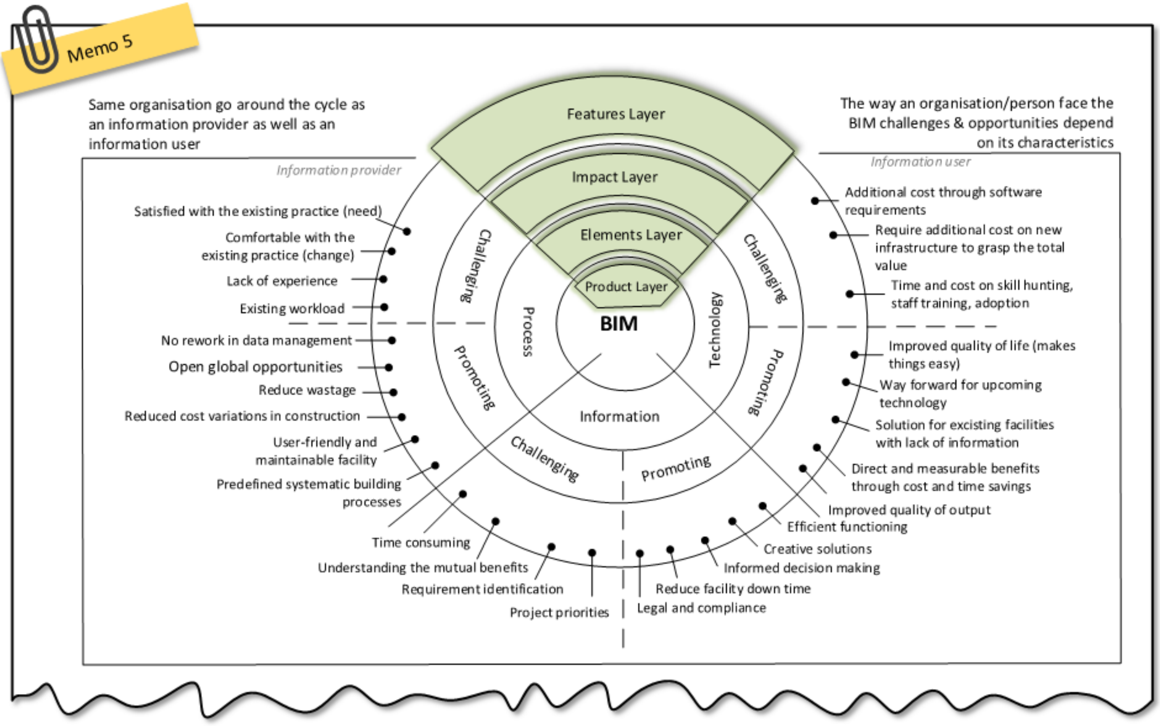


FIGURE 6.7: Memo 5 - BIM elements, features and impact

to existing theories to support this hypothesis. The leads received from Schwartz's theory brought more rigid theories explaining that expressing human needs is a key function of values (Gouveia, Milfont and Guerra, 2014). Theoretical insights received from the basic human value theory helped in discovering and proving that BIM value is expressed in terms of BIM barriers and benefits. On the other hand, barriers and benefits are needs either to be fulfilled or already being fulfilled through existing features of BIM.

Understanding the psychological aspects behind the BIM decision had an influence on rearranging the themes under three different categories (Figure 6.7). Accordingly, all BIM users identify and describe BIM in terms of what it does (benefits) and what it doesn't do (barriers). These BIM benefits and barriers are the result of a combined effort of information, technology and process.

This explanation given to themes provided two categories; i.e. what BIM does was straightforward to recognise as BIM features. Secondly, the negative and positive impressions towards BIM features separately recognised as the impact of BIM. Finally, some of the features made a direct link to either a benefit of the technology, information or process of BIM execution.

Technology is recognised as the heart of BIM providing the reasoning for the common notion of identifying BIM as a 3D model. The acceptance or rejection of BIM is highly dependent on technology rather information or process. This is again defended by the human value theory and economic theory. As an economic man, people continuously carry out cost benefit analysis when making daily decisions. On the other hand, practising BIM in facilities management is a behavioural change. Therefore, BIM needs to carry promising and short-term benefits to act as incentives to stimulate the behavioural change. The support

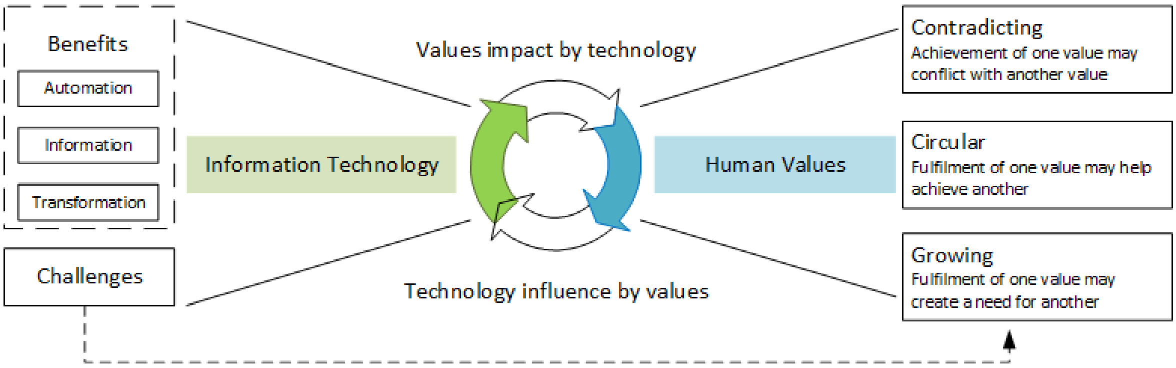


FIGURE 6.8: Theoretical model

provided by the technological features of BIM is what make things possible for information and process to bring its own value additions. Current BIM technology is highly in favour of design and construction tasks but not for FM. To create a BIM accepted by facilities managers, the developments needs to focus on recognising everyday need of building operations and maintenance and being creative with the human element.

This leads to agreeing with the existing literature and recognising BIM as an IT system. The value play between IT and humans was recognised. As an IT system, BIM contributes at individual, project and organisation level through automation, information and transformation. In the short term, the features of technology were decided and influenced by human values. What is admired by the people is presented by technology. In the long term, technology reshapes the human values.

The concepts of smart cities, smart meters and connected buildings are such a transformation of the society. An identity created by technology. At some point technology will change the very nature of human beings as a part of uplifting human life – i.e. making man immortal (Kaplan, 2009). This close relationship between human-technology interventions shows that both mutually enrich each other. Currently keeping humans in control over the technology yet, with the possibility of technology to override this cycle.

Based on findings, the Constant Comparative Method summoned the substantive theory that communicated this principle (Figure 6.8). Through automation, information and transformation capabilities, information technology has managed to fulfil vast collection of human needs since late nineteenth century. Regardless of the tremendous developments in technology and changes in human life style making technology more acceptable still, there are challenges. The same human values make technology possible, brings the challenges.

Emerging from data and supported by basic human value theory, it is identified that there are certain features in human values which cause the challenge. That is the contradicting, circular and growing nature of the human values. People value world peace however, reject war creating a contradictory situation although war is a fight to gain peace. Similarly, BIM helps users to have a ready to use set of information at the in-use phase however, this requires early efforts of defining the information requirement. Secondly, agreeing with

Abraham Maslow, human needs are growing. Fulfilment of the desire for having information will create a need for fast and boundary free access to information. Therefore, technology is consciously pushed for further developments. These continuous developments slowly direct human values into things that technology can provide rather than what it is necessary. Finally, circular – a feature of human values which may work both positively and as a challenge. Sometimes technology is capable of fulfilling values more than what it was initially invented for. Therefore, fulfilment of one value may lead to discovery of a new value which was not anticipated before. In terms of BIM, access to information also fulfils the need for recognition by labourers. Providing access to information which was previously only accessible by a supervisor provides a sense of recognition to the lower level employees. On a negative note, the circular nature of the values makes the case difficult to pin down the direct impacts of a decision.

This brings the background to understand what to expect from BIM and what developments are necessary for BIM to move forward beyond construction. Answers for both questions are possible through understanding human values. Benefits and barriers of a discrete product or service are identified as expressions of values related to that particular unit of analysis. This claim is also supported by well recognised behavioural economic theories (see Figure 6.11) such as Theory of Reasoned Actions and Prospect Theory (Kahneman and Tversky, 1979) which emphasise that human decisions are made on risky choices focusing on the negative outcomes of the decision. The BIM value model (see Chapter 7) was developed based on this substantive theory and used as a mechanism to validate practical application.

6.3 Phase 2 - Focus Group Discussion

The second phase of data collection was designed to give the opportunity to engage a different data collection technique in order to clarify some of the recurring incidents generated at the Phase 1.1. Lack of information was continuously highlighted by both information users and suppliers. A common pattern emphasised within this high level theme was that, the information user (client) laid the responsibility of incomplete handover information on the suppliers' (contractor) hand while the information suppliers transferred the responsibility for lack of information onto the information users' hand because of not providing an exhaustive EIR. This contradicting nature of the theme enforced a change of method in data collection and creating an environment allowing both parties to come together and clarify the theme in detail. Therefore, a focus group discussion was conducted at the Phase 2. On the other hand, a combination of in-depth interviews and focus groups in a single study is known as an advanced way of conducting a research by securing its strong position on deep understanding on the phenomena and validity of the study (Crabtree et al., 1993). Additionally, successful results gained in studying BIM through focus group discussions under grounded theory research strategy speaks for the appropriateness of the decision (Liu et al., 2016).

TABLE 6.2: Focus Group participant profiles

Participant	Experience in years		Input to discussion
FG1.1	Industry and academic	>20	Civil Engineering
FG1.2	Industry	>20	Digital aspects of architecture
FG1.3	Industry	>20	Public sector client
FG1.4	Industry	>20	Public sector client
FG1.5	Industry and academic	>20	Academic Quantity Surveying
FG1.6	Industry and academic	>20	Academic Quantity Surveying
FG1.7	Industry and academic	>20	Academic Quantity Surveying
FG1.8	Industry	>20	Contracting Organisation
FG1.9	Industry	>20	Design management
FG-110	Industry	>20	M&E Engineering
FG1.11	Industry	0-5	M&E consulting organisation
FG1.12	Industry	0-5	M&E consulting organisation
FG1.13	Industry	>20	Contacting organisation
FG1.14	Industry	>20	Public utility servicers
FG1.15	Industry	>20	Consulting organisation

6.3.1 Data Collection

The structure of the Focus Group as a data collection technique allowed a debate and a discussion between the participants and provided the opportunity to observe the value play between information users and providers. To reach a diverse group of participants, an open invitation was sent to professional bodies linked to the North West construction industry however, due to lack of response most of the participants were recruited through the snowballing technique although they were part of the population of professional membership bodies. Fifteen experts from both industry and academia participated and the participants' profiles are presented in Table 6.2. The session was led by a facilitator and supported by the moderator and an observer. The facilitator was acting based on the instructions received from the researcher and the moderator had a mute role but helped in managing the audience. The observer's role was played by the researcher taking notes and observing the conversations. The two hours long session gave the opportunity for all the participants to contribute to the discussion. Interesting counter arguments placed in the audience by diverse cases made a natural engagement among participants.

6.3.2 Data Analysis

Staying true to the grounded theory methodology, data gathered from the Focus Group was merged with Phase 1 data without making a distinction between different phases. The majority of the data contributed to the analysis of Phase 1. However, this section is dedicated to presenting the major contributions made through the focus group. Figure 6.9 presents the mind map created during the focus group by the facilitator. The mind map brings the evidence for an equal struggle from both information users and suppliers to gain the BIM advantage. At the time, skill shortage, lack of technical support and guidance on BIM execution were heavily emphasised as common causes for hardships in BIM projects by both clients and contractors.

Both parties agreed that it is crucial to know the difference between "what you can have" and "what you need" in terms of BIM when thinking of a whole life application. Discussion on this theme revealed that current BIM beyond construction is purely making an extra effort to make use of the information and features that BIM has to offer, rather than BIM being a ready-made solution for in-use phase tasks.

One of the key contributions of Phase 2 is to develop the themes generated at an earlier phase through understanding properties of the categories. Therefore, the responsibility of the information handed over through BIM is brought into the discussion. Bringing similar data as interviews; both information users and suppliers started justifying their position on how the opposite party holds the responsibility over the information. Information users highlighted the absence of facility management experts at the design stage to inform the information requirement and lack of client knowledge on construction and built environment. On the other hand, information suppliers emphasised the need for client representatives to express the unique needs of the client and expectations from the building to produce a customised BIM rather a standard BIM model which is more applicable to construction than facilities management. These interesting arguments made by parties with diverse experiences expressed an underlying question that everyone in the BIM process has - *"why should I do that?"*

Memo 3 (Figure 6.10) was written contemplating on this question. The first property revealed through the counter arguments between information users and suppliers is that focus on information deviated into "process" and was introduced as an equally important element in BIM. This is to emphasise that producing a client brief and handing over as-built information is business-as-usual however, the process of how it is done now with the support of technology and guided standards distinguishes BIM from conventional projects. The process of BIM demands to act in certain way which requires extra effort and creates a platform to share information. Both properties of the BIM process raise the question why one should do the extra work for another person's benefit.

This is partly due to how the BIM process is explained by both academic and industry-focused literature. The client is responsible for preparing an EIR so that the design team gets the idea and makes their work easier. On the other hand, the contractor provides handover information partly due to statutory requirements but mainly because it will be useful for the client to operate and maintain the building. According to this interpretation, both parties are making a selfless effort for the benefit of other party. This is not an economic choice in the long term, especially for the contractors who go through this cycle over and over again in comparison to the client who will mostly follow the cycle once or twice. Therefore, continuous failure in handover information is noticed at the expense of contractors.

Bringing a long-lasting solution, the BIM process and technology work together to extend this value cycle with the help of the Soft Landings strategy. By producing an EIR clients not only communicate their need to the design and construction team but also streamline

FIGURE 6.9: Focus Group Facilitator's Mind Map

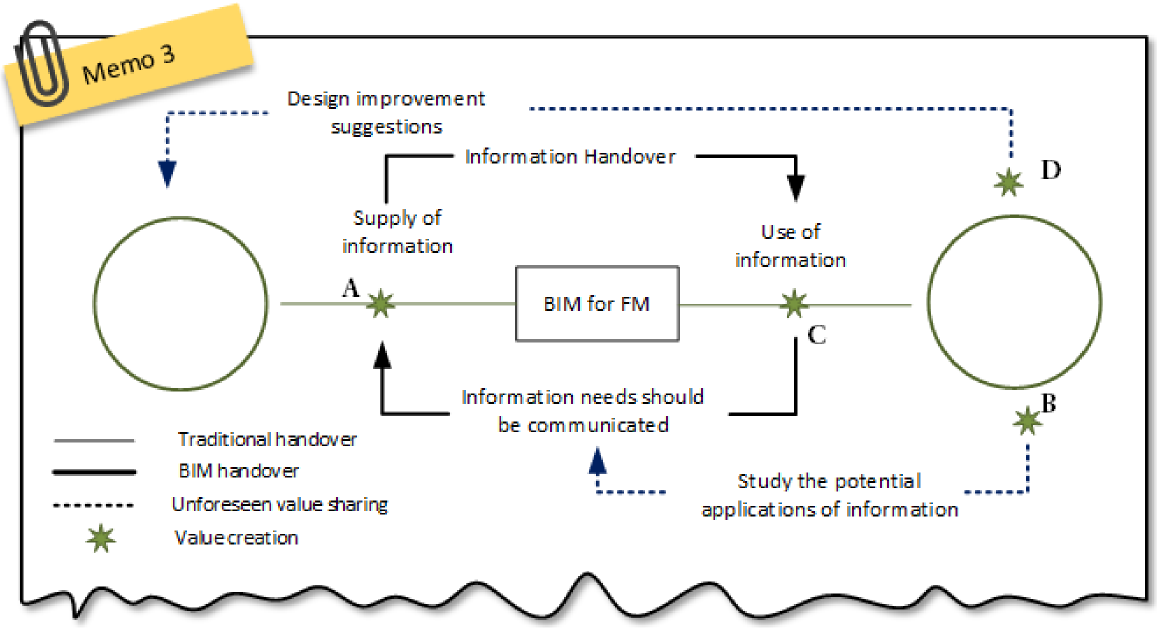


FIGURE 6.10: Memo 3 - BIM value cycle

the building operations and maintenance requirement. As a result, when the information is handed over in the required formats clients have much more control over the quality checks as well as a direct application of the information to efficient and effective facilities management.

On the other hand, construction companies have a market opportunity to support the client in preparing the EIR given that client experience in built environment is low. This is one of the tactics used by large construction companies with a facilities management arm. This provides the opportunity to win the facilities management contract standing ahead of any other bidder. Further, even the design and construction team have no interest to provide services beyond construction; providing accurate and up to date handover information has further applications through BIM. This will be the beginning of "Tesco Club Card" or any other loyalty card system used by manufacturing industry to collect data on consumer behaviour.

Most of the BIM objects used in the 3D model such as windows, doors, furniture and lighting are provided by the manufacturers and they are just one step behind reversing back the data to manufacturers about their usage, repairs and replacement providing priceless data for manufacturers for product improvement and innovation. Also, with the wide spread of Modern Methods of Construction (MMC) the entire building construction is moving into a manufacturing process, creating more reasons to gather in-use data to improve the product. Therefore, providing accurate and complete handover information is not anymore limited to the benefit of the client but for the wider development of the construction industry including research and innovation. In confirm with existing knowledge, Fairhead, 2015 argue that RIBA Plan of Work should be cyclic promoting information management and use. Lack of information about the industry has been a key reason for the lack of client knowledge compared to customer knowledge in other industries (i.e. manufacturing). Although buildings have been there before computers, customers are much more aware about their requirements of a computer or a motor vehicle than of a building.

Another theme strongly developed during the discussion was "Technology". Although this came up during interviews with contractors, the open discussion between contractors and the client side made a clear distinction between how technology is the key reason for wide adoption of BIM in design and construction. On the other hand, how technology has failed to cater for the building operations and maintenance needs. However, both parties agreed that with the past experiences and continuous development in technology this problem is "only a matter of time". The focus group discussion further informed the difficulty and risks in separating BIM by its individual elements – i.e. information, technology and process. Therefore, herein after BIM was recognised as a combination of information, technology and process. Also, it was profoundly important not to replace the entire aspect of the technology with the 3D model. Technology referred to at this stage had a wider coverage including virtual reality, system integration, artificial intelligence, robotics, internet of things, etc.

Although a separate analysis was presented for the focus group to maintain the structure of the thesis, in real life it was not a smooth step by step process. The memos were written in the order they are presented but both data and memos were reviewed along with theoretical insights developed over the time to reach the substantive theory. Taking away the noise from the picture of three years long analysis carried out under Constant Comparison Analysis principles brings a much clearer path of themes informing categories leading to the core category. Figure 6.11 presents how the core category emerged from data and theoretical underpinnings supporting the claims. Each main theme is explained in detail under the BIM value model in Chapter 7.

The ground breaking discovery made through a later reflection on memos and revisiting data was the relationship between benefits and barriers. It was common in both Phase 1 and 2 that participants communicated BIM value through benefits and barriers. Although some general statements were made on BIM value sometimes talking about information value; the specifics were explained in terms of the advantage they experienced. Similarly, late adopters soon start talking about the challengers in BIM when talking about BIM value as a reasoning for their backwardness towards BIM. Another property of benefits and barriers were that some benefits were barriers to another and vice versa. With this, it was concluded that barriers communicated by information system users are equally important as benefits of a system, as they communicate either the perceived or expected value. People recognise the benefits and barriers because these features communicated through positive and negative impacts matters to them. This property is also in line with the motivational theories. On the other hand, since value is a high level abstract concept, there is the freedom to interpret barriers as benefits or there is a degree of freedom for creativity or manipulation whether one sees a particular feature in an information system as a benefit or a barrier at the experience strata of the reality. These findings were taken back to the industry for validation in the next section.

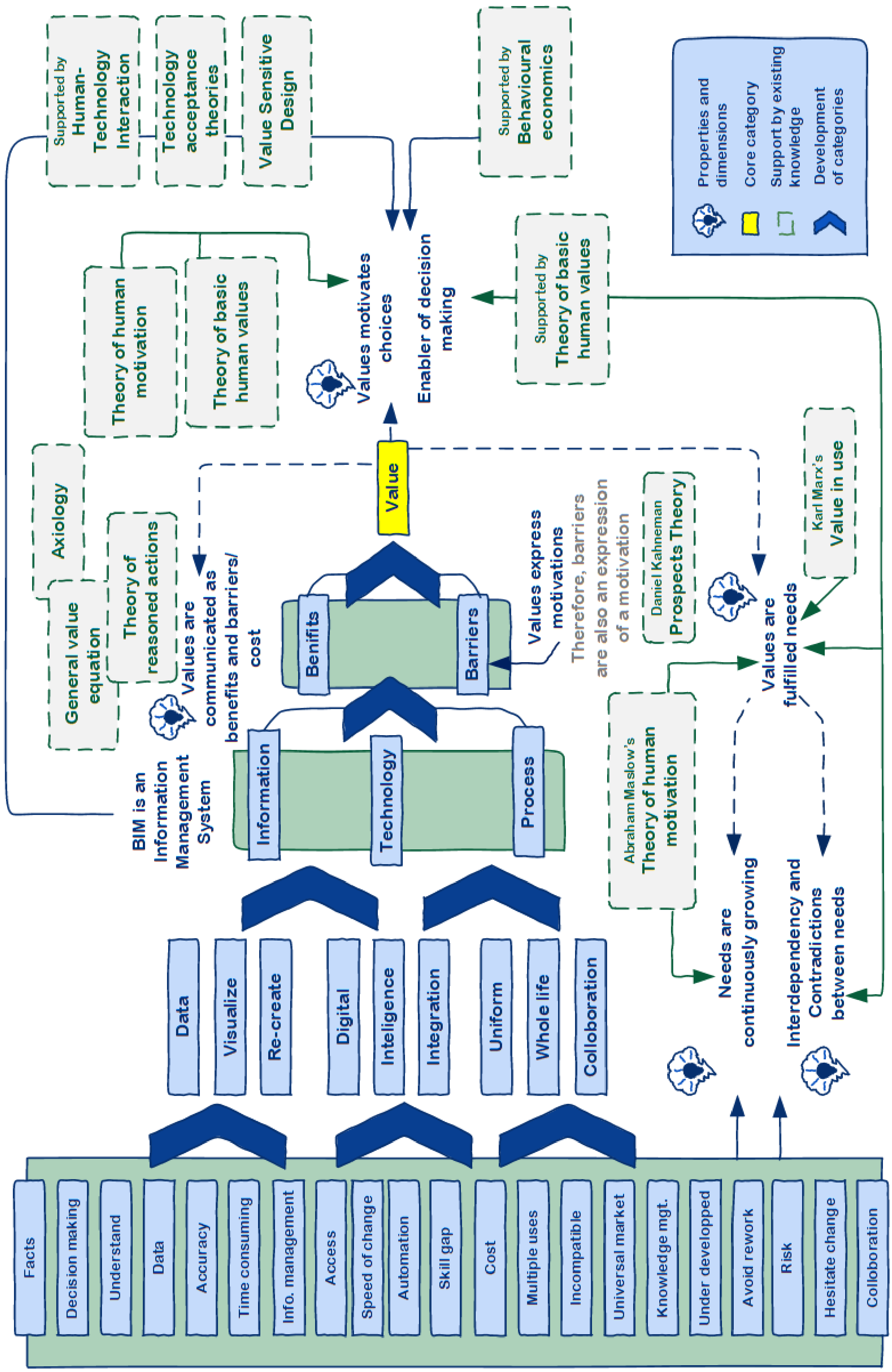


FIGURE 6.11: Extract of analysis with theoretical underpinnings

6.4 Phase 3 – Validation Focus Group Discussion

Phase 3 was designed and executed to achieve the final objective of the thesis – i.e. model validation. BIM value model (see topic 7.3) was developed summarising the findings of Phase 1 and 2. The purpose of Phase 3 was to validate the model for its accuracy, practical application and generalisability beyond building operations and maintenance bringing evidence for both internal and external validity of the work.

It is common among built environment researchers to embrace a different research method from its primary method of data collection and analysis as a readymade solution to enhance validity of the research through triangulation. With this stance, having followed a pure qualitative methodology for theory development; it is more likely to think of a quantitative research method as ideal for the validation phase. However, experts on mixed method research methodology have constantly highlighted that the benefit of mixed method will only be achieved when it is in line with the research question, aim and objectives (Tashakkori and Teddlie, 2009; Teddlie and Tashakkori, 2009; Creswell, 2018). Therefore, blind choice of mixed methodology will only lead to bias or philosophically conflicting findings.

On the other hand, qualitative methods are known for their capability to gather rich data by allowing the participants express themselves freely rather being limited to a predetermined scale which can mean many things individually. Focus Groups are specifically known as an effective method to gain comments on results of a previous study (Flick, 2014). Hence, the focus group data collection technique was used for the validation of the model due to its unique interactive aspect along with the opportunity to explain the model, gather extensive views on multiple aspects in a short period of time and flexibility to adopt and prioritise according to responses. The selected method allowed a true evaluation of the model, providing space for both appraisals and criticisms. Due to the incapability of the Constant Comparative method to provide provisional testing and generation of theory (Glaser and Strauss, 1967) a separate method of analysis is employed for Phase 3.

6.4.1 Data Collection

It was considered necessary in this thesis to bring in the opinion and situation of the average construction companies in the UK. To respect this and for the ease of access, construction companies in Merseyside were selected as the population of the study. This was also supported by the other objectives of the validation phase - achieving internal validity. Further, it was important to select the sample which will create surroundings in which to openly discuss critical and applausive features about the value model as this is the aim of the validation phase. Staying within the geographical boundary of the population and to avoid being exposed to the Hawthorne effect, a group of experts already working together under a widely known branding for betterment of the construction industry were selected. The profiles of the participants are given in Table 6.3.

With the approval of the committee chairman, focus group discussion was held after their monthly meeting for the ease of participation. Each participant was given the focus

TABLE 6.3: Focus Group 2 - participant profiles

ID	Expertise	Organisation category	Years of experience	BIM experience
FG2.1	Contractor	SME	<20	Expert
FG2.2	Contractor	SME	<20	Expert
FG2.3	M&E	SME	<20	Champion
FG2.4	Architect	SME	<20	Expert
FG2.5	Client	Not for profit cooperate	<20	Novice
FG2.6	Consultant	SME	<20 mixed industries	Champion
FG2.7	Architect	SME	<20	Novice

group guideline kit which included the programme for the session with topics for discussion, BIM value model, BIM value evaluation form and an example of BIM value thermometer. Value thermometer is a graphical representation of the project BIM values gained through BIM elements – information, technology and process. It is the output produced by completing the value evaluation form.

The researcher explained the content of the focus group guideline during the first 7 minutes and embarked on the discussion. The total duration of the focus group was 1hr and 20 minutes and the discussion was voice recorded using a digital recorder. Some enthusiastic participants continued the discussion for an extra 45 minutes after the focus group was formally ended as scheduled. Since some of the participants in the validation Focus Group were previously interviewed, this also created the environment for member validation.

6.4.2 Data Analysis

The aim of the validation (Phase 3) was to reach both internal and external validity of the main output of this thesis - BIM based value model. Thematic analysis as the "foundation of all qualitative analysis" is well known for its capability to "draw and verify consultations" (Saunders, Lewis and Thornhill, 2012). On the other hand, in Grounded Theory, theory verification is advised to be conducted as a separate study due to complexities in theory generation itself. As a result, Grounded Theory strategy does not naturally bring suggestions for verification other than the techniques embedded within the process of theory generation grounded in data. Therefore, deviating from Grounded Theory conventional principles, Phase 3 data was analysed using thematic analysis.

Following a deductive approach, the objectives of the validation phase were used as the prerequisite and the data is analysed to identify statements made related to internal validity, practical applications of the model and external validity. Accordingly, there were no major comments made about the content of the model. All agreed on the key elements of the model and flexibility to adjust according to the person, project and organisation. Representation of the human resource within the model was questioned however, explanation provided by the researcher that the human resource and skill requirements are embedded in the process element could resolve the argument over the representation of the people in the model. The capability of the model to represent both client's lack of knowledge and contractors' lack of BIM experience was applauded as this is a key problem among small and medium construction companies and almost all clients. The only comment made critically on the internal validity of the model was the place given for "cost". Although, in the model cost is given an equal place as any other barrier and benefit, it was identified that most of the barriers are reflections of cost - *"We are back to money"* (FG2.2). This statement was supported by two other participants. However, all those who highlighted the cost were information suppliers. Neither client nor the client representative (consultant) seemed to agree on cost as the driver of the barriers.

The model was found to be complex to understand at a glance or in other terms time consuming. The importance of being simple and easy to comprehend with the least time spent was suggested to be the best solution to promote a practical application in industry. This was a recurring theme from the Phase 1 interviews for poor adoption of BIM although there are sufficient guidelines to start with. Having considered these comments, the BIM value model was re arranged taking off information flows and stakeholder characteristics leaving only BIM value adding elements and features. Importantly, comments on practical applications triggered the need for a much simpler method to communicate the substantive theory rather than a model with long instructions on how to use. This is also one of the main reasons for failed integration between academic research and industry. While academia applauds a theoretically sufficient, rigorous procedure, industry is looking for quick fixes. The expectation of the industry practitioners was something similar to 5S. Less time invested in preparing and learning the concept to reserve more time in application. Nevertheless, flexibility of the solution to fit into individual situations in different organisations. Inspired by truth within these facts, the BIM value model was refined into a value principle (see Chapter 7).

In terms of wider applications of the value model, a common view among participants was drawn towards the "value thermometer". Value thermometer is the graphical representation of the values expected to be gained by the client (Figure 6.12). This is the output of completing the value evaluation form (Appendix H) which guides the user to rank the BIM features according to the project preferences. At a glance, the value thermometer will present the proportion of the project strengths and weaknesses under each BIM element – i.e. information, technology and process. The recurrent theme in the discussion is a sense among participants that the BIM value model can be used by clients as well as contractors and other project team members especially by the project lead. The proposition was to consider the model as a maturity model for other stakeholders (contractors and suppliers). Value thermometer is to provide a sense of the maturity level of the supply chain. This leads into multiple applications such as assessment of

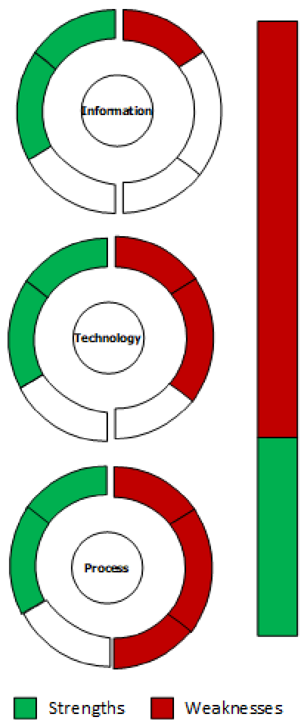


FIGURE 6.12: Value Thermometer

BIM value achievement within a project by comparing the
value thermometer before and after a BIM project, comparison between two BIM projects within the same organisation and most importantly selecting a supply chain to support achieving the expected BIM value. However, this still stands within the limitation of time consumption as a secondary activity.

6.5 Chapter Summary

It was the purpose of this chapter to illustrate the skeleton of the BIM value model presented in the next chapter. The work presented includes the procedure of data collection followed using interviews and focus group techniques and findings from the analysis. Data gathered through 21 in-depth interviews and two focus group were analysed following constant comparative and thematic analysis techniques. The constant comparative method of analysis involved parallel data collection and analysis, memo writing and continuous comparison of data by revisiting previous data with new. Parallel data collection was supported by theoretical sampling. Accordingly, initial findings informed the succeeding data collection samples and adjustments to the data collection techniques. As a result, a focus group was conducted in between interviews. Finally at the Phase 3, output gained through Phase 1 and 2 was taken back to the industry for verification for its accuracy, practical applications and generalisability.

The key findings of the 3 phases are;

- BIM is an information system identified through its 3 key elements – information, technology and process. It belongs to a project rather than an organisation. That is to confirm that the true BIM experience is received by the project through its life cycle while each organisation is contributing to the process for mutual benefit
- Human technology interaction - Human values provide the groundwork for the content of technology in the short term and technology reshapes the human values in the long term.
- Circular, growing and contradicting nature of human values creates a challenging situation for technology catering for the human needs and for technology acceptance
- Values are expressions of human needs. Accordingly, when a person is explaining his or her values it is more likely that the person is reflecting on basic human needs as prioritised by the individual
- Values are expressed in terms of barriers and benefits. Although, value is a widely known, day-to-day used term; what is exactly referred to as value was ambiguous. When the evaluation of value is focused on a specific product or service, value tends to be expressed through recalling benefits and barriers
- Simple and short term solutions brought through academic research are important to fast track the BIM adoption in practice

Summarising these findings of the next chapter presents the BIM value model for FM. This will introduce the model while discussing potential practical applications.

Chapter 7

BIM value model and value principle

7.1 Introduction

Bringing together the essence of findings from the literature review, interviews and focus groups, it is the purpose of this chapter to discuss the development of the BIM based value model for FM. The model will assist the whole-lifecycle BIM decisions made by the client and facilities managers when following the existing BIM standards and guidelines. The model development discussed in this chapter is based on the substantial theory (See Figure 6.8) emerged during the data collection and analysis process. Therefore, BIM based value model is a more elaborated and grassroots level presentation of the theoretical model. The BIM based value model is structured in four themes namely; BIM elements and features, barriers and benefits, BIM roles and adopter categories. These four themes are used in the BIM based value model to present the substantial structure of BIM in a simplified form. The purpose of this simplification is to make the BIM concept reachable by operation level facilities managers and support when faced with a bottleneck on the process of BIM adoption following current BIM standards and guidelines. Therefore, this is also an enabler for practicing BIM standard and guidelines and having a whole-lifecycle approach.

The introduction of the model begins with a debate on model vs framework in terms of a research output specially under a Grounded Theory research strategy. Following the detail discussion of the model under the four key themes, applications of the model and discussion on theoretical support on each aspect of the model, the second section of this chapter focuses on the inputs from the model validation. Having considered the comments and suggestions received during the validation process; a simplified version of the BIM value model is developed. This leads to the introduction of the value principle which is the theoretical abstraction of the value model. Finally, the chapter concludes by stating the key contribution to knowledge and practice through integrating the value principle.

7.2 Model vs framework

One of the major tasks of scientific research is the development and use of theories (Graziano, 2010). Conducting research following a Grounded Theory (GT) strategy is a promising methodology to theory building. Derived from GT roots, a theory is an explanation of a phenomenon (Creswell, 2013). In a more general sense theory as a scientific as well as an everyday concept has three qualities; an abstract hypothesised statement rather than observable, the statement is general, and finally offers an explanation to a phenomena (Given, 2008). The reason to consider the definition of theory is that, as Graziano, 2010 explains "model" as a form of theory. He argues this by emphasising that a model is a representation of a phenomenon, a replica of reality. A model is a “mini-theory”, less developed than formal theory and helps scientists to understand something unseen or complex (ibid). All models (i.e. physical, conceptual and mathematical) share common characteristics;

- Simplified representation of the reality with point to point correspondence with some of the characteristics of the reality
- Convenient, manageable and compact representation of the large, complex and mostly unknown reality
- Incomplete tentative and analogical
- Helps to organise information illustrate relationships, create new ideas and predict new observations

On the other hand, frameworks are the most commonly discussed type of research output. This is again a characteristic that research has absorbed from its early practices under positivistic assumptions – research framework. A theoretical framework is developed often when research is conducted under the deductive approach as a blueprint of the research process, or how the researcher arrived at given conclusions. On the other hand, conceptual frameworks are developed as a result of taking an inductive approach. One of the objectives of this study is to develop a BIM based value model for FM as a means of bringing the substantive theory into practice and more approachable for both academics and practitioners alike. Therefore, next section presents the BIM value model for FM presenting the essence of the research findings.

7.3 BIM value model for FM

BIM based value model (see Figure 7.1) is an application of the substantial theory (i.e. value principle) emerged through the research. This model represents the theory under BIM in FM phenomena. The presentation of the model is structured giving room to act as a decision support tool to understand the value of BIM at the facilities management stage. Using the BIM value evaluation form (Appendix H), BIM value model can be converted into a decision support tool which is names as the Value Thermometer (see Figure 6.12. This is a major contribution of the validation phase and it upgraded the BIM value model from a representation of a theory to a decision support tool.

From many frameworks and guidelines available for best practices, BIM value model stands out as the bridge between operational and strategic level FM. This is to emphasise the BIM value model's capacity reflect operational level BIM needs at the strategic level decision making especially considering the existing bottlenecks in whole-lifecycle BIM adoption. Although, theoretically existing best practice has emphasised the need for early involvement

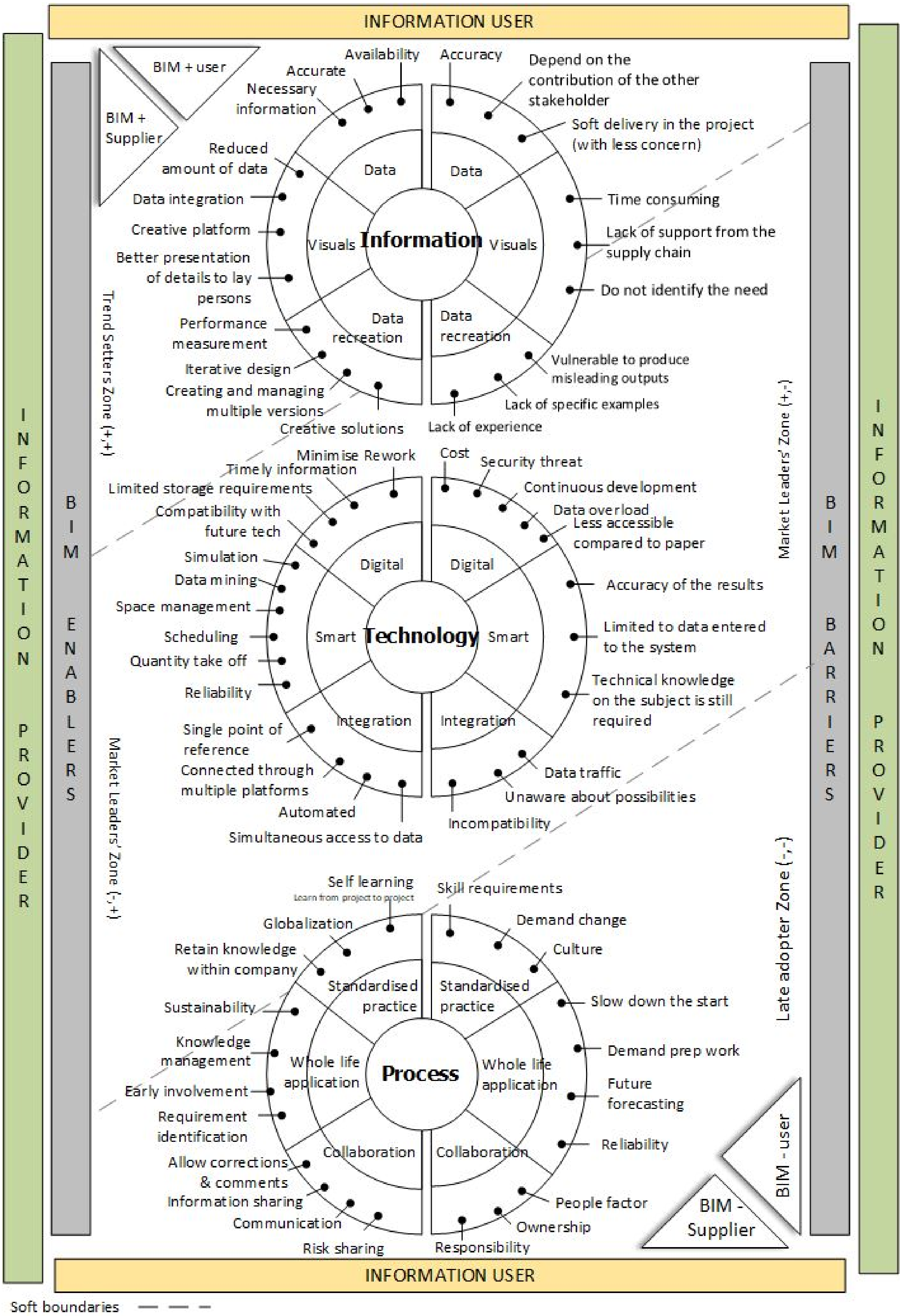


FIGURE 7.1: BIM in FM value model

of facilities managers or in-use stage stakeholders at the design stage it does not happens in the current practice. Addressing this loophole, BIM based value model is a tool to represent the operational level FM needs during early BIM decisions where the physical presence of FM expertise is not available. However, this does not discount any of the well accepted BIM guidelines such as Publicly Available Specifications (PAS) or more recent extension ISO 19650 series yet, uplift the application of these local and international standards reaching the common barriers faced at the operational level BIM adoption at FM stage.

Therefore, BIM value model is a grassroots level tool reflecting and reaching the objectives of multiple industry strategic initiatives such as Digital Built Britain, Industry Strategy and Transforming UK construction. It is in support of the digitisation of the construction industry and making a meaningful change rather enforcing the change through enactments. Promotion of digitisation, supporting a smooth transition to go through changes and identification of human values as a means of tackling the current challenges and developing future scenarios are the key contributions of the model for the broader context of digital and conscious (i.e. sustainable) construction age. Hereinafter the BIM value model for FM will referred to as the value model for ease of communication. The model is comprised of four themes. Introduction to each section is discussed below.

BIM elements and BIM features

BIM elements and features placed at the heart of the value model (Figure 7.2). The model simplifies the complex and at times vague BIM by breaking it down into three key elements namely; information, technology and process. Each of these element is currently identified with a unique set of features. For example, the information side of the BIM provides features such as data as usual, information through visualisation and opportunity for data recreation. Introduction to each element and feature is given in Table 7.1 and the development of these high level categories through themes emerged through data are presented in Figure 6.11.

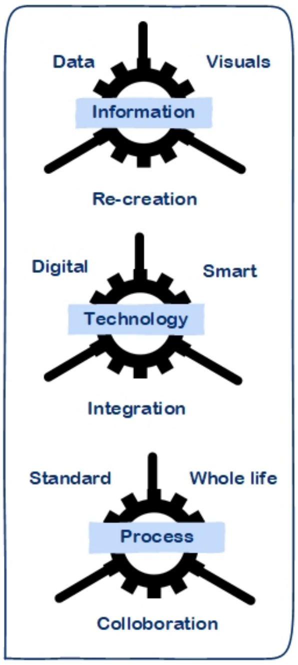


FIGURE 7.2: BIM elements and features

Referring to the Figure 6.11 in Chapter 6, BIM elements are the group of third level categories while features are at second level. Accordingly, people tend to communicate value of BIM through barriers and benefits. These barriers and benefits soon developed 6 themes (see Table 7.1 which are identified as the BIM features in the value model. Further abstraction of the themes to generate the core category, enlightened by the multiple theories such as human technology interaction, technology acceptance and value sensitive design supported the development of BIM elements, defining the BIM as it is currently recognised in literature - i.e. BIM as an information system.

Although BIM elements (i.e. information, technology and process) are extracted as separate entities; all three work hand in hand to provide a BIM delivery. For example, data

TABLE 7.1: BIM features and elements

BIM Elements	BIM Features	
Information	Data	As-built information which is expected to handover to the client with or without BIM
	Visualisation	Communication of previously unspoken information through visualisation
	Data re-creation	Generation of information out of existing data and creation of new data sets
Technology	Digital	Assistance gained through information technology. The use of computer aid methods for information creation and management
	Smart	Having created information in digital platform allows for working smart through automation and artificial intelligence
	Integration	Provide possibility to merge existing and future technologies to be controlled by a single platform
Process	Standard	Introduce and maintain standard method of working within and around construction industry
	Whole life application	The BIM process promotes a whole life thinking from the early stages of a building life cycle
	Collaboration	Provides guidance and support to collaborative work in local and global context

visualisation takes place with the support of digital information. Similarly, delivery of accurate data has been possible due to the standardised process in BIM delivery.

This interdependence feature of the three BIM elements is denoted through the gear wheel icon. Accordingly, the true BIM delivery or in other terms full list of exclusive BIM benefits is only possible when all three gears are working in their full capacity. Failure of one will affect the other. In contrast, achievement of one will provide the first step to the achievement of the next element causing growth. Therefore, it is vital to understand an organisation's BIM capability and match it with the supply chain BIM capabilities to make an informed decision about BIM implementation.

However, BIM elements and features are causal mechanisms of everyday life experiences of built environment professionals. Taking a step further, BIM value model has map most common experiences caused by each BIM feature (Figure 7.3). This will support in recognising the consequences of adopting BIM for both experts and novice by translating BIM into everyday activities. Further, when look into the experiences caused by BIM elements and features, it is a definite possibility that these experiences bring both positive and negative impacts on BIM adoption. This negative and positive impacts are discussed in next section.

BIM barriers and benefits

One of the common ways of expressing value of an information management system is evaluating its benefits and barriers. This is often a common practice when economic value (price) isn't readily available or when price does not do justice in terms of communicating its value. Upon identification of BIM elements and features, the second most important attribute of the BIM value model (Figure 7.1) is communicating BIM barriers and benefits that come along with each BIM feature (Figure 7.2). this section of the value model is based on the findings of the lietrature review (See Chapter 2) and reaffairmed during the data collection and analysis. At the validation phase, this portion of the BIM value model was uplifted above others because of its pragmatic nature and concreteness effect. As a result, value thermometer (see Figure 6.12) was developed holding only this theme out of four themes in the original BIM value model. Interestingly, the BIM value model makes an innovative twist to the conventional benefits and barriers based on the value principle which is introduced later in this chapter (see topic 7.6).

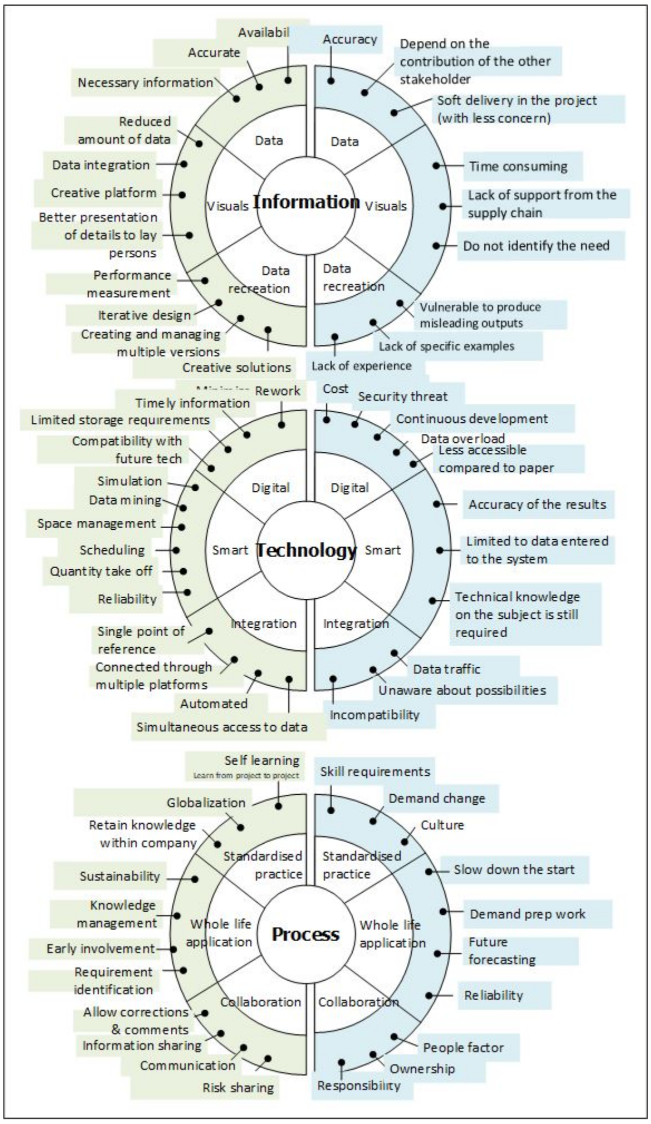


FIGURE 7.3: Barriers and benefits

Instead of benefits and barriers, the value model comprises of values (highlighted in green on Figure 7.3) and value opportunities (highlighted in blue on Figure 7.3). This claim of identifying barriers and benefits as different forms of value is supported by the combination of Schwartz's Basic Human Value theory and Karl Marx's value in use (see Figure 6.11). The left side of the model presents benefits which will hereinafter be referred to as values and the right side presents the BIM barriers which will hereinafter be referred to as value opportunities. However, it is important to note that values and value opportunities listed on the BIM value model is not a comprehensive list but a guide to discover users' own values and opportunities. Creating such an exhaustive list is identified as a "theoretically unsound" task (Maslow, 1987) especially when the absence of it makes no difference to the practical and theoretical application of the considered model.

This view on benefits and barriers will provide a positive impression on BIM adoption for many stakeholders in comparison to other existing BIM related models which promote adoption of BIM either based only on benefits or by ignoring BIM barriers. However, the BIM value model openly invites its users to acknowledge their own strengths and weaknesses in order to understand areas in which BIM will provide promising benefits under business as usual and areas which require special attention in order to gain complete advantage of BIM adoption.

Documentation of value opportunities (barriers) will be vital especially in terms of technology and policy developments. Value opportunities will communicate unmet needs giving insights to necessary improvements which will ultimately help in wider adoption of BIM. Therefore, in the long term it is more important to identify value opportunities (barriers) than values (benefits). However, from the nature of human needs, organisms are self-centred at the very basic level. In contrast, the BIM process functions collaboratively creating an interdependency between information users and providers.

BIM Roles – Information users and providers

The BIM value model acknowledges the role played by different stakeholders in the process of BIM adoption and use. BIM as a pioneer of a collaborative work environment creates two basic BIM roles – i.e information users and information providers. Key stakeholders in the BIM process often go back and forth between these two BIM roles (Figure 7.4). In general discussions, the client organisation is soon recognised as the information user while the lead contractor and the others along the supply chain are left as the information providers. These well-known roles in the BIM process have raised the question on what incentive is there for information providers to make extra efforts to provide information for their users. This question is raised due to the rigid roles played by the construction stakeholders in their silos work environment and economic considerations of time and effort spent on handover information.

In contrast to the existing view on these roles, the BIM value model emphasises the dynamic rather a static nature of the BIM roles. Accordingly, at the beginning the client plays the information provider role through the production of the Employer Information Requirement (EIR) while the project team takes up the information user role and vice versa at the handover stage. Moreover, with the industrialisation of the construction industry and popularity in modern methods of construction these BIM roles will be switched again by clients providing valuable information about design failures and maintainability issues which will provide a tremendous contribution for the industrial production process. Therefore, in order to understand the value of BIM to the client or contractor it is necessary to understand the interdependency in the value creation process as well as the circular motion

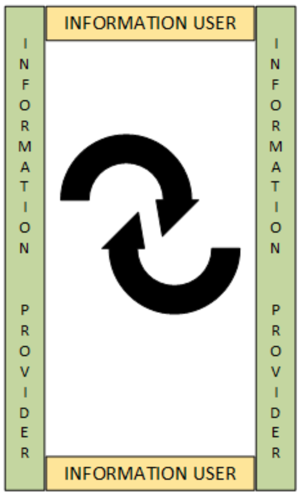


FIGURE 7.4: BIM Roles

of the BIM roles played by each at different stages of the building
life cycle. As a result, one would benefit from BIM as much as one contributes. Although, the BIM value model presents a wider range of options to recognise BIM value by the clients and other stakeholders; the total value of BIM is based on priorities placed by the user on each of the options given. Accordingly, three trends of BIM users were recognised which are placed under four zones.

BIM adopter trends and zones

The initiative of a BIM project is expected to be influenced by the client. However, the majority of the construction project clients are not expert enough in the subject to demand a BIM delivered construction project. On the other hand, the client request for a BIM delivered project is often used by the project team to increase the project cost creating extreme contradiction between cost and time savings predicted by the literature and practitioners. When looking at iconic BIM projects and most of the BIM case studies provided in the literature, all of them are government funded construction projects constructed by award winning contractors. Comparing different construction projects, the BIM value model presents three adopter trends (Figure 7.5).

This is in line with adopter categories discussed in theory of Diffusion of Innovation (see Chapter 5). Large scale client organisations such as government and construction companies with long term reputation are identified as trend setters. They have the resources and capacity to initiate a change in the industry. Trend setters tend to focus on existing BIM benefits and overlook BIM barriers. Due to their position in the market, this behaviour has a different impact on such individual organisations compared to others. On the other hand, the majority of the market players (both clients and contractors) are middle range players. They consider both benefits and barriers giving equal emphasis to each element. The urge to take the market leadership is an incentive for them to promote BIM delivered projects. Therefore, in such incidence either client or contractor compels the BIM execution even with the lack of initiation from the other. Finally, when both client and contractor is not enthusiastic about change or has negative experiences on previous attempts, they tend to focus on BIM barriers overlooking the benefits. Therefore, they are categorised as "late adopters" who wait to adopt BIM till most of issues are solved and the BIM market reaches is maturity. In this way, they expect to earn savings from multiple changes in technology which could occur over the time, trial and error and efforts on creating a BIM market.

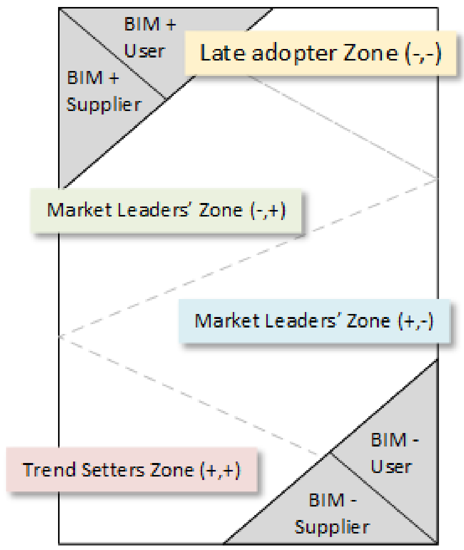


FIGURE 7.5: BIM practitioner trends and zones

In summary, BIM value model brings four themes in to attention. The model emphasised looking at BIM as a combination of information, technology and process. Since information is the key output of the BIM delivered project it is placed at the top. However, at the heart of BIM lies the technology. Most of the BIM user expectations and motivations are based on the technological solution offered through BIM. Though it is the BIM process which energises the system for technology to perform as it is intended to and deliver the expected information output. On the other hand each of these BIM elements has value as it is and value opportunities which need further attention. The way each stakeholder perceives the value of BIM through existing values and value opportunities is based on the each individual organisation's motivation as a trend setter, market leader or late adopter.

7.4 Applications of BIM value model

The BIM value model is a representation of the substantial theory introduced in this thesis (see Topic 7.5). As the model has applied the theory into a specific context, it is therefore to be recognised as a representation of the substantive theory which later leads into the middle range theory. The primary use of the value model is twofold and both are focused on client organisations especially higher education institutions. What it is specified as higher education clients are organisations with decentralised control of real estate decision making and building operations and maintenance. Often in higher education institutes the built environment development plans are initiated through student surveys therefore, face difficulties in executing changes or achieving the purpose of changes through built environment operations. On the other hand, execution of multiple construction projects by a single client over time gives the opportunity to learn through trial and error.

To begin with, the first application of the BIM value model is for the client to assess their BIM capability at the initial stage of a construction project. The model will take through multiple aspects of BIM, avoiding being only focused on a 3D model. Further, the interplay between BIM elements (i.e. information, technology and process) is taken into consideration along with the nature of the human needs; that is fulfilment of one need may affect another and will highlight potential confusions and failures earlier on thus avoiding any disappointments once the BIM journey has started. Therefore, one could have a better idea of what is meant by a BIM delivered project and make decisions accordingly. The BIM value evaluation form (Appendix H) can be used as a guidance tool or create a customised version best suited to the situation and aim of the assessment. With this initial self-assessment, a client can use the same model to assess the suppliers to choose a supply chain capable of delivering the same BIM values.

However, the decision can be made differently based on its strategic application. It is a possibility to select a supply chain with similar BIM values therefore, both parties understand each other's expectations and create a smooth environment for value delivery. On the other hand, there is another possibility to select the supply chain to match with the client's value opportunities. Therefore, if the client is stronger in the information aspect but weaker in technology; suppliers will be selected with high technical capabilities to bring in the missed value opportunity by the client. Other than inter organisational comparison, the value model can be used to compare between two building projects within the same client organisation. This will guide to map the BIM maturity of the organisation over time. Finally, conducting the value assessment twice on the same project during the inception and in-use stages will evaluate the actual value gained through adopting BIM on a particular project. In a nutshell, application of the BIM value model as an assessment tool will take an organisation through a guided learning curve.

Currently the decision to practise BIM is made at two stages; initially at the inception of the project by making the decision for the project to be designed, constructed and handed over through BIM and secondly, the use of BIM beyond handover. The second key application of the BIM value model is at the in-use stage of a building helping to promote BIM beyond handover. Most of the recent projects delivered through BIM by the pressure of the UK 2016 BIM target are currently at the in-use stage. They are given a 3D model with some information however, have not made any progress of application during FM tasks. In terms of existing literature, most of the case studies presented related to BIM applications in FM have carried out the BIM process with a specific FM target in mind (CRC Construction Innovation, 2007) making a completely different scenario from what is experienced by most of the client organisations involved with a BIM project. The facilities management department of these organisations had no pre-plan for what or how the BIM model is to be used. They are often still to find a purpose to use the BIM model and information. In most cases, the re-entering of the BIM information into existing information systems is as far as it goes. In such instances, the BIM value model will help identify potential uses from the existing BIM model and information by directing through three dimensions (information, technology and process). Therefore, even at the handover stage, facilities managers can request the necessary information in required formats and make the maximum benefit from the given opportunity.

Even if the involvement with BIM began at a later stage i.e. the in-use stage, the BIM value model can be used as a team building activity among many operational level employees due to its simple presentation and make them involved in the process of BIM adoption. This will not only bring a sense of ownership and individual contribution to the changes made within the organisation causing a positive reaction to change, but also provide the basic awareness necessary and training to uptake BIM in daily tasks.

Apart from these primary applications, the BIM value model defines BIM as an Information (Technology) Management System. Even that is not what its inventors needed it to be, that is what it is to the practitioners. Making it complicated by what policy makers want it to be will only scare people, and cause them to reject it because anything more is not something operational level personnel can handle. The BIM value model keeps it simple by taking technical jargon out of this complex system and presenting it with three elements that people are already familiar with. The strategy promoted through the BIM value mode is – keep it simple, let it win and then go for the next step. The complex explanations, applications and benefits of BIM will flatter the academic and strategic level community but will detract from BIM in reality/practice. Therefore, the BIM value model is a constant reminder of BIM as it is now rather than emphasising all its future capabilities.

Finally, the BIM value model will provide an indirect but a significant use for IT companies, policy makers, contractors and subsequently all stakeholders. This is achieved by taking a positive approach to the BIM barriers. As the model explains, all BIM barriers are value opportunities. One organisation's barrier is a readily available business opportunity. It is an identified need but not yet fulfilled. For instance, technology incompatibility is an often raised BIM barrier. However, looking through the value principle which will discuss later in the chapter will change the view to create a business case out of the situation. Although this is a new way of thinking in the construction industry, it is a proven and well-practised concept in the tech industry. Even to up to a level to convert tech products into consumables. With the popularity of industrialisation in construction, this future is not far off.

7.5 Discussion

Building information modelling has many definitions, each highlighting a weight towards beneficial features to the organisation or to the research project that the definition was made for. Although this is a result of biased assumptions, it is also has an element of truth because even when looking with an open mind, BIM is many things. It is a process, business model, information and indeed technology. Keeping all these features under check, BIM can be identified as an information system (IS). However, what it exactly is still unknown and as a physical product, process and uses are yet to be discovered.

In agreement with some literature, BIM as experienced by operational level employees can be identified as Information Technology (IT). Its current status brings the same values as IT – i.e. information, technology and transformation (Mooney, Gurbaxani, and Kraemer, 1996). Often BIM is recognised as development of a three dimensional (3D) model of a building. As this 3D model is currently developed by the design team or in other words human beings, the process of BIM has a precise start and a finish; i.e. starts and ends with the development of the model. When a construction project is handed over with a 3D model, it is recognised as a BIM project carrying a limited view on BIM by many practitioners involved in the design and construction stages.

The problem of having such a narrow view towards BIM could be easily explained through how the construction industry reacted to 2D Computer Aided Design (CAD). Firstly, CAD was rejected by many and there are still some architects heavily reliant on paper based design. However, now 3D modelling such as Revit has superseded 2D CAD because of the successful transition of paper based drawings into CAD. Therefore, the narrow view on BIM could be considered as a behavioural response to change. What is interesting is that the basic concept of drawings, the need for communication, common language and information sharing requirement is still the same. While how it is done has been changed over the time from paper based to 2D CAD and now 3D CAD. Although, many predict the success of BIM by comparing it with the transition from paper based drawings to CAD; it is necessary to recognise that this transition took more than 20 years. The time lag in user adoption is supported by the time taken for development of technology hence, not seen as a time consuming behavioural change (see Appendix B). Now the question is, whether to expect complete BIM project uptake in 20+ years or with the rapid development of technology whether the construction industry will have 20 years to change their ways.

Recognition of BIM as the generation of a digital prototype of a building continuously appeared and was argued over in the literature however, identifying reasons or providing solutions for this wrong impression has been neglected. One of the reasons for this delusion is the pragmatic nature of the industry. Construction as a pragmatic industry often overlooks theory. Although literature, academic and professional qualifications on BIM provides a sophisticated definition for BIM, the everyday practice of creating a 3D model in BIM projects has formed a limited view on BIM as creation of a 3D model. More in support, even academic qualifications related to BIM teaching Revit, Navisworks, IES, Tekla, etc. under the module name of BIM even making the new blood taken into the industry carrying a wrong message. These reasons as well as the motivation provided through technological features for BIM adoption has limited what is recognised as a BIM project. There are multiple ways of approaching this problem such as increasing awareness, controlling through policies, giving time to change, etc. however, the most efficient way out of this is the rapid development of the technology. The sooner the digital building starts interacting with the everyday products such as smart watches, motor vehicles, fridges and others closely related to human activities, BIM will be a delivery as obvious as a roof is an expected on a building. This will be the beginning of the simulated built environment.

On a different note more focused on BIM adoption beyond design in construction; most of the reasons for avoiding or slow adoption of BIM are deep rooted issues and only remotely related to BIM. Under existing circumstances, BIM has not even made an attempt to solve them. One such is that FM is a business support service therefore given less priority compared to the core business. This is how FM is defined and from its outset it is true because, it is apparent that an organisation should give priority to its core business over a support service. However, the true reasons for this experience is that the service of FM is indirect while the core business and some other support services are direct. For example, the management will feel it more when a low level administrative staff (i.e. catering or cleaner) calls in sick than when a technician calls in sick. With this comes the issue of low budget allocation, less resources, etc. to adopt BIM even to maintain the information already there. But now that is the problem which BIM cannot solve at the moment. However, from cross industry learning BIM can be revised as a solution with no effort. The bottom line for this twist is understanding human values, not any expensive tech piece. When approaching the issue with the value principle, the objective of the solution is to give access to users, i.e. building tenants. Then the accuracy of the model is continuously validated and use of building information creates a direct contact with the core business. This will not only be a win for BIM but also for FM.

These findings confirm previous research (Azhar, Malik, and Tayyab, 2012) that BIM is not designed to cater for FM needs but all its key features are purely in benefit of design and construction needs. Therefore, adopting BIM in FM will not solve FM needs immediately but have to structure the FM needs to fit with BIM capabilities. In contrast, BIM as a concept was introduced with a long term agenda. The complete experience of BIM is designed for the benefit of FM and long term users involved throughout the building life cycle. However, uptake of the BIM adoption is heavily based on the technological support offered by BIM. Regrettably existing BIM tech features are highly favourable for design and construction needs while offering very little for FM (Azhar, Malik, and Tayyab, 2012). Therefore, major improvements in BIM technology in support of FM needs is to be expected to experience a whole life application of BIM as anticipated.

Kujala and Väänänen-Vainio-Mattila, 2009; user values need to be at the centre of the design process of information systems and products for them to be successful. This again is another confirmation of the dual nature of the technology – i.e. physical formation and social function (Faulkner and Runde, 2009) and acknowledging technology as the core of BIM rather than information. Failing to have an interactive social function in BIM specifically for facility managers fails a further use of the 3D model.

The majority of the work in this thesis is focused on understanding the values held by operational level facilities managers within the limits of BIM. In the philosophy of technology it has been recognised that the victim (i.e. in the context of this study - operational FM) has a better awareness of the impact than the polluter - strategic FM (Feenberg, 2012). In the review of value, the study has brought theories from both behavioural economics and psychology together to provide a substantial understanding of the phenomenon. The theoretical insights gained from basic human values and human motivation led to the understanding of causal mechanisms underlying the BIM experience. As a result, all BIM benefits and barriers were recognised as mirror images of basic human needs. In-depth studies of the structure of values shows that sometimes values conflict with each other while others support each other (Schwartz, 2012a). Application of this characteristic of values brought new insights towards human classification of benefits and barriers. When values are the deep-rooted cause of motivation towards this classification, the new knowledge was generated by recognising barriers as benefits which are not yet delivered.

Another explanation for this could be gained from "loss aversion" in prospects theory (Barberis, 2013; Kahneman and Tversky, 1979). For a client to adopt BIM during 2011 to 2016 was a gamble just like any other new technology. There weren't many case studies to learn from nor did anybody knew certainly what BIM was. As a result, most of the ordinary clients (such as higher education institutes) who weren't governed by the UK 2016 BIM Level 2 target adopted loss aversion behaviour. That is to be more sensitive to the pain than the gain of BIM. Therefore, when identifying the value of BIM, the barriers outweighed the benefits. Kahneman and Tversky, 1979 introduced prospect theory as a critique to expected utility theory, introducing the weaknesses in expected utility theory for risky decisions. Accordingly, they argue that negative impacts have a similar weight to positive impacts of a decision supporting the claim of this research on identifying barriers of BIM as much as benefits of BIM in order to conceptualise the value of BIM.

Agreeing with Abraham Maslow's theory of human motivation, human needs related to BIM are continuously changing. Although, there are many other motivational theories such as prospect theory; Maslow's human motivation theory is has gained the favour because of its focus on human needs and understand over basic assumptions for human activities. Fulfilment of one need leads to another and this change is more rapid than ever in human history. In the 19^{th} century the slow pace of change in human needs and disconnection between one function and another in non technical products gave a head start for technology to bring in new products and services. However, fast changing needs and interdependency between markets in technological products and services has given no choice but to go for the trial and error approach. Therefore, most of the IT released is not in complete form but goes through continuous development over time and it is the same with BIM. Therefore, there is a second thought in promoting BIM after all with all possibilities it could change the reality of human life. It is right to conclude, that the better the understanding of technology the better it will be integrated into living (Feenberg, 2012).

7.6 Introducing Value Principle

As a key contribution to knowledge, this thesis introduces value principle. Principles are objective, static and universal while values are personal and change over the time. What is produced by this thesis is a universal statement about value. The universal aspect of this statement is defended by its underpinning theories as this is supported by multiple existing theories claimed to have a universal application such as the theory of human motivation by Abraham Maslow, the theory of basic human values by Shalom Schwartz, but with an innovative twist. As the supporting theories confirm, their universal application refers to the age, race, nationality and professional boundaries, hence this is not universal in terms of a grand theory. Therefore, the value principle is a middle range theory which is context dependent. It is limited to structuring the value of a product or service. It refers to understanding the user value of a product or service providing an especial contribution where customer and consumer are two separate but inter connected entities. The primary beneficiary of this principle as it is at current status, are product developers, policy makers and strategic level managers in organisations to identify the value of their products/strategies by understanding user value. Key features in value principles are as follows;

- It takes away the discounting factor in the general value equation in understanding the value of a single product and acknowledge the place of discounting when comparison takes place between two options
- Consider the difference when customer knows what he/she wants (product/service) with what customer needs (requirement)
- Recognise the interplay between needs contributing to the total value of a product or service

The necessity of developing a value principle is to bring a full picture of an underlying principle of decision making. Value is recognised as a motivational factor which influences choice or taking decisions. Therefore, a broader understanding of value reveals the hidden facts which can be used to improve a product or system to make it the first choice of its user.

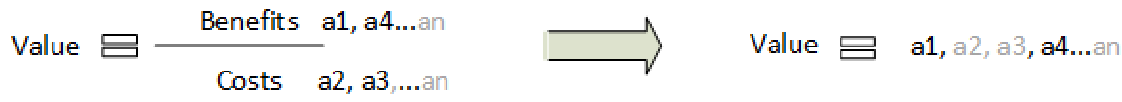


FIGURE 7.6: Value Principle

Value principle was emerged with two key elements. First, value is communicated in terms of cost and benefit (Figure 7.6). This is a well-known and universally accepted statement in economics, marketing, manufacturing, etc. Accordingly, social scientists and economists have done the majority of the hard work on value principle. Almost every value function introduced by the current literature manages to identify cost and benefit as independent variables of value. Although there are many variations of equations to present this general principle, cost benefit ratio is its basic form. In view of that, it identifies benefits as a positive variable to value while cost, which could be time, money or effort as a negative contribution to value. This is where the value principle brings a whole new outlook to way value is seen. The value principle stays in agreement with existing value theories up to the point of identification of cost and benefits as variables values however takes a turn in describing the relationship between these independent variables with a dependent variable. This is better understood with the second element of the value principle.

The second element in the value principle identifies and agrees with previous scholars defining value as a fulfilment of needs. However, this new principle turns the narrow minded perception of adding a condition that value is fulfilment of needs (benefits) but above the cost it incurs into a much broader equation that values are purely fulfilment of needs. Individuals identify and appreciate their needs through value and how they do it is through communicating fulfilled needs as benefits and unfulfilled needs as costs. It is a need of individuals that a loaf of bread should be cheap or affordable, good in quality and they could get it any time they want. The bread maker who fulfils all these needs is valued above the baker who only sells in one town. However, this does not mean that the other baker or bread is rejected by the majority of the customers but it offers an opportunity to grow when the situation is analysed through the value principle.

Therefore, in view of the value principle, every criticism of BIM is an opportunity to enhance its value. At an individual level, this principle is useful to understand values which are often neglected or overlooked because they are previously identified as costs, negatives or weaknesses. With the value principle one would get the opportunity to assess the value of a product or service openly without being limited to organisational, or social cultural norms. It is good that by using the value model, an organisation can identify whether they are more capable of adopting BIM. More importantly, if an organisation is on the weaker side of adopting BIM, they are even better as there are more potential to increase value to customers than what is already on offer.

It is often easy to see the link between benefits and value because both of them are communicating positive aspects and awareness of true cost will not trigger unless there is a decision to be made. Therefore, people attach different value to the same unit of analysis before acquiring it, while having it and when it is no longer available. As a result, it's the goal of today's businesses to retain the value throughout this time frame by playing with different human needs. That is fulfilling a need that they missed in the previous stage.

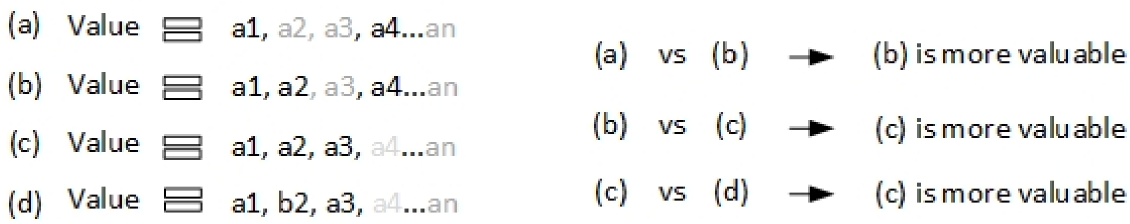


FIGURE 7.7: Application of value principle

What is more, by bringing cost from the previous equation to the same level as benefits, the value principle enriches its capacity to represent challenging characteristics of needs such as growing, interdependent and counter active. Referring to Figure 7.7, compare the three value equations. It is obvious and even understood through the general value equation that (b) is more valuable than (a) because (b) has more benefits than (a). The interesting finding one gets by application of the value principle is the comparison between (b) and (c). There are an equal number of benefits and costs but overall value is higher in (c) in comparison to (b). That is because of the interdependent nature of the needs when a particular need is fulfilled another need is fulfilled with no effort. The same could happen with two contradicting needs. Fulfilment of one need could avoid another creating less value. The final combination is that although both (c) and (d) fulfil an equal number of benefits (d) achieves this with a secondary need which has less priority therefore (c) is identified as valuable.

The reason for failure in the experience of most products and services including BIM is not being conscious of the interdependency of the human needs. One need which is important and fulfilled by the product may detract from a need which is already being fulfilled in the absence of the product. The negative impact of this is partially identified in the general value equation by discounting the costs from the benefits. However, this only visibly acknowledges the negative relationships but not the positive.

Although there are some value equations which bring both benefits and costs visually into a single line they still discount the benefits by its costs. The reason why the value principle is not discounting the benefits from its cost is that it is functioning on a more strategic level than an operational level. Which takes back to the roots of human needs. According to the classical value equation people tend to buy things more if the cost was £0. However, this is merely theoretical as it does not take place in reality. Going back to the diamond and water paradox, people don't value water more than diamonds because it's cheaper. Similarly, in contemporary society people do not expect a product, service or any form which fulfil their needs to be cost free. This includes both monetary sacrifices and physical/mental effort. This is for two reasons; (a) if there were no cost the value is questioned because cost embedded creates value in some instances. In particular regarding the price as a cost, people volunteer to pay a sum for fulfilling their needs but, the trick for the seller is to judge the extent of that willingness. (b) Humans by nature are active creatures. They do want to make a physical or mental effort. Being active and making that cost is part of the value cycle. Getting one product free might be valuable to a middle class person with a busy life yet, fulfilling every need effortlessly makes no value but creates a different group of values such as being active, using organic and homemade food.

Even up to this point the classical value equation may look attractive to the seller in deciding the customer value of a product by adjusting the price to distinguish it from its alternative but the grand prize in value principle is its sustainable impact. With continuously growing human needs, changing price will increase the value of a product for six months (short term) and will force to make changes to retain the value. Taking a different perspective, the value principle brings insight that the price variable is not the only or key contributor of the value of a product therefore, direct towards other forms of value contributions. This will involve adjusting or not adjusting the price while being aware about the other independent variables moving along with the price. If the circular nature of the needs is neglected then the adjustment will make a short-term impact. This same circular nature of needs is what resolves the diamond and water paradox. Diamonds are high in price yet high in value because their price supports the fulfilment of another human need such as limited buying capacity and vice versa its limited availability influences a higher price. Therefore, it is a question whether the high value of a diamond is caused by its price, limited access/availability or its socially constructed value.

In summary, the value principle brings the opportunity to see the positive side of costs and allow a single line comparison between different needs fulfilled to uncover the invisible function which takes place in other equations due to the nature of human needs. This will not override the general value equation. That's not the purpose of the value principle. Its purpose is to act as a contemplative tool for strategic decision making. It's not a tool to help buy "A" over "B". It's a tool to provide mechanisms to bring "A" up to "B" or beyond. It is a tool to decide the price for "B", it is a tool to forecast what is expected from "B" with what can be offered. This is the theoretical insight missing in BIM and this is the theoretical insight that brings a demand for every iPhone release overlooking its economic value (price).

7.7 Chapter Summary

This chapter presents the core output of the research – i.e. BIM value model and value principle along with its applications. The following statements can be given as the summary of analysis;

- BIM will be sustained in the construction industry regardless of existing views and experiences about its long-term sustainability among different stakeholders due to human technology interactions driven by other industries and human lifestyle. However, capturing the maximum value in construction industry through this change is still open to interpretation

- BIM value model will help the clients and facilities managers to understand their BIM requirement and select a supply chain capable of delivering their expectations

- Both benefits and barriers are replications of value.

- To succeed in long term BIM adoption, the developments need to be based in framework of Transformation Model of Social Activity (TMSA)

The next chapter brings together final comments for the research summarising essence of each chapter in the thesis. Accordingly, successful achievement of research aim through set objectives are discussed along with recommendations and future research directions.

Chapter 8

Conclusions, recommendations and future research

8.1 Introduction

This chapter summarises the research process and findings revisiting the purpose of the research and explaining how each objective has been achieved through the three phases of research investigation. Previous chapters elaborate each step taken throughout the research project in detail. This final chapter focuses on the essence of the research by bringing together the contribution of each step taken towards achieving the research aim through objectives. In discussion, it revisits the research aim and objectives and how they have been achieved by cross referencing to appropriate chapters for more elaborated reasoning. Most importantly, it presents the contribution made to the knowledge as well to the industry practice followed by recommendations based on research findings. In order to bring a complete understanding of the research as well as to support the validity of the findings, it acknowledge the limitations of the research and how this study informs further research by making future research suggestions.

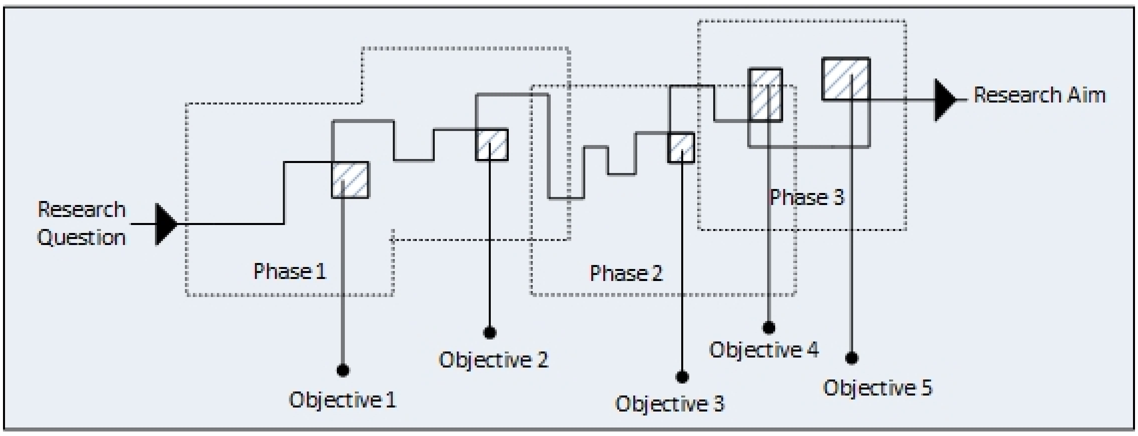


FIGURE 8.1: Research objectives and research process

8.2 Achievement of objectives and research summary

The research presented in this thesis was motivated by the ambition to find solutions to the research question:

"Why BIM is not adopted in FM as anticipated?"

Having initiated the research with the curiosity of exploring the answers to this question, the research aimed to specify a better approach to value apprehension of facilities information management which could be fulfilled through BIM. Accordingly, the aim of the research was to;

"Develop a value model for BIM in Facilities Management that is to act as a decision support model applicable along with existing BIM standards and guidelines and promoting BIM in FM"

Five objectives were formulated to achieve the research aim;

1. Identify the drivers of BIM in facilities management that are adopted within the built environment facilities
2. Understand the factors affecting slow adoption of BIM in facilities management
3. Determine the value of BIM for facilities management
4. Develop a BIM value model for facilities management
5. Validate the model for its usability within the built environment facilities.

Figure 8.1 is an illustration of when each research objective was achieved throughout the research process. Accordingly, first two objectives were fulfilled through the work carried out during the first phase. The first objective, which is focused on identifying the existing practices related to facilities management and BIM was mainly fulfilled by the study of existing literature presented in Chapter 2 and 3. The richness of the study was enhanced by the starting the exploration from the beginning by studying the anthropology of built environment to modern concepts such as Modern Methods of Construction and BIM. Summary of the analysis is presented in Chapter 2 (see Figure 2.6). Accuracy, automation through digitization, integration and collaboration are some of the key features drives BIM in built environment. These findings were confirmed and expanded through first round of interviews. As a result, lack of FM specific BIM features (see Figure 2.8) such as inter-operational issues with current FM software, automation features in support of building maintenance and lack of FM relevant information were identified.

The fulfilment of the first objective formed the way to Objective 2. Same BIM features such as information sharing, automation and collaboration which were identified as BIM enablers in literature were recognised as the factors affecting slow adoption of BIM in FM. The in-depth discussions with industry practitioners helped in understanding the application and challenges in the existing BIM features. Literature constantly emphasised on lack of FM knowledge and experience in information management as the key constrain for

BIM adoption in FM. However, methodological influence on understanding causal mechanisms promoted in discovering the reasons for lack of interest towards information management within FM specially, in an information age where many other industries have move forward benefiting from the power of information. The responsibility over defining information needs where reoccurred during the first round of interviews through the questions directed towards identifying the reasons for slow adoption of BIM in FM. Contradictory themes were emerged referring to the information responsibility. Clients' identified as layman it is contractors responsibility provide necessary information. In contrast, contractors expect client to define the information requirements referring to their particular needs. This led into bringing both parties together to therefore, a focus group discussion was conducted. As a result from the input of both parties, defining and understanding value became a key concern within in order to develop the case for information responsibilities. It was noted that most of the conflicts between the two parties (i.e. client and contractor) takes place due to lack of understanding on value of BIM for each party and collaborative responsibilities come along with the BIM process.

Objective 3 - determine the value of BIM for FM, stands at the core of the research contributing to the novelty of the work. Therefore, longer period of time was spent on the task with multiple rounds of analysis following Constant Comparison Method. Extended interviews after the first focus group were focused on achieving the 3rd objective. Based on themes generated during the analysis which was carried out in parallel to data collection feed into ongoing data collection process in selecting the samples and refining the interview questions. Further, existing theories related to the developing themes such as human technology acceptance, economic value and human value theories were referred along the analysis process to derive meaning. Work presented in Chapter 5 through a literature review of value theories and technology acceptance is one of the key output of Objective 3 (see 1.2). Further, the review of value in the context of BIM laid the foundation to development of BIM value model.

The knowledge gathered through studying the existing literature and the knowledge created through multiple rounds of data collection was put together to make a useful and accessible form of the theory for practitioners and further research. Relationships between categories identified during the analysis process was graphically represented through BIM value model (see 7.1). The production of the BIM value model led into the achievement of Objective 4. However, at this stage the primary focus was to develop a model representing all findings.

Objective 5 was achieved by conducting the second focus group to asses the validity and usability of the BIM value model and upgrading the model based on the input during the process of validation. Accordingly, multiple concepts such as adopter zones, information supplier and user roles and their inter changing nature was taken away to maintain the simplicity and promote wider application during BIM adoption process. As a result, BIM value thermometer was introduced as a decision support tool to set BIM expectations, asses individual project performance and supplier selection.

8.3 Conclusions

Building Information Modelling (BIM) is a popular subject in the construction industry. This new trend is an advanced approach that brings information, technology and best practice processes into a single platform. BIM streamlines the development of both hard and soft deliverables through effective information coordination using technology. It is worth the attention BIM has gained with the tremendous input it brings into the industry to move forward with the others such as manufacturing and aerospace industries, to be equipped to face the digital economy dilemma under current circumstances. Although there have been doubts about BIM since its introduction in 2011 to date with the slow adoption, the concept of BIM will stay in the form as it is known now or in all likelihood an outsmarted version. This will result either by the growth of construction industry through complete knowledge of BIM capabilities or through enforcement of digital industrialisation. Hence, adopting BIM as early as possible will ease the transition for any organisation.

BIM creates value and opportunities by capturing, storing and managing information from the information generation point to its disposal. More importantly, it does not limit itself to a specific task or a stage in a building life cycle but, considers the whole life cycle with a positive impact. BIM has enforced the practitioners to make a change in the way information is handled during construction and post construction stages. The success factor of BIM is its ability to synchronize information, technology and people and bring them together onto a single platform. Due to its uniqueness in presentation of information, it has been recognized as more than an information management system. Thus, it is necessary to recognise BIM as an approach that promotes best practices of information, technology and processes rather identifying it for one of these features.

In fact, BIM should be the standard way of working in the construction industry, in the UK by 2025. The growing interest towards BIM has attracted the attention of both practitioners and academics to move forward with the trend. Many researchers discuss benefits, whole life cycle applications and case studies related to BIM adoption to promote this best practice (Giel and Issa, 2015; Cavka, Staub-French, and Poirier, 2017). Out of many, accuracy, interoperability and usability of information are the key immediate issues BIM can solve for FM (Cavka, Staub-French, and Poirier, 2017). However, all these scholarly works have acknowledged that application of BIM is being limited to design and construction phases in practice.

The Government enforcement and the market trend has attracted designers and contractors for BIM practices. Although current BIM practices are dominant in design and construction phases of a built asset, it was found that owners and facilities managers benefit the most out of BIM with its lifelong application (Eadie et al., 2013). Importantly, it's a solution in which all stakeholders involved in a construction project could benefit from each other's actions (Saxon, 2013). This long-term value addition of BIM strictly demands a good effort of understanding the whole life cycle application of the built asset. As a result of lack of knowledge and experience, a reluctance in adopting BIM among facility managers is noted confirming the previous research findings (Giel and Issa, 2015).

The construction industry is still geared by the best price over best value. Project stakeholders, for example, clients, contractors and investors are concerned about the physical product, cost and time of a construction project. Different research communities have pointed out the drawbacks of this mind-set on many occasions. High operational and maintenance cost is the key reflection of the poor decisions made at the early stages. The focus on time, cost and ambiguous notions of quality result in neglecting soft deliverables and their whole lifecycle value addition. Hence, whole life thinking of construction projects carries a vital importance for BIM adoption as well for an efficient and effective economic contribution from the construction industry. As a civilised and educated generation of mankind, it is necessary to understand price is a mere representation of value and value itself fulfilment of needs.

It is not only current practices of the construction industry and facilities management but, BIM also needs to be further developed to cater the FM needs. For instance, maintenance accessibility is a commonly identified issue in largescale construction projects. Although, BIM is used to identify design failures through the Clash Detection feature, none of the existing features of BIM is capable of detecting maintenance accessibility (Liu and Issa Raja, 2014). Thus, BIM in terms of technology needs to develop focusing on FM requirements. Integration with existing CAFM packages are one such technological element BIM is now working on. Nevertheless, more attractive features such as artificial intelligence and fuzzy logic are expected. Barriers presented in BIM based value model provide directions for required developments.

The BIM based value model presents the BIM value concept based on FM expectations. It communicates the value in terms of benefits and barriers in line with BIM features. Without being limited to a specific feature of BIM such as 3D modelling or clash detection to perform a specific task in FM, the BIM value model brings the overall picture of value of BIM for FM. The model is developed to promote BIM adoption in the FM stage by understanding the BIM based FM expectations by clients and facilities managers as well as the design and construction team. There are different standards and guidelines to take through the BIM adoption process. They provide detailed guidance for each step in BIM and for each individual. However, they are a set of time-consuming reading and do not provide the insight to make that initial step towards BIM. The BIM based value model is a simple and quick reflection on what to expect by adopting BIM at the beginning of the process. Also, it is a BIM compliance measurement tool to be used at the handover to make sure the project is delivered fulfilling operation and maintenance requirements. Cavka, Staub-French, and Poirier, 2017 concluded their research emphasising the importance of such tools and methods to evaluate the BIM compliance with in-use requirements.

In Summary, reasons for slow adoption of BIM in FM are twofold. First, lack of understanding and recognition of how BIM can bring value in FM. Secondly, lack of FM specific or related features offered by BIM as it is identified today. To a certain extent both of these reasons inform each other. BIM users in the FM stage do not recognise the value of BIM easily due to a lack of straightforward FM related features in BIM. On the other hand, existing FM supportive BIM features are not appreciated due to poor awareness of value expectations.

The BIM based value model will guide the facilities managers and owners to understand their BIM expectations while data generated through the model will be useful to design and construction teams to understand client requirements. In a positive note, the barriers in the model are to be identified as market opportunities. In conclusion, it is important to take forward BIM to be the agent of a digital/automated feedback system to act as a standard knowledge base for client requirements. The research concludes emphasising that the reasons for slow adoption of BIM in FM are twofold yet, the contribution of the best practice touches many lives reaching every corner of the built environment and even further (e.g. manufacturing, hospitality industry).

8.4 Contribution to Knowledge

The number of research projects carried out on BIM and its application in the operational phase is increasing up to such a level that it requires making it a habit to search through the topics to keep up with the updates. The early publications between 2010 and 2015 bring in the knowledge on BIM as a concept and potential benefits. The more recent research studies have been about the best practices performed by successful BIM projects and lessons learnt. The unique contribution of this research is to bring in the view of operational level BIM users whose existing knowledge about BIM has not been considered before. It brings a solid definition for BIM-to-date (BIM as it is practiced today) emerging from data. Accordingly, the knowledge contribution made by the research is explained under two areas namely; contribution to academia and practice.

8.4.1 Contribution to theory

The key factors of the research have been identified and presented below to highlight the contribution to the theory.

- **Key contribution 1** - Identification of negative impressions as a component of value.
  The output of the research has narrowed the knowledge gap among current literature that discusses BIM benefits and barriers under the broad topic of BIM value addition. The work has produced a concrete explanation for this abstract concept and argued to highlight the failure in existing knowledge to identify negative impressions as a component of value.

- **Key contribution 2** - Exploration of operational level BIM application in FM.
  The current knowledge on BIM application is highly dominated by design and construction. The few which emphasise the FM point of view on BIM are purely based on strategic level FM. The lack of knowledge on operational level expectations on BIM has restricted its application in its basic levels. Thus, this research contributes by acknowledging and bringing operational level facilities managers' BIM requirements to the literature.

- **Key contribution 3** - Development of relationship between BIM benefits and human values.
  The research explored psychological aspects behind BIM adoption at operational level. This interdisciplinary study succeeded in defending the human value theory in the construction industry by presenting the achievement of basic human values through BIM benefits.

- **Supplementary contribution**
  Identification of relationship between BIM elements, features and values. The model developed conceptualised the relationship between BIM elements and features which are often misinterpreted as BIM values. The BIM value model further demonstrate the business opportunities hidden in existing BIM literature as "barriers of BIM". Theoretical underpinnings metatheory of the research has made this possible. Accordingly, barriers are introduced as unfulfilled values. Thus, they no longer have a negative effect but space for improvement.

- **Supplementary contribution** - Encounter of value as it is an abstract concept.
  This research has accepted the challenge of studying the concept of value to identify its original meaning in everyday life in the construction sector. Findings challenge the notion of time, cost and quality which is practised merely because quantification of these outputs makes it easy to fathom. This positivist/post positivist approach consciously accept that quantification of time and cost does not by itself serve the true purpose of value in construction therefore, uses the word "quality" to bring justice. Combining two extreme ontologies (subjective and objective) has only motivated one to see quality as the usual safety net made through "other" categories in financial accounting.

- **Supplementary contribution**
  Application of Glaser and Strauss' Grounded Theory. The research is an example and step by step guidance for the application of Grounded Theory research strategy in facilities management research. Although, the original version of Grounded Theory takes through a stressful process with continuous uncertainties over the time, it is a guaranteed process of theory generation from data. It is recommended to embark on Grounded Theory with the original version and proceed to further endeavours with later versions which provide much more effective and efficient guidance for theory generation. The experience gained from the original version of Grounded Theory will provide the awareness and consciousness for the risks related to subjectivity and influence from existing theories.

8.4.2 Contribution to the practice

The contribution made by the research to the industry is presented by introducing the application of the findings and recommendations to the industry and policy development (see Topic 8.3). At the strategic level, BIM value model is a simplified guiding tool to use along the current suit of BIM standards and guidelines such PAS 1192 series and much global applications such as ISO 19650 series. Simplicity and personalised features of the BIM value model is focused at getting the organisations back to the BIM adoption process when they encounter a bottleneck when following current BIM guidelines. How to use the knowledge created in the research under existing circumstances is discussed below. BIM value model and the value principle is aimed at promoting BIM in the operational level therefore, contribution to practice is discussed in the organisational level.

- Understanding the expectations of BIM implementation is a key to successful BIM adoption. Using the BIM based value model to assess the organisational values will give a snapshot of BIM strengths and weaknesses of the organisation as well as to know the unique meaning of BIM to individual organisations. Even in the absence of knowledge on the use of the BIM based value model, it is recommended to use organisations' own evaluation method to identify their BIM needs before making any organisational changes or investment. As there are many alternatives available in the market to fulfil these needs.

- Once the client organisation is aware about its unique BIM proposition, the second step is to recruit a supply chain that can deliver the client expectations. Among many other documents and paperwork happening at the initial stages of a new build or a renovation there is a high possibility to ignore the impact of such assessment or for the assessment forms/record to go the bottom of the pile. BIM based value model helps to communicate client expectations as well as to map these values against the supply chain. Following the BIM based value model will provide BIM based value thermometer which is a graphical representation of BIM capabilities and this will help to screen the supply chain at a glance for their capability of providing client expectations. This will avoid most common disappointments that take place due to miscommunications at early stages.

- The key benefit of BIM for Facility Management (FM) is the opportunity of acquiring as-built information for building operation and maintenance. The long-term application of BIM in FM highly depends on the information passed through the BIM process. Therefore, it is necessary to identify facility management information requirements and communicate them to the project team beforehand. However, since information is always beneficial information users are tempted to request for more information believing in the possible benefits it could bring. This unconscious decision may lead to information overload, inaccurate information and missed opportunities to make optimum use of BIM by having a lighter BIM model.

8.5 Recommendations

The application of research findings to solve existing issues in practice is discussed above. This section presents the recommended changes and developments to promote BIM in FM. Recommendations are made under the three key drivers of BIM adoption; Government policies and regulations, technology and individual organisations adopting BIM.

8.5.1 Policy development

UK Government policies on BIM adoption play a crucial part in promoting the application of BIM in construction and project through-life. Most of the BIM initiatives, especially in practice were influenced by the government policies. Therefore, strengthening the policies in BIM and their continuous development to reflect the pragmatic benefits and barriers are important for the wider adoption of this technology and process of information management. Below are a few key points to focus on.

- Policies and high-level standards on BIM reflect the strategic level needs and expectations. They have reached their purpose by drawing the attention of the construction industry towards BIM. However, they are not motivational factors for operational level practitioners to take BIM on-board. Therefore, it is recommended to consider the operational level concerns and reflect them in policy development. In the short term, translating the strategic level BIM values to operational level individual gains would be appropriate to transform adoption of BIM to fulfil regulatory requirements to adopting BIM by making a smart decision to stay future proof.

- Acknowledge practical limitations behind policy expectations. Standards and guidelines have high expectations on client knowledge and understanding over built environment requirements. This has resulted in expecting clients to develop an EIR. However, the majority of the small-scale clients do not have the capability or capacity to produce an EIR.

- Introducing trialability of innovation to enhance the rate of adoption through design, construction and management of buildings. Developing a scheme to provide an instalment opportunity to adopt BIM over a limited period of time is expected to enhance the rate of BIM adoption among SME and self-employee. Especially when self-employment is a considerably higher number (37% of total jobs) in construction sector compared to average of 13% in other industries. Electric Vehicle Charging scheme is an example for such Government initiation.

8.5.2 Technological development

- More FM specific features are to be developed in order to promote a whole life cycle application of BIM. This stands as a key concern among the informed clients to practising BIM beyond construction. Such developments include interoperability with existing FM software packages, replacing existing software with advanced features, direct contact with suppliers, etc.

- Need of a controlled and automated data feedback system to capture the information usage and patterns to develop a standard EIR. The fragmentation of the of the supply chain from tier 1 to lower levels and nature of the product tends to hold information knowledge in silos rather than having a smooth flow as in manufacturing. This feature of the construction industry has been the root cause for many inefficiencies. BIM as an approach which has the capacity to manage information needs further development of robotic mechanisms to trace the use of information to benchmark the cost effective level of information to be stored and managed through life.

8.5.3 Organisation management

- Promote an open door policy to get the operational level employees involved or at least make them feel that they are involved in making decisions on BIM adoption so they will find a personal value towards the BIM implementation efforts.
- On the grounds of skills and competencies demanded at the strategic level decision making, it is accepted that what is to be done at the operational level is decided by the strategic level concerning what is right to do and what is in benefit for the organisation. Turning the table round, as intellectuals at decision making level, it is necessary to recognise that an organisation cannot benefit without making a positive contribution to its employees. Hence, translating the organisational benefits into employee level achievements will be a promising method to promote BIM on the shop floor.
- In terms of information sharing, construction organisations are challenged to learn from manufacturing industry and change the organisational cultures. Creating a long-term feedback loop (information sharing system) among product and service suppliers and users will be of the utmost importance to benefit from upcoming developments (e.g. Artificial Intelligence).

8.6 Research Limitations

The research was structured and conducted to achieve its aim and objectives to its optimal level in the given circumstances. As a part of upholding the reliability of the study, the researcher is conscious about the limitations on which the research is based on.

- The first and the core challenge accepted by the researcher was to conduct a study on an abstract concept without substituting it with one or more concrete concepts. Due to the concreteness effect (Katja Wiemer-Hastings and Xu, 2005) there is a limitation in perceiving the knowledge created through this research.According to concreteness effect, when engaged in cognitive activities, concrete concepts or nouns are understood and processed faster than an abstract noun. Therefore, further development is necessary with careful consideration on holding the multi-dimensional aspect of the value concept before making it available as a self-assessment tool for individual use.

- Secondly, the research is conducted following a pure qualitative multi method approach. Even though it is the most suitable methodology to follow under given circumstances; application of different quantitative methods such as scientific experiments on cognitive neuroscience could provide/validate essential clues to concepts emerging in this qualitative study. The application of analysis based on grounded theory may have resulted in some researcher-induced bias and re-application difficulties however; these limitations were acknowledged during the process and minimised by strong industry collaboration and validation.

- None of the participants in the research had a complete BIM experience; which is from inception to demolition of a built facility. Therefore, it is a collection of experiences from different stakeholders involved in different stages of the building life cycle. It was challenging to find a project with complete BIM application and would have been biased to depend on single project information to generalise the findings. However, findings at this level are helpful to promote the adoption of BIM and its life cycle application.

- Although BIM is designed to reach a globally connected built environment and construction practice this research is limited to the UK context. This highlights a few of the key assumptions made in this research on both BIM and value perspectives. As BIM is mandatory in the UK since 2016 for government projects, the attitude towards BIM was more about regulatory concern rather economic action. On the other hand cultural and behavioural influence of value definition is also necessary to consider when generalising the value model. However, this is theoretically reversed by adopting universal human value theory.

- Judgements of value are time and context dependent and therefore imminent impacts may not be fully predictable and forecastable. As such, uncertainty may always be in value-based research. The model introduced in this research is based on BIM as identified to date. Although future technological developments are being concerned, the model requires regular updates with continuous development of BIM and changes in priorities in human needs.

8.7 Future Research directions

The acknowledgement of contribution to knowledge and research limitations leads to further research directions. These could be twofold; firstly aiming at addressing the research limitations to improve the validity and applicability. Secondly, further development of the knowledge contribution could be done by advancing with other theories. Accordingly, the actions below can be suggested;

- Translation of the value principle into mathematical equation to validate and promote its wider application

- Development of the model focusing on each element of BIM. Further studies could be carried separately under each BIM element; information, technology and process. This will provide a detailed appraisal of the features of each element and the findings will help the users to understand the value according to individual priorities. As these extended studies will concentrate on BIM features of a particular element, it will be possible to quantify the value contribution. Hence, this will explore the quantitative results of the value concepts overcoming limitations of current status.
- Integration of other technology and practices with BIM (e.g.; Virtual Reality, Internet of Things, Block Chain, etc.). The definition of BIM will surely change over the coming years with the new technology. Therefore, keeping up with continuous developments in technology and practices will be required. Further development of the model to make it future proof will be an exciting way forward.
- Development and testing of the BIM value model as a stakeholder maturity model. As suggestions made by the practitioners during the validation process, application of the model with different stakeholders could be proposed with the aim of converting the BIM value model into stakeholder maturity model.
- Justification of the theoretical basis that benefits and barriers are reflections of values. Initial findings of this research could be taken forward to a theory development study based on reflection of values through benefits of barriers.
- Application of the model to develop a system architecture form BIM-FM requirement identification add-on is another multidisciplinary research which will enhance the pragmatic application of the value model.
- Test the value theory model by applying it to a mature information technology system, such as in information technology used in banking where its application is regular and international. Selecting a regular case will help to study different scenario in a short period of time while international application will bring insight about the legal, policy and cultural influences.

8.8 Chapter Summary

As the final chapter of the thesis, this brings the essence of the research project into a single chapter. The content provides evidence for achievement of the research aim and objectives hence, the thesis has accomplished its work. The contribution made by the thesis is discussed separately highlighting the impact made in academia as well as the knowledge provided for the betterment of the industry practices. Also, it acknowledges the strengths and limitations. Bringing a pure understanding of the value playing behind the human technology interaction is identified as one the key strengths while providing directions for future researchers.

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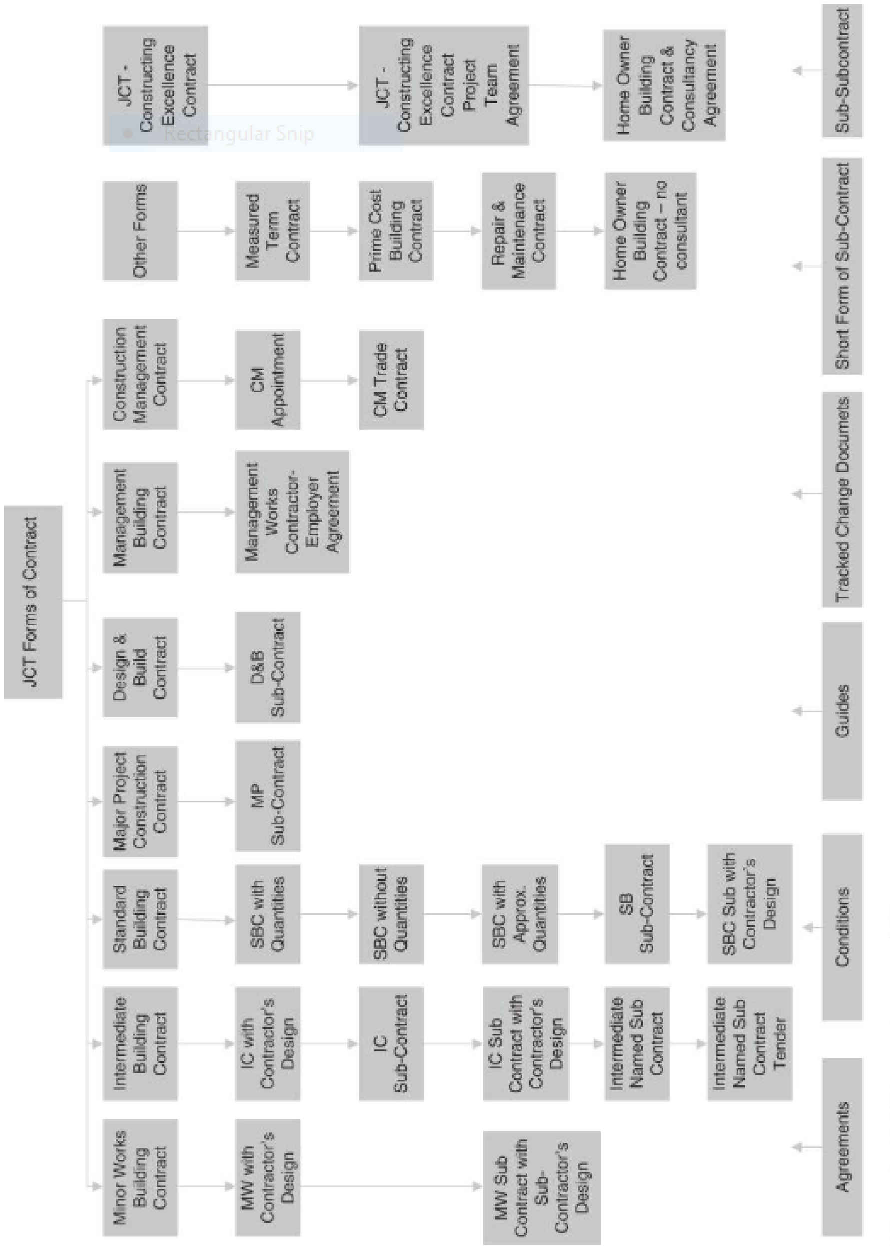
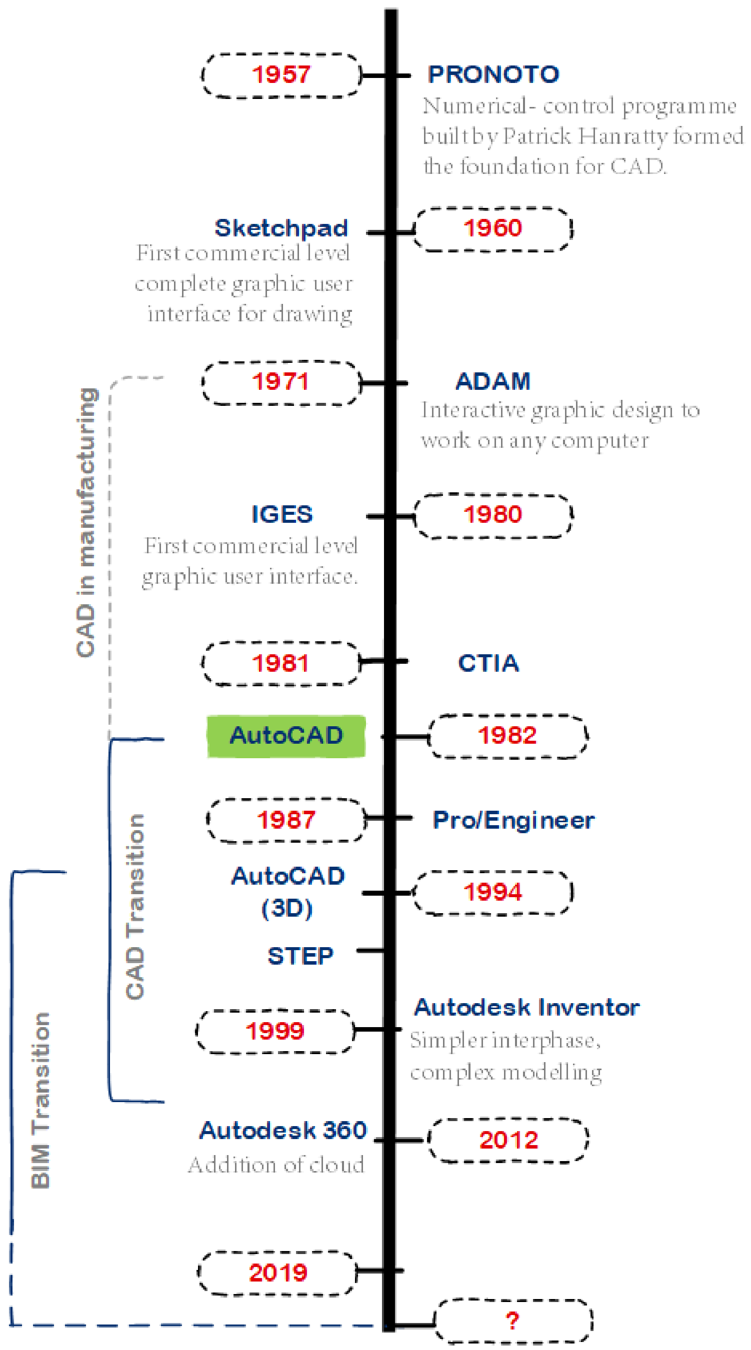
Appendix A

JCT Forms of Contract



Appendix B

CAD Transition



Appendix C

Participants information sheet

Liverpool John Moores University

Optimising adoption of Building Information Modelling (BIM) in Facilities Management (FM): A model for value apprehension

Christaline Wijekoon
Department of Built Environment
Faculty of Technology and Environment

You are being invited to take part in a research study on use of construction information for facilities management. This will gather your experience on information management in construction projects and use of information in building management. Before you decide it is important that you have a clear understanding on what details will be explored from you and how they will be used for the research purpose. Please take time to read the following information. Please do not hesitate to ask if there is anything that is not clear or if you would like more information. Take time to decide if you want to take part or not.

1. Eligibility Criteria

To be eligible to participate in this research you should meet at least one of the below criteria.

- Currently working in the construction industry with minimum of 5 years industry experience as a construction professional.
- Director level employee in a Higher Education institution who hold responsibilities in facility procurement

2. What is the purpose of the study?

Every piece of information has some value to somebody meeting in the building life cycle. Moreover, in this era where technology has become the gear with the digital economy; value of information is highly depend on in what form they are in. These facts brings the research aim to provide a framework to support the understanding of information requirement in Facilities Management.

3. Do I have to take part?

No, it's voluntary. You can decide whether or not to take part. If you do, you should verbally communicate your willingness at the beginning of the interview. You are still free to withdraw at any time and without giving a reason. A decision to withdraw will not affect your rights.

4. What will happen to me if I take part?

You need to share your ideas by answering a set of questions related to information generation and information flow from construction stage to in-use stage of a building. There will be approximately 10 to 15 questions and the interview will take max. 1 hr. the interview will be audio recorded to prepare the full transcript. You can choose a place and time convenient for you to conduct the interview. If there is no such preference; meeting rooms available in Liverpool John Moores University will be used for interviews at a time convenient to the participants.

5. Are there any risks / benefits involved?

There is no risk with participation and no direct benefit. Yet, final output of the research will be useful for industry practice. Therefore there is an indirect benefit of being a part of the development.

6. Will my taking part in the study be kept confidential?

Yes. The data provided is handled complying with Data Protection Act. Your name, organization or any person identifiable information will not be recorded or used for the research. Your ideas shared during the interviews will be used for the research purpose only. Conclusions drawn through your ideas will be published anonymously.

This study has received ethical approval from LJMU's Research Ethics Committee (insert REC reference number and date of approval)

Contact Details of the Researcher
K.A.Wijekoon@2015.ljmu.ac.uk

Contact Details of Academic Supervisor
Dr. Anupa Manewa R.M.Manewa@ljmu.ac.uk
Prof. Andrew Ross A.D.Ross@ljmu.ac.uk

If you any concerns regarding your involvement in this research, please discuss these with the researcher in the first instance. If you wish to make a complaint, please contact researchethics@ljmu.ac.uk and your communication will be re-directed to an independent person as appropriate.

In the interests of safety for the researcher LJMU ethics committee would advise researchers not to include home addresses or personal telephone numbers (mobile or home) as contact details for participants.

Where questionnaires are to be returned by members of the public as part of the study the ethics committee would advise researchers to consider the use of collection boxes at third party locations.

Note: A copy of the participant information sheet should be retained by the participant with a copy of the signed consent form.

Appendix D

Participants consent form

Liverpool John Moores University

Gatekeeper consent form

Title of Project:
Optmising the adoption of Building Information Modelling (BIM) in Facilites Management (FM): A model for value apprehension

Name of Researchers:
Christaline Wijekoon

Please tick to confirm your understanding of the study and that you are happy for your organisation to take part and your facilities to be used to host parts of the project.

1. I confirm that I have read and understand the information provided for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. [ ]

2. I understand that participation of our organisation and students/members in the research is voluntary and that they are free to withdraw at any time, without giving a reason and that this will not affect legal rights. [ ]

3. I understand that any personal information collected during the study will be anonymised and remain confidential. [ ]

4. I agree for our organisation and students/members to take part in the above study. [ ]

5. I agree to conform to the data protection act [ ]

Name of Gatekeeper: Date: Signature:

Name of Researcher: Date: Signature:

Name of Person taking consent:
(if different from researcher)
Date:
Signature:

Appendix E

Participant approach email

Dear Sir/Madam,

I am a PhD student in Liverpool John Moores University and currently undertaking a research on the "Optmising the adoption of Building Information Modelling (BIM) in Facilites Management (FM): A model for value apprehension" which is an essential part of my PhD dissertation.

You are being invited to share your ideas on value of information.

Please take your time to go through the Participant Information Sheet and Interview Questionnaire herewith attached – it should last no longer than 6 minutes.

It will be a great contribution if you can share your viewpoint as it will be helpful to uphold the quality of service provided in higher education institutions. The interview will take 45 minutes. If you're happy to take part in an interview please reply to this email before [Date completing 2 weeks from the email sent date].

I really appreciate your participation and please be kind to share your experience.

If you have any queries please do not hesitate to contact me by emailing k.a.wijekoon@2015.ljmu.ac.uk

Thank you
Christaline Wijekoon

Appendix F

Interview template

1	**Generic questions**
1.1	Your name
1.2	Your designation
1.3	Your organisation
1.4	How long have you been working in construction,building sector?
2	**Information management and BIM**
2.1	What is your role in estate management? a. Procurement level b. Operation and management
2.2	What are the services provided by the Facilities Management team
2.3	What are the key issues in building operation and maintenance you face due to lack of information?

2.4	What information you receive at the completion of a building project? a. Drawings, warranties, building insurances, supplier info, Maintenance plan, to what detail? b. Who is responsible for supplying those information? Main contractor or any other party? c. How do you communicate your information needs to the responsible party? d. Are there any guidelines / policies adhere for information management?
2.8	What information do you require to operate and manage the building (FM)?
2.5	How do you manage (collect / store / retrieve etc) building information? Who's responsibility? a. Software (ArchiBus, Revit, Navisworks etc.) b. Procedures c. Costs and issues

2.7	How do you use those information during the project life cycle? In what frequency/ circumstance?
2.9	What are the barriers/issues you face related to the information management?
	a. Understanding the full information requirement
	b. Getting all necessary information from the contractor
	c. Have you found any experience on information mismatches? If yes how did to overcome those challenges
2.11	What are the potential improvements which can be made or which should be made for an efficient management of the facility?
2.12	What are the criteria you will use to value the information?
	Frequency of use/ savings it make/ cost of generating and managing information?
3	**Ethical approval**
	Do you mind if I use this information in my future publications anonymously?
	Thank you

Appendix G

Validation focus group

Focus Group Guideline

Introduction

In early years 2010 – 2015 BIM was recognised as a 3D model. Then with the development of the guidelines and best practice materials, the importance of the information was highlighted. The findings of this research pointed out the complete view of the BIM as a combination of Information, Technology and process. All these three aspects together creates a BIM experience. For instance, it is already identified that a model without information is nothing but a visual impression of the building but, from information perspective, all information which should pass down to the client through asset information register was there in the construction industry even before BIM. Therefore, what BIM really does is communicating the importance of information for design, construction and maintenance of a building and help capture the value to the business through predefined process and technology. This research map operational level BIM values with Schwartz's theory of basic human values.

Purpose

The purpose of this focus group discussion is to validate the model. This is to answer two questions;

- How the model does reflects true industry experience?
- How does the model can be used in practice?

Structure

- Explanation of the model
- Which valuable aspects **INFORMATION** was fulfilled through BIM (10mins)
  - Which valuable aspects of information was yet to be improved/introduced
  - Is there anything else to add to model other than what is listed
- Which valuable aspects **TECHNOLOGY** was fulfilled through BIM (10mins)
  - Which valuable aspects of information was yet to be improved/introduced

  - Is there anything else to add to model other than what is listed

- Which valuable aspects **PROCESS** was fulfilled through BIM (10mins)
  - Which valuable aspects of information was yet to be improved/introduced
  - Is there anything else to add to model other than what is listed

Programme

- 8.30a.m-9.00a.m - CE Liverpool meeting
- 9.00a.m-9.15a.m - Grab a coffee/ Introduction to the model
- 9.15a.m – 10.00a.m – Discussion

Appendix H

BIM value evaluation form

Use this form to assess the expectations of BIM. The form is structured with three different sections (information, technology and process). Each section subdivided into enablers and barriers to take through both positive and negative impacts of BIM.

Please rank how likely is your BIM project experience related to each area listed below. The ranking indicates least to most from left to right. If any area is not applicable leave the ranking blank and if any area of BIM enabler or barrier as per to your experience is not listed kindly write down in the additional space given at the bottom of each section.

Least						Most		Least						Most

Information											
Enablers						*Barriers*					
Availability of information	1	2	3	4	5	Accuracy of information	1	2	3	4	5
Accuracy of information						Depend on the contribution of the other stakeholder					
Necessary information											
Reduced amount of data											
Data integration						Soft deliverable in the project					
Creative platform											
Better presentation of details to lay persons						Lack of support from the supply chain					
Creating and managing multiple versions						Need skills and resources					
Iterative design						Lack of specific examples					
Creative solutions						Lack of experience					
Performance measurement											

Technology

Enablers						*Barriers*					
Timely information	1	2	3	4	5	Cost	1	2	3	4	5
Limited storage requirements						Continuous development					
Minimise Rework						Security threat					
Simulation						Data overload					
Data mining						Accuracy of the results					
Space management						Limited to data entered to the system					
Scheduling						Accuracy of the results					
Quantity take off						Data traffic					
Reliability						Incompatibility					
Connected through multiple platforms						Unaware about possibilities					
Single point of reference											
Automated											
Simultaneous access to data											

* If any BIM enabler or barrier as per to your experience is not listed kindly write down in the additional space given.

Process											
Enablers						*Barriers*					
Develops a learning cycle	1	2	3	4	5	Skill requirements	1	2	3	4	5
Interoperability						Demand change					
Retain knowledge within company						Culture					
Sustainability						Slow down the start					
Knowledge management						Demand prep work					
Early involvement						Future forecasting					
Requirement identification						Reliability					
Allow corrections & comments						People factor					
Information sharing						Ownership					
Communication						Responsibility					
Risk sharing											

* If any BIM enabler or barrier as per to your experience is not listed kindly write down in the additional space given.

Appendix I

Sample interview transcript

Client - FM (BIM) Birmingham City University n***.****@bcu.ac.uk
01. How do you got inspired to use BIM? Is it the Government influence?
Universities are not governmental bodies so there is no mandatory requirement for university to do BIM. We thought BIM would be good so we went ahead with it.
02. Who identified the FM information requirements?
Facilities management as you can see is coming from estate departments. University is divided into different departments like library, student facilities so on and they all come together to decide what we want and the requirements goes to senate and finally comes back to estate department. Compared to the previous years estate department is now better at making the requirements into information requirements because in previous projects they struggled a bit. You know in traditional construction projects we don't do this. We come up with the sketch designed and just go ahead with it. But now we have to identify the information requirements as well. It's the 3rd BIM project now so it is a learning curve from first to second. First one started in 2012 there was only one report in 2012 saying BIM is good and we need it by 2016 and that's it.
03. Did you use COBIE or any other guideline in deciding your information requirements?
No we decided not to use COBIE. Actually the question should be other way round; why we should use COBIE? We don't want to find problems. We are doing what we are doing for thousands of years. Buildings are constructed and used all around the world and hardly they come down. Introducing BIM or any new thing is a problem. If the problem gives us more advantages, then will take it and if not we won't. So in COBIE, we didn't see that's it gives solutions or benefits so we dropped it.

So in which format you got the information? we got the information in Revit files and we also saved the IFC files because sometimes different contractors use different software and by contract we have asked to use Revit and Revit relevant software. Level of details of the information was specified in the contract document. In a sense it wasn't well understood in the first project. It basically said we need this and we need Revit to start with and let's do BIM. But in second project it was slightly better because we found that when it comes to M&E problem starts because level of detail is very important. until that it was ok but M&E was troubling. The Level of details is given as a supplementary document in the contract document.
04. How did you get the BIM information? As separate documents (hard copies or soft copies) or embedded in the model itself
It varies from object to object. Most of the architectural details were embedded on the drawing itself but for example other fittings like boilers we are using a software call BIM 360 which allow us to sort of attach documents and SharePoint to upload documents which connects back to the objects, so all the information is in electronic but separate. But all these were decided by discussions. We want all the information on the model but we have to be realistic as well because the software we have is not advanced enough to have everything on the model.
05. What kind of information do u ask at the moment? Having a COBIE as a standard do you ask similar amount, less or more information?
Hmm.. mostly its left up to the contractor. We had worked with 2 contractors and one provided more than what we needed and it was easier to produce the COBIE. The other one didn't even give the basics. Contractually there is no statement like that. It doesn't say what information we want it just say provide information. The supplementary document says the level details and not the level of information. The basic COBIE information will be provided by every contractor because it's a part of the specification but on top of that any other information; specially this happens in M&E. Going back to the question, LOD and LOI is important but its not detail enough to decide the exact level of information.
06. As a BIM user, do you prefer to have a standard framework to decide on which information is necessary for FM purposes?
Hmmm.... (more towards NO expression) We need each and every stage what LOI we need to have is what we want and what we have but object wise what LOI we want to have; hmmm.. do we want to go to that extend? I don't know.

If you got to PAS 1192 guideline it shows objects and LOD but we don't follow that guideline. We made it through negotiation with the contractor. We can make it contractually. At this stage (2016) it will just increase the price. We could do year before last because it was the growth period and contractors wanted money. But now it has completely changed. Contractors are choosing with whom to work and if you put too many obligation we are going to lose as a client.
07. As a client do you recognise a value of construction information for FM? how do you value it?
Yes, certainly. It is important in many different ways marketing, operations, maintenance and I can go on. It specifies creating business opportunity. Client doesn't build a building is not because they want a building but because they want a business. If the building is connected to the business, then there is no point. We have buildings and we have information to a certain level but how these information is used for business is a huge gap. With the additional information we got through BIM one of the things we do is space management. We had a manual system where we have to physically go and check but with BIM now we have an online system. We are planning to use the information for the business. Currently we have put many sensors around the university to monitor the user patterns. We have gone to a level we don't know which sensor is what. Also due to the high weather changes, information is very necessary to have information to create a comfortable environment because even your class room it's too cold one day and warm next day. Potential it (information) could provide is what means value to me. The world is moving. Everything is being captures and analysed and interpreted. Buildings is also included in this but we are still behind this process. Businesses have some business objectives which are connected to the building and we need to see this connection. But currently there is a gap here. People don't see this connection.
08. What's the efficient level of information to be on a BIM?
It's a very tricky question to answer. The first project, when it was started the estate's mentality was to get all the information possible. We found it is a disaster, that's not what we want and it pushed the contractor too much. These are all negotiation. In construction it's very important, all thought it seems that everything is made contractually but it's not. LOI is a subjective one. Cobie is not enough. Think about it, it's just the basic information. We go more than COBIE. In order to do this, we need mutual understanding and agreement between contractor and client to move forward. It's not easy.

So in second project we didn't request for full details and this is where LOI and LOD matrix was introduced. We struggled to specify the information we wanted but contractor was willing to provide more information. In 3rd project we had all these LOI and LOD but contractor said No and he agreed only to provide minimum level of information. At the end of the day we can't get all the information we want. It's a negotiated level rather having a contractual agreement. You can have a contractual agreement but, you need to do it in forefront and it's a chicken and egg situation because we don't have the building do decide what information we want.
09. What is BIM for you?
It's a business opportunity for me. A model to a system to an opportunity. It's certainly beyond modelling. For me, its information but, if you stop it as collection of information then what's the meaning of it so definitely it's an business opportunity