Assessing Information Management as a Tool for the Ongoing Maintenance of Built Assets

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A thesis submitted in partial fulfilment of the requirements of the University of Reading for the degree of Doctor of Engineering.

Technologies for Sustainable Built Environments Centre

January 2018

DECLARATION

I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged.

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January 2018

ABSTRACT

Much attention has been made of optimising information modelling in the construction sector. Government bodies have mandated collaborative working environments as a means of enhancing the process of delivering assets that not only meet user expectations, but also reduce project costs and enhance timely completion. An impetus is being placed on the need to reduce total lifecycle costs – 33% by 2020 (Construction Leadership Council, 2013) – so, more emphasis needs to be placed on the acceptance and use of information for the ongoing operation and maintenance of our built assets. Central to this concept is breaking down the disparate silos that constrict the architecture, engineering, construction (AEC) and asset management (AM) industries.

This research project attempts to explore the phenomenon of whole-lifecycle asset information management, from the perspective of those critical to the process, the asset managers. Using cases from the UK Higher Education (HE) sector, individuals at all levels of the organisational structure (i.e. managerial through to technician) were engaged and an understanding of the varying roles and responsibilities used as a starting point for discovery. A grounded theory approach is adopted, iteratively collating qualitative data from four universities, as well as concurrent thematic analysis of said data, finally validating the theoretical findings against a fifth university. Working a cross-section of universities through semi-structured interview sessions allowed for a fluid approach, capturing the true narrative of the individual whilst adapting one's understanding of the overarching phenomenon.

Findings highlighted:

- The wasteful model of information management, as currently exists within HE AM departments; roles, timeliness, accuracy, duplication and missing information all contribute towards delays and costly resource demands.
- Inefficient and ineffective handover from the capital AEC teams to the AM teams, at the point of practical completion; greater preparation was requested by means of pre-planned site visits at scheduled intervals.
- AM subjects were generally unwilling to adapt to the increasing demands of digital technologies and visual displays; the process was therefore found to be superfluous activity.
- AM subjects' experiential knowledge was underutilised and not captured / incorporated within project development; cyclical lessons were not learned.

This thesis contributes to knowledge by way of a theoretical framework, developed in response to the findings from the interviews. The PPTC Lifecycle Framework introduces the concept of ‘channels’ as an additional project dimension to the pre-existing ones of ‘people’, ‘process’, and ‘technologies’, linking each to key activities and their respective lifecycle stages. The framework highlights the necessity for a ‘softer landing’. It also provides the means for asset managers to be more inclusive in the end-to-end development of built assets, so that they can ensure the successful preparation of all asset management information for ongoing operation and maintenance.

ACKNOWLEDGEMENTS

This thesis would not have been possible without the support and guidance from a number of people. First, I would like to express my immense gratitude to Dr Stephen Gulliver for his understanding, unbound enthusiasm and encouragement; and to Dr Dragana Nikolic for continuously challenging my technical appreciation of the research. Without their 'augmented view' of the research, this project would not have become reality.

The Engineering Doctorate programme relies upon the strong support system of a sponsoring company. My sincerest gratitude goes to all at Faithful+Gould who have contributed towards this project; whether it be to a simple discussion over a coffee, or their invaluable insight into the multi-stream working environment of a construction consultancy. Special thanks go to Mac Muzvimwe for his patience and ability at making train-working look easy, and for picking up the pieces when they were thrown your way. To Terry Stocks and Andy Green for their enthusiasm for the subject matter, and determination to continually inspire with their work. I would also like to thank Adrian Malone, for his out-of-the-box thinking and support in the initial stages of the research, without which the project would not have been possible.

I wish to acknowledge the funding provided by the Engineering and Physical Sciences Research council, without which this research project could not have been conducted. I would also like to express my appreciation to those many members of University who endured my constant email communication and provided me with such vital research data.

To Jenny and Emma at the TSBE Centre, you keep us all sane with your continual support and encouragement, your kindness helped to bring back the blue when the skies became cloudy. To my peers at the TSBE – it's quite a journey we committed ourselves to – my thanks for supporting my nomad ways and always putting a smile on my face. Finally, but by no means least, to my wonderful friends and family who have shown love and support throughout these many years, I cannot even begin to express how incredible you all our, my thanks for everything.

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ACRONYMS AND ABBREVIATIONS

AEC	Architecture, Engineering and Construction
AIM	Asset Information Model
AM	Asset Management
BIM	Building Information Modelling
BMS	Building Management System
BS	Building Surveying
BSRIA	Building Services Research and Information Association
CAD	Computer Aided Design
CAFM	Computer Aided Facility Management
CAPEX	Capital Expenditure
COBie	Construction Operators Building Information Exchange
DLO	Direct Labour Organisation
EIR	Employer’s Information Requirements
EngD	Engineering Doctorate
FM	Facilities Management
GSL	Government Soft Landings
HE	Higher Education
IFC	Industry Foundation Classes
IFMA	International Facilities Management Association
IM	Information Management
ISO	International Organisation for Standardisation
NRM	New Rules of Measurement
OGC	Office of Government Commerce
O&M	Operation and Maintenance
PAS	Publicly Available Specification
PM	Project Management
POE	Post Occupancy Evaluation
PPTC	People; Process; Technology; and Channels
QS	Quantity Surveying
RIBA	Royal Institute of British Architects
RICS	Royal Institute for Chartered Surveyors
SAM	Strategic Asset Management
SFG	Service and Facilities Group

CHAPTER 1 RESEARCH SYNOPSIS

1.1 RESEARCH MOTIVATION

It has been stated that over the complete lifetime of a built asset, 85% of the costs are inherently created during the operational phase, i.e. when a construction project has been completed and the physical asset is handed over to those owning, occupying and managing it (Javier et al., 2016). In an attempt to cut project delivery costs, and increase project efficiency returns, advanced 'Information Management' (IM) strategies have been developed in the Architecture, Engineering and Construction (AEC) industry. These IM strategies also benefit the asset management sector, through the delivery of a proposed 'single source' of construction information, in a 'ready format' for handover to the operational team. In context of the Higher Education (HE) sector, where asset managers have the task of maintaining a portfolio of physical buildings varying in size, scale and function, for an extended operational life, better methods of delivering useful information are needed to help to reduce operational costs. Yet the questions remain: Do the asset managers want the information? Is it the 'correct information'? Is it given to them at the right time? Is there still a disconnect between AEC professionals, and those in Asset Management? This research intends to investigate the social need for information management in the HE sector, in an attempt to connect the capital teams of AEC professionals, with those maintaining the built assets for their complete operational life, as a means to further understanding the issues currently effecting the ongoing maintenance of built assets.

This chapter introduces the research domain of 'information management as a tool for the ongoing maintenance of built assets'; identifying the research problem and overriding motivations that have guided the development of the thesis. In addition to this, the chapter defines the research aim and objectives, which focuses on the development of a framework to guide the preparation and creation of operational information through four dimensions – *people, process, technology* and *channels*. To conclude, a readers' guide will outline the structure for the remaining chapters of the thesis.

1.2 PROBLEM DOMAIN

To further understand the context of the research project, the wider domain shall now be introduced.

1.2.1 INFORMATION MANAGEMENT: THE DOMAIN

The UK Construction sector has long been critiqued for failing to produce built assets that are on time, within budget, and that successfully meet the standards and requirements defined by the user (Egan, 1998, 2002; Latham, 1994). In 2011, the UK Government decided to address these challenges by mandating Building Information Modelling (BIM) as a route to increase efficiencies and reduced related capital costs. From early 2016, 'fully collaborative 3D BIM' was required as a method of producing product and asset information for all publicly funded projects (HM Government, 2011). As a first step towards a more 'joined up industry', these initial targets have evolved to specify an expected reduction in costs, using BIM, of 33% by 2025 (Construction Leadership Council, 2013); a target, however, that does not clarify if the critical savings should be made in the initial Capital Expenditure (CAPEX) phase, or post-handover during the Operational Expenditure (OPEX) phase.

If we consider that 85% of all life-cycle costs are accumulated during the operational phase of an asset (Korpela and Miettinen, 2013), it becomes increasingly important that information is created and managed throughout the operation and maintenance phases, in order to support total project cost reduction. Adopting advanced information management techniques within these phases, however, requires an understanding of the processes, responsibilities and interactions of stakeholders in said operation and maintenance phases, as well as a detailed set of requirements for the relevant asset data (Shiem-Shin Then, 1996).

Asset Management (AM) as a work stream, involves many differing roles, responsible for a variety of tasks ranging from the *hard* maintenance issues, such as: hard physical maintenance of the built assets like the walls, floors and doors, etc. (Arayici et al., 2012); to the *soft* maintenance issues, such as managing the occupant functions, i.e. cleaning, security and space management (Arayıcı and Coates, 2013). It has been argued that more stringent information management techniques allow owners and operators to mitigate lifecycle costs (Rundell, 2006); optimise resource efficiencies (Parn et al., 2017; Schuh et al., 2014) and develop an integrated approach to capturing and reusing knowledge and information about building components and systems (Motawa and Almarshad, 2013). The more that appropriate information is available to asset managers, both semantically and syntactically, at the right time and in the right format, the greater the opportunity for the refinement of processes throughout the operational phase of an asset's life.

1.2.2 A FUTURE PERSPECTIVE

Advancements in technology offer improvements to everyday life in both the speed by which simple tasks are done, and the ways in which we communicate with others. The advanced efficiencies led by computerisation have revolutionised industries across the globe; ,such as the construction industry, where embedded practices now revolve around the use of computers (Parn et al., 2017). The drive to make built assets 'smart', using the most up-to-date technologies can be recognised throughout the complete asset lifecycle – i.e. from the earliest stages of design, through the construction process and into operation – where the internet of things is predicted to allow a greater awareness of assets and the people living and working within them (Bew, 2015). Yet, with the ever-increasing reliance on technology, the question of information use becomes more prevalent. With the prediction that 85% of existing assets will still be operating in the year 2050 (CIOB, 2011), the process of creating and using information to allow for smarter decisions needs to be further investigated and refined. This will be especially critical for those communities who own and operate large portfolios of built assets – for example the HE sector.

The recently published government strategy document, 'Digital Built Britain', devises a four-stage framework for furthering the adoption of digital strategies, to "save owners of built assets billions of pounds a year in unnecessary costs, and maintain the UK's global leadership in digital construction." (Bew, 2015) A vision of a single model environment, coordinating all construction-related, time-related, and activity-related information is being sought; delivered in a manner to enable clients to use the model for both life-cycle and asset management; throughout the operational life of the built asset. However, the push towards this single-model environment does not necessarily mean it will successfully achieve the Government's intentions, as a client. Is this not merely allowing members of the AEC industry to jump through hoops, and ignoring the overriding aim at improving total information management? If better methods of management are to be achieved, a shift needs to occur bringing the concept of designing for operational excellence into the forefront of our thinking.

1.3 AIMS & OBJECTIVES

In the scope of the research domain, the overriding question and objectives can now be introduced.

1.3.1 RESEARCH QUESTION

This research project aims to understand the issues with how information is currently handed over to HE asset managers; identifying areas to develop the front-end creation of projects and improve overall project efficiencies through effective information transfer. In terms of a single overriding question focus needs to be on: *How can information appropriately be created and managed to enhance the operational life of an asset?*

Investigating the issues of the existing state – the 'as-is' – will allow for knowledge to be generated and used to develop a lifecycle framework that would benefit construction professionals and asset managers alike. Breaking the area in question down into three core objections will aid a detailed extraction to take place. The objectives are now discussed, introducing the thinking behind each, as well as the data necessary to lead towards the intended theoretical and practical outcome.

1.3.2 OBJECTIVE 1

Objective 1 aims *to understand where waste occurs in the existing model of information transfer*. Focusing specifically on the 'asset manager's' perspective, a narrative will be captured, contextualising what information is needed and how that information is used daily – operating within a 'business as usual' setting. The collected data therefore needs to allow for an honest narrative to be understood, allowing for varying perspectives to be captured, potentially simultaneously. The data will be used to identify issues with the current practice – whether they be relating to the governance structure or priorities inherent with the HE Institution's (HEI's) long-term goals – as a means of proposing process changes that will prepare for, and combat the issues within operation, i.e. instilling new patterns for creating and sharing information from the earliest stages of project/programme development.

1.3.3 OBJECTIVE 2

Objective 2 aims *to investigate how asset managers may benefit from better methods of transfer*. In other words, creating a picture of the successes and failures in how information is passed from the AEC stakeholders onto the asset managers, i.e. handing over from capital into operation. Understanding those elements that contribute towards frustration, delayed work and costly changes within the project environment, will enable a clear structure of preparing for handover to be developed.

1.3.4 OBJECTIVE 3

Objective 3 aims *to evaluate how lessons learned can be best captured*. Understanding if there is an existing perception of using thoughts and lessons and whether it is seen as a positive activity. A successful pattern of feedback can be proposed. Capturing the types of lessons and the most suitable point at which these lessons may be shared - and between who – a framework can be suggested so that wider project and programme management can continuously feedback and learn, developing towards the proposed lifetime cost reduction targets.

Each of the three objectives will be investigated relating to four dimensions: *People* – the roles and responsibilities of the AM stakeholders and their dependencies on information; *Process* – the methods by which tasks are achieved; *Technologies* – the tools used to create, manage and maintain said information; and *Channels* – the ways that information are shared between stakeholder groups. The PPTC dimensions will be explored and further discussed later in this document.

1.4 CONTRIBUTIONS & DELIVERABLES

This thesis is submitted in partial fulfilment of the requirements of the University of Reading for the degree of Doctor of Engineering (EngD). The approach of this EngD research is expected to develop an academically rigorous approach to address a real-world problem; with the intention for the research to benefit both academia and industry stakeholders alike. For that reason, any output should contribute to theoretical knowledge, but also to the practical application of academic theories, within real world situations.

1.4.1 THEORETICAL CONTRIBUTION

The research attempts to contribute to knowledge by evaluating how asset managers interact with information and better understanding: their patterns of use, the potential existing waste patterns; methods of preparation and storage; and suitability of information with regards to completing operational activities.

Analysing data from several HEIs allows for greater understanding of the social need for information; more specifically breaking down the theory into four dimensions of classification: people; process; technology and channels. Each classification challenges the social perspectives of specific stakeholder with regards to their specific information needs; identifying the variance across roles and across university types. The theoretical deliverables of this research aim to provide a cross comparison of the demands for successful whole-life, asset information management, and guidance for how these demands may be transferred into business goals.

The research also presents a collated project lifecycle, combining each of the demands of the construction consultancies' work streams into a single lifecycle, leading towards the holistic delivery of projects. The construction lifecycle is broken down into seven stages, from initial definition of the project's need, through planning, design, construction, handover and into use, with the final stage critical for when a change in need or function occurs. Even though the revised lifecycle follows the work stream structure of Faithful+Gould, the intention is for it to be adoptable by all other multi-disciplinary consultancies working in the construction sector.

1.4.2 COMMERCIAL CONTRIBUTION

A major contribution of this research is to provide a guided method to capture client/users' information needs within the HE sector, presenting them so that members of the AEC industry – more specifically those working within construction consultancies – may better prepare for the whole-life management of asset information. The HE sector offers an opportunity to cross-compare portfolio cases (i.e. campus versus city) in a way that will be applicable to other sectors.

The research develops a standardised approach to delivering an asset management strategy, so that members of the Design and Construction team can fully understand the ongoing requirements for asset information management. The research's commercial contribution refers also to the technical structuring of as-built models in preparation for strategic asset management solutions. By fully understanding the users' information needs – both technically and socially – a whole-life approach to information management may be successfully achieved.

We intend to present a PPTC lifecycle framework, providing guidance at each stage of construction consultancy project lifecycle as to the key considerations for people, process, technology and channels; aiding the development of a project with a soft-landing.

1.5 READER'S GUIDE

The structure of the thesis is briefly explained in this section, with Figure 1.1 offering a visual illustration of the key stages. As Grounded Theory has been adopted as the research methodology, the thesis has been divided into eight distinct parts, following an iterative approach to the collection and analysis of qualitative data: Introduction; Research Foundation; Research Methodologies; Exploratory Study; Analysis Phase 1 – Objective Analysis; Analysis Phase 2 – People: Process: Technologies: Channels Analysis; PPTC Framework Development; and Discussion and Conclusions.

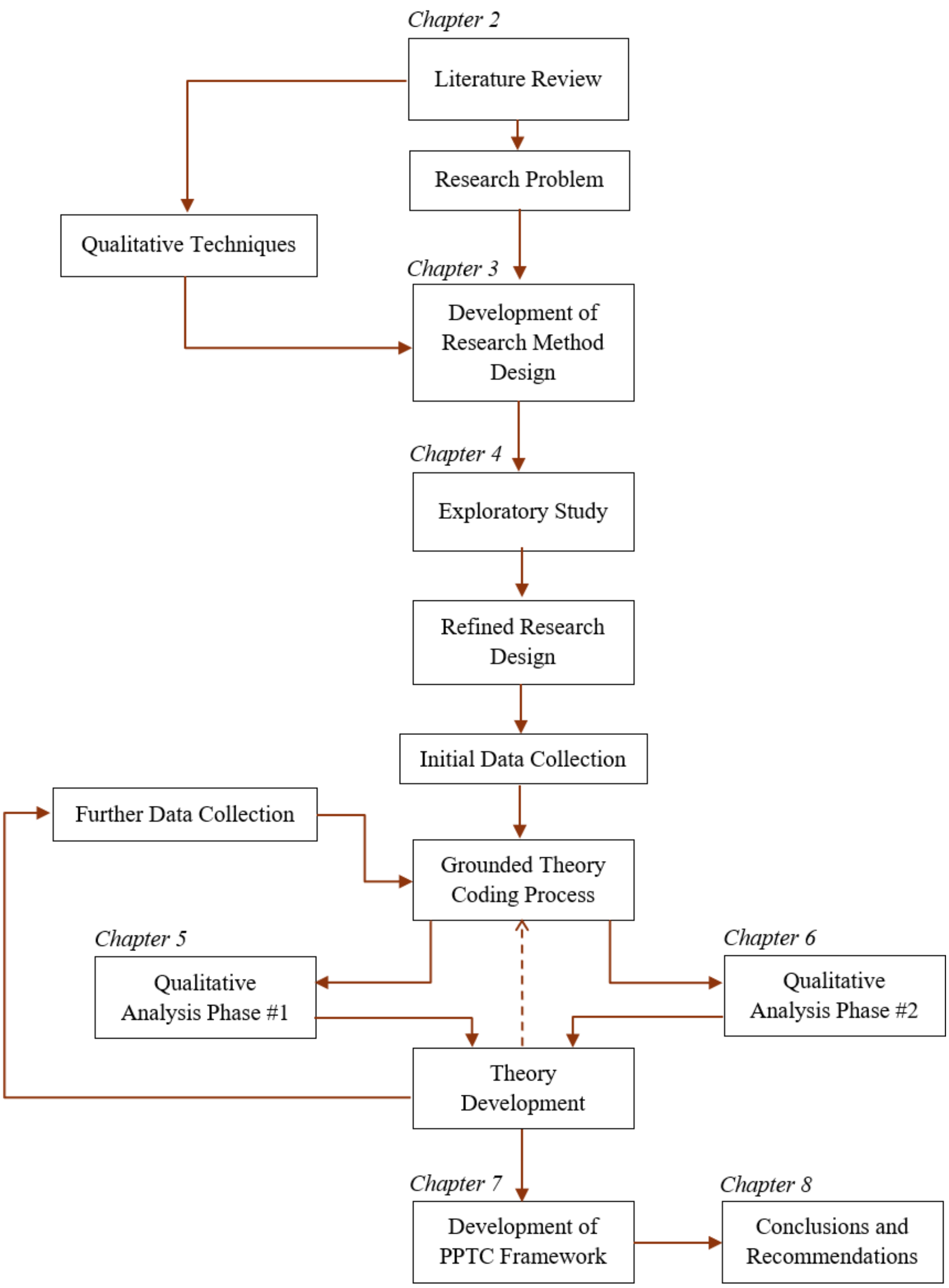

Figure 1.1 - Thesis Structure and Development

Chapter 1 presents the research in terms of the initiating motivations, the domain in which the research sits, and the overriding research problem. The research context is introduced in terms of the social and economic influences, the aim and objectives are defined, finally proposing the theoretical and commercial contributions of the research, and a detailed thesis structure for the benefit of the reader.

Chapter 2 provides a critical foundation for the project, reviewing both academic and commercially relevant literature to illustrate the wider context of information management within the construction sector. Current perspectives and theories will be considered in order to develop a grounded understanding of the existing systems of thinking, and lead to the proposal of a focused research problem supported by three clear objectives.

Chapter 3 explores the development of the specific method by which research data may be collected going forward. Research philosophies, approaches and strategies are examined, comparing the characteristics of each to the requirements of each objective. The research design is then proposed, offering guidance to how the data can be collected and consequently used to create meaningful theories. Grounded Theory is presented in terms of both the associated positives and negatives of the theory, and how these may be combatted within an iterative approach to support investigative research.

Chapter 4 offers an opportunity to test the chosen method of investigation. Exploring the domain with regards to a single case study project, qualitative data is collected and analysed with the overriding aim at refining the specific method of collection and analysis so that a comprehensive understanding of each of the three objectives can be reached. The chapter will introduce the refined method, clarifying the sample, population size and constraints surrounding the actual collection and analysis of the qualitative data.

Chapter 5 presents the first stage of the analysis process; applying a lens of observation taken directly from each of the three objective questions. The data is compared vertically across roles, as well as horizontally across case studies, to identify patterns of discussion, relevant for the development of a theory-driven framework.

Chapter 6 develops on the findings from chapter 5, taking a different focal lens to analyse the data against the topics of People, Process, Technologies and Channels. The comparison also considers the vertical and horizontal analysis of roles and cases, further identifying patterns of discussion, relevant for the development of a theory-driven framework. The chapter also presents a validation process, which utilises data collected from a further group of subjects, as well as a refined lifecycle that incorporates the findings from each analysis phase and explaining the need for the 'handover' stage.

Chapter 7 will use the findings from chapters 5 and 6 to propose a framework for using and developing asset information; a commercial output that highlights whole-life information needs, applicable for all construction projects and wider programmes. The chapter verifies the framework through a final consultation with construction professionals.

Finally, chapter 8 discusses the conclusions for the thesis and summarises the main theoretical and practical contributions to the literature. An overview of the thesis in terms of each chapter's contribution is briefly explained, as well as the research project's industrial relevance, limitations and further research opportunities.

CHAPTER 2 RESEARCH FOUNDATION

2.1 INTRODUCTION

Advancements in technology offer improvements to everyday life in both the speed by which simple tasks are done, and the ways in which we communicate with others. The advanced efficiencies led by computerisation have revolutionised industries across the globe, such as the construction industry, where embedded practices now revolve around the use of computers (Parn et al., 2017). The drive to make built assets 'smart', using the most up-to-date technologies, can be recognised throughout the complete asset lifecycle – i.e. from the earliest stages of design, through the construction process and into operation – where the internet of things is predicted to allow greater awareness of assets and the people living and working within them (Bew, 2015). Yet, with the ever-increasing reliance on technology, the question of information use becomes more prevalent. With the prediction that 85% of existing assets will still be operating in the year 2050 (CIOB, 2011), the process of creating and using information to allow for smarter decisions needs to be further investigated and refined. This will be especially critical for those communities who own and operate large portfolios of built assets – for example the HE sector.

This chapter will explore how the AEC industry currently utilises information for the development of assets, as well as the processes adopted by the AM industry, which allow for the ongoing maintenance of built assets. It offers a critical review of the existing understanding of whole-life information, presenting the argument to further investigate the social need of information management as a route to bettering the ongoing process of maintaining built assets.

2.2 ASSET INFORMATION LIFECYCLE

The Oxford English dictionary defines a 'lifecycle' as being the "series of changes in the life of an organism, including reproduction" ("life cycle | Definition of life cycle in English by Oxford Dictionaries," n.d.), where all 'living' things develop from a single thing – cell, idea, problem-case – into one that can go through adaptation and change. Applying this notion to the construction industry: all built assets have a point of conception, a passage of development, followed by a period of existence, before then being subjected to a series of changes. These changes in the case of a built asset could be simple modifications such as a new paint job, or more complex refurbishments that involve the addition or reduction of key structural members. All changes demand the formation of a bespoke team, comprised of a designer, a construction professional and specialist consultants, as required by the complexity and demands of the project. Each discipline has its own innate methods for completing work, adhering to a set of principles governed by both the practice they represent, and the specialist accreditive body they belong to. There is often the case, therefore, that multiple viewpoints are attempting to work succinctly, within a single environment, bringing together conflicting ideals and viewpoints. With respect to the progression and creation of information, this adds another level of complexity, where different governing lifecycles demand differing stage requirements.

If a complete lifecycle approach is to be taken, the disparate entities that make up the AEC and AM project teams need to be more joined up, more cohesive, aiming at achieving a 'total asset information management' approach.

2.2.1 PROJECT LIFECYCLES

Cost is the metric most often used in critiquing project success; with the UK construction sector frequently criticised for its inability to complete projects within budget (Egan, 1998, 2002; Latham, 1994). It has been stated that the majority of lifecycle costs – the total cost of both the capital expenditure phase (CAPEX), and the operational expenditure phase (OPEX) – are accumulated during OPEX, where 85% of lifecycle costs occur after the asset's construction has been completed and it handed over to its occupants (Arayici et al., 2012). However, it is not clear where within the operational phase these costs occur; nor is there any clear definition of approach to reducing these costs. Questions remain over whether better methods of managing information need to be established, in order to reduce lifecycle costs and meet the target.

The publication of the UK Government's Construction 2025 report iterated the need to reduce whole life costs, defining a need to meet a 33% reduction target by 2025 (Construction Leadership Council, 2013). Approaching a reduction benchmark as that targeted would indeed drive the industry to meet greater project delivery efficiencies and become more aware of the allocation of resources, yet further guidance over the specifics is needed. When approaching a construction project there are a number of routes a team could take, not only in terms of the type of contract – novated, design and build for example – but also the standard lifecycle approach adopted. Table 2.1 comprises a systematic comparison of each of the six core standards utilised by the AEC industry, itemising the stages in terms of the core functions dictated by each approach. A simplified process lifecycle has been created for ease of comparing the intended timeliness of each function, i.e. the first stage being planning, through design, construction, commissioning, into operation and then eventually onto the point of demolition.

The RIBA Plan of Work has been adopted by architects for many years, breaking down project progression into eight stages. The priority is very much on the process of design, with the first five stages demanding activities to develop a solid solution for the client (Sinclair, 2013). There is little to no clarification, however, for the functions during operation. So, too, is the case for OGC Gateway Review, BS ISO 22263 or for ACE Work Stage, where priority is given to the early justification of the client's need and little to the practicality of the asset once completed (ACE, 2009; British Standards Institution, 2008; Office of Government Commerce, 2007). In contrast, the BSRIA standard does attempt to incorporate guidance for functions during the operational phase, citing 'post-occupancy evaluation' tasks as a method of tracking and maintaining the condition of the built asset, throughout the initial stages of its operational life (BSRIA, 2009).

Building on this, BS ISO 15686 presents a whole life approach to the management of assets, including provision for the complete end-to-end life of the asset such as: initial feasibility tasks; commissioning post completion of construction; through to the potential need for refurbishment, change of use or demolition. Although this protocol is the most complete in terms of its guidance offering for both AEC professionals, and those in AM roles, it is infrequently used, with the RIBA process being chosen as the preferred process. In terms of reducing total lifecycle costs, BS ISO 15686 presents clear areas for improving efficiencies, influencing the decision making throughout the different phases of an asset's lifecycle (British Standards Institution, 2010).

With respect to utilising a pattern of flow that enhances the creation of information and allows for a positive stakeholder interaction – one that is essential for the successful implementation of design (Olander and Landin, 2005) – there seems to be a lack in an offering that provides holistic structure and guidance.

OGC Gateway Review Stages (2007)							
Review 0. Strat. Assess. Review 1. Bus. Justification	Review 2. Delivery Strategy	Review 3. Investment Decision	Review 4. Readiness for Service	Review 5. Operations Review and Benefits Realisation			
BS ISO 22263:2008 Organisation of information about construction works –Framework for management of project information							
Inception Brief	Design	Production		---			Demolition
BSRIA Building Services Job Book – Stages of work for the construction project process (2009)							
Stage 1. Preparation	Stage 2. Design	Stage 3. Pre-Construction Stage 4. Construction	Stage 5. Com. of Eng. Works Stage 6. Pre-Handover	Stage 7. Initial Operation	Stage 8. Post Occupancy Aftercare		
ACE Work Stage (2009)							
Appraisal Strategic Briefing	Outline, Detailed and Final Proposals	Mobilisation Construction	Completion				
BS ISO 15686-10:2010 Buildings and constructed assets – Service Life Planning. *Part 10: When to assess functional performance*							
0. Portfolio Strategy, requirements, initiation. 1. Conception of need 2. Feasibility 3. Authorisation	4. Initial concept design 5. Preliminary design 6.1 Detailed design 6.2 Construction procurement 7. Production Information	8.1 Construction	8.2 Commissioning	9.1 Asset Operations	9.2 Maintenance and condition management 9.3 Occupants' facility administration.	9.4 Refurb., adaptation, alteration, change of use 9.5 Change of function 10.1 Disposal preparation 10.2 Transfer 10.3 Reinstatement	10.4 Decommissioning 10.5 Deconstruction 10.6 Recycling 10.7 Demolition
RIBA Plan of Work 2013							
0. Strategic Definition 1. Preparation & Brief	2. Concept Design 3. Developed Design 4. Technical Design	5. Construction	6. Handover & Close-out	7. In-Use			
Stage 1. PLAN	**Stage 2. DESIGN**	**Stage 3. CONSTRUCT**	**Stage 4. COMMISSION**	**Stage 5. OPERATE**	**Stage 6. MAINTAIN**	**STAGE X.**	**Stage 7. DISPOSE**
						MISSING FUNCTIONALITY...??? **MONITOR; CONDITION; REFURBISH; ADD; MODIFY; REPLACE; RECYCLE.**	
INFORMATION REQUIREMENT?							
- Project Scope - Objectives & Brief - Risks - Operational Standards - Demands - Soft Landings	- Design Massing - Design Constructability - Project Strategies - Design Programme - Cost Allocation & Quantification	- Construction Sequencing - Resource Allocation - Design Queries - On-site amendments - Information Validation	- Testing and Certification - Asset Registry - Verified 'As-built' conditions - Soft Landings Initiation	- Operational Strategy - Operational Environment. - Peak Load Demands - Functional Life Targets - POE Testing	- Bus. Focused Maint. Regime - Annual Maintenance Programme (Planned, Reactive & Proactive) - Task Requirements - Resource Allocation *Measure>Report>Address*	- Terms of Compliance – Stat.>Man.>Fun. Cr.>Dis. - KPI's - Resource Requirements - Hist. Da. St.> Hist. Da. Min. - Cost-Benefits Analysis - Emergency Protocol.	- Decommissioning - Process of Demolition - Recyclability - Cost Significance - Carbon Tax? - Cannibalisation? - Sus. Route for Change...
BIM DELIVERABLE? *(as per UK Standards)*							
- EIR. - BIM Execution Plan - MIDP (Master) - TIDP (Task)	- Responsibility Matrix - CDE. - Information Exchange - Project Library Development	- As-Built BIM - Project Information Model (PIM)	- Asset Information Model (AIM) - Digital Operation and Maintenance Manual	- Asset Registry Database - Asset Tagging - Internal Function i.e. Room Booking System	- Relational/Non-Relational Database - Data Management Protocol. - Task Record Functionality?	- Asset Registry Database - Condition Surveys - Historical Archiving - Benchmarking Data	- 'As-built' BIM -Service Life Database...

Table 2.1 AEC Project Lifecycle Comparison

2.2.2 END-TO-END THINKING

In the context of management of information, the stage-by-stage information requirement remains relatively consistent across each of the six standards; building the volume of information from the briefing documents, into strategy for the construction and operation once handed over. Yet there are conflicts in terms of the perspective from which the information is created, with the RIBA process being from the designer's perspective, whilst the BSRIA process taking the perspective of the building services engineer. The conflicting ideas of each role influences how the information is created and therefore handed over. What is distinctly missing from this area of knowledge is how the process allows for the creation of operational-focused information that may lead to increased operational efficiencies. 'Stage X' illustrates this missing need by further questioning what information would be needed to establish whether the asset should be refurbished, continually maintained or changed completed, and when. Explicitly, there is a lack of clarity in how the standardised lifecycle process may be used to ensure AMs have access to the critical pieces of information that will allow them to make smarter decisions relating to operational use, at the right time. This will be further discussed in chapter 4.

2.2.3 NEW-BUILD VS. EXISTING

Considering asset functionality changes draws in the argument of 'most appropriate starting point' for projects. When comparing the flow of information for a new build project and that of an existing asset's refurbishment, there are distinct differences. Figure 2.1 illustrates the comparative flow, when considering the existence of an asset model (or BIM). Where there is access to a working model, the first instance for a retrofit project is to ensure that the data is valid and accurate, an often extensive task that is sufficient reason to dissuade teams for adopting IM strategies (Volk et al., 2014). Digital scanning technologies (such as LiDAR) provide means to enhance this process of creation, improving productivity and assurances (Jung et al., 2014). Yet, even then the asset management teams are unequipped to manage large data files of indeterminable data. However, McArthur argues that although modelling and subsequent management of existing asset information is overtly complex, there is potential for breaking down the process into constructive parts, to then create a rudimentary model of information (McArthur, 2015).

With respect to fully quantifying new build versus existing in terms of the whole-lifecycle capability of managing the information, the question of definition still remains: how does the starting point affect the method by which information is created, and the subsequent manipulation throughout the complete asset lifecycle?

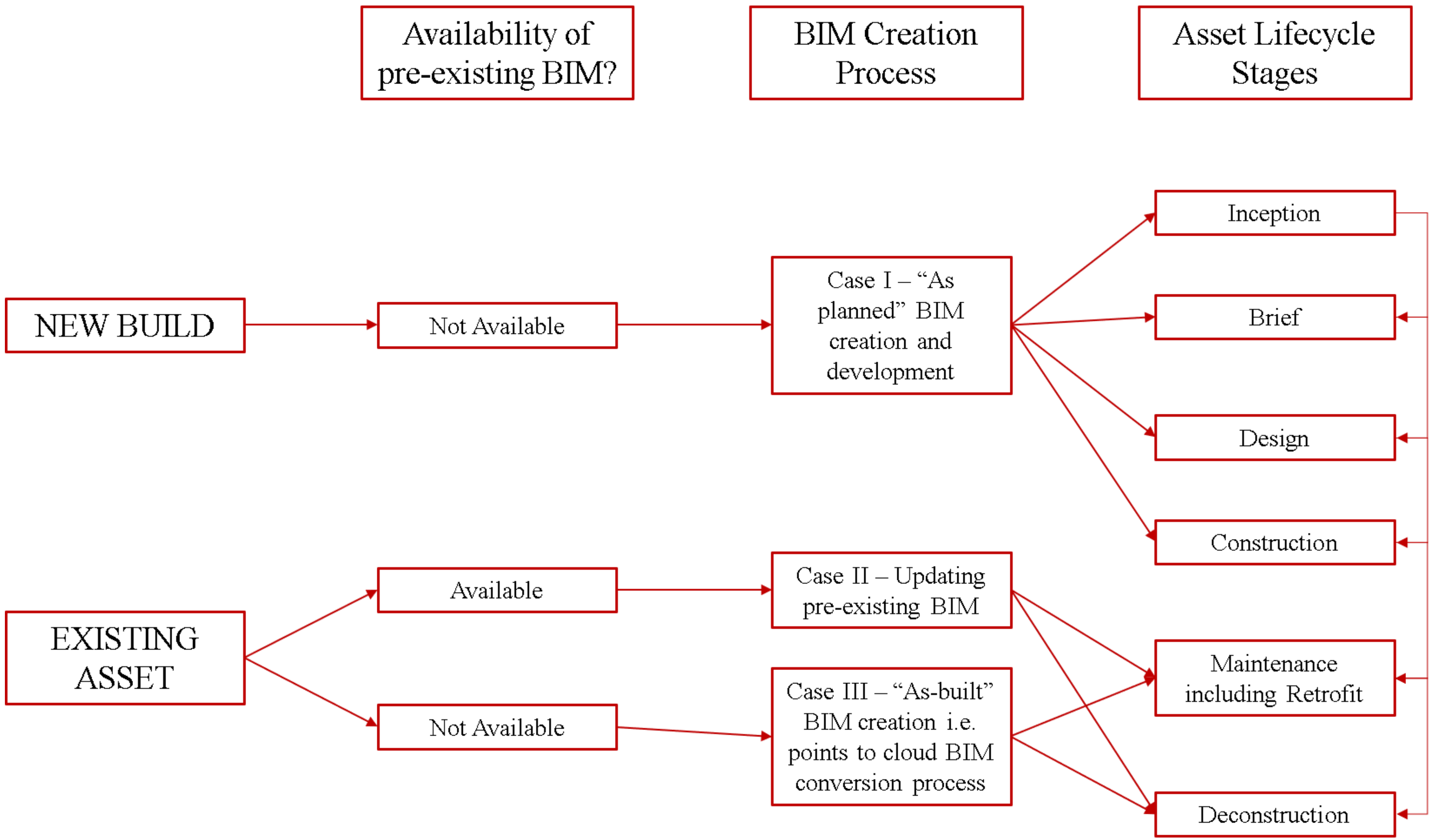

Figure 2.1 New Build vs Existing Works BIM Workflow Comparison

2.3 TRADITIONAL ASSET MANAGEMENT

The role of the AM must first be understood when considering the operational life of an asset. It is the priority of the owner and operator to establish the business goals that can then be aligned to the set of processes by which the asset is then managed and maintained. The IFMA defines the role as a one that "encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process and technology" (International Facility Management Association, 2017). No matter the size, scale or typology of the asset, the AM's responsibility can be classified into three core function areas, as illustrated in figure 2.2. The first – Maintenance and Operational Management – incorporates the monitoring and tracking of performance efficiencies, the alteration and repair of identified issues, and the management of spaces, e.g. planning the use of specific rooms as per the occupancy demands. The second classification – Property Management – responds to the business need of the owner, where sites are selected and allocated, and buildings are assessed for the continual or changing need of the business. The final classification incorporates the services required for ongoing operation, such as security and emergency service planning.

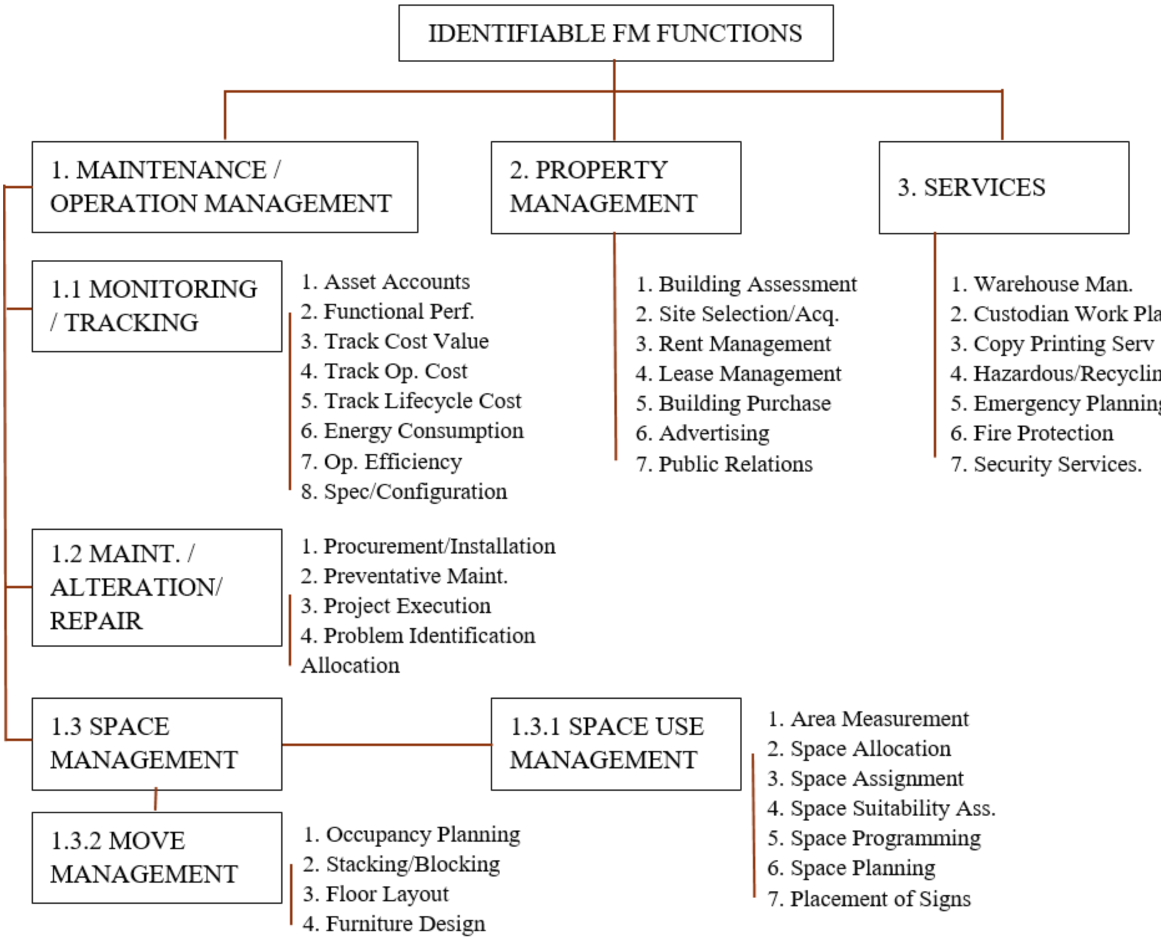

Figure 2.2 Identifiable Facilities Management Functions (International Facility Management Association, 2017)

Both Alexander (1999) and Tay and Ooi (2001) consider that the FM sector typically deals with business support services such as the management of space and the workplace. AM offers a wide range of services; but these services are linked with core facilities management functions due to their purpose of meeting organizational needs (Sillanpää and Junnonen, 2012).

2.3.1 ROLES AND RESPONSIBILITIES

The most commonly referred to responsibilities of the AM are the physical repair and upkeep of the walls, floors, ceilings and plant material (mechanical and electrical equipment) – or the 'hard' maintenance tasks – without which the asset would soon fall into disrepair and become uninhabitable (Puckett, K.; 2015). However, the importance of the softer side of asset management needs to be emphasised; for the continued success of a business, human activities need to be protected and a basic level of health and safety adhered to (Checkland, 1980). The IFMA's classification does to an extent proffer the dual importance of both 'hard AM' and 'soft AM', yet when it comes to understanding the information requirements for each of the itemised functions, further detail is needed.

There are numerous pieces of research attempting to quantify operational information with regards to their relative computational structure. However, most attempt to understand the technical constructs of the information and disregard the human-factor. Chen et al's study explored the functionality of Asset Management in the simplest of terms, attempting to group together the information in response to a human responsibility(Chen et al., 2013). Table 2.2 illustrates the seven information types concluded by the research, with an example of said type used for everyday operational management. These 'types' can be found in most CAFM systems and linked through a relational database for quick and continual access.

Information Type	***Example***
Basic Information of Facility	*Facility name, building, designer, power consumption, region, and facility category.*
Engineering Drawing of Facility	*Elevations, sectional, plan view, perspective, construction and electromechanical equipment drawings.*
Documents	*Agreements, design contract agreements, construction supervision agreements, regulations, notices, financial record charts,*

Information Type	*Example*
	construction and installation manuals, pricing reports.
Inspection Record	*Equipment records, operating state, daily workload, time cycle.*
Facility Real-Time Monitoring Information	*Temperature, humidity, stress, strain, displacement, elevator position, fire alarm, energy consumption.*
Analytical Results	*Equipment reliability, optimum maintenance schedule, system failure graph.*
Maintenance Records	*Maintenance and accident records, failure mode, frequency and standard requirement.*

Table 2.2 Asset Management Information Types (Chen et al., 2013)

Similarly, research conducted by Bercerik-Gerber et al (2012), attempts to break down operation and maintenance information into a geometric structure (figure 2.3), which simplifies the technical structure into meaningful parts. The pyramid illustrates the classification on the basis of the sequence in which the data should be captured in the cycle of maintenance, with the volume of data increasing significantly from the top of the pyramid to the bottom. The requirements for the data – especially those found in the lower pyramid levels – are said to be 'operator-defined', where the internal business needs are used to set specific parameters for each.

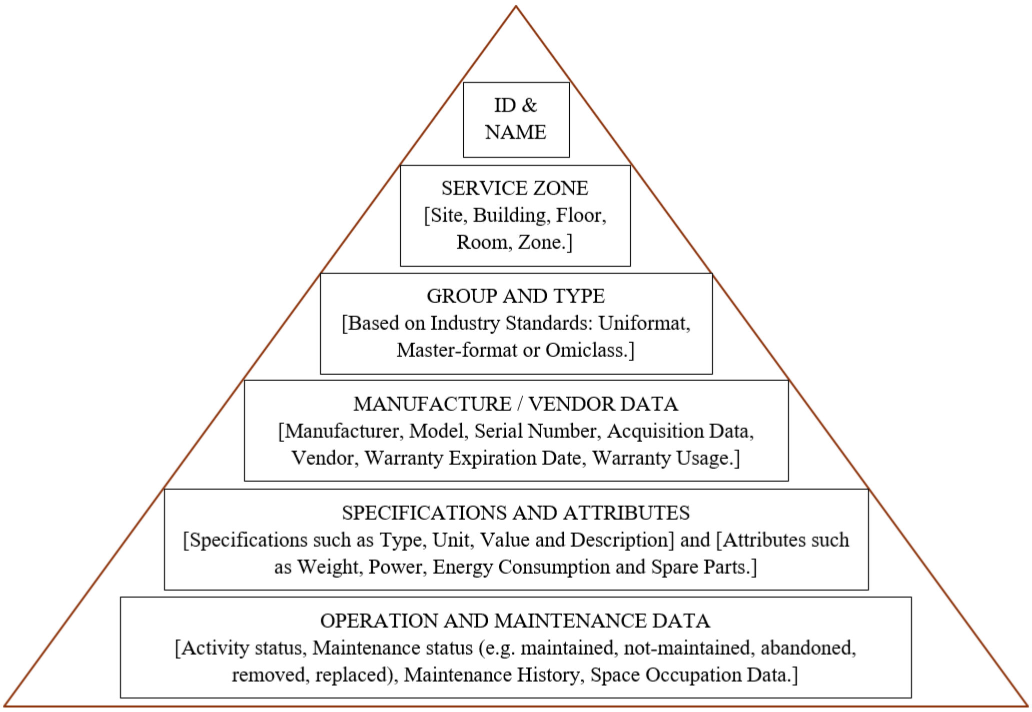

Figure 2.3 Geometric Structure of Non-Geometric Data Req's (Becerik-Gerber et al., 2012)

Even though the research attempts to itemise asset management in terms of information need, both studies unfortunately place too great an emphasis on the use of technology in order to create and access this information, and less on the quality of the information or how it is actually used in the day-to-day functionality of an AM's role. An appreciation of both would lead to better decision-making throughout the complete operational life of an asset.

2.3.2 KNOWLEDGE CAPTURE

Decisions for building maintenance require the integration of various types of information as well as the inherent experiential knowledge; each contribute to asset lifecycles by various members of a project team, information and knowledge such as: maintenance records, work orders, causes and knock-on effects of failures. Failing to capture and use this informational knowledge results in significant costs due to ineffective decisions (Motawa and Almarshad, 2013). Computer aided facilities management (CAFM) systems offer the potential for consolidating this experiential knowledge within a single source location. An added benefit when considering the decision-making process and sense-making with relation to exploring existing asset's ongoing functionality.

Attempts need to be made to alter the perception of knowledge creation and capture across an asset's complete lifecycle, moving from disparate sources of knowledge, towards a 'single source of truth'. Understanding knowledge in terms of how it may be categorised, with relation to its internal content (i.e. the subject matter and/or asset to which the knowledge refers), as well as the contextual environment that it is bound by, will aid the process by which it can collectively be stored and used as a form of influence or guidance. Tacit knowledge – or the knowledge that cannot easily be communicated from one person to another in the medium of text – offers a further complexity. Considering that most knowledge held by asset managers can be said to be experiential, or tacit knowledge, where the 'knowledge-base' has been in development for an extended period of time and would therefore consist of many layers, there such needs to be a rigorous method of converting said knowledge into workable pieces of information. The 'stickiness' of certain types of knowledge depends on the depth at which they are stored by the individual, and often has a direct effect on the individual's ability to adapt, change or innovate (Walker, D; et al, 2007). Problems associated with organisations achieving 'replicable transfer' of experiential practices from one context to another and such encouraging innovation, can be combatted through codification. Again, process is key to successful transfer of useful – non-sticky – knowledge.

Strategic knowledge management (SKM) can be considered as the conceptual process by which aspects of knowledge, both tacit and explicit, is codified. i.e. the capturing of valuable knowledge in documents and/or systems therefore fostering a ‘people-to-documents link’ (Venkitachalam & Willmott, 2017). It is too often the case that organisations are overloaded with information yet are lacking in truly useful, codified knowledge, and even less so in easily accessible repositories. Social media networks can facilitate the continual updating of tacit knowledge into structured formats, yet these networks also lend themselves to overwhelming numbers of perceived ‘useful’ insights. There therefore needs to be further quantification of what can be determined as ‘useful’ so that a balance may be achieved between structuration and the proliferation of knowledge.

When considering the construction industry and the project environment context, there lies further complication with collation and transfer of codified experiential knowledge. In order to innovate, organisations must be willing to share elements of their internal knowledge-base with external partners. An ability to search and find useful knowledge has been characterised by Schumpeter as the need to carry out “new combinations of technologies, knowledge and markets…to produce other things, or the same things by a different method, means to combine these materials and forces differently” (Laursen & Salter, 2014). The concept of openness both internally within an organisation’s departments, and externally with collaborative partners can be worked towards by applying an ‘appropriability strategy’, i.e. a series of mechanisms that have attributed levels of importance and can be used to evaluate certain situations. However, efforts must be made not to overload the complicated nature of sharing knowledge, or individuals will be discouraged from handing over and exchanging said knowledge – a consideration that is infrequently accounted for within the handover process of a built asset.

While emerging handover standards such as COBie and ‘FM Handover MVD’ discussed by Love et al, provide a structure for how information should be gathered over the project lifecycle, they do not support the asset owner with what to populate this structure with in order to leverage benefits (Love et al., 2014). The impact of understanding how knowledge can be translated across the various boundaries of whole-lifecycle practices so that they may influence the decision-making process without inhibiting collaborative activity is enormous. Work needs to be done to overcome the hurdle of incorporating situated, embedded knowledge, into the forefront of project conception and development, enhancing the ability of asset managers to highlight working patterns and inform AEC of their inherent requirements.

2.4 'SMART' MANAGEMENT

The term 'smart' is defined as being quick and 'having intelligence'. Yet when used to describe the management of something – in the case of this research the management of an asset – the words 'specific, measurable, attainable, relevant and time-bound' are used, attempting to capture an ideal of better awareness, insightful actions and meaningful conclusions (Forbes, 2016). Further to the previously discussed concept of standardised process development, the following sections will explore the flow of information so that it may be used by multiple stakeholder parties.

As a means of developing the connectivity across projects and within the sector as a whole, the UK Government's industrial strategy for 2025 highlights the importance of three dimensions: *people* – those persons working individually or part of a larger organisation, within a complex project environment; *process* – existing and future practices that facilitate the successful briefing, design, construction and operation of a built asset; and *technology* – or those tools that the people of the industry use in order to complete certain tasks in specific manners that lead to the completion of a construction project. The vision of an industry that utilises world-class research, driving efficient practices, to enhance the digital landscape to one of smart construction (UK Government, 2013).

The use of these three dimensions can be historically linked with several studies, from all known sectors, including that of construction. Yet it is Orlikowski's model of technology that holds great influence here. Developed in 1991 out of Massachusetts Institute of Technology, the model underlines the importance of analysing three distinguished components – historically referred to as people, organisation, and technology, or POT. The model goes a stage further by addressing the influences of these components on their reciprocal interactions, numerating four distinct influences as follows: 1) technology as a creation of human action; 2) technology as an instrument of human action; 3) organisational conditions of interaction with technology; and 4) institutional consequences of interaction with technology (Belfo, 2012). Central to the requirements analysis is the inherent priorities given to each of the three dimensions. Orlikowski criticises early research that assumes technology as being an objective, external force, that impacts an organisation's structure, as well as the later views that technology is an outcome of human choice and social action, commenting that only through the structuration of a set of requirements may the interaction between technology, an organisation and the people using it may truly be understood. The triad of people, process (originally organisation in Orlikowski's model) and technology has long been the cause of difficulties within organisations, with the struggle remaining as a constant throughout generations of technological advancements – from paper, through document management and now into digital environments. Solutions have proven difficult to quantify in terms of the exact requirements to meet all needs, with organisations often mandating multiple platforms to contend with the conflicting needs of practice. The challenge remains for industries such as the construction sector, in conceptually understanding how each stakeholder's PPT requirements may be used as a route to furthering collaboration across the disparate silo groups.

Building Information Modelling has been professed by many, as the means of advancing collaboration in the construction industry, where a 'BIM' is the digital representation of an asset and its components 'in a virtual assembly of interconnected database objects and metadata in a coordinated, scaled 3-dimensional model (Davis and Harty, 2013). The domain of construction research and the use of information in construction is saturated with research into the adoption, application and future perspective of BIM, with most reflecting on an anticipated shift towards an information-centric approach to design, construction and operation that includes both 'process automation' and improvement. This ideal that BIM will provide the solution to all existing issues across the full lifecycle is misguided. Capturing an asset's 'intricate and ever-expanding portfolio of data requirements' within a single-model environment is a complicated process that draws heavily on the success of a number of factors. These will now be explored in an attempt to determine the precise gap in knowledge, needing further investigation.

2.4.1 AEC VS. AM

The nature of construction is complex. The creation of bespoke projects demands the coming together of many actors across multiple disciplines such as that of specialised consultancy firms, subcontractors, suppliers and designers, where each discipline is focused on embedded practices and domain knowledge. Bryson and Yetmen have commented on said complex environment, identifying that the lack of interdisciplinary exposure results in the creation of 'divergent vocabularies' responding to an independent culture of information creation (Bryson and Yetmen, 2010). Such a fragmented process has led to the rise of misinformation, miscoordination and misalignment of the innate project goals, whilst the opportunities to innovate and advance collaborative processes are lost (Whyte et al., 2013).

Pertinent to this project is understanding the conflicts that may arise when bringing together the actors from both the AEC and AM industries, especially when considering the interplay of information from capital development into operation. As one of the main purposes of a construction project is to interpret the requirements of the client, executing a set of actions to satisfy these needs and wishes, it makes sense to point focus on the stage of handover. The BSRIA soft landings framework was introduced as a means to break down the silo mentality of the AEC, and establish a culture of learning, both initially between parties – taking into account their perspective for project and information development – as well during the early stages of operation, capturing live data from the asset in order to assess whether it is meeting the expectations (Way et al., 2009). An ethos of 'starting with the end in mind' is introduced, bringing together project teams with the client and asset managers, to streamline the construction process. A 'soft-landing' is supposedly achieved when the asset can be operated, without issue, by the in-house asset management team, from the first day of occupation. The framework presents the argument of putting the client and AM at the very centre of the project team and hence integral to the development of said project. However, since it was first introduced in 2009, the framework has struggled to make traction in the UK construction industry, with minimal documentation as to the reasons why. As a key player in the discipline of construction, AMs should be offered the opportunity to influence the decision-making process, integrating knowledge and acting as an advisor for the creation of long-lasting functional assets. Further understanding of the connection between AEC professionals and AM in terms of the exchange of information at the point of asset handover, is therefore required.

The works within the Sydney Opera House were influenced predominantly by the need to drive whole-lifecycle efficiencies, improving practices through information modelling strategies. The vision of implementing systems that allowed for the visualisation and constant comparison of multiple data-sets, lead the project team to explore an internally developed web-based service (Mitchell et al., 2005). One of the main barriers, however, was the lacking competence of all stakeholders, not only in the AM team but also within the AEC specialisms; the newly devised working methodologies were therefore restrictive. Even with the creation of numerous documents and guidance notes, transitioning from the old process to the new was long-winded and ineffective. Whilst there was still a conflict between the individual stakeholder groups, no clear understanding was gained as to why the AM operatives aren't fully committed to the 'new'.

2.4.2 A GOVERNMENT EXECUTION PLAN

There is a recognition that the move to a fully collaborative industry will be both progressive and longwinded. In an attempt to simplify the processes of transition, guidance is presented in the form of the BIM levels, where the first level (Level 0) refers to the state of complete independence, with each discipline working in their silo, utilising 2-dimension drafting skills as a means of presenting ideas. Levels 1 and 2 introduce 3-dimensional displays of information, where CAD standards such as BS 1192:2007 itemise the electronic sharing of data between parties, allowing for the use of interoperable formats to enable collaborative working. The final defined level (Level 3), represents the 'holy grail' of collaborative working, where a single-source model is developed and coordinated from each discipline's relevant information, giving access to all parties and mitigating the risks inherent with single-discipline model working (NBS, 2016). Understanding the practical implications of these levels is then supported by the numerous published documents – *PAS 1192-2:2013 Specification for information management for the capital/delivery phase of construction projects using building information modelling* and *PAS 1192-3:2014 Specification for information management for the operational phase of assets using building information modelling* – offering a cyclical process for developing asset information at both the concept stage of a new build or the clarification of a retrofit and/or refurbishment project. Although these documents make headway in terms of providing consistent guidance for when certain tasks should be completed, there is a distinct lack of specifically how one may achieve full collaborative adoption of BIM.

In 2008 a research team at Penn State University devised a reverse-perspective approach to project development, by first pushing the project team – including the AM and/or owner – to understand their required uses for information modelling. Beginning with the end, the team allocates the priority for each use, moving from operation, through construction, to design and finally planning (Messner, 2011). This execution plan was then backed up by a secondary piece of research from the same team, which provided guidance for the intended owner-operator team of an asset. The principal function was to offer a clear protocol that aided those with limited experience of BIM processes to quantify their requirements and formulate a strategy that fully incorporated their organisational goals (Messner, 2013). Both documents successfully introduce the concepts of coordinated information delivery and project collaboration, as a means of aiding those with limited understanding of AEC processes, yet they lack in providing clarity for how the information may be managed beyond handover – development towards the point of practical completion but no further. There is still a disconnect between the priorities of AEC and AM, whilst a holistic approach to an asset's life is quite clearly missing from current executive planning.

2.4.3 INTEROPERABILITY

Several initiatives have been developed to address the issue of a lack of suitable standard for interoperable information exchange within the construction industry. The most notable is the Industry Foundation Class (IFC) schema developed by the International Alliance for Interoperability (IAI), now buildingSMART, which serves to enable the exchange of conceptual and detailed design information between project participants. IFC was developed in collaboration with a number of institutions and software vendors; however, commercial support for and certification of the scheme as an interoperability standard is predominantly restricted to software within the architectural domain (Steel et al., 2012). Consequently, there are some limitations to the process of exchange that make it unsuitable for the ongoing utilisation throughout the asset lifecycle, i.e. it is an exchange format rather than a common format.

During the process of export, model information is converted from its native format into an IFC construct that must then be interpreted and transformed into the importing software's native format. In many cases a match is not possible and missing data in the information exchanged between tools occurs as a result of a lack of uniformity between IFC objects and the object schemas adopted by individual BIM tools (Cheung et al., 2012). Consequently, IFC is suitable when exporting for the purpose of analysis – where static geometric data is all that is needed – but unsuitable for multiple exchanges between authoring software – where the parametric modelling capability is one of the major process improvements of using BIM (Golabchi & Kamat, 2013). Additionally, localised procedures for information exchange continue to develop to meet the specific performance requirements of the project; IFC standards provide a comprehensive level of data about a component of which much becomes redundant when passed over to the client (Whyte et al., 2010). Therefore, interdisciplinary project teams must still collaborate to develop workarounds to address the limitations of technological interoperability and slow-moving process of standards development (Hardin & McCool, 2015).

Several studies look at developing methods to overcome the technological gaps in IFC to improve information retrieval and analysis of large amounts of construction data (Borrmann & Rank, 2009; Soibelman et al., 2008), yet these studies are responding to the salient user requirements at project level, and completely disregard the wider context of use across the complete asset lifecycle. Emerging handover standards such as COBie offer the opportunity to explore the delivery of asset management information in the form of a simple spreadsheet detailing the entirety of data relating to said asset. The structure allows for the static inclusion of information vital for key decisions to be made, yet the non-dynamic nature of said structure is counterintuitive for the coordination with existing CAFM systems (Love et al., 2014). The MediacityUK project is an example of where attempts were made to integrate a newly created information model, with the pre-existing CAFM system. The use of information model for maintenance operations of the MediaCityUK building are dependent very much on how the model is populated, the available information on electrical, M&E, and machinery/plant issues within the model and how this information in the model is maintained over time(Arayici et al., 2012). If this is the case, the model serves as the virtual replica of the building with important information on the maintenance histories of each component within the building. However, even in the early stages of transition, conflicts arose with regards to the alignment of the information with the associated CAFM database. Without the ease of transitioning information from COBie into CAFM, there will continue to be a disjoint between the AEC and AM industries.

2.4.4 RELIANCE ON TECHNOLOGY

In an attempt to further define the technical challenges of applying 'BIM processes' to project development, there have been multiple studies focusing on the various applications of 'technology'; when 'technology' could refer to the simple use of pen and paper, to the more advanced fully immersive virtual reality. Modelling asset information in digital form opens up a dialogue for stakeholders to interact and respond to a planned scheme in ways unlike that gained with pen on paper; a strategy that is said to offer greater whole-life value for the asset (Chapman et al., 2014).

The refurbishment of Manchester City was actively shaped by the technological advances of digital scanning, where the client's requirement to capture and evaluate the conditional survey of the building as a means of enhancing decision-making, as well as archiving (Kiviniemi and Codinhoto, 2014). Opportune in the development of skills, the project was, however, affected by substantial time delays, where works were halted due to the project team's inability to interrogate and assertively utilise the scanned data. Too great a dependence was placed on the transition from the digital modelling of existing conditions, to the proposed refurbishment works, as well as then continuing into active management and maintenance, i.e. conflicts between the physical and digital environments. Nonetheless, the overarching perception, with regards to the utilisation of visual data gathering to capture existing conditions was one of success.

Advancing this principle further, fully immersing oneself within the model environment using augmented reality lenses and cave structures, allows a simulated occupation to open one's view of potential design solutions. The use of virtual reality is becoming ever more commonplace in the construction industry, with companies such as Skanska utilising the principle to evaluate on-site safety prior to works taking place. However, through the excitement of innovative visualisation techniques, it is important that the properties of said virtual reality model support the purpose, and is not used as a costly gimmick (Westerdahl et al., 2006).

Even with the numerous commentaries on how advancing the visual element of a project's development can lead to better decision making throughout design and construction (Succar, 2013), what is unknown is whether the use of visuals across the whole lifecycle will enhance the operational phase. In other words, do asset managers and operators see 3-dimensional representations and virtual reality as being critical for the ongoing successful management and maintenance of their built assets?

2.5 KNOWLEDGE GAP

Whilst the industry is far beyond understanding information management strategies as simply 3D CAD, there is still an overreliance on technology as the solution to process problems inherent within the industry. Emphasis on the technical solutions for exchanging information has led to the replacement of tacit knowledge, required for asset design solutions to be successful. The human factor is being somewhat ignored, in terms of the way in which asset information is being created – limiting the collaborative effort of asset management within early design stages – as well as prioritising the ongoing information requirements of those operating and maintaining the assets once practically complete.

There is a definite need to explore the social interactions with information, beyond that known within the AEC industry; instead focusing on how asset managers socially respond to information. It is unknown if AMs would want to use processes such as that of BIM, or if they would make use of interoperable exchange formats and virtual reality representation. In addition, there needs to be an exploration into how knowledge can be captured, so that it may be utilised in the front-end decision-making process. The process of development remains very linear, which may be why change has been slow to come to fruition; there is a need for understanding if and how a cyclical approach to projects would enable better learning to take place, therefore advancing the practices within both the AEC and AM industries.

Advancements in technology offer improvements to everyday life in both the speed by which simple tasks are done, and the ways in which we communicate with others. The advanced efficiencies led by computerisation have revolutionised industries across the globe; such as the construction industry, where embedded practices now revolve around the use of computers (Parn et al., 2017). The drive to make built assets 'smart', using the most up-to-date technologies can be recognised throughout the complete asset lifecycle – i.e. from the earliest stages of design, through the construction process and into operation – where the internet of things is predicted to allow greater awareness of assets and the people living and working within them (Bew, 2015). Yet, with the ever-increasing reliance on technology, the question of information use becomes more prevalent. With the prediction that 85% of existing assets will still be operating in the year 2050 (CIOB, 2011), the process of creating and using information to allow for smarter decisions needs to be further investigated and refined. A potential review against the PPT dimensions may aid the understanding of patterns currently in play and may be especially critical for those communities who own and operate large portfolios of built assets – for example the HE sector.

Factors relating to the creation of information have been reviewed and critically understood in this chapter, in terms of: the current use of lifecycle standards for the linear progression of projects; the functions and tasks identified as crucial for asset management; the potential opportunities and hindrances of interoperable exchange formats; as well the relative need for incorporating knowledge and learning into the creation process. Existing understanding within the domain of asset information management focuses more on the front-end creation, and less on the actual use of the information. It has been highlighted that there is a need to explore these factors from the perspective of AMs; understanding the processes they use to conduct daily activities, the technologies that enable these activities, and the routes through which information is shared, both internally amongst the asset managers, and externally connecting with people beyond the organisation.

It is critical that the industry, addresses the problem of access to knowledge, particularly if it is to meet the future demands of smart management. The iterative process of knowledge creation and sharing – both explicit and tacit knowledge – beyond the design and construction phases is an undiscovered area, a gap in existing understanding that would prove immensely valuable to both the AEC and AM industries.

It can be concluded, therefore, that in order fully to assess the opportunities of using advanced information management strategies as a tool for the ongoing operational maintenance of built assets, the following three areas of investigation need to be explored: the wasteful approaches to information transfer, as is experienced by AMs; preparing for handover of information from design and construction, into operation; and the iterative creation of knowledge.

The following chapters will explore this gap in knowledge, by means of identifying an appropriate methodological approach, as well as suitable data collection methods and strategic analysis of said data.

CHAPTER 3 RESEARCH METHODOLOGY

3.1 INTRODUCTION

Discussions in chapter 2 highlighted a twofold need for a detailed investigation into the process of whole-life information management. First, to understand how all information relating to a built asset may be handed over to those responsible for its management throughout the course of its operational life. Secondly developing an understanding of the requirements set out by said managers, so that efficiencies can be increased, and operational costs decreased.

What follows in the remainder of this thesis is the progressive collection, analysis and dissemination of useful findings from a series of data sets. Chapter 3 explores the potential methods that may be applicable for such a research enquiry, whilst chapters 4, 5 and 6 apply said approach to collect and subsequently analyse the data. As a means of clarifying the progressive flow from one chapter into the next, section 3.6 *Research Design*, provides details as to the specific methods utilised throughout each key phase of the investigation.

This chapter acts as an introduction to the concept of a 'research methodology', identifying the potentially applicable paradigms and theoretical approaches for this research, commenting on their strengths and weaknesses with respect to answering the overriding research question. A review of the specific processes for collecting, coding, and analysing the data is offered, examining the challenges surrounding validity and generalisability of the results produced.

3.2 PROBLEM PERSPECTIVE

Considering the research field of Information Management (IM) and its application within the construction industry, there have been many focusing on the advancement of information structures (i.e. the technical structuring of interoperable file formats), methods of incorporating cost and time elements into programming techniques and the general approaches to increasing efficiencies in the design and construction phases. Chapter 2 of this thesis described the key developments in the field of IM research, and highlighted the specific gaps available for further development. Accordingly, the overriding macro lens of investigation for this research project relates to '*the operational use of as-*

built information during the ongoing management of the built assets' in-use phase'. Breaking the macro lens down further, three micro areas of investigation can be defined as follows:

3.2.1 OBJECTIVE 1

Objective 1 aims *to understand where waste occurs in the existing model of information transfer*. Focusing specifically on the 'asset manager's' perspective, the narrative will be captured, contextualising what information is needed and how that information is used on a daily basis – operating within a 'business as usual' setting. The collected data therefore needs to allow for an honest narrative to be understood, allowing for varying perspectives to be captured, potentially simultaneously. The data will be used to identify issues with the current practice – whether they relate to the governance structure mandated by the asset management team, or priorities inherent with the HEI's long-term goals – as a means of proposing process changes that will prepare for, and combat the issues within operation, i.e. instilling new patterns for creating and sharing information from the earliest stages of project/programme development through all phases of the asset's life-cycle.

3.2.2 OBJECTIVE 2

Objective 2 aims *to investigate how asset managers may benefit from better methods of transfer*. In other words, creating a picture of the successes and failures in how information is passed from the AEC stakeholders onto the asset managers, i.e. handing over from capital works into operation. Understanding those elements that contribute towards frustration, delayed work, and costly changes within the project environment, will enable a clear structure of preparing for handover to be developed. The data should therefore enable clear understanding of these trigger points, taking into account the demands specific to the individual roles, and the wider context of the assets being managed.

3.2.3 OBJECTIVE 3

Objective 3 aims *to evaluate how lessons learned can be best captured*. Understanding if there is an existing perception of using thoughts and lessons to make reasonable change within the management structure, and whether it is seen as a positive activity. A successful pattern of feedback can then be proposed. The data must therefore enable one to capture the types of lessons, and the most suitable point at which these lessons may be shared - and between who. If said data is successfully acquired, a framework can then be suggested so that wider project and programme management can continuously feedback and learn, developing towards their proposed lifetime cost reduction targets.

When considering the data demands of each of the above three objectives, and the relationship with regards to collection strategy, considerations must ensure the strategy:

- Provides a method for collating research findings into a usable framework;
- Supports and enables the modelling of a multi-dimensional, stakeholder perspective, i.e. allow for a number of differing perspectives to be compared and contrasted;
- Allow the researcher to adopt the perspective of the insider, without affecting the data outcomes, enabling a true narrative to be documented.

If these three considerations are met, the chosen design should allow for a true representation of an asset manager's information needs to be collated, and the new phenomenon to be understood.

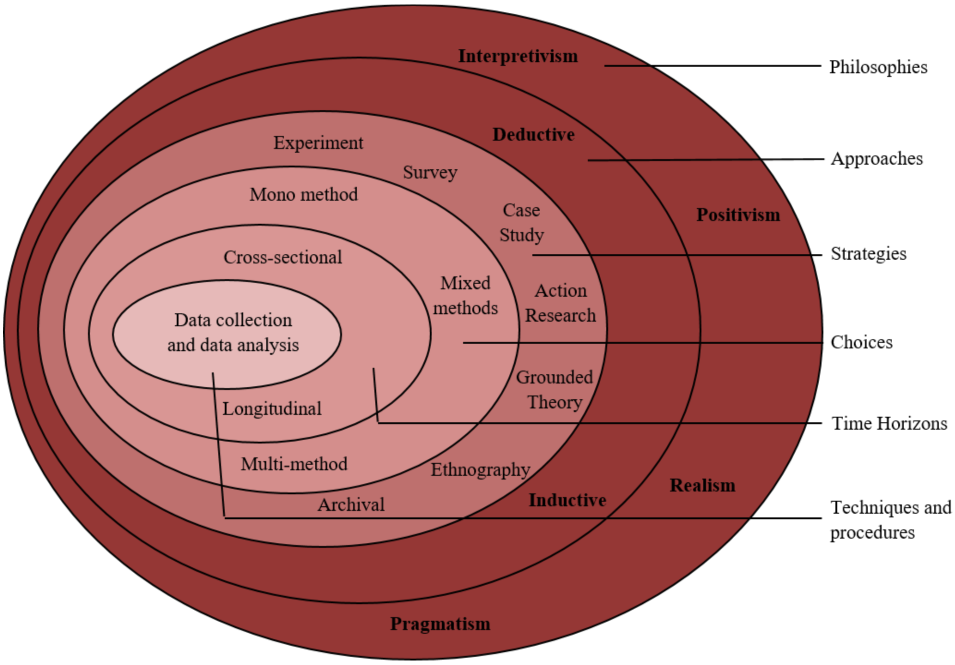

Figure 3.1 The Research 'Onion' (Saunders et al., 2009)

To satisfy the above research objectives, this study must adopt a method that enables flexible reaction to the data, as this is such an unknown phenomenon, it is unclear at the outset what data will actually be collated. As a route to formulating the most suitable research method, the varying philosophies, approaches, and strategies must first be processed. To do this, the *'Research Onion'* as seen in figure 3.1, will be used to guider the decision-making journey, as discussed in sections 3.3 through 3.5.

3.3 RESEARCH PHILOSOPHIES

Research paradigms are the philosophical perspectives – world views – regarding what is constituted as being 'valid research' (Myers, 1997). They're based on three key areas for assumption, those relating to: epistemological, ontological and the metaphysical; covering the nature of knowledge creation and how knowledge may be obtained for specific situations (Meredith et al., 1989; Myers, 1997). Below is a discussion of the three core research paradigms – *positivism, interpretivism, and realism* – followed by how this research will be positioned in relation.

3.3.1 POSITIVISM

Positivism is one of the oldest research paradigms, which assumes that the real world can be studied objectively by a research instrument (the researcher). As Hammersley and Atkinson (1995) point out, central to positivism is the assumption that reality is an inert amalgam of facts "out there" waiting to be discovered. There is also the assumption that theories can be tested with certainty and that all intervening variables can be controlled. The philosophical stance of positivism assumes that our universe is ordered and regular, and that regular laws and patterns can be investigated objectively as they exist independently of an individual's cognition. Positivist research therefore is research which aims to understand the patterns governing a specific phenomenon that can be tested and quantified.

Positivism has been criticised by Oates (2006) as being "less suited to studying the social world", as it is too complex to be reduced to a simple stimuli-response. As higher education institutions'-built assets are designed to accommodate a social 'system' whereby the university develops hierarchical, meaningful structures, trying to break that social system into smaller segments is sometimes not possible; meaning the positivist approach is therefore not suited to this specific research project.

3.3.2 INTERPRETIVISM

Interpretive research assumes that "people create and associate their own subjective and inter-subjective meanings as they interact with the world around them" (Orlikowski and Baroudi, 1991). As Morgan and Smircich (1980) argue, the conception of the world as a concrete structure reduces the role of people to inert objects and leads to grossly over-simplified models of human behaviour. The belief is that behaviour is not caused in a mechanical way and that any hope of discovering laws of behaviour is misplaced. Thus, in a behavioural sense, interpretivism questions the ability to test theories with certainty, and is primarily concerned with the formulation of theory through the provision of data and evidence to support it. In contrast to the positivist's inert view of reality, interpretivists believe that reality is constructed and maintained over time by people in the social world. Research methods are not seen merely as a way of releasing a reality that exists in a rigid sense but as instruments to develop an understanding and accurate account of reality in the most natural environment possible.

Interpretive studies therefore attempt to make sense of unique phenomena that can only be accessed through social constructions such as language, consciousness and shared meanings (Myers, 1997). In construction research, interpretivism provides an understanding into the contexts of an organisation, allowing the researcher to fully immerse oneself within the study.

3.3.3 REALISM

The idea of 'independence of reality from the human mind' is a fundamental concept within the realism research philosophy, where direct realism portrays the world through the senses – what you see is what you get (Saunders et al., 2009). Critical realism, by comparison, argues that sensations and images of the real world can deceive the true portrayal of the real world (Novikov and Novikov, 2013). A researcher adopting the principles of Realism would, therefore, have to hold an appreciation of the contextual relationships between the individual and the wider group or organisation, as well as those factors influencing them.

3.3.4 PHILOSOPHY JUSTIFICATION

As this research is exploring a relatively unknown phenomenon, adopting a positivist view would lead to complications. Although the aim is indeed to understand the 'laws' governing whole-life management of information, said patterns and regulations can be assumed to be directly relating to the 'individual's cognition', therefore meaning quantification would be unachievable. So too can be said about the realistic view, especially the critical realistic approach, where senses would directly affect the response from said asset manager, when approaching the use and management of information. In other words, this research is dependent of discovering the precise steps each individual asset manager goes through, when conducting business-as-usual activities. The narrative would therefore include sensational evidence of specific situations, meaning an interpretive approach is needed to understand the social constructions relating to this phenomenon. The theory formulation approach through continual interpretation of said social situation – mandated by Strauss and Corbin

(1990) – is well suited to this research project, where the lack of theory relating to whole-life, asset information management, makes this research purely exploratory in nature.

3.4 RESEARCH APPROACHES

An approach to research incorporates the planned steps that takes the researcher from broad assumptions through to detailed methods of data collection, analysis and interpretation (Creswell, 2013), following decisions at each key stage in order to clearly define the method adopted. There exist two main research approaches: deductive and inductive; where hypotheses are paramount to the deductive approach and is the main distinction between deduction and induction. This is further discussed in the next section, considering each for their applicability to this study.

3.4.1 DEDUCTIVE

The purpose of deductive research is to test and evaluate pre-existing phenomena, or hypotheses about said phenomena. Data is collected in order to explore an existing theory, moving from the general pattern of thought, towards that which is case specific. Understanding the validity of said hypotheses is key to the concise verification of the theory in question. Figure 3.2 exemplifies a deductive approach, which moves through testing to either confirm or reject a research hypothesis.

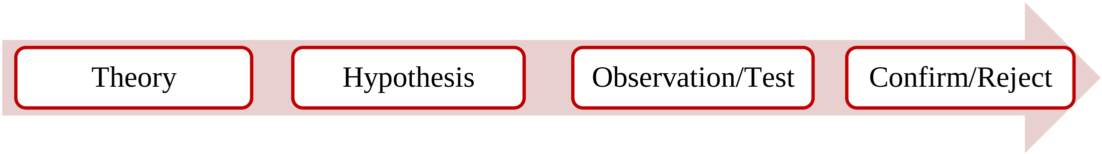

Figure 3.2 Deductive Process in Research (Creswell, 2013)

3.4.2 INDUCTIVE

In comparison to deduction, an inductive approach utilises data for the exploration of phenomenon, identifying themes and patterns in order to conceptually understand a theoretical solution. Figure 3.3 offers a simplified version of an inductive research approach.

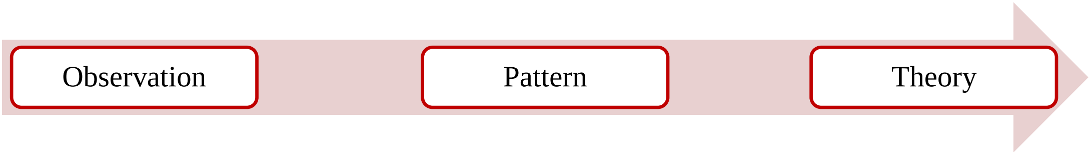

Figure 3.3 Inductive Process in Research (Creswell, 2013)

3.4.3 APPROACH JUSTIFICATION

Taking the pre-existing understanding gauged from the review of literature in chapter 2, and the consequential creation of a research question and subsequent objectives, one clear agenda for this research is discovery. The scope does not however, include the creation of initial hypotheses that influence the way in which the research would be carried out, nor does it have a clear set of variables that bounds the data collection and analysis process; the inference being that this research is therefore suited to an inductive approach to theory creation, with inductive strategies being the focus of design going forward.

3.5 RESEARCH STRATEGIES

Since the philosophy and approach have been discussed, it is necessary for the various strategies to be explored. As construction research often relies upon investigating a bespoke project or unique contextual environment, the data must be collected in a way that enables conclusions and theories to be drawn, whilst also giving a holistic portrayal of said context. It must be noted, however, that at the time of conceptualising this research, there were minimal construction cases with plentiful stakeholders aware of advanced information modelling and management strategies. The restricted accessibility to raw data is a concession that will affect the style of strategy for this project, therefore restricting the type of collection and analysis methods adopted.

3.5.1 QUANTITATIVE

When the origins of a research project can be found in the observation and eventual explanation of a theory, relationships may be tested through the measurement of set variables. The resulting numbered data is then statistically analysed, so that meaningful conclusions can be made about the specific conditions and/or characteristics of said theory. An example of this – determinism – suggests that "examining the relationships between and among variables is central to answering questions and hypotheses", where a strict sense of procedure endures to the formation of valid and reliable conclusions (Creswell, 2013).

A study into the *'organisational response to the management of operational property assets and facilities support services as a business resource'*, investigated the management processes as well as the nature and strength of the links between strategy and individual roles within corporate real estate agents (Shiem-Shin Then, 1996). The process by which findings were achieved was through a series of sample surveys and questionnaires, supplemented by follow up interviews. Rich empirical data was collated by investigating multiple cases, where designs were adopted and validated against experts in the field. It is a great example of how surveys could be utilised to capture a rich understanding of assets and facilities management. However, it focuses on the individual organisational cases, something that is unattainable when considering whole-life information management.

Although quantitative research can take numerous forms, its success is dependent on the clear-cut story from start to finish. Whether the collection process be a survey or a laboratory-based experiment, attempts must always be made to control the conditions of said process, so that precise measurements can be made. 'Normal science' has been noted as the true form of investigation (Kuhn, 2012), yet it does not offer the flexibility of adaptation to new discoveries throughout the process of testing. As the subject matter of this particular project objectifies unknown phenomena, using quantitative methods would restrict the formation of new theories and ideas, and will therefore not be considered going forward.

3.5.2 QUALITATIVE

In contrast to quantitative research, qualitative strategies offer a pluralistic approach to data collection, where behaviours can be studied in their natural environments, contextualising the multiple factors that may enhance, dictate or change. The use of a wide-angled lens would allow for a greater depth of exploration, meaning that the data collected would be more comprehensive and adaptable in terms of the individual perspectives. Studying the use of asset information in the context of a university – i.e. the natural setting – would give a pluralistic understanding of the issues found in the creation and sharing of said information (objectives 1 and 2), as well as an active method by which learning can be captured (objective 3).

According to Sandelowski and Barroso (2003) research findings can be placed on a continuum indicating the degree of transformation of data during the data analysis process, from descriptive to interpretation. The use of qualitative descriptive approaches such as descriptive phenomenology, content analysis, and thematic analysis is suitable for researchers who wish to employ a relatively low level of interpretation. In contrast, grounded theory or hermeneutic phenomenology demand a higher level of interpretive complexity (Vaismoradi et al, 2013). Commentary will now be made on the virtues of the varying approaches, with the intention of selecting a specific strategy.

x`Ethnography

Ethnography takes it derivation from anthropological study, providing insight into a group of people and their social environment, offering the opportunity to see and understand the bounds of their world (Collis and Hussey, 2013). Researchers adopting the approach tend to submerse themselves within a specific social situation, with the overriding aim of interpreting said social world in the same way that the members would. Building trust is critical in the successful adoption of Ethnography, capturing first-hand data from lengthy periods of observation as well as gaining access to the various artefacts that contribute to the subject's social environment are crucial for making synthesised conclusions. The researcher must take care to be constantly aware of the difference between what is truly observed, and their own subjective interpretation. Brewer takes this point further in his criticism of reliability within ethnographical studies, stating that the written account of a social world only ever captures a singular perspective of said field (Brewer, 2000). Researchers should not therefore attempt to make "foolish authority claims" in order to validate their account as a complete and accurate representation of reality.

An example of how in-depth ethnographic observation was used to make reasonable research conclusions was the study: *'to deliver a sustainable built environment, the management and operationalisation of sustainable facilities management'* (Price, 2015). Exploring the influence of policy mechanisms in the development of 'sustainable added value', Price sought an immersive approach to data collection, which allowed them to share in individual's lives, whilst attempting to learn about their social and governance influences. Although participant observation is a pragmatic approach when attempting to theorise about the application of strategies, there appears to be a lack of continuity with regards to a clear procedure for whole-life information management. The adoption of ethnography would therefore prove complicated and unattainable.

Archival

As a qualitative approach, Hermeneutics focuses on understanding underlying historical and social situations through the interpretation of literary texts. Initially applied to theological scripture, it is more commonly concerned with questioning whether human action can be viewed as a physical phenomenon, with the scope of the process exploring the 'meaningful outcomes' of said actions (Mantzavinos, 2016). Philosophically it is interested with the representation of perceptions, lending itself to being suited to studies of documented social situations. That does, however, mean that as a research strategy it is not suitable for exploring 'new' social phenomena such as that which is being investigated in this thesis.

Action Research

An applied research approach, action research is used when a conscious change is needed, where the researcher and process of research directly contributes to the making of said change, in a partly controlled environment. The research project is initiated to solve a specific issue, where full submersion within an environment allows theories to be directly tested and monitored. The approach has often been stated as being most where the objectives of both the researcher(s) and the subject organisation – more specifically those in the position of making decisions – are to gain a factual insight and observe the consequential action implications (Whyte, 1991). With respect to the aims and objectives of this specific project, the focus on gaining an insight from multiple stakeholders, from a variety of independent stakeholder groups, does not lend itself to the application of action research.

T. McKinley utilised the action research strategy for the project entitled, *'a community architecture framework for designing sustainable communities'*, enabling stakeholders to adapt a research-created tool to test varying approaches to the design of community spaces (McGinley, 2013). When combined with the principles of design science research methodologies, it provided a flexible approach to comprehensively understanding participants' reasoning behind the iterative learning and design of projects. A strategy with great potential for making conscious change, it does, however, depend on there being a clear hypothesis at the offset.

Case Study Research

A further approach consideration comes in the form of case study research. In the instance where the problem domain can be linked to real-world situations, such as is common with research in both the construction and information management domains, collating data relating to a single case or project enables the researcher to explore a single phenomenon in great detail. Yin (1994) defines case study research as an empirical enquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between said phenomenon and its contextual environment are not clearly evident. Developing this further, Fenton explores the complexity of cases in terms of their technical distinction, commenting that prior theoretical understanding is required to guide the clear collection and analysis of case-oriented data. (Fenton, 2016). The case study approach is such that causal relationships must be created, establishing the internal validity of findings, yet there must also be a broader awareness of how these relationships link directly to the wider social setting. In other words, the data captured must be generalisable, enabling meaningful conclusions to be drawn that would be beneficial to the immediate environment, as well as those that are more loosely connected.

If the reliability of the resulting findings can clearly be explained, case study research can lead to an investigation that proves both enlightening and truly invaluable. Selecting and determining the number of cases to be analysed often proves to be the most complex part of adopting the case study approach to research. When investigating *'integrated lifecycle requirements management in construction'*, Jallow opted for an approach that combined exploration, description, and explanation of several cases, to analyse the process of managing client requirements as applied in the context of construction projects (Jallow, 2011). The difficulty arose when attempting to cover all phases of the construction lifecycle. A single case was not available to allow for end-to-end analysis. Instead Jallow incorporated the qualitative data from varying cases, crossing construction phases to attain a full understanding of lifecycle requirements management. Although the findings are useful to this specific research domain, the project proves that difficulties would soon arise when attempting to gather data from asset managers involved in the end-to-end process of a single construction project.

Grounded Theory

Turner (1982) defines a theory as a set of logically interrelated propositions, presented in a systematic way, which describe and explain sociological phenomena. A theory should summarise and organise knowledge in an area, and be open to testing, reformulation, modification and revision. A systematic strategy for the generation of theory which complements an interpretivist approach is "grounded theory" (Glaser and Strauss 1967, Strauss and Corbin 1990).

Philosophically, grounded theory is underpinned by the assumption that change is a constant feature of social life, and that its specific direction needs to be accounted for in a research context. Strauss and Corbin (1990) assert that a grounded theory is not acquired passively but through an interactive, continuous and rigorous process. During this process, the researcher repeatedly moves between data collection and analysis until the "best fit" theoretical theme is developed which can link facts in a comprehensive and coherent way. The cognitive process inherent in grounded theory is movement through the phases of comprehension, synthesis and theorising (Morse 1994). Comprehension is achieved in two steps which start with the development of a ‘paradigm model’ or ‘problem domain’, built from a basic understanding of the existing state. The value of this abstract model is that it indicates concepts and preliminary propositions which can guide the research effort through refinement to the development of a grounded theory. The second step towards achieving comprehension is the collection of qualitative data through means such as unstructured interviews and observation. In essence, the process seeks to elicit a range of participant's stories and narratives, describing them in a longitudinal fashion. Figure 3.4 illustrates this refinement process through continual deduction, induction and verification of data sets. Comprehension is finally achieved when enough perspectives have been collected to produce in-depth understanding of the sociological phenomena under investigation, in other words, at the point of data saturation, when no new themes are discovered.

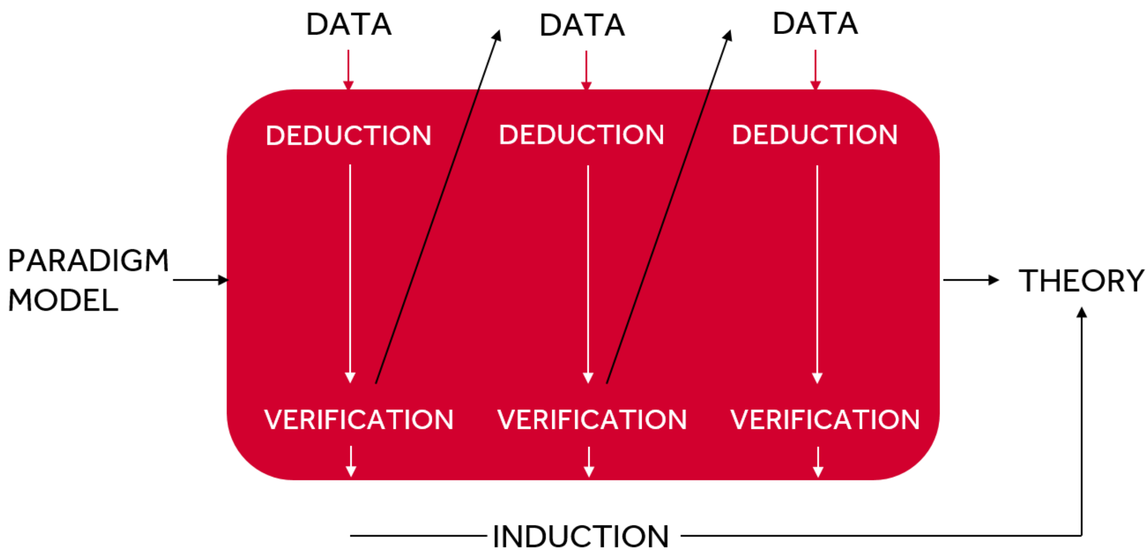

Figure 3.4 Iterative process of data collection and analysis, used within Grounded Theory

Grounded theory is essentially one of the interpretive methods that shares the common philosophy of phenomenology (Strauss 1994); that is, methods that are used to describe the world of the person or persons under study from their perspective (Stern 1994). The term "grounded" is used because the resultant theory emerges out of and is grounded in the collated research data. Grounded theory research is highly flexible, responsive and reflexive, which aims to develop theory through qualitative data analysis.

3.5.3 STRATEGY JUSTIFICATION

With respect to the development of a design for this particular research project, it has been previously concluded that quantitative methods would not allow the process of collection the flexibility required to fully investigate the phenomenon of information management use within the operation of built assets. Each of the qualitative strategies explored in section 3.5.2 are evaluated in table 3.1, with regards to allowing for the collection of multi-stakeholder, multi-perspective, narrative data, providing in-depth insight and learning into the phenomenon of the creation, management and sharing of asset information.

Requirements for Data Collection	*Archival*	*Ethnography*	*Action Research*	*Case Studies*	*Grounded Theory*
To provide a method for collating research findings into a usable framework.		√	√	√	√
To support and model multi-dimensional stakeholder perspectives.	√	√		√	√
To allow for the researcher to adopt the perspective of the insider, without affecting the data outcomes of the research.				√	√

Table 3.1 Research methods-requirements review

Archival research is dependent upon pre-existing texts, commenting on said social situation to derive theories about the way things were. Although its ability to critique a situation that has happened would be suitable, the lack of distinct texts making valid commentary on projects adopting information management strategies within the education sector, mean that the project would find difficulty from the offset. In contrast to forming commentary on historical situations, ethnography forms conclusions about a real-time situation. Even though this allows detailed discoveries to be made, the singularity of the process would restrict the quality of any said conclusions, whilst placing oneself within the domain of discovery would also risk the validity of the data capture process by clouding the judgement of the researcher. A degree of separation must be acknowledged to ensure that the validity remains true.

With regards to *'action research'* and *'case study research'*, both approaches demand the interaction with stakeholders within the 'project' environment. In the case of the construction sector this is most relevant, as each construction project can be seen as an individual, bespoke entity. Yet, when considering construction within the higher education sector – i.e. the management of a university's built-assets – there may be more difficulty, especially when considering the precise phenomenon of adopting advanced information management strategies, as there are limited cases published.

Ontologically speaking, the approach needs to aid the researcher in extracting the knowledge from the collected qualitative data, so that the social nature of information use in higher education asset management can truly be understood (Weed, 2009). Researchers are social beings whose experiences, ideas and assumptions may contribute to their understanding of a social phenomenon observed (Baker et al., 1992). In terms of the five potential approaches, grounded theory is the only method that allows the phenomenon to fully be explored. Accordingly, it shall be used as the strategy for this research project.

As a means of summary: to satisfy the research objectives as detailed in section 3.2, this investigative study adopts the interpretive paradigm, an inductive strategy and a grounded approach to data collection and theory development. The specifics of this design are detailed in the following section (3.6), in addition to a narrative mapping of the process of collection, analysis and theory generation.

3.6 RESEARCH DESIGN

Research designs are about formulating a structure about which specific research activities may be organised. At an abstract level, knowledge is built about the exploration of facts, assumptions, deductions, theories, hypotheses, and law (Simon and Burstein, 1985); more generally considering the main elements of a research study comprising operational definitions and concepts, propositions, theories and hypotheses. Regarding the 'technical', a research project may be defined as "…the logic that links the data to be collected (and the conclusions to be drawn) to the initial questions of a study" (Yin, 1984). Yet, in order to resolve several issues when designing research, Easterby-Smith describes five areas for comparative thought, that lead to a clear structure; these are illustrated in table 3.2.

Researcher is independent	vs	Researcher is involved
Large sample	vs	Small sample
Testing theories	vs	Generating theories
Experimental design	vs	Fieldwork methods
Verification	vs	Falsification

Table 3.2 Key Decisions in the Research Design Process (Easterby-Smith et al., 1991)

Researchers aiming to fulfil the requirements of an inductive, grounded theory approach need to be wary of the above comparisons, ensuring that they are considering the internal creation of their theory, but also how said theory is relatable outside the contexts and bounds of the research.

3.6.1 COLLECTION NARRATIVE

In consequence to the grounded theory approach being adopted, it is necessary to first inform the reader of the overriding narrative to the research documented in this thesis. Chapters 4 through 6 have been systematically produced in order to provide an accurate account of the progression of method refinement, from the first exploratory study, through the collection of the four core data sets, and validating with a fifth and final data set. From there, a truly grounded-theory is then discussed. The narrative is as follows.

Chapter 4 – Exploratory Study

As a means of initialising this research, a single case is examined, gathering first-hand, experiential data surrounding the successful application of Building Information Modelling (BIM), as well as the potential it provides for developing the ongoing management and maintenance of a built asset. The chapter will introduce the case, identifying the participants, their context and their drivers, as well as the protocol used to obtain the raw data and furthermore analyse. The chapter also builds on the literature reviewed in chapter 2, introducing a fourth conceptual dimension – *channels* – to the three originally discussed – *people, process, technology* – as a key piece of learning concluded from the study. These are integral for the ongoing research, and therefore will aid the explicit definition of the method protocol going forward. Hence, a further refinement of the interview questions is given, itemising a semi-structured interview approach that incorporates the needs of the research objectives, with further questions highlighting a relationship to the four PPTC dimensions.

Chapter 5 – Analysis Phase 1

In response to the learning gathered through the initial review of literature and the exploratory case study, the revised protocol is used to collect four core data sets. The discussion within this chapter pertains to the first phase of analysis – a horizontal approach that uses the original research objectives to explore: where the subjects create information waste; the collaborative process of exchange with external stakeholders; and a gauge of how iterative knowledge creation and sharing may occur. This chapter is essential in scoping the findings with respect to the macro-problem perspective, taking the core responses as a means of beginning the process of grounding a theoretical conclusion. It offers insight into the responses from each participant, considering their respective contexts, and perceived dependencies, comparing similar roles across the university cases, as a means of understanding the existing process of information management.

Chapter 6 – Analysis Phase 2

In contrast to chapter 5, this sixth chapter takes a vertical analysis view – i.e. using the four dimensions – *people, process, technologies,* and *channels* – to dissect and further assess the four sets of data. For continuity's sake, the participant's roles, contexts and perceived dependencies are used as a means to compare and contrast each university case; yet this further, distinctive layer of analysis lends itself to understanding the findings with respect to the complete asset lifecycle, i.e. are there commonalities during design, as well as during construction and initially in operation? The chapter also responds to the qualitative research need of validating the data sets. When adopting the grounded approach, iterative collection and analysis is conducted until a point of saturation is reached and no new findings can be deduced. A fifth university data set is therefore required to conclude that saturation has been obtained and is discussed within the later sections of this chapter.

Following these three key phases of the investigation, the resulting theory can then be discussed, with the final chapters – 7 and 8 – referring to the practical implications of the findings and the proposed lifecycle framework.

3.6.2 METHOD FOR COLLECTION

It has been made clear that a narrative is needed to be obtained as part of the raw data, so that one may understand the daily trials for asset managers and their working patterns. There are various ways in which the personal account can be captured, such as interviews, observations and focus groups.

Interviews

Probably the most widely used method within qualitative data collection (Bryman, 2008), when conducted properly, interviews are an effective technique for collecting a vast amount of data, over a relatively short period of time. As well as being a means of obtaining highly personal data, explicit meanings may be extracted from implicit – tacit – accounts; however, to achieve this, special interviewing skills are required, which in most cases are learnt through experience and practice (Gray, 2009). Interviews can be categorised into three main contexts: structured, semi-structured and unstructured.

Structured interviews use standardised and pre-defined questions, remaining consistent for all interview sessions, i.e. the same fixed wording is used to ask each participant the same set of questions, in the same order. It has been stated that structured interviews are employed as a strategy for collecting data for quantitative analysis, meaning interactions between the interviewer and interviewee is kept to a minimum (Gray, 2009).

Semi-structured interviews include both standardised and non-standardised questions. In other words, a pre-defined protocol of questions is created and covered within each interview session, but the route by which the questions are asked may not be true for all interview cases. Additional questions are used to probe deeper about a certain subject, ensuring the collected data creates a holistic representation of the interviewee's narrative. The flexibility of including fixed questions, as well as open-ended questions allows for a more thorough approach to data collection.

Unstructured interviews are free from any pre-defined questions, with all questioning remaining open-ended and in any order. Unstructured interviews are therefore more informal and conversational. The interviewer uses sets of points about a general topic of interest as an aid to asking said questions, whilst the interviewee is allowed 'conversational space' to respond freely (Gibson and Brown, 2009). The informality of unstructured interviews means a process of control is needed, in order to ensure that each interview is comparable to the next. Gray (2009) makes further emphasis that conversational interviews are at risk of being influenced by the interviewer and could cause difficulties when analysis is conducted.

Observational collection may be performed through two distinctive techniques: participant observation and non-participant observation. The former allows for one to see the world as others see it, i.e. in their own terms, with researchers entering into the world of that which they are attempting to study (Gray et al, 2007). According to Gray (2009), the meaning of observation is to produce data through seeing and listening to the subjects, within their real-life settings, in order to study their social meanings and understand the route of their activities. Researchers must, however, be wise to the approach of observation, whether they adopt the *overt* or *covert* style. An overt approach, although being simpler to conduct, has the counter point that subjects may alter the way in which they act, in response to being aware of said observation. Ethics are a key consideration when conducting observation, especially if the covert style is adopted, and the researcher must make it known that the rights of the participant are always taken into consideration.

Focus groups are used in research to conduct interviews surrounding specific issues, often utilised within market research or developmental situations. According to Barbour (2007), a common application for the focus group is in the exploratory phase of a research project, where problematic areas within professional practice are investigated. Collecting data from several participants concurrently can eradicate issues usually found with one-to-one interviews – data that has remained on course and on topic – whilst there is the advantage of reducing both time and cost of repeated interview sessions.

Interviews, observations and focus groups can and should be conducted in conjunction with note taking and memo creation. Transcription of audio can be a long and tedious task, where supplementary notes can enhance the process and kick start the analytical understanding of the collected data. The sample for both phases of data collection will be discussed in sections 4.3, 4.6.2 and 6.7, i.e. the exploratory study phase, the classification of the first four university cases, and then the final university case respectively. The designed steps to theory creation are portrayed in figure 3.5. It is the intention to cyclically approach the collection process, i.e. conduct interviews with members of the universities' AM department, notating points of interest, then during the process of analysis and thematic understanding, complete the next set of interviews. This process will continue until a point of saturation is reached – in other words, at the point of no new themes or ideas are found. At this stage, the remaining universities will then be used as a means of validating and confirming the theoretical framework. Iterative progression allows for a fluid approach to theory generation, one that is key for the successful adoption of the grounded theory method.

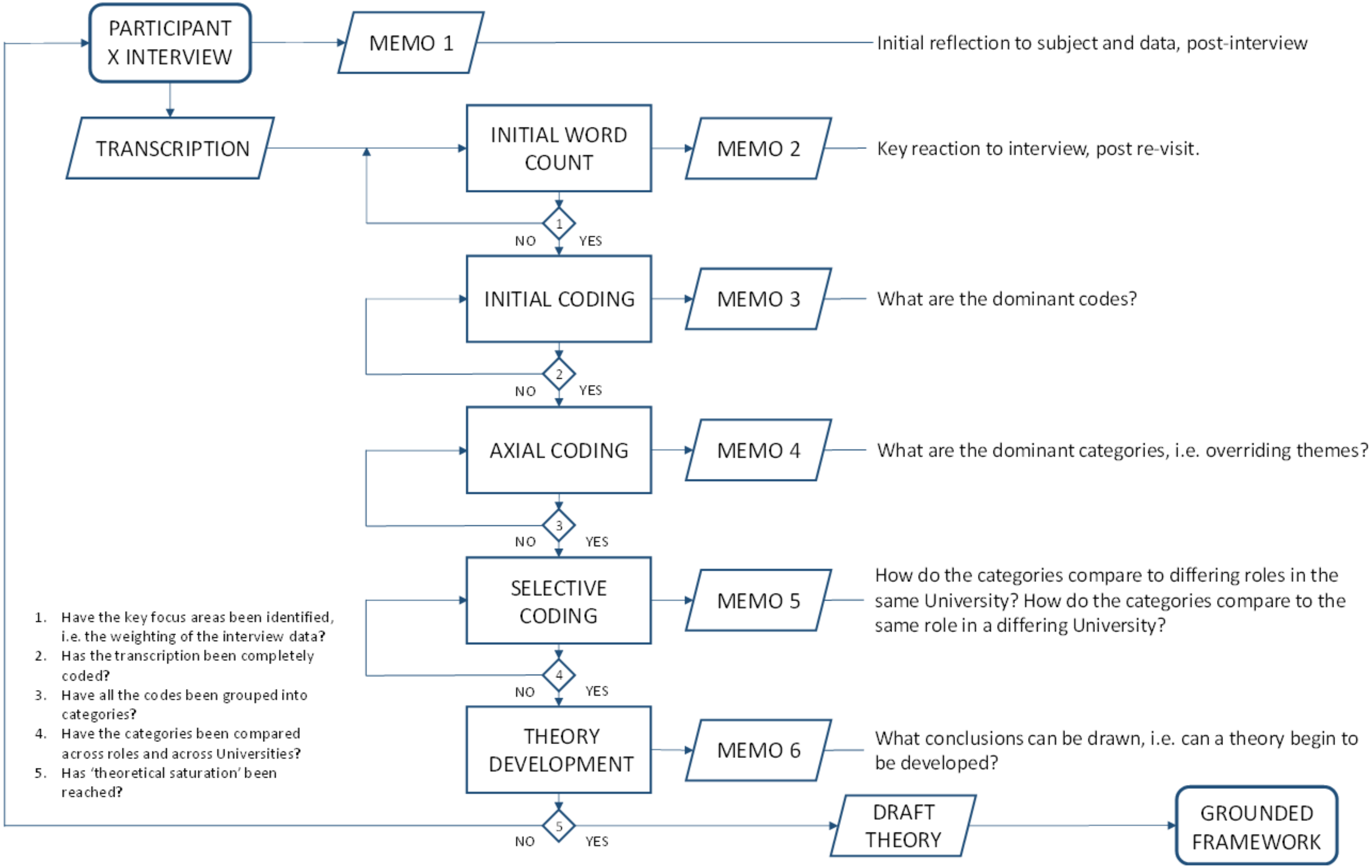

Figure 3.5 Grounded process of theory development

3.6.3 METHOD FOR ANALYSIS

Often in qualitative research – as is being applied in this investigation – analysis is conducted about the creation of themes represented within the initial questions, and the responding answers collected from each participant. Pre-formulated emergent themes are commonly used to categorise collected data (Gibson and Brown, 2009), however, the grounded theory approach tends to react to the content in a free manner, developing theory about unique data sets.

According to Creswell (2007), there are four key phases common to all forms of qualitative data analysis. They are discussed as follows, commenting on the key elements that make up a grounded approach.

- *Data managing* involves the organisation of the collected data, either manually in paper form, or digitally using a computer programme (such as NVivo). Conversion of the data into the appropriate text units is also critical, i.e. transcribing interviews and focus groups into stories, sentences and words.
- *Reading and making memos* from entire transcripts, making notes either in margins, in digital form, or separate files, in order to absorb the content in detail. The concurrent process of reading and note-taking will enable ideas and concepts to be developed, and an idea of categorisation to begin.
- *Describing, classifying and interpreting* – a core part of thematic coding and critical for grounding theory in the data. Describing the content into themes, that may then be collected into open categories and further coded through axial and selective coding (to be further defined in section 4.5). All themes and codes will however be somewhat based on the researcher's view, individual insights and intuition of the data, and must therefore be understood as such in all theory creation and commentary. This phase of analysis is iterative, with several rounds required to fully explore the themes, codes and categories; finally developing a theory that is conditional upon the resultant themes.
- *Representing and visualising* is the final phase of analysis, where data is presented in the form of findings, which could be in text, tabular or figure forms.

With regards to creating a grounded theory from the collected qualitative data, that is replicable and validated, the above analysis steps should be clearly set out and determined, at each phase of the process.

When adopting a grounded approach, the use of coding is critical to understanding meaning from the collected data. Strauss and Corbin's 1990 approach consists of three phases:

- Initial coding – or open coding – breaks down the text, examining, comparing and contextualising the data into themes or categories.
- Axial coding then puts the data back together, by forming new connections between the categories formed during the initial coding phase. Codes may be linked through contexts, through consequences, patterns of interaction or causes, with the collection process becoming more abstract.
- Selective coding is the procedure by which a core category is selected to systematically relate the previously formed code-categories. By introducing an overarching category, the relationships of ideas are validated, and the core storyline is provided, which can then be used to frame the developing theory.

In other words, the data is first digested into thematic codes, comparing code against code so that their concepts can be itemised into a specific category of thought. These categories are then related back to the original literature to gauge their validity and create a theoretical framework that would prove beneficial to both the academic and industrial fields. Examples of the codes and categories disseminated from each phase of analysis are summarised within chapters 5 and 6, commenting on those themes that directly lead to the development of the theory.

Considering this practically, there are several actions that the researcher must undertake, in order to maintain a replicable process of analysis, and to create a theory that is grounded in the data and not on assumptions or unvalidated details. When contending with large volumes of qualitative data, details from individual participants can quickly become absorbed into other's information. It is therefore essential that the researcher notes down not only reference markers pointing to specific ideas and thoughts, but also their own experiential understanding of the data. In other words, after each interview is completed, noting down stand-out discussion points will aid the next stage of analysis. Similarly, the use of notes after the first round of initial coding will enable the researcher to quickly pick out the heavier weighted discussion points, aiding the development of categories and theories. It is important to maintain a clear direction of travel when practicing grounded analysis, where each iterative round will build another level of complexity upon the initial thoughts, without a visible trail the researcher can quickly become confused and lost within the data.

It must be emphasised that integration of the theory is best when it emerges naturally, in a similar way to the original codes and categories; it should never just be 'put together'(Heath and Cowley, 2004). To enable the naturalistic formation of a theory, the analysis will go through two phases. The first looks specifically at the data captured for each objective, going through the iterative coding cycle for each one of the three objectives, for each subject and case. The secondary phase will then analyse in terms of the PPTC dimensions to develop a further depth of understanding from the data. In other words, the analysis will first look horizontally through the objectives, then vertically across the dimensions, as is detailed in figure 3.6.

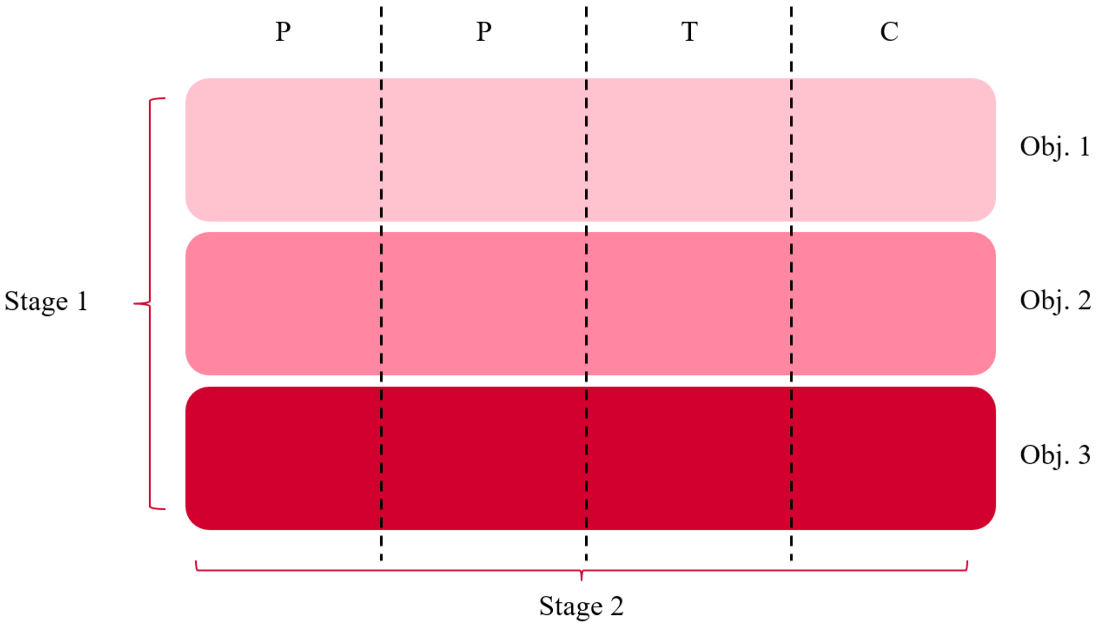

Figure 3.6 Two-phased process of data analysis

This two-phased process of analysis will enable not only individual datasets to be compared, but also a comparison across each role classification and university case to be undertaken, giving rise to a theory developed through rigour and reason.

3.6.4 RESEARCH DESIGN CHALLENGES

It is worth stating that qualitative data collection and analysis tends to be subjective and may therefore produce varying results to others conducting a similar procedure. The overriding aim of the research is to understand the varying contexts of information management within ongoing asset maintenance and management, aiming to discover a theory that aids this understanding.

The challenges of adopting grounded theory have been widely documented, with the following four being specific challenges applicable for this research project:

- Difficulty dealing with large amounts of data;
- Time-consuming research process;
- Set within specific context – may limit the generalisability of the findings;
- Coding is only part of the grounded theory methodology – generation of theory is vital to the success of the project;
- Pre-determined influence may dictate the lens by which the data is viewed and analysed.

Interview Bias can consist of systematic favouritism present in the data collection process – i.e. the interviews – that can result in misled research. Bias can be developed when choosing the subjects or cases to take part in the study, which in this case was influenced by the access through the supporting company. However, attempts were made to reduce bias by using first hand methods of collecting data, whilst recordings of each session would ensure that said first-hand data was not lost or misconstrued over time. Weaknesses in a singular subject or source, are also reduced by increasing the number of subjects used for comparison and analysis. Qualitative researchers contend that because the nature and purpose of the quantitative and qualitative traditions are different, it is "erroneous to apply the same criteria of worthiness or merit" (Golafshani, 2003). Agar (1986) suggested that terms such as 'reliability' and 'validity' are only relative to when a quantitative research lens is applied, with the need for a different language to be used when viewing research qualitatively. Terms such as 'internal validity', 'external validity', and 'neutrality' should instead be used to judge qualitative research on its ability to reliably develop theories.

Internal validity asks whether the researcher has established confidence in the true meaning of the findings. It is argued that internal validity is based on the assumption that there is a 'single tangible' reality to be measured(Krefting, 1991). In the case of this research, the human experiences as they are lived and perceived by the subjects are subject-oriented by the use of consistent open-ended questions. Care must be taken, therefore, to stay true to the original interview script, and maintain a flow of conversation that sticks within the lens of investigation. It is essential that the supplementary questions do not dictate a specific response and allow the subject to answer truthfully, from their perspective at all times – to learn from the subject rather than attempt to control them. Open-ended questions will reduce the risk of bias, whilst allowing for the subject to narratively explain their perceptions.

External validity differs to internal by establishing if the research findings can be generalised beyond the specific university cases. The process of managing and maintaining built assets differs greatly from one case to the next, and there are various activities with large variability so one must be careful when generalising said specific issues. The findings of this research will serve as a means to articulate the issues present, highlighting those relevant to other HE institutions and potentially even those portfolio-based asset management groups that are beyond the HE sector.

Neutrality refers to the degree to which the findings are a function solely of the subjects and conditions of the research, and not of other biases, motivations, and perspectives (Krefting, 1991). The neutrality of the qualitative data was strengthened by decreasing the distance between the researcher and the subjects through prolonged sessions of conversation and observation. A key intention of this research is to capture both the positive and negative ideals of adopting advanced information management strategies, understanding both the success factors and the failures in order to understand a holistic perspective for asset information management.

As discussed above, the main challenge when conducting qualitative research, especially research where the causal conclusions are complete unknowns, is to ensure that the participant's narrative is freely given, without being influenced or directed. This researcher found the tensions between being subjectively apart from the research, whilst not having too much distance initially quite challenging. For a first time grounded-theorist, the concept of 'neutrality' can be quite a mind-field. However, practice was opportunely gained through the exploration of the initial study, where a pre-existing understanding of the relationships within the project team meant that a degree of separation could be adhered to whilst allowing each participant to guide their interview about the subjects, they deemed important. The use of a clear protocol of interview questions was quickly gauged as being vital to enabling this, where the rigid, fixed subject questions would begin initial conversation, then falling onto the unstructured questions to further probe into the specifics of a subject. In other words, having both rigidity and flexibility in the line of questioning meant that the participant was allowed time and space to freely divulge their qualitative data, without the researcher influencing the discussion.

3.7 SUMMARY

This chapter has made commentary on the available philosophies, approaches and strategies for the process of conducting research, identifying the interpretivist, the inductive and a grounded approach as being most suitable for attempting to tackle the research question and objectives. The first phase of investigation will now be looked at, through the exploratory study, from which further definition of the practical collection process can be concluded and the core data sample collected and analysed in the two-phased approach as discussed above.

CHAPTER 4 EXPLORATORY STUDY

4.1 INTRODUCTION

Previous chapters have detailed the necessity for greater understanding to be gained surrounding the macro problem of asset managers' whole-life use of information, for the ongoing management and maintenance of built assets. A generalised methodological approach was introduced, citing grounded theory as the most pragmatic approach to investigating and theorising about said unknown phenomenon. Successful completion of this research will only be achieved through a thorough and detailed qualitative exploration, yet there is a need to explicitly define the lens of investigation, i.e. formulating a protocol that will aid the interviewer to meticulously question the participant, so as to capture data that will satisfy the measurement of objectives 1, 2, and 3, as justified in section 2.4. This chapter undertakes the first phase of investigation through the means of studying a specific practical case – the Birmingham City University Parkside development project.

4.2 BCU PARKSIDE PROJECT

The case selected was accessible due to the opportunist relationship between the researcher and the company sponsoring this research. Birmingham City University's consolidation and redevelopment of their city centre campus allowed them the opportunity to investigate current and 'future' strategies for creating, storing and managing information. Originally conceived prior to the publication of the UK Government's 2011 mandate, the term *Building Information Modelling* was an unidentified concept. However, the university – driven by its estates and project office – drove to innovate through practice-in-action, trialling new working environments as a means of increasing efficiencies and stakeholder relationships. The project was the first of its kind for each discipline team, yet they collaboratively sought to develop understanding and enhance their BIM-capability. For these reasons, the case enabled a fresh perspective to be captured, as a first step to understanding information modelling as a tool for the ongoing management of built assets.

4.2.1 PROJECT BACKGROUND

Birmingham City University (BCU) is one of the UK's largest universities, serving around 25,000 students, situated in Britain's second largest city. As a part of the University's legacy strategy their £180million investment is helping them to consolidate their assets, by building two new facilities within the heart of the city centre campus. The two-phased project saw the construction of the *Birmingham Institute of Art and Design* (BIAD), and a new *Student Centre*, with additional teaching and administrative facilities, where the BIAD centre makes up the first phase, and the Student Centre the second.

Figure 4.1 Birmingham City University Development Construction Site

A significant goal of the client team was for a solution that enabled better management throughout the operational life of the building, post practical completion and hand-over to their estates team. This not only meant a 'state-of-the-art' physical structure where sustainability was a key driver for design, but also in terms of the coordinated delivery of useable asset information. For BCU, the use of BIM gave them the appropriate leverage to enhance their process for managing and maintaining their new facilities, and the wider estate, for future years to come (Fillingham et al., 2013).

The University's Estates team had worked with structured information for many years, yet BIM offered them an opportunity for developing their method of collection, whilst consolidating their existing relational databases. Utilising BIM for asset management presented the estates team with a solution to the common problem of missing archives and incomplete asset information, long associated with the traditional methods of management (Fillingham et al., 2013). It was their ambition of developing a single database of both 3-dimensional, graphical model data, and the associated document information; which could then be used to manage all activities run within the

University – including administration processes such as room bookings and timetabling. A fully-coordinated, ‘clash-resolved’ BIM model was a key output, with this being the core deliverable that will be used to continually manage the ‘forward planning’ and ‘reactive’ maintenance schedules of the assets.

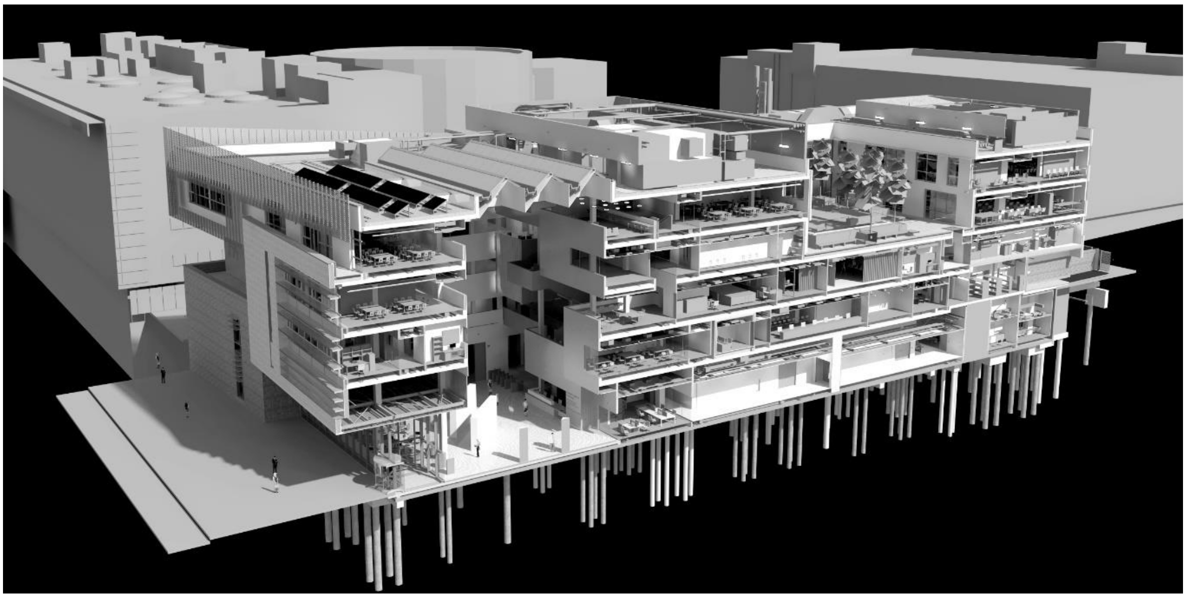

Figure 4.2 Cross-sectional Model Perspective, Birmingham City University Centre Development

The *Birmingham City University Parkside Development* was an innovative project that pushed the boundaries of known construction methods and practices, mandating strategic use of BIM with the desire of achieving optimal performance for the complete life of the asset. One of the first of its kind in the UK making BIM for AM a key aspect of the strategy for whole-lifecycle thinking, that was wholeheartedly decided upon and governed by the operational requirements of the user; starting with the end in mind.

4.3 METHOD

The overriding goal for the exploratory study was to investigate how the adoption of information management strategies allowed the Parkside project team to introduce innovative methods of delivering and maintaining the assets, with an intention to identify areas of change and lessons learned to inform future projects. Semi-structured interviews were conducted with core members of the project team (see table 4.1) to document each of the stakeholder’s learning journey, as well as the recognized benefits, challenges and lessons learned. As the project was conducted following a two-stage novation contractual environment, it was vital that the views of all key parties were captured, to cover the thoughts and development from conception through to close.

Project Stakeholders		*Number of Participants*
Client	*BCU Estates and Facilities; Project Office*	2
Employer's Agent & Cost Consultant	*Faithful+Gould*	1
Architect	*Associated Architects*	1
Structural Engineer	*Ramboll*	1
Services Engineer	*Arup*	2
Contractors	*Willmott Dixon*	1
BIM Consultants	*Excitech*	1

Table 4.1 Project Stakeholders Participating in Exploratory Study

The interview questions were structured to reflect the process development of the RIBA Plan of Work stages from concept and design development, to construction, commissioning and handover (Sinclair, 2013) (Royal Institute of British Architects, 2013). The questions addressed key tasks in adopting the 'state-of-the-art' to itemise how the BIM implementation potentially changed the stakeholders' perceptions and their work. The full interview protocol and the associated project information sheet can be found in the appendices of this thesis.

As a means of analysing the transcribed interviews, concept mapping was used to understand and categorise the responses, identifying research themes relating to the phenomenon of information management within AM. Ideas were pinpointed to further understand the challenges in using BIM to optimise the operational management of assets.

4.4 DISCUSSION OF RESULTS

The intent to adopt BIM was three years ahead of the publication of the UK Government's BIM Strategy, which subsequently acted as a catalyst for the wider adoption within the UK construction sector (Fillingham et al., 2013). Before the design commenced, a set of workshops helped the team discuss the client's intentions for the built asset and learn more about each other's daily tasks and objectives. Understanding better about the teams' comparative strengths and weaknesses was a critical starting point for the project, and it aided the teams to collaborate more effectively to deliver a well-coordinated project, compared to more fragmented and traditional discipline-based practice.

BCU's request for a BIM-platform at the time was met with hesitation and scepticism. Although it potentially meant that in the future the University might encounter difficulties in retaining the data in the proprietary model format, BCU felt it was vital that the model was developed in a stable and familiar environment. The use of digital technologies and information modelling were seen as 'project unknowns', particularly in the long-term asset data use after the handover, which was a major factor for altering the mindset and the environment within which the project progressed.

Procured as a two-stage, Design and Build contract, the original design team was replaced at the technical design stage, or Stage E of the 2012 RIBA Plan of Work, thus progressing to a contractor-led construction phase. Although offering certain advantages for cost and programme management, the transitional hand-over from design into construction lead to some unwanted rework and realignment. The process of design and construction through to hand-over and operation is discussed in the following sections.

4.4.1 PRE-HANDOVER DEVELOPMENT

The University's intention to use BIM within AM was clear at the initial design stages. Despite this, however, when methods for creating and sharing information needed to be standardized, particularly when the initial BIM protocols were written, confusion over processes led to numerous misunderstandings between stakeholder groups, resulting in complex information coordination issues. Lack of any initial formal guidance to appropriately set up a project resulted in constant process iterations. To clarify the work process, the client requested that the design team continually meet to discuss the protocol and collaboratively refine the project execution plans. Throughout the majority of the design and development phase, all team members were involved in an iterative process of formalizing creation and exchange requirements.

Developing a project design within the digitally enabled BIM environment brought opportunities to relatively quickly advance existing practices, both within the project team and beyond the bounds of the supply team, i.e. outwardly to the University community. Weekly meetings gathered the representatives of each core stakeholder group to review the design. The participants used the model to discuss and refine specific design elements, check for 'clash detection', or simulate specific operational activities. An extranet system was created to facilitate a 'Common Data Environment', allowing easy access to the same raw modelling data for all parties. Although the idea of a common data environment is not new (British Standard Institute, 2007), a single coordinated location for the project information meant structuring the data in such a manner that allowed objects and associated classifications to be more easily itemized. Single discipline model files were issued and uploaded to the extranet prior to the weekly review meetings so that they may be coordinated, and the clash analysis could be prepared, ready for discussion.

The model was continually used, from the conceptual design to the construction documentation to inform and discuss with the University stakeholders. Although traditional practice consultation of the affected parties is necessary with larger design schemes, Lead Architect, James Hall, commented that it was "probably the biggest exercise in stakeholder engagement that we've ever done as a practice" (Hall, J., 2013). Rendered images and animated walk-through were created from the federated model files, providing a combined visual representation of the structural, architectural, mechanical, electrical, and landscape design solutions of the proposed design scheme. Both staff members and students were invited to virtually inhabit the designed spaces and provide relevant feedback before any site works commenced. With the significant offerings of Virtual Reality in creating an immersive user experience, the question remains whether the model could have been used to achieve more extensive advantage throughout the developmental process.

As the project transitioned into the construction phase, the design team passed the model ownership and management to the Lead Contractor for both Phase 1 and Phase 2 of the City Centre Campus Development. At this stage, the University Client Team felt it was necessary to extend their internal BIM-capability, and employed the BIM Manager, who was placed within the Estates and Facilities department. The University saw this appointment as crucial to continue with the 'good management practices' established in the initial stages of the Parkside project. From this stage, the BIM Manager monitored all BIM deliverables, ensuring that the supply chain maintained the required level of adoption that is ensuring that developed models and all associated documentation were at an appropriate level of detail to the associated stage. The BIM Manager's responsibility was therefore critical in terms of aligning model deliverables to the University FM Team's standard, as demanded for all future operations.

However, the model handover from the design to the construction team was particularly contentious. In preparation for tender, the Lead Contractor sought guidance from an external consultant, who helped with their tender documentation development in advancing their capability and understanding of BIM. Discussions regarding the model quality assurance led the Lead Contractor to be critical of the adopted modelling methods and information classification used in the design phase. Once the contract had been awarded, the protocols were entirely rewritten to support the contractor's perspective. Although this decision aligned with a mandated, consistent and controlled process for construction, revising the protocols caused some friction with the new design team. In addition, to meet the construction protocols standards, a large proportion of the design model had to be significantly reworked as well, resulting in an unwanted delay.

When commenting on the design model handover, members of the construction team made it evident that bringing them into the project at an earlier stage would have increased the awareness of existing protocols and allowed for more effective collaboration between the two teams.

Reviewing the construction schedule within the 3D model prior to site works helped the supply teams understand construction-critical elements of the design organize necessary training and prepare off-site. Consequently, there were few coordination issues discussed with the design team, which is overall unusual for projects of this size and complexity with traditional methods of construction.

The model, however, was not used to manage the daily works on site. At the time of construction, the contractors had no intention to use digital technologies and information management in the manner that BIM offered. For them, on-site BIM meant additional time-consuming administration, and therefore avoided on the Parkside Building development. When asked about their decision, the contractors admitted they would begin to mandate the BIM use on site, and consequently did so – to an extent – on Phase 2 of the City Centre Campus Development.

4.4.2 POST-HANDOVER OPERATION

In preparation for handover of the completed Parkside building, the team was also required to deliver the model, ensuring that all raw data held within its structure was not only consistent, but also accurate in terms of the 'as-built' facility. If the model was to be fully used for operational management and maintenance, it was essential that it was an exact digital representation of the as-built conditions. For the client, it was imperative to ensure the model was reliable enabling them to take it forward and advance other University-wide systems.

Validating the model, however, caused great concern for the project team. Being one of the first fully coordinated BIM projects in the UK meant that little guidance from previous projects could be drawn upon concerning how specific areas should correctly define the term ‘as-built’. There will always be tolerances that govern the accuracy of the physical built asset, yet to validate the model, it was key for the project team to have a clear process for when and how to update the model to reflect the as-built conditions. Refining the validation requirements proved to be quite a challenging and extensive process that required further work even beyond the completion of construction. The protocol was once again iterated to facilitate this project stage.

To maintain the accuracy of the collated record data for use post-handover, the University introduced a requirement to take photographs to capture the conditions above ceiling tiles and below flooring constructs. Subsequent referencing of these photographic files within the model created a simplistic approach to detailing the unknown, without overloading the level of detail of the model; i.e. technicians within the facilities team now have the ability to discern what lies above and below fixed construction units, and analyse the service-maintenance process, without having to physically come to the site.

LiDAR technologies, such as Laser Scanning were considered at the time as a secondary method of validation. The project team – specifically the clients – saw the vast opportunities that LiDAR offered. At the time of construction, however, the complexities of managing the existing programme was such that the introduction of a laser scanning surveying would have only increased the number of conflictions on site. For future projects, the University has committed to Laser Scanning surveys as an accurate and reliable method of capturing as-built conditions and has developed their internal capability of managing the raw data for historical auditing purposes.

Reviewing this case study highlighted the opportunities for innovative project development within the field of construction, when mandating and utilising the process of BIM for AM. Through the exploration of a single project, it can be concluded that, although there are numerous benefits from BIM such as heightened collaboration and advanced awareness of long-term processes, there are still areas for progression and refinement. It is clear, however, that in order to explore the phenomenon of whole-lifecycle information management, to be further explored, understanding the 'end-goals' of the asset managers is essential.

4.5 THE PPTC PERSPECTIVE

From the work conducted with the BCU case, four main dimensions can be identified: *people*; *process*; *technologies*; and *channels*. Without the desire and governance from BCU's estates team, the principle of better understanding their information flow wouldn't have become an integral project point. Processes were enhanced through the strategical use of technologies, yet it was made known that the lacking availability of technologies for the post-handover management of construction information would lead to further issues and future restrictions. In terms of fully utilising the information itself, knowledge about the creation process was critical, i.e. who authored the information, how did they go about creating it and using which technological mechanism. Government documentation (Bew, 2015; The Infrastructure and Projects Authority, 2016) has often referred to PPT – people, process and technologies – as being key aspects for better management of information (as is defined in 2.4), yet the work with BCU identified a further dimension – channels – as being equally, if not more important for success. Without a keen understanding of the passage of flow of information, where it has come from and for what purpose it is being exchanged, issues with clarity soon become of detriment to any project. This would be even more prevalent when thinking in terms of the end-to-end lifecycle of a built asset; contextual understanding of the phase at which information is created will affect its use and availability throughout the operational life.

In chapter 3, the objectives were defined in terms of their individual data need (3.2) and a generalised approach to collection and analysis. Following the work conducted with the BCU case, it is evident that approaching the objectives needs to also consider the four dimensions PPTC. Each of the three objectives will therefore be investigated relating to four dimensions: *People* – the roles and responsibilities of the AM stakeholders and their dependencies on information; *Process* – the methods by which tasks are achieved; *Technologies* – the tools used to create, manage and maintain said information; and *Channels* – the ways that information are shared between stakeholder groups. Only with this secondary level of interrogation will a comprehensive understanding of the asset manager's needs be truly gained.

4.6 REFINING RESEARCH DESIGN

The nature of the Engineering Doctorate is one of dynamic knowledge creation. Interactions between the academic and industrial partners must remain context-driven, problem focused and interdisciplinary, to coproduce new knowledge that considers the needs and perspectives of both audiences. Pettigrew (2003) emphasised the importance of studying reality in flight, where contexts are ever changing and should be considered as an active part of the collection and analysis process, meaning current behaviour should therefore be considered in the context of its historical antecedents. Reconstructing historical contexts, processes and decisions in order to discover patterns and find the underlying mechanisms is discussed by Green et al. (2009) as a way of combining inductive searching with deductive reasoning, essential when fulfilling the grounded theory methodology.

Researchers adopting grounded theory, however, must be conscious of the starting point of the project, i.e. generating theory from an initial idea or data-set appropriate to the area of investigation, then further elaborated and modified as incoming data is 'meticulously played against them' (Strauss and Corbin, 1994). Some discuss the use of existing literature or data to generate a research pathway is not true to the classic grounded theory approach – preunderstanding can lead to a warped sense of reality, a biased view of a context before any investigation can reveal otherwise. Yet in this specific research case, the exploratory study (BCU) allowed for further clarification of the specific research lens. Although this meant the project was not free from existing ideas, it follows true to Strauss' approach to grounded theory whereby "specific understandings from past experience and literature may…stimulate theoretical sensitivity" (Heath and Cowley, 2004). Sense-making through continual feedback discussions – both initially using the BCU data and going forward throughout further data collection – will aid the ongoing process of creating contextual understanding as the theories are revealed.

4.6.1 FOCUS OF INTERVIEW

Likening the process of interviews to that conducted with the BCE case, a semi-structured approach will be taken. Semi-structured interviews are of central importance to the adopted process, used not only to capture individual perspectives from a variety of opposing sources, but also as a flexible means of adapting to those points of interest that lead to diversions and development of thought. A clear, robust structure is required to ensure that data sets are comparable. Without the structure, the interviews will be no more than an individual's perspective and not the meaningful information necessary to develop a theory. The structure – defined prior to the first interview taking place (found in appendix E) –details both fixed questions to pointedly initiate the conversation around a specific area or thought, as well as further probing questions, that will enhance the narrative. For interviews to be successful, there must be a sense of security and neutrality between the participant and the interviewer (Giovannoli, 2000), which can be cultivated using these secondary questions.

The interview structure takes into account the relative learning from the precedent case study yet differs simply because the subjects are not part of the AEC capital team, but the operational AM team, and therefore do not utilise the RIBA process of development (which was the basis for the previous study's interview questions). Instead, the interview will attempt to satisfy each of the three objectives, breaking down the fixed questions into three distinct parts. It should be noted, however, that attempts will be made to make the conversation seamless, and not communicate the move from one objective area to the next, to maintain the natural fluidity of question posing and answering. The first set of questions aim to understand the existing state – how the individual uses information, where it is stored and how it is shared with colleagues. The second part will then investigate the individual's interaction with external stakeholders; with the final section aiming to understand how the individual approaches growth and learning. To further understand the synergies of information management, the four dimensions – People, Process, Technologies, and Channels – will be used to probe the subjects' initial responses, gaining further details into the reasoning behind their personal narrative as it was "lived, felt, undergone, made sense of and accomplished" (Schultze and Avital, 2011).

An example of this is as follows. The core structured question will be **"what is your role within the university?"**, whilst the secondary probing questions will be:

People	Please could you summarise your position in terms of the overall University hierarchy?
	Who do you directly work with on a daily basis?
	Who do you report to?
Process	What are your typical daily tasks?
	Could you explain how you go about completing XXX task?
	What is the output of XXX task, in terms of work delivered and handed over?
	How do you confirm that a task is complete?
Technology	What tools do you use to complete your daily tasks?
	Do these tools help or hinder you to complete your tasks? Why?
Channel	How do you log your daily completed tasks with your superiors?
	How do you share your successes and failures for each task?

The development of each core question and subsequent probing questions has been directly influenced by the BCU case work, the responses given, and the gaps in areas specific to the ongoing management of information.

It must be noted that interviews can be timely to conduct, especially considering that time is critical in HE asset management, the sector within which these interviews will take place. —. As a means of ensuring that the full scope is covered, both across objectives and in terms of the four dimensions, it is the intention to conduct a single interview with each participant. If said interview does not successfully capture the required data, supplementary interviews will then be organised.

The researcher is aware that it is not always easy to articulate the true meaning through a singular conversation, as some interviewees may 'find it difficult to stay in an appreciative mode and tend to drift toward a problem-solving mode' (Schultze and Avital, 2011). For that reason, informal interactions, observations and collated documentation will act as secondary collection methods, providing additional depth and aiding the generation of rich data sets from each subject. It is the hope that the how, the why, the when and the who will all be discovered through the interview process.

Acknowledging that a significant volume of data will be generated throughout the collection process, it is the intention to use analytical memos as a way of tracking thoughts and reactions of the researcher. After each key stage – as detailed in figure 4.3 – a memo will be created as a means of summarising the activities and emerging themes. The existence of these memos will be specifically beneficial during the analysis process, especially where the context or true meaning may not be clear. The memos will be a touch point for the researcher to allow the focus of the research to remain true. Although the data is intended to be collected in response to a set of pre-determined objectives, it is also understood that the exact data will be generated as a part of an unfolding piece of research.

4.6.2 SAMPLE

As of August 2017, there were one hundred and sixty-seven HE institutions operating in the United Kingdom (HESA, 2017). One of the main challenges of working within this sector is attempting to incorporate data from this volume, where each institution has its own individual population of both staff and students, without overloading the project in data analysis. Interpretivist approaches to research can conduct their data collection with a sample of one. However, because the phenomenon is relatively untested, more than three universities will be needed to gauge an in-depth understanding of the pluralistic nature of their organisational contexts, and the strategy by which they manage and maintain their built assets.

Putting the sector in context of the problem, a key strategy when selecting institutions was to focus on universities that had a prior awareness of Information Management processes. Faithful+Gould, as a multidisciplinary construction consultancy, have pre-existing contacts within the HE sector – having offered expertise for capital projects and guidance for ongoing Strategic Asset Management. The project therefore utilises these existing relationships to collect primary data, basing the selection process on opportunity sampling. Table 4.2 describes those higher education institutions chosen as subjects for this study, including details as to their contextual relationship, relative structure, and existing state of their IM awareness; factors that will be used within the comparative analysis of their data. Care was taken to select specific universities that offered an individual take on the management of asset information, whilst also having a characteristic that was comparable. In other words, the full spectrum of campus-to-city university was incorporated, as well as the relative understanding of IM strategies. For example, University 1 offers insight into an institution that has an academic awareness of IM, but not a practical awareness within their AM department, whilst University 3 provided insight into an IM approach that has been developed and used for several years. It must be stated that the number of university subjects is intended to allow for full thematic saturation to be achieved, yet further universities may be required if this is not achieved.

	University 1	*University 2*	*University 3*	*University 4*
Approx. Student Population	15,000	22,000	25,000	26,000
Historical / Modern	Historical – est. 1926.	Historical – est. 1876.	Modern – ‘uni’ status 1992.	Modern – ‘uni’ status 1992.
Campus / City.	Campus	City	City	Campus
Asset Management Capability	In-house direct labour organisation.	In-house direct labour organisation.	Externally contracted direct labour organisation.	In-house direct labour organisation.
Information Management Adoption	• Academic IM awareness high. • Drive to adopt IM strategies low. • Non-relational database management.	• ‘CAD’ standards in use for 5+ yrs. • CAFM used. • Developing IM adoption standards. • Trialling Soft Landings.	• Developing advanced IM strategies for all capital works. • Employer’s Information Requirements documentation. • Aligned with NRM and SFG20.	• Adopting IM for CAPEX; exploring IM for OPEX. • Intention to use 3D geometry for management. • Dedicated IM team.

Table 4.2 – University Subject Overview

With regards to selecting specific subjects for interview, the direct connection through Faithful+Gould is either a single member or couple of members of each university. The connection with the initial subject will then be used to gain access to further members of the same university.

The responsibilities of an asset manager incorporate a wide range of functions and tasks, including but not limiting to: ‘long-range facility planning’; financial forecasting and management; real estate acquisition and/or disposal; interior space planning; architectural and engineering works; security and administration services; and maintenance and operations (Golafshani, 2003). There is no set descriptor for how to categorise these functions into specific roles, with each higher education institution taking a different approach and making use of differing naming classifications. In other words, no two universities have the exact same role and responsibilities structure. As a means of simplifying the point of comparison, literature has been used to identify five core areas of interest, with the specific names of the role being defined as follows:

- Information/CAD Manager:

  working with the creation and structuring of drawings/models/databases.

- Capital Projects Team:

  a member of the estates team who works directly with the external capital team to deliver projects from a 'maintenance' perspective.

- Hard Services *Manager*:

  more focused on the ongoing management and maintenance of the physical assets.

- Soft Services Manager:

  someone focusing on the people-based tasks of the university, i.e. security, cleaning, space organisation.

- Maintenance technician:

  a member of the 'direct labour organisation' – someone who daily manages and completes tasks related to maintenance; will spend core time on site rather than in an office environment.

It is the intention to compare these roles both internally within a single university – how the members in management roles perceive the use of information compared to those working out on site – as well as then across the selected universities. The vertical and horizontal comparison will lead to a more thorough understanding of the patterns of use and potential areas of change and development; points by which a theory may be developed.

	University 1	**University 2**	**University 3**	**University 4**
Information/CAD Manager.	Participant 1. D.	Participant 2. A.	Participant 3. A.	Participant 4. A.
Capital Projects Team.	Participant 1. C.	Participant 2. G.	Participant 3. B.	Participant 4. C.
Hard Services.	Participant 1. A.	Participant 2.D. Participant 2. C.		Participant 4. B.
Soft Services.	Participant 1. E.	Participant 2. B.		Participant 4. D.
Maintenance Technician.	Participant 1. B.	Participant 2.E. Participant 2. F.		Participant 4. E

Table 4.3 Interview Participant Selection

It should be noted that University 3 does not have a committed ‘in-house’ asset management department beyond the capital projects team, and instead exports its main asset management responsibilities through external contracts. The structure of University 2 led to the connection of two subjects who are ‘Hard Services Managers’ and two subjects who are ‘Maintenance Technicians’. It should also be noted that prior to the interview, an information sheet and consent form was given to each subject, providing them with a full explanation of the purpose and objectives of the discussion, as well as the awareness that they could withdraw their involvement from the project at any time. Both documents can be found in the appendices of this document.

4.7 SUMMARY

This chapter has provided a review of an exploratory case study, initially aiming to identify the issues and known criticisms of information modelling within a project environment; developing these learnings into an understanding of the four dimensions PPTC. Knowledge gained from this study was then used to redefine the process of data collection and analysis going forward, used to fully investigate the unique phenomenon of advanced information management strategies within the ongoing maintenance and management of built assets.

Chapter 5 will discuss the analysis about each of the three objectives, speaking generally about the commonalities from each participant, commenting more specifically on how the views differ when comparing university case type and role of the participant. Chapter 6 will then develop this learning further by analysing the data with respect to the four dimensions – *PPTC* – using the core outcomes as a route to creating a theoretical framework for advanced, whole-lifecycle management of asset information. It will also include a validation phase, introducing a fifth university to ensure the findings correlate for other HE institutions. The framework will then be discussed with regards to its practical application and its potential commercialisation in chapter 7.

CHAPTER 5 ANALYSIS PHASE 1

5.1 INTRODUCTION

In response to the learning gathered through the initial review of literature and exploratory case study, a protocol for collecting qualitative data was devised. A total of 19 semi-structured interviews were conducted, with the average time of each interview being approximately 1hour 45minutes – in other words, 437 pages worth of qualitative data, all of which was then put through systematic stages of initial word counts, focused coding and thematic analysis. A brief description of the analysis process will be given, defining a selection of the codes and consequential categories found. Following that is commentary relating to the first phase of analysis – itemising the content against the three individual objectives: the first attempting to discover areas where the subjects create information waste; the second exploring the collaborative process with external stakeholders; with the final stage aiming to gauge how iterative knowledge creation and sharing may occur.

5.2 ANALYSIS PROCESS

As was first discussed in chapter 3, a cyclical approach of analysis was used to discover the initial themes, itemising the qualitative data into initial codes. Table 5.1 illustrates a small selection of the codes discovered during this initial stage, providing a brief explanation as to the relative understanding of each code. What should be noted is that with the first set of interviews – University 1's subjects – an initial word count was taken. Although effective in providing a broad understanding of the content in terms of the subject's contextual narrative, the process did not provide clarity of meaning that could not then be discovered in the initial coding stage; it was therefore discounted from the process and the word count tallies disregarded.

Coding the Data

A clear starting point when attacking the coding process was to reacquaint oneself with the interview. By re-listening to the interview recording, whilst simultaneously using a paper-version of the transcript to annotate, continuity between initial memo taking and the first iteration of coding can be achieved. Although some may deem this process redundant, when attempting to deal with the volume of raw data as was the case with this research, it is useful to create stepping-stone points of reference as a means of guiding the iterations whilst maintaining clarity of thought.

The programme NVivo was used as the primary tool to codify and categorise the data. A simplistic software that allowed for several iterations, NVivo was beneficial at storing the digital analysis in a succinct and proficient manner. Analytical memos written after each interview took place, and then again after each consecutive stage of coding, were used to maintain consistency between iterations – in other words, commentary such as '*subject's focus leaning towards the duplication of information – explore the context of duplication and if any other factors responsible for this narrative*' would aid the next iteration of coding, ensuring that a clear process of analysis could be followed when contending with such high volume of qualitative data.

Code	**Relative Understanding of Code**
Access	Discussion over how technology allows access to information.
Accuracy	Discussion relating to the process for assuring accuracy of information.
Capital Projects	Discussion relating to the interaction of the participant with said capital projects; whether they give or receive feedback and have a direct relationship with the development process.
Change	Discussion relating to the method by which information changes are made.
Chasing	Discussions about occasions when the participant has had to seek out information or chase persons for incomplete information, and how they may have gone about said chase.
Feedback	Discussions regarding the cycle of verbal information in terms of gathering lessons learned and reviewing work performance.
Risk	Discussion relating to inherent risks known or managed by the participant: including how that risk may be mitigated.
Roles and Responsibilities	Discussion relating to the participant's role within the university: description of their tasks; responsibilities; contextual relationships with others; influencing factors etc.
Student Experience	When the participant directly refers to the wider student experience.
Training	Discussion relating to any training or development that the participant may or may not have had, to allow them to complete their tasks.

Table 5.1 Thematic Coding Examples

Aiming to code the complete transcript into a theme or thought bracket, the above codes were a sample of those that appeared more than once within a single transcript. During the first iteration, the description of the code was given more detail that directly related to the wider context of discussion, i.e. *roles and responsibilities* would be supplemented with "*out of remit*" or *"would like more trust"*.

This then aided the secondary iteration where the codes were simplified, as a process of identifying those themes that had the strongest route through the data.

Categorisation

During the design of this research project, it was made clear that there was a requirement for a strict protocol of questions, broken down into core question sections that would attempt to tackle each of the three objectives. This was crucial for the success of the categorisation stage, and without it, confusion would quickly have been experienced. Within each of the core question sets did there appear several key categories, as illustrated in table 5.2.

Objective	Category	Generic Meaning
1	*Roles*	Where discussions related to the specific roles of participant or colleagues, as well as the inherent responsibilities of said role. Discussion could be either positive or negative.
	Timeliness	Discussion held around the concept of time, whether the processes where completed on time, or there was a delay, and the complications that were felt in response to delay.
	Accuracy	Understanding the accuracy of the information as it was shared and exchanged.
	Missing	Discovering the information was incomplete and the inherent disruption this then caused the success of business.
	Duplication	Where trust was lacking, duplications were used as a buffer and security protocol.
2	*Effectiveness of Handover*	Those factors that meant work could being as soon as handover was completed.
	Efficiency of Handover	Those factors that delayed the completion of handover.
3	*Type of Lesson*	Understanding the various types of lessons, captured by each participant and wider group.
	Communicating Lesson	Exploring the means by which lessons could be explored.
	Cycle of Learning	Suggestions for the change in culture: accessing lessons, using them to develop processes and practices.

Table 5.2 Categorised Objectives

From the above categories, it can be seen that the general reaction to the subject matter of whole-life information management was one of ‘there needs to be more done’. Whether that stemmed from an overtly positive remark or simply a criticism against the existing pattern of completed work, there was a strong desire from all to keep pushing and developing the strategies by which they conducted their day-to-day roles within their university.

5.3 OBJECTIVE 1 FINDINGS

The following discussion shall explore the findings of the thematic coding and categorisation of the raw data, gathered about the topic of the first objective.

5.3.1 CURRENT DEFINITION OF INFORMATION WASTE

The first objective – *where does waste occur in the existing model of information transfer* – aimed at understanding how asset managers created, interacted with, shared and stored information relating to their daily tasks and everyday role. The idea of information waste in construction projects is not new, with researchers such as C. Dubler posing a study surrounded the concept of waste in 2011, where eight core areas of waste were explored: *overproduction; inventory; extra processing steps; motion; defects; waiting; transportation; and intellect* (Dubler, 2011).

Table 5.3 illustrates these categories and their associated description and waste ‘cost’ – which is not monetary but resource. Focusing the analysis on the construction phase of a project’s lifecycle, it should be noted that the stakeholders creating said waste were contractors and design specialists, all of whom have a greater technical awareness of information, i.e. their relative understanding of how information is structured and formatted is specialised. This differs to the subjects of this research, where the asset managers had a basic understanding of information, with the majority of said information being non-graphical.

Lean Waste Category	IE Waste Description	Cost of IE Waste
Overproduction	More information than required by users. Early delivery of information	Resources necessary to overcome excessive or early information
Inventory	Information that is requested, but never received. Push instead of Pull – take what is given approach.	Activities required to produce information requested (waiting if not able to produce).
Extra Processing Steps	Information that is under-designed or under-engineered.	Tasks necessary to overcome unfinished processing of data.
Motion	More file transfers than necessary. Not placing the model in a common location.	Activities associated with excessive file transfers and information not shared (waiting if not complete).
Defects	Incorrect/unclear information.	Resources necessary to correct or verify information and unnecessary activities that result from its use.
Waiting	Late delivery of time sensitive information.	Activities that are required to re-sequence tasks to allow for work to flow.
Transportation	Inoperable hand-off of information. Improper sequence of information exchange.	Steps taken to convert information into usable format.

Table 5.3 Information Exchange Waste Taxonomy (Dubler, 2011).

That being said, there is some correlation between the ideas of waste found in this research and that of Dubler's. Waste, in the context of asset information management can be broken down into five parts: waste pertaining to an individual's *role*; waste through *untimely* access to information; waste through poor information *accuracy*; waste from *missing* information; and waste through the *duplication* of information. Each dimension of waste will now be explored.

5.3.2 UNDERSTANDING 'ROLES'

The role of an asset manager encompasses a whole array of tasks, ranging from maintaining and repairing physical structures and mechanical engineering, through to the cleaning of public service spaces. As a working entity within a university, they can be described as the 'hidden figures', with one technician commenting that:

> *"It's hard to tell the successes because we tend to be defined by the failures." (Maintenance Technician)*

Quite a substantial number of the work force have been in the role for a number of years, meaning they are not only integral to the successful running of the department, but also that they can be said as being 'fixed' in their ways – their inherent daily processes.

> *"It's going to be a slow process. A lot of these guys have been there 20, 30 years, 20, 30 years older than me, half of them. But it is, so it is a slow process and it is trying to change that mentality of years will take time, but there is definitely a feeling that we are moving in the right direction." (Hard Services Manager)*

The demand of migrating away from traditional ways of working (i.e. with pen and paper and storing in A4 ring bound folders) is not only proving difficult for some, but the speed at which the skills are needed is often unattainable.

> *"…they've had to learn what computers do whilst they've been here, and it's trying to bring those people along with us at the same time as the people who are just, whizz whizz, know everything that they need to know and know how to share information on (shared system), which I'm afraid, I don't." (Hard Services Manager)*

Difficulties and frustration were often felt, not just from those nearing retirement, but many members of the asset management work force. It was left to those in managerial roles to create a strategy whereby those struggling would not be left behind and would instead be brought along at the same pace.

When attempting to modernise and introduce more advanced computer strategies within their departments, more than one subject made comment that a lack of trust in the new processes led to a delay in making the change.

> *"The only thing I find is that people probably only do it if it's an advantage to them." (Visual Information Manager)*

"…because the remit of my role is strange, do I have the power, if somebody doesn't do it, do I have the power to say, 'no you haven't done that properly, do it like that'. Because there are three of four teams within (AM department) who can produce drawings and I set the standard, but it is down to the department, to ensure that people are following procedures." (Visual Information Manager)

The secondary quote above – stated by someone responsible for introducing strategies for managing old and new asset information – makes it clear that there is often friction between teams in the way they individually approach standardised procedure; where one team would rather prioritise the information as per their specific need and not follow the mandated standard. This disregard for the departmental standards not only disrupts the consistency of information from one team to another, but it would also lead to potential discrepancies in accuracy and then cause there to be a potential need for rework.

In situations where there was an accepted use of digital management techniques, there then became an issue with trust. Working around the system to avoid work and make statements that it was complete, when that was not necessarily the case was seen as inconvenience. Whilst the use of digital tools enabled greater awareness of tasks and responsibilities, it also doubled the volume of auditing necessary to ensure the quality did not fall short.

"…we've got staff who you can trust, and you've got staff who potentially will just slap a plaster on something and walk away, so those people need to be audited more often than the people that we can trust, so it is a balance…" (Hard Services Manager)

"…one of my bugbears of the university really and obviously moves towards…being more collaborative…how do you measure what people are doing and how they're performing and are they doing what they need to do?" (Visual Information Manager)

There was a desire for a mechanism to be put in place, complementing the digital tool and works through said tool, that gave peace of mind to those in managerial positions, but also allowed those 'technicians' to feel comfortable enough to be truthful. Greater structure of time was suggested as a means to combat this issue. By suggesting a job took a certain amount of time – changing a light bulb for example would be allocated half an hour per bulb depending on the location – but then applying a buffer to said time allocation, like is commonly practised by project managers on construction sites. Applying this strategy, along with a reward procedure for quick completion of jobs, was suggested as being potential for combatting the pressure of and information-centric digital tool for management.

A final thought that was repeated by a number of participants, was the added responsibility for checking: checking the information to ensure that it was firstly there, but also that it was in a state of preservation. The added bonus of having all information in one place – whether that be a CAFM system or a shared drive for storage – did however, have the knock-on effect that there was a newly appointed responsibility to keep the information 'live' and up-to-date.

> *"…responsibility of making sure the data is up, is reviewed and updated on a regular basis…probably hasn't been done for two or three years." (Hard Services Manager)*

When this process fell short, those responsible for the information had to either incorporate an element of interpretation, or simply manually repeat the work - an inefficient process that required a structured approach.

5.3.3 UNDERSTANDING 'TIMELINESS'

When it comes to the management of existing building stock, especially those often found in a university's portfolio, one ongoing challenge is to maintain the assets to a certain level of performance. This is made even more complex when the assets in question are historically relevant, as is the case with a number of the university cases.

> *"We've got a huge group of very old estate, but we had a period…where we had basically no forward planning whatsoever, and no backlog maintenance, so it was literally, there were all these complaints coming in about bad reactive maintenance. There was no preventative maintenance done, there was no service maintenance done, there was no forward planning, and there was no backlog maintenance carried out at all, and so unfortunately an already old deteriorating estate became even older and more deteriorating and we're in a position now where we need millions…" (Hard Services Manager)*

Monitoring the condition of each asset, as well as contending with the vast number of reactional maintenance requests can quickly lead to a backlog, which not only causes frustration for all that inhabit or manage said asset, but also effects the successful pre-planning of future preventative maintenance. When the principles for managing all the information pertaining to an aging asset rely on historical folders and paper, the timely recognition and allocation of resources is even more essential. In some cases, technicians have resorted to jotting down details on separate bits of paper, so that they may attend a reactive maintenance call, without being restricted by a folder hunt.

"…would write it down somewhere and then when I have (the) update, either chase it up with the person involved or I might just go and make some modifications to the asset register or the tasks and just have it in there." (Maintenance Technician)

Yet, in cases where the information is ready to use, in a digital format, timeliness is still a prevailing cause of frustration:

"If you pushed a button and said, tell me what's outstanding, you wouldn't actually get an accurate picture because we do have a time lag…" (Maintenance Technician).

Especially when considering the time critical maintenance that is legally required to take place at pre-set intervals, such as annual tests to lifts:

"There are about 80 outstanding annual tests for the lifts, they've been done, they were done in March, April and May…it takes them a long time to compile the reports and send them back to us. But until that happens, I'm not ticking off to say they've been done." (Maintenance Technician)

Relying upon external specialists to compile and hand-over the necessary reports so that the internal systems may be updated, and regular maintenance scheduling resumed, often leads to a delay. Pre-determined protocols for requesting and receiving information such as reports, or certificates are seemingly lacking from most of the university cases.

"…a bit chicken and egg…of sort of knowing what you want from (the process) and then having to ask people to give you that information. It's all a bit up in the air and sometimes vague." (Visual Information Manager)

Clear demands need to be set for timeliness to stop being a disruptive issue for asset managers.

Often within the university environment, the asset managers are dictated to by building managers and academics, especially when the preventative or reactive maintenance has the potential for disrupting teaching time.

"…sometimes the building will come back and ask for active hours working but that can be quite a substantial cost in what we're doing. We normally get there…it rarely stops something from happening altogether, but it can delay it." (Maintenance Technician)

Alternatively, schools will have capital works completed by an external team and not inform the asset managers. Without prior knowledge of these changes and amendments, the information quickly becomes outdated, therefore thwarting the efficiency of the technicians to conduct their jobs.

"One of the project managers will either find out that the project's happened and we weren't told, so we'll go and chase them for (the information) and that can be any one of…us in our team…" (Capital Projects)

In either case, the commonality was for the need to chase. If the asset managers knew of the works, they still had a number of examples of when they were required to go and seek out the person responsible for the change, to obtain the up-to-date information; or they would have comments regarding the specifics of the change and not have time to request confirmation. Suggestions were made for the responsibility for the auditing of the information to be given to an external resource, which would free up time for them to concentrate on other more pressing matters.

"We haven't got time internally to go and sit and do an information audit on a model, but if we're paying somebody else to do it then we've got the resource." (Capital Projects)

Yet if external resources are successfully to be used to reduce the time lag, strict processes will need to be mandated to not be left searching for information in another time delay.

5.3.4 UNDERSTANDING 'ACCURACY'

Working with external contractors is a positive activity for many; however, for those participants using CAFM systems, there were frequent inconsistencies in terms of the accuracy of the contractor's information:

"…some of our contractors can actually go in through an external link and close down their own jobs, but we still have to do checks and things on that to make sure they're not just making it up." (Maintenance Technician)

This then meant that mechanisms had to be put in place to check and audit the contractor's work to ensure adherence to the university's quality control measures. Participant's pre-existing experiential understanding of said potential inconsistencies here enabled the checks to be conducted quickly and coherently, yet still adding additional loading to the technician's already overloaded schedule.

"…periodically do a kind of, right it's 50 jobs they say they've done, lets spot check some of those to see have we actually got the records for them?" (Maintenance Technician)

"When we have big new buildings, the project manager will often employ a third party to go and do the asset survey and do the barcoding. And then I'll get that as a spreadsheet or they might…input it directly into (CAFM system), but I will need to go and check that." (Maintenance Technician)

Systematic checking is essential but timely, yet it can be simplified through the use of smart-barcodes. A couple of the universities had already adopted the barcoding of assets, one with distinct success, the other with significant failure:

> *"…because (CAFM system) is constantly being updated with new information, new jobs get issued, jobs get completed, as soon as you run a report it's out of date." (Maintenance Technician)*

Combining the continual refreshing of asset registry data, the barcode machines were soon forgotten and consequentially left to gather dust.

A common issue found by a number of the universities, at both technician and managerial level, was a lessening of accuracy if the originator of piece of information was unfamiliar with the content of said information registry, i.e. they were not familiar with the asset, or they were not familiar with the maintenance requirements.

> *"…I've got standard abbreviations I'll use, but sometimes I forget what I've used and come up with something else." (Maintenance Technician)*

> *"…it's often done by a spreadsheet by an admin person who doesn't understand what it is they're doing, and they can't check the information to check its accuracy." (Visual Information Manager)*

Similarly, when the records went through a process of updating – commonly when moving from paper to digital – the accuracy of said information was not checked, meaning participants frequently came across inaccurate documentation or drawings.

> *"…about 10, 15 years ago probably, they had all the drawings on paper and they did a mass job of CAD'ing them all up, which was great, but they scanned in all the paper drawings, they then traced over the top, but some were warped through the scanning process, so they weren't really accurate. They did no measured checks." (Visual Information Manager)*

> *"Unless you go around, and you walk the whole building, or you do a proper accurate measured survey with…all your asset that are in there, unless you do that, you're not going to know; and then you've got to keep that information up to date." (Visual Information Manager)*

By simply walking around the built asset, the managerial participants felt that quick access and understanding could be gained, reducing the requirement for re-work and increasing the accuracy of the information. Again, experiential knowledge here proved to be greatly advantageous, and begs the question of how to capture these 'best-practice' processes, if and when the participant was to move on.

One final point of interest within this category was the idea of supervision, not in terms of supervising the lower levels during their day-to-day roles but supervising that the work done is as specified and then translated into information as required.

> *"…they should be doing that for more, not so formally but they should be supervising the actual operatives and making sure that they're doing the right job, and it's done right first time, and it's obviously to a standard." (Hard Services Manager)*

Reducing the wasteful re-working caused by inaccurate information would vastly alter the day-to-day ability of asset managers to maintain their asset portfolio.

5.3.5 UNDERSTANDING 'MISSING'

As previously mentioned, maintaining the condition of the HE's built assets is vitally important; outwardly displaying the university as being of good quality and therefore a sought-after place to study. Conditional surveys are therefore key in the continual quantification of the asset's condition, with regular review of the assets being required at all universities. Yet conditional surveys are often the site for missing information.

> *"Occasionally there are gaps in the condition information we hold, and…that can compromise our ability to prioritise repairs…" (Hard Services Manager)*

Where information is missing, activities are thwarted, and the efficiency of the management programme is significantly affected. One visual information manager had spent some time attempting to combat this problem, not only with conditional surveys, but also when receiving information from design teams.

> *"For me, it's about being clear about what information should be expected… (the designers) are not very good at telling us." (Visual Information Manager)*

A clear protocol for asset information, as well as the parameters by which they should be created, should be a key starting point for all HE AM teams. If a clearly defined handover strategy was utilised, examples such as that which follows would not take place:

> *"…the length of time things can take, say a boiler replacement, it could be a really minor thing but if I don't get the information that a boiler has been replaced with a new commissioning certificate I can't update our…so we'll have a task, we're going to service*

> *that boiler, and we'll either go far too early because we don't know it's a new boiler, and that's a wasted trip because we'll come back saying 'oh it's only been in there 30 days'; or potentially we miss the date altogether…then two years down the line – oh do we have a safety certificate for this boiler? What boiler?" (Maintenance Technician)*

This particular technician had numerous examples of missing information, and the counterintuitive reaction from their colleagues in terms of attempting to maintain and review said assets. As a route to trying to solve this issue, processes for the use of the university's adopted CAFM system were altered, incorporating a fail-safe check that highlighted and reminded when information was missing. However, there came another issue when said CAFM system's security was changed, meaning the required access was not granted to the necessary personnel.

> *"…it might be useful to see it, it might be on (CAFM system) but (CAFM system) access is limited so there aren't as many people who can modify asset records and they can't even see the option. If you don't have it, you can't even see you don't have it." (Maintenance Technician)*

This is unfortunately a regular issue, where a technician attempts to reduce the causal effect of missing information, and a manager unfortunately introduces a conflicting change. Communication is critical to the successful use of information across each phase of the lifecycle - no matter what your role or responsibility.

Shared information repositories were found as being the quick move from paper-based processes, to digital-based processes. However, all parties need to be accepting of the shared repository, in order for it to be a successful change, especially when communicated and exchanging information with external contractors:

> *"We try to make sure people are sharing information through (shared system) on project sites, which we've sent the structure of and we're trying to be quite specific with where the stuff goes, so we can find it." (Visual Information Manager)*

However, one university discovered that their numbering system, through which jobs and maintenance procedures could be allocated, was still based upon the original paper directory, meaning the asset listings were not truly aligned. Without said alignment, details such as volume of maintenance required – both preventative and reactive – were missing.

> *"…at the moment, jobs come in against the building, so we'll have thousands of jobs against physics and a thousand jobs against medical school and they just come in against buildings, which is…when you're trying to analyse the data, it's very crude. We want to load the space,*

load the assets against the space and the jobs can be put against the assets..." (Hard Services Manager)

"I'd be absolutely convinced there are lots of things missing, but the trouble is we don't know what's missing." (Hard Services Manager)

The resounding commentary from all participants interviewed, was that information is frequently missing, for various reasons, yet the most frequently stated reason was a lack of clarity in process.

5.3.6 UNDERSTANDING 'DUPLICATION'

The final area within the concept of information waste, is duplication. There are multiple cases where participants could recall a situation where duplication of work had resulted in being unaware of the 'one-truth'.

"…the vast majority of jobs produce some form of paperwork, log, electronic paperwork, or hard copy…working off of a (CAFM system) job sheet that is not stored on (shared system), so (CAFM system) will show that it's been finished but either there's no need to keep the paper copy, it gets destroyed, or it's held in a hard copy building file." (Maintenance Technician)

Even when attempts are made to consolidate historical information into a single repository – i.e. the scanning of printed documents to include them within a CAFM system – duplicates are still commonplace. The following is an example of when lack of trust in the original creation of the repository leads to the use of further paper, which was counterintuitive to the process of consolidation.

"…I don't believe the…version was written by someone who knew what was needed…there's so much that will need tweaking and double checking, and then you either end up with not enough bits of paper or you've got too many." (Maintenance Technician)

Lacking communication as to the location of specific information leads to frequent duplication, by both managers and technicians alike.

"I tried having it in one location on a shared drive, but a lot of people didn't find it, couldn't find it, whether they really looked for it or not is another thing…and then I had it on our website, which captures external and internal (information)." (Visual Information Manager)

Multiple locations for the same piece of information is a frequent cause for wasteful activities:

"…we use that (system) and I download information off that for projects, and then I've been using (a different system) to view the information, but I've also downloaded it in (a further different system) …" (Visual Information Manager);

"…everybody has read-write access to it and so you get duplicate folders, you get things that are filed in the wrong place, you get everybody saving the same document in different places and calling it something different. …There are no specific rules on how to use it." (Soft Services Manager);

"…I spend quite a lot of time each month reconciling (the information from) the two (systems), to make sure that we do capture all expenditure and that the information is consistent on (both)." (Hard Services Manager)

If the system in use had continuity with all other systems and repositories, there would not be an inherent need for the duplication of certain files. Yet it is recognised that the processes by which information is created within HE AM teams is going through a constant cycle of review and change. Multiple participants made it clear that moving from paper to digital was a successful process, and then from a multiple repository system to one that held all available asset information. However, there is still a desire for the tools to be able to adapt and evolve further.

"the (AM system) …I would like it to be an evolving thing where we can just take a snapshot of it and it's up to date, as opposed to having to backfill and make sure it's up to date each year…so there isn't then that operation of maintaining the (information), it's done automatically." (Visual Information Manager)

If design and construction information is going to really become useful throughout the complete lifecycle of an asset, there needs to be work done to coordinate the method of storage and access for all internal and external personnel.

5.4 OBJECTIVE 2 FINDINGS

The following discussion shall explore the findings of the thematic coding and categorisation of the raw data, gathered about the topic of the second objective.

5.4.1 EXISTING PROJECT DELIVERY LIFECYCLE

In section 2.2.1 of this thesis, a review was undertaken to assess the variability across project delivery lifecycles. Six standards were examined (OGC Gateway Review, 2007; BS ISO 22263 Organisation of information about construction works, 2008; BSRIA Building Services Job Handbook, 2009; ACE Work Stage, 2009; BS ISO 15686-10 Buildings and constructed assets - Service Life Planning, 2010; RIBA Plan of Work, 2013), commenting that not a single one offered an end-to-end complete programme of works, especially when considering the flow of information from original conception through to the point of change. There was a distinct disparate nature across the six processes, with capital works and operational works often conflicting. As the intention of this thesis is to understand the patterns by which asset information is created and used, it is very important that the process of handover be examined.

During the analysis and coding process, two key categories became evident: the effectiveness of handover and the efficiency of handover, i.e. the preparation for handover, and the timeliness of handover respectively. These factors will now be discussed.

5.4.2 EFFECTIVENESS OF HANDOVER

In all major construction works, the lead up to practical completion and handover can be quite a fraught period. However, from the AM's perspective, it is what happens next that holds more weight. Project teams set out to deliver not only a fully operational built asset, but also all the associated asset information. That may be a ring binder of documents (as is the traditional way), a CD of drawings and commissioning documentation, or a fully 3-dimensional working model of said built asset (as was presented during the BCU development, in chapter 4), setting up for operation is key for the initial success of the asset.

When approaching key decision points throughout the development process (i.e. through concept and into detailed design), some participants made it known that they sought out the end-stage presentation, as an early way of alerting them to what is being intended for construction.

“(At the end of stages 2 and 3) …I’ll go the presentations, I get the end stage pack as well, which is a volume of stuff. So, I will go through it all and provide my feedback and make sure that what is in there now is what was originally requested.” (Soft Services Manager)

This approach to up-coming handover stages allows for greater awareness to be gained, offering an opportunity to provide commentary on the project in terms of furniture they should avoid or location of engineering spaces for ease of access. Many of the participants stated that, if they were given more of an opportunity to become involved in the earlier stages of development, they would welcome it.

Capital project works are an opportune moment for all outstanding maintenance items to be highlighted and combatted. One university, for example, was undertaking a large series of works on two of their key buildings, both of which were in a state of disrepair from inconsistent management of conditional surveys.

“It's certainly my intention that the refurbishment of the library, for example, sweeps up any backup maintenance on the library, so that when the building's fully refurbished and refurbishment’s complete, there is no maintenance liability for us.” (Hard Services Manager)

Refreshing and revitalising existing assets is often a costly process to conduct. However, if said works allow for the asset to have a renewed lease of life and consolidating pre-existing issues, then it is said to be very much worthwhile. Refurbishments are also an opportunity to renew the asset information, allowing the managers to reprioritise the operational works going forward. Yet, with new build projects, the asset information is being created from scratch, putting added pressure on the handover stage, ensuring that the asset managers do indeed have all information ready. A consistent cause of frustration for all managers attempting to plan works post-handover is the lack of preparation in terms of the asset registry.

“…what would be great is if for example when we get the room data sheets, I don’t need every room data sheet, but I need some.” (Soft Services Manager)

Having access to a simple piece of information, such as the room data sheet, would enable the soft services to be pre-planned and the personnel trained, allowing for a smoother transition into operation.

Another issue commonly spoken about in relation to handover was the creation of the set of ‘as-built’ drawings. There were cases spoken about where the accuracy of said drawings were so incorrect that entire walls had moved:

"…we just got dumped with a load of information without any proper demonstration that they'd gone through their own validation process, to the point where you'd physically look on site and walls weren't where they should be, so they weren't, all they were doing is the old traditional approach of just rebadging construction drawings as 'as-built'." (Capital Projects)

As a means of reducing the risk of discovering these types of drastic inconsistencies, participants had taken to walking around site, before it was completed, taking photographs of the key assets and their locations. Such foresight not only meant they had an existing idea of what the asset would look like at handover, but it also offered an opportunity to create rudimentary asset information registries so that compulsory maintenance could begin immediately.

"…I just take my phone with me and photograph everything…I put the label on and take a picture of it, then come back and manually create those assets, or the vast majority are manually created…" (Maintenance Technician)

Working off blank records and using their own knowledge to create an asset registry was offered as a quick solution to what could potentially be a vastly detrimental mistake by the handover team.

Higher education asset managers must contend with the added pressure of academic term times. Put in terms of a closing construction project, the handover timeline is usually so finite, that the AMs must simply accept the asset as is:

"We tend to compromise, because of the pressures of us wanting to take the building and needing to have an operational facility for the start of term." (Capital Projects)

If asset managers were given the opportunity to visit and tour the asset, prior to practical completion, preparatory works could begin that would not only ease the transitionary period, but significantly improve the effectiveness of handover.

5.4.3 EFFICIENCY OF HANDOVER

It was mentioned briefly above the tight time constraints that HE institutions must contend with when constructing or refurbishing their assets. This pressure was also known in terms of the handover of the information:

"(have to request further information) all the time, because it's just not there or the level of detail…I think it's probably the scale and complexity of the projects we do…when you're either refurbishing a hundred year old building which is grade II listed, that's an issue in

itself, or when you're creating a new building which no one has done before because it's all about cutting edge research, so there's no template that you can rely on." (Soft Services Manager)

"…our duty manager comes in and says…there's no electronic communication to say officially this has happened or this is where we are with the handover status here." (Maintenance Technician)

Situations like that above, where communication between the project teams and the asset management teams restricts the successful handover of a built asset are frustrating for many reasons. Understanding that certain pieces of information may be delayed due to commissioning delays is something that regularly occurs and is manageable, yet when the actual date of handover is unreasonably moved or changed is an inconvenience unwanted by, HE AM.

Timeliness is not only an issue during the day-to-day management of an asset, it is also critical to handover, with most of the participants commenting that they had experienced delay in receiving asset information.

"…it can be months before an O&M manual actually surfaces because they have to finish compiling it and then get it in the right format, and so it can be a long time before I actually finally see it, and then I have to look through it and go, oh we should have been doing X, Y, Z for the last three months and we haven't." (Maintenance Technician)

In cases such as this, a simplified version of the asset registry, if given at the time of handover (or before) would mean that compulsory and operationally critical items of maintenance could be undertaken, even while the closing commissioning period was still taking place.

It was also the case that when the information was eventually given to the asset management team, various details were incorrect, causing the AM to have to conduct essential surveying in order for their CAFM systems to be accurate.

"…then we had comments at the end, so we could say… 'does this just need a quick update, do we need to chase up the project information, or is this just a complete nightmare and we need to basically go and resurvey it." (Visual Information Manager)

On the whole, the process of handover needs drastically to be changed, considering the needs of the asset manager, pre-empting their ability to operate the asset from day one. Only if the time is given to AM shall they be able to advance practices and reduce lifecycle costs.

> *"In terms of hand back and handover it's a bit more complex…it doesn't come at one time or when you want it, you must fight to get it, and it does come in…segments. The handback part of it could be a lot smoother certainly." (Soft Services Manager)*

> *"…the handover needs to be something that you discuss, maybe not at concept initiation but pretty shortly after that." (Soft Services Manager)*

5.5 OBJECTIVE 3 FINDINGS

The following discussion shall explore the findings of the thematic coding and categorisation of the raw data gathered about the topic of the third objective.

5.5.1 THE 'SOFT LANDING' THEORY

The theory of a 'soft landing' is a concept first developed by BSRIA, where the incorporation of knowledge in the development of design may lead to a built asset that not only fits the brief but is also energy efficient and sustainable to manage. The development of the Government Soft Landings Strategy (2011), aimed at improving the transition between construction and operation, would indicate that the solution to cost and carbon reduction goes far beyond process automation. An important aspect of the Soft Landings Strategy is 'clearly defined information requirements' achieved through early client engagement and collaboration throughout the project, contrary to traditional design and construction methodologies. Furthermore, this information needs to be managed effectively throughout the project lifecycle and it is increasingly expected that technology-enabled process improvement can deliver it. However, the knowledge and expertise to do this remains within the design and construction project team; more specifically, the knowledge and expertise associated with existing processes and practices to identify inefficiencies and reduce variability within them. Taking this ethos of 'starting with the end in mind', the next sections will evaluate the responses from HE asset managers, when questioned whether they capture lessons and feedback, and if they were given the opportunity to communicate them with AEC professionals.

5.5.2 TYPES OF LESSON

When questioned if they had had an opportunity to provide experiential knowledge at any stage of a project's development, most participants stated that they had not. Those that had were grateful for the chance to be involved in the decision-making process, with one participant stating a great success story was involving:

> *"…the cleaning operation's manager who has some very specific requirements for cleaning cupboards. We have a requirement for a…cupboard on each floor of every building, and this…needs that type of sink…that type of flooring, three shelves…" (Soft Services Manager)*

Being such an important item of knowledge to instruct the design teams with, it then went on to influence each construction project from then on, not only the large-scale new build projects, but also each and every refurbishment works, endeavouring to enhance the performance of the university's cleaning staff.

Unique pieces of experiential knowledge become critical when they relate to project altering decisions:

> *"because of a particular bespoke piece of equipment, there's only two or three manufacturers, and one of them has now been bought out by another company, so the amendment was simply, do we want this other company to be someone who supplies the service?" (Soft Services Manager)*

Although not often offered the chance to be involved with projects, this participant stated that by sharing this information with the project team, they felt as though they were party to the wider project. Ownership being referred to as a route to satisfaction, it was also made known that the types of lessons useful were not always given from the asset managers to the project team. In the case of the visual information manager below, a shared interest in a specific visualisation technique meant that learning was gained:

> *"…I ended up having to spend time and go onto LinkedIn, and somebody went 'yeah, send it to me, I'll (do that) for you." (Visual Information Manager)*

Seeking out help from beyond that which was next to them enhanced the participant's understanding, as well as providing satisfaction through collaborative working.

> *"Reputation is everything for universities now, it's absolutely pivotal to the student experience and I think the condition of our buildings, it's a huge part. You want, if you're*

doing a degree you want to come where that, somewhere that's welcoming, warm, light, don't you? Stimulating. I think the maintenance service has a big part in making sure that university's buildings are as pleasant as we can make them really, yeah." (Hard Services Manager)

The main thought one can take from this investigation is that asset managers have a desire to be brought into the conversation. Their work is crucial for the operational success of a HE institution, and, given the opportunity, would relish the chance to share and contribute in the wider HE community.

5.5.3 COMMUNICATING LESSONS

Thinking in terms of how said lessons are communicated, a case study review is often seen as a simplistic form of collating the information pertaining to a project, with most of the participants making it clear they have or would wish to be included in the review. The point to take forward, however, is the need for that study:

"…it's only as useful as the outcome, if you get the outcomes it's essential, if you don't then it's a waste of time." (Soft Services Manager)

It was stated on several occasions, that the maintenance teams were often overlooked, and when they were doing their jobs successfully, they'd be invisible. Saying that, there was a desire to find a way of communicating their successes as well as the failures, highlighting the 'good news' stories to the wider university and beyond to other universities. Maintaining usability, however, was key:

"…I had an interview…with a guy going through the whole thing and what we got out of it, what we didn't, how we'd have done things differently…it was very useful until the point where the report didn't get published." (Soft Services Manager)

Understanding the context through which the lesson and feedback shall be given was another factor that many commented on, with contrasting approaches needed for students, staff and the university governing body.

"If it's an executive group they want very short, sharp information sharing rather than a detailed review so I never try to present to a group like that for anything more than five minutes on lessons learned. Whereas a new design team you'd probably spend a good hour on what we've learned from these previous projects, just so they can appreciate and understand the issues." (Capital Projects)

Generally speaking, the question was not if they should be given the chance to offer feedback and lessons, it was more the appropriate route of sharing. Opportunistic blog posts and short-scale articles were given as examples of potential methods of communicating their knowledge, with presentations and seminar talks being less amenable. It can be concluded, however, that asset managers have a preference of feeding back their understanding, as a way of developing their standing and aiding progression of construction projects.

5.5.4 CYCLE OF LEARNING

Discussions surrounding the types and style of lesson have already discovered that there is an unmet willingness from HE AM to capture and share their experiences and knowledge. The question remains of how to incorporate these lessons in the wider project development process, as is originally described in the Soft Landings guidance.

Appropriate timing of said feedback would seemingly lead to the progressive learning of their peers:

> *"…you hope it's a proactive thing, this happened, we reviewed it, and now we've learnt our lessons, this is the action plan to go forward." (Soft Services Manager)*

Where capturing and utilising elements of learning to make change internally within the AM team would be deemed of great worth. Taking this further in terms of capturing others' thoughts, one university sent out an annual survey to all students:

> *"I think it's a very useful tool. The challenge we've got particularly with students is survey overload, so there's lots of surveys that are out there that students are encouraged to complete, so for them it's a burden." (Capital Projects)*

In terms of maintaining the university's aesthetic and reputation, such simple tools can quickly and easily generate feedback that would aid future discussions of growth.

> *"What we tend to do is focus more specifically around the significant end user, so they're involved with the project for the first evaluation then give it a 12-month cycle and then start pushing out questionnaires to people and then specific interviews with certain individuals that are either willing to talk to us or we have to bribe to talk to us." (Capital Projects)*

The key area for capturing learning, however, is about the end user. Post-occupancy evaluations conducted at set intervals after practical completion would provide greater understanding of how the asset is being used and maintained and may well beneficially advance future projects.

The concept of capturing learning is one that has only been briefly investigated here, with a need to further develop the ideas, especially considering the cyclical process of capturing, collating and sharing experiential knowledge from the asset manager's perspective.

5.6 SUMMARY

This first phase of analysis has highlighted a series of ten core issues, common to all participants: waste from roles; waste from timeliness; waste from inaccuracies; waste from missing information; waste through duplication; the effectiveness of handover; the efficiency of handover; types of lessons; communicated lessons; and the cycle of learning. Each of these topics could be classed as the 'big issues', with there remaining a further need to dissect and evaluate.

The inconsistencies found in most handover strategies also pose the questions: does more need to be made of the handover? If given greater impetus in terms of preparation and set-up, would that lead to a greater success factor for the initial period of operation and long-term operational goals? How could these successes be realised when considering the timeliness and resource-dependent nature of projects?

A secondary phase on analysis will now be discussed within chapter 6, where the data is evaluated against the lens of PPTC, aiming to build upon the existing theoretical findings as is concluded here, and further understand the finite issues of whole-lifecycle asset information management.

CHAPTER 6 ANALYSIS PHASE 2

6.1 INTRODUCTION

Discussions in previous chapters have introduced the idea of using the four lifecycle dimensions – *people, process, technologies,* and *channels* – to dissect and further assess the project asset information requirements. The UK Government has frequently stated the need to focus on elements relating to people, process and technology for 'advancing project delivery' for all publicly procured projects (Construction Leadership Council, 2013). Defining communication by way of classifying the who, the what and the how in this manner does make positive headway in terms of improving overall project delivery (REF BCU). Yet the concept of channelling information flow is incorporated under each subject discussion, and not seen as individually valid. It is proposed that channels instead are itemised as a critical factor for ongoing provision of information creation and use.

This chapter will highlight the process undertaken to analyse the data against the *PPTC* dimensions, briefly reviewing the steps taken and the codes/categories reviewed. Theory development will be discussed, and this will be validated against a fifth university case; finally giving rise to a suggested practical application of said theory.

6.2 ANALYSIS PROCESS

Likening the process to that conducted during the first phase of analysis (discussed in section 3.6.3), a cyclical approach was used to thematically codify the data with reference to *PPTC*. The computer programme NVIVO was crucial at itemising the codes, as suggested in table 6.1, as well as the responding theory relationship; whilst maintaining distance from the initial round of analysis. This was essential to fully comprehend the concepts and themes discussed in specific relation to *PPTC* and not be influenced by the previous iterations of analysis.

Analytical memos were again used as a form of mapping the research discovery process. Meaning was extracted from the data, including commentary such as *'subject is overtly negative when discussing the relative communication with external stakeholders.'* This highlighted the potential areas for change within the existing organisational structure of information creation and communication. Table 6.1 offers a selection of the codes as per the completion of the axial coding stage, where the initial thoughts and narrative points were translated into a wider theme.

Code	Relative Understanding of Code
External Stakeholders	Discussion relating to the interaction of the participant with said capital projects; whether they give or receive feedback and have a direct relationship with the development process.
Communication	Discussion that directly refers to 'communication': the methods by which communication occurs, the potential issues and the potential adaptations to make it quicker and easier.
Criticality	Discussion relating to the critical nature of information.
Cycle of Work	Discussion surrounding the repeated requirement for a specific task: the duration of said cycle and the reasons for said repeat.
Efficiency	Discussion referring to the efficiency of existing processes.
Familiarity	Discussion referring to a task or moment that is conducted due to common understanding and reference.
Feedback	Discussion regarding the cycle of verbal information in terms of gathering lessons learned and reviewing work performance.
Governance	Discussion specifically referring to the governance structures and implications of the patterns of information flow.
Handover	Discussion surrounding the process of handover: the preparation for the process itself and the relative pros and cons.
Inclusivity	Discussion stemming from the inclusion or lack of inclusion in a wider university activity.
Lessons	Discussion relating to the collection of lessons: how they are collected, what they may contain; who they are linked to.
Sharing	Discussion relating to the ways in which information is shared.
Student Experience	Discussion relating to when the participant directly refers to the wider student experience.
Training	Discussion relating to any training or development that the participant may or may not have had, to allow them to complete their tasks.
Understanding	Discussion regarding the relative understanding or mis-understanding of information.
Visualisation	Discussion relating to the potential for visualising information differently and the relationship that would have with the ongoing tasks, including relative pros and cons.
Waiting	Discussion relating to 'waiting time': what may cause it, the main effect of said waiting time and the emotions surrounding said wait.

Table 6.1 Thematic Coding Examples: Analysis Phase 2

This secondary phase of analysis could be criticised as being less inductive than the first phase; the researcher already had a selection of categories pertaining to the content. This did influence the number of iterations undertaken before value could be extracted from the data. However, it is believed that applying the initial focal lens of understanding *PPTC* made the process more efficient.

Once the initial and axial coding had been completed, each coding classification was then evaluated against the referring dimension. Codes such as *'visualisation'* and *'training'* were classified under the 'technologies' area of thought, whilst *'inclusivity'* and *'cycle of work'* could be evaluated against process. What follows discusses the discovered themes and their relevance to the wider context of information creation and communication management.

6.3 UNDERSTANDING 'PEOPLE'

Previous discussions have introduced the idea that individuals can have the causal effect of wastefully duplicating information due to miscommunicated responsibilities. A route to reducing said miscommunicated wastes is through a supported approach to information allocation. Several participants highlighted the implementation of access to construction projects, where the pragmatic navigation and review of the information structures, as they are being created, lends towards greater awareness of what is to be expected.

> *"I would be asking to be in at concept initiation…and then there's certain…points at the end stage reviews as well, and that would pretty much be to make sure that what I need is accurately captured at the beginning and then captured at the end stage points throughout." (Soft Services Manager)*

By continuous communication with the project environment, the participant benefited from a 'before and after' comparison, tracing the development of the asset information in such a way that instils confidence in the content. The acceptance of the participant's role in terms of their specific information need was met with encouragement at all levels, identifying to others that a clearer method was achievable and should be maintained for all future projects.

Pressures of construction combined with the pressures of the HE context have been shown to lead to high-risk handovers; handover is conducted in situations when the information set does not meet standard specification and will inhibit work when transferred to operation.

> *"I think there's a lot of pressure for people to get things wrapped up and move onto the next job, and an external consultant will send us some drawings that aren't as built as they're supposed, they're not to our standard. It is down to the project manager to basically make sure that happens, but they're under pressure to go onto the next job so they go." (Visual Information Manager)*

More needs to be done to facilitate the smooth transition from one project into the next, enabling those responsible to fully create the information registry before it is handed to operation. Mechanisms such as clear protocols of inclusion will lead to better clarification of the time demands for specific projects and efficient allocation of work.

Training was again an area for great discussion and contention. Little was offered in the way of a successful approach to training from any of the case universities. One case stands out, however. An in-house commissioning manager played a key role in identifying the specific areas with a need for training, which aided the conceptualisation of the training schedule for using and operating a series of complex new facilities:

> *"…most of it is hard services, compliance, and I suppose my (soft services) team would require greater detail…" (Soft Services Manager)*

Yet, even with this case, the full need for training was not entirely appreciated. The use of self-discovery remains very much integral to the comprehensive approach to development, whether it be for continuing to maintain existing assets, or grasping how a new asset will be used.

> *"Part of our snagging, we just have to go around and physically snag the building. So, what we do now…is we do physical snagging and digital snagging, so (members of the project) team will physically walk round with the model and check it on site and we'd physically pick up things like, making a tour, carpet tile that's dirty, that sort of thing." (Capital Projects)*

Experience acts as a driver for moving from digital into the physical, commonplace for all approaches to information management. Participants relied on their ability to understand a situation by way of drawing on experience, proving that owner-operator knowledge is essential for the ongoing successful management of assets.

6.4 UNDERSTANDING 'PROCESS'

Preparation for handover was a core part of discussion, often being the route to issues experienced throughout the operational phase. For successful achievement of this lifecycle phase, and so provide potential for reducing operational costs, it is critical for the project team to approach the eventual handover with structure and rigour. Quantifying the approach to handover, at the optimal point in the development process, will ensure that a soft landing is achieved, consequentially instilling confidence to the AM team.

> *"…part of that conversation of what handover looks like has to be had at the beginning. What are our success criteria? How are we actually going to measure it? And if you've got*

that at the beginning then it's streamed throughout the process, then you should get something a lot better at the end of it." (Soft Services Manager)

"Time, not enough time to do things, or they don't let you know to the last minute, that's the normal thing." (Soft Services Manager)

Strict allocation of process, as well as gauging who is responsible and for what, will simplify the process of handover, whilst reducing the time lag often experienced. An overriding goal of the asset manager for a project development is to obtain clear instructions for the inherent processes once in operation. One participant commented that:

"…hopefully at the end, the process is there to allow us to get a fully coordinated as built model which is data rich with everything that we've asked them to provide in it, and also set up to fire directly into a CAFM system." (Capital Projects)

It may appear to some that this is an unattainable aspiration. But the asset management sector will only suffer further without drivers for said data-rich environments.

Likewise, when contending with the commissioning process:

"It's fundamentally flawed how we operate our facilities at the moment, we can't demonstrate compliance, so it's almost a point of extreme exposure from a risk point of view for the organisation, and that's the bit I'm trying to push out there as a message…" (Capital Projects)

Knowledge of the work being done is commonplace, yet there remains a flaw with the timeliness of producing the certification that is required to prove compliance.

"…I know the work's been done, I'm just trying to chase down certificates and I'm not going to sign the jobs off without having actually seen the evidence." (Maintenance Technician)

Chasing people for information is a restrictive process that not only instils a culture of mistrust, but also has a detrimental knock on to the remaining management processes.

"…we spend at times between 30% and 50% of our time going around chasing people for information." (Visual Information Manager)

"They can be informal handovers or non-official handovers, and that process sometimes doesn't get used as fully…things can fall down the cracks, things are more likely to fall down the cracks in small projects." (Maintenance Technician)

If said processes of acquiring the information were more rigidly adopted, there is a greater chance that the pragmatic move from constructed asset to commissioned asset, through to fully operational asset will lead to enhanced working practices.

6.5 UNDERSTANDING 'TECHNOLOGY'

Technology or the lack of it has been a constant discussion point throughout this research project. Although many subject cases have made efforts to move more into the digital environment, there remain issues with access and control.

> *"…most of the O&Ms were produced electronically…and that was on a, you could basically go into this website, username, password, and then everybody could access it…" (Soft Services Manager)*

A single source of information is deemed as being a logical next step to developing an information-centric approach to management. Yet this often then leads to issues of compatibility, where movement of information from one shared source relegates specific attributes that would otherwise be of essential use.

> *"…I think it's a combination of the shared (information) then supplementing that with…email, then I suppose it's the right solution for the right problem. So, where we've got O&M manuals and we can go in, that's fantastic as room bookings and (CAFM) when you dial in and get your own reports, but that doesn't work for everything that you need to make sure isn't shareable or it needs to be controlled release." (Soft Services Manager)*

The decision remains for the technology adopted to allow full control of access, whilst ensuring the manoeuvrability and flow of information from one person to the next.

> *"…it needs to be something that's there and accessible for the business, so it's got to be transparent, whether that's in a single format or multiple formats." (Capital Projects)*

Efforts also need to be made to ensure that the technology allows for implementation of clear structuring of said operational information. Asset tagging, for example, has been proven as a great means of reducing time and effort, when accessing warranty details. Technology should enhance this process, whilst ensuring that it remains adaptable for independent governance over what is included.

> *"the naming protocol is really important and getting our asset tagging correct in (the shared) environment is very important." (Hard Services Manager)*

"…has to be capable of accepting information, so if…we'd been given information from an outside source, say an asset register from somewhere else with a contractor, if it's in a very specific format…you have to manually input it." (Maintenance Technician)

Auditing of historical assets was a frequent point of discussion, where previous versions of asset information – sometimes found in paper format – were illegible when converted into the most up-to-date format.

"It doesn't recognise everything because it's been scanned in or photocopied several thousand times and the information's a bit of a mess…It's just being tighter on the way that we specify how we have stuff delivered to us…" (Visual Information Manager)

Technology can enhance procedures and approaches to information management but will not be able to fulfil ambition without clearly defined objectives as to the method of use and the appropriate method of storage. What can be concluded here is that highly advanced technology should not be used just for the sake of using it. The AM's approach to technology is for it to enhance existing practices, such as allowing for freedom of movement, whilst futureproofing relevant information.

6.6 UNDERSTANDING 'CHANNELS'

With respect to the developed model of information transfer, it is often the simplest form of communication that engages and creates the most positive response. For example, when attempting to quantify details for a new construction fit-out, the simple case of holding workshops with multiple stakeholders can quickly enhance the decision-making process.

"…we got the key stakeholders together including the operation teams to actually go through the process of selecting furniture, which seems quite mundane but we got everybody down to the showroom, but at the end of the process you've got a product book, with all the different furniture items in that gets circulated with a presentation…getting students involved as well, that's quite key for us." (Capital Projects)

Although workshops seem old-fashioned and simplistic in this current world of technological advancements, they remain one of the most valid tools for channelling and exchanging ideas. Repeated sessions have been shown to not only advance procedures relating to a specific area of thought or development, but also to engage personnel with the accepted culture of feedback, capture and learning.

> *"every three months we'll have a workshop…discussion about the various stages of the projects. The initial launch of that is just to talk about lessons learned from previous projects that we've looked back at, any post document evaluations, general conversations around what doesn't work, what works. It gets down to the very minor detail like oh we don't like built in microwaves because when they fail you have to actually source a specific replacement, that type of conversation." (Capital Projects)*

These workshops facilitate creative thinking through brainstorming, engaging all levels of personnel to ensure common ownership and control over the finalised product.

When time issues have a knock-on effect to the transfer of usable information, such as the following example:

> *"…the delay in getting the O&M manual information off of a project, it's not consistent. Some project managers are absolutely great at giving me the basic asset list but then it'll be a year before I see the O&Ms; or they may have uploaded the O&Ms onto the (shared) system, but I don't know they're on there." (Maintenance Technician);*

the simplistic approaches to communication will always lead toward optimal management strategies. Better maintenance strategies will be achieved through good communication and equal relationships among peers.

> *"We work very closely with the security and the cleaners, because they identify a huge amount of jobs for us, they're the first one in every day…so across departments the information is always there, just not always when you need it most." (Hard Services Manager)*

If the flow of information is enabled by good communication practices, the resultant environment will not only enable better management of assets but will also instil a shared interest in the betterment of one's environment.

Finally, no matter what level of digital-maturity, appropriate management of asset information will only truly be achieved through a collaborative, structured and well-informed approach to whole-lifecycle operation. Clear, concise protocols will drive more effective, more efficient engagement of both the AM and architectural-construction project teams and lead towards a seamless approach to whole-life operation and management of assets.

6.7 UNIVERSITY FIVE

One of the ever-persistent considerations when conducting research is the validity of the respective findings. With quantitative research such validity is achieved through the use of variables and control measures. In contract, qualitative data requires there to be a level of repeatability in order for the results to be deemed valid. It is worthwhile bearing in mind that qualitative analysis is a cognitive process, where each individual has a different cognitive style – one's explanation of analysis may seem crystal clear to someone with a similar cognitive style, yet very confusing to another (Heath, and Cowley, 2004). For the purpose of ensuring that these findings have validity within the wider context of HE asset information management, it was necessary to include a final iteration of qualitative data collection. Through the inclusion of a fifth university, the saturated findings were then compared to that of a neutral data set, understanding if there were variations where said variations stemmed, and how they would affect the theory as created.

6.7.1 UNIVERSITY CLASSIFICATION

This fifth university was again sampled through opportunity - in a similar approach to the way in which the first four universities were accessed. A secondary reason for choosing this particular university, however, was their pre-existing maturity in using advanced information modelling and management techniques. The premise behind such a decision was one of exploring the ideas and practices of individuals "in the know". Such individuals may have detailed experiences of the successes and failures of the domain, and specifically the use of information management as a tool for the ongoing operation and maintenance of assets.

	University 5
Approx. Student Population	35,000
Historical / Modern	Historical – est. 1826.
Campus / City.	City
Asset Management Capability	In-house direct labour organisation.
Information Management Adoption	• Established IM procedures for all capital works. • Trialling IM for O&M. • AM team prominent in publication of UK Government standards and working groups.

Table 6.2 University Five Overview

Table 6.2 briefly overview the characteristics of University 5. The use of an in-house labour force is of particular interest when gauging their methods of creating information for the purpose of managing the assets internally. It should be mentioned that the university still operates closely with a series of external stakeholders, such as when in a project environment, but also when dealing with specialist maintenance such as the statutory upkeep of chemical laboratories. It should also be mentioned that the university is undergoing extensive refurbishment and construction works, both to develop their existing building stock, and as an investment in future-proofing their university's status globally. The size and scale of these works are also directly affected by the context of the city, as well as the need to adhere to strict timeliness of the academic terms – both variables that drive the AM team to be as efficient and effective in their working styles as possible. The variation available from utilising University 5's data means that a holistic impression of the importance and dependencies on information can quickly be appreciated.

	University 5
Information/CAD Manager.	*Participant 5. F.*
Capital Projects Team.	*Participant 5. A.*
Hard Services.	*Participant 5. B.*
Soft Services.	*Participant 5. C.*
Maintenance Technician.	*Participant 5.D.* *Participant 5. E.*

Table 6.3 Interview Participant Selection

The subject selection followed that which was previously defined in section 4.6.2, where both managerial positions and technician roles were interviewed, gaining an insight into not only their varying patterns of use, but also the relevant governance structures. It was deemed necessary for participant 5.E to be included in the collection process; even though the role of the technician was covered during the conversation with participant 5.D, the extent to which they interacted with the wider university team and external project teams was such that little could be gauged from the conversation beyond the understanding of their singular context. It was decided, therefore, that a secondary technician role would be interviewed, so as to obtain data that was comparable to the first four university cases.

6.7.2 ADAPTED INTERVIEW PROTOCOL

From the experience gained through conducting the previous 19 semi-structured interviews, the protocol of questioning could be refined, taking into account those questions that created points of interest, and those that negatively impacted the fluidity of conversation. The adapted interview protocol removed the following questions:

- *When there are issues, are you given the opportunity to feedback?* [obj. 1, q. 6]
- *If you were to be asked to detail your ideal solution to how you create and use information, what would that be?* [obj. 2, q. 3]
- *Are you ever included in projects, if so, then how?* [obj. 3, q. 3]

The first was not necessary as the conversation held under the first six questions covered the positives and negatives of information use, with all participants openly discussing their feedback approach. Similarly, question 3 from objective 2 was deemed redundant, as the classification of 'ideal solutions' were also covered in previous conversation; the use of this question when interviewing universities one through four was usually met with confusion and stunted the progression of conversation. The final question was removed to avoid repeated discussion topics, covered in the series of questioning of previous objective (objective 2).

6.7.3 RESULTS

The responding data gained through interviewing participants at University 5 not only imitated the data from universities one through four, but some of the direct responses were like-for-like. Participants in managerial roles had continually to combat the changing pressures of university governance – where changes to personnel disrupted targets and future planned orders of work; whilst the technicians struggled with conducting their daily tasks, under strict use of remote technologies.

All participants made comment to the increasing frustration of information loss, where unclear guidelines for exchange led to the frequent missing of specific information pieces. An attempt by the university to combat this information loss was to introduce a steering group, with representatives from each core management stream.

> *"…we have a GPR (generic project requirements) steering team, which is key people in estates…and anyone can propose something to the GPR and then we'll look at it and decide yes or no, and we've got a list of champions as well. So, there's particular people assigned*

to security systems and to cleaning, and to maintenance and air conditioning…" (Soft Services Manager)

The allocation of requirements in direct response to individual roles meant that the university was able pragmatically to assess the developmental need of a project. Fortnightly meetings enabled face-to-face discussions about successful completion of tasks, such as the maintenance of the storage heaters, of the reallocation of space within an asset in response to changing need of the academic body. The meetings also gave an opportunity to communicate with external stakeholders, where presentations of specific 'solutions' (whether they be a proposed design or proactive maintenance scheme) could be actively discussed and reviewed.

This use of collaborative review was the first case of successful feedback approval from any of the universities. It is proof that, by adopting a cycle for capturing lessons learned, the university can continuously make conscious change, learning and progressing their relative understanding of asset management demands.

6.8 SUMMARY

The resultant data collected from University 5 proved the research objectives of investigating the appropriate creation and management of information, as a means of enhancing the operational life of a built asset. The comparative analysis is summarised in the table that follows:

		Analysis Phase 2			
		People	**Process**	**Technologies**	**Channels**
Analysis Phase 1	**Obj. 1**	Distinct roles and responsibilities explanation are required to define who is the lead author of information, and the relative meaning of said information.	Asset use and change-of-use principles essential for understanding daily information breakdown; collating as-used asset info structures for future capital works.	Training and continual development of existing technologies necessary to retain trust in information that is created – i.e. efficient use of paper vs efficient use of CAFM system.	Understanding the location and requirements of each information strand, i.e. allocation of valid approach to accessing information to reduce inefficient activities.

	Obj. 2	Strategic protocols of responsibilities at and preceding handover are required, ensuring a soft landing is achieved.	Defining a strict policy for handover, in terms of the generic project information requirements, as well as timed gateway of key asset registry.	Evaluating technology appropriateness to individual university case essential in order to gauge relevant strategies for creating manageable information, both immediately at handover and throughout operational life.	Exchange method that enhances the ability to immediately use said information, whilst maintaining a clear audit trail for clarity of authenticity; information accuracy critical.
	Obj. 3	Efforts to capture experiential knowledge prior to it leaving the university bounds, learning from existing understanding.	Instilling a cyclical nature of feedback, allowing internal and external stakeholders alike to contribute to learning.	Visual presentations useful to successful feedback, but not essential.	Face-to-face discussions between all roles and levels of governance essential for full scope of learning to be attained.

Table 6.4 Associated theory created through two-phase analysis

Table 6.4 illustrates the key items of learning with regards to the theoretical contribution of ascertaining asset management information requirements as relating to PPTC. What remains, however, is understanding how practical application of each dimension may lead to wider success, both at a project level, and potentially beyond to programme management. This will be the premise for discussions that continue in chapter 7, which explores application according to the relevant asset lifecycle.

CHAPTER 7 PPTC FRAMEWORK DEVELOPMENT

7.1 INTRODUCTION

Findings from the research up until now have explored the domain of asset information management within HE institutions. The focal lens has been theoretically to gauge the existing conditions of use, itemising issues that lead to frustration as well as the mis-use of said asset information. Previous chapters have conducted analysis of the collated qualitative data, highlighting significant theoretical findings in accordance with the research objectives originally set out in chapter 1. These findings (regarding waste, effectiveness of handover and optimising learning), were then rigorously inspected against the four project dimensions (of *people, process, technologies,* and *channels)* as a route to further deciphering the domain question.

In terms of developing the theory, the next stage of the research is to translate the findings into a workable framework, one that may be advantageous not only for construction professionals, but equally advantageous for asset managers and those who represent the field of AM. The following sections of this chapter will: introduce the handover stage as a singular entity, relating it to pre-existing lifecycle standards; apply the restructured process of development to the four dimensions, justifying the inclusions, suitability and use of the proposed PPTC Lifecycle Framework.

7.2 THE 'HANDOVER STAGE'

The secondary objective of this research was to investigate how asset managers may benefit from the better methods of information transfer. The term 'benefit' can often be misleading. In the case of this research, however, the term was used to focus the responses of the asset managers toward the idea of 'betterment'. Through a detailed understanding of the existing mode of transfer from the AEC stakeholder teams to the AM teams, it has been identified that handover needs greater governance. Applying restricted measures of management will aid the successful transition from CAPEX into OPEX. However, it is clear that existing processes used in project development by architects and construction professionals alike do not place enough emphasis on the handover process, or the gradual preparation for it to take place, i.e. complete the physical build as well as collate all associated documentation and reference materials. The RIBA plan of work makes some suggestion as to the processes that may lead up to successful handover yet does not offer details as to how foresight and planned preparation may benefit the immediate use of the asset, especially not from the perspective of the asset managers.

It is proposed, therefore, that a new lifecycle be created, highlighting 'handover' as being critical to the joined-up progression from CAPEX into OPEX. Figure 7.1 illustrates the proposed lifecycle, with handover at stage 4 of the 6-stage process.

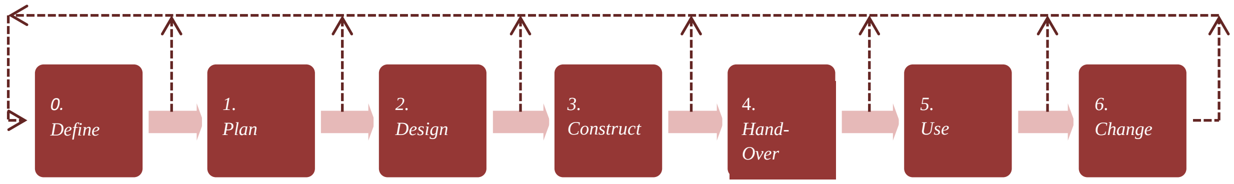

Figure 7.1 PPTC Lifecycle Illustration

An overriding intention for creating the above lifecycle is simplicity of thought. A couple of participants commented on the insufficiency of any existing lifecycle to coordinate the "before" and "after" in a manner that is flexible yet supportive. It is understood that, although the RIBA plan of work does not wholly satisfy the detailed requirements of handover, all design houses and construction firms consistently use it. For this reason, stages 0-6 (*strategic definition* through to *construction*) have been simplified to create the above lifecycle flow. It should be noted that stage 6 'change' is the point at which decisions are made to either change, refurbish or demolish. The stages will be further discussed later in this chapter.

As the literature discussed, there are two main categories of 'user involvement', the first when a user is conscious of their interactions due to pre-existing knowledge of a subject matter, whilst the second category deals with the 'uninformed' user who is ignorant to the fact they are involved in the developmental process. When discussing the idea of feedback, many participants identified that the process was lacking although vitally important to enhance the opportunity to feed-back, not only within the operational phase but also throughout the process of development. In other words, opportunities should be presented to capture lessons and feedback at each key stage of the lifecycle, capturing the successes and failures and storing them in a 'lessons learned repository', enabling the continual review of what has happened, and preparing for what it to come.

Users actively and consciously contribute to shaping the development of new functionalities and 'products', focusing on those aspects and principles that are deemed an accomplishment, in addition to those which would negatively affect the asset manager's ability to complete tasks. Focusing on user input throughout the entire developmental cycle, it is proposed that stakeholders would be able to increase their speed of learning, as well as developing the practice of cyclically capturing and utilising said lessons. The volume of learning captured through continuous user feedback alters the speed at which processes are optimised, i.e. the more learning is fed back into the process, the greater the chance for positive change.

7.3 PPTC FRAMEWORK

Taking the learning gained through the two-phased analysis of the interview data, the theory can now be applied to the PPTC Lifecycle (figure 7.1). The practical application of said theory will now be discussed.

7.3.1 DEVELOPING FINDINGS INTO FRAMEWORK

Considering first objective 1, and the existing pattern of information waste:

- Visibility is key at all levels; managers have the desire to be able to distribute work and associated information to the technicians, enabling self-organisation following the understanding that the work will be completed to the necessary standard.
- Training is essential for use of technologies that enable remote working; developing the skills of the workforce with respect to the key principles, up to the advanced use of said working system. Treated as a regular cycle of training such as that adopted for chartered professional development or health and safety, advancing trust in both the ‘technology’ and the information.
- Face-to-face meetings is essential for better quality of relationships and consequentially better management of daily activities as well as reducing the inherent feeling of “us and them”.
- Key knowledge is lost when the experience moves on, meaning an aided ‘handover’ is needed in order to halt the loss.
- Records “fall down cracks” – clear continuity for auditing the information trail is required for all projects, no matter the size and scale.
- Periodic conditional surveying would allow for greater distribution of the budget, both in terms of the ongoing maintenance, and resourcing the process of survey; lead to an increased ability to keep up-to-date whilst reducing the pushing of too much information at incorrect times in the lifecycle.
- ‘As-built’ scanning suggested as a means of ensuring complete and total accuracy of the information as and when it is handed over.

Considering objective 2, understanding better methods of information transfer:

- Effectiveness of handover would be improved through staged access to the asset registry, prior to practical completion, enabling the AM team to formulate expectations for immediate operation.
- Statutory requirements for maintenance considered at least a month prior to handover; essential if immediate operation is to take place successfully from day one of habitation.
- Efficiency of handover would be increased if there was representation at each key project meeting, identifying the need for a soft-landings guide to underpin all communications within the project team, and internally within AM. A secondary point here is the need to bring all levels into the discussion, from managerial positions down to technicians, allowing for conversations at each key progress stage of the lifecycle. Feedback would then become the norm if all levels of personnel were present – or at least represented – at some stage of the development.
- A strict protocol for exchange is needed, ensuring all specialist services are directly able to update the AM register, with pre-determined contracts of access to be concluded at a set term during the use.

At each identified stage of the lifecycle there are several issues causing challenges to AM, itemised from the learning gained through the qualitative analysis and illustrated as follows:

- Stage 0. Define - articulating the operation and maintenance needs in terms of information;
  - knowing the location of all existing case-specific 'drawings';
  - articulating the predicted asset depreciation and renewal expectations.
- Stage 1. Plan - attaining representation for those with relevant experiential knowledge;
  - ensuring their voice is heard;
  - communicating preferences for asset use and space allocation.
- Stage 2. Design - ensuring that conversations are consistent;
  - being part of a complete design process.
- Stage 3. Construct - being excluded from the conversation;
  - vital lessons being ignored through value engineering.
- Stage 4. Handover - delay in 'vital information';
  - communicating associated teething issues to relevant stakeholder

- Stage 5. Use - no ongoing support for continuing 'issues';
  - long-term plans for upkeep and change;
  - changing governance structure affecting budget plans and maintenance structuring.
- Stage 6. Change - starting a new process, creating relationships that appreciate AM;
  - lack of support both internally and externally.

To be aware of these challenges is to be aware of the asset manager's perspective, something that is infrequently done in the current climate of construction.

The above findings taken from discussion in both chapters 5 and 6, are proposed to then be practically applied to the lifecycle, and so creating the PPTC Lifecycle Framework. At each key stage of the lifecycle, there are itemised principles for specific roles, specific processes, technologies, and specific channels of information flow. Simply defined in a single flow chart, the key items will now be distinguished.

7.3.2 PEOPLE

At each stage of the lifecycle, it has been suggested who should be involved in the key decision-making process, from both the AM and AEC teams – client-side and construction consultancy side ('consult') respectively.

As a support to the AM team, the role of a soft landings consultant is proposed. The role of the soft landings consultant is a suggested undertaking for someone with access to both project team and operational team, with an understanding of the main information demands at each key stage of the lifecycle. For example, at stage 0 'define', the role would entail appreciating the information needs of the technician as well as the manager and have the capability of aligning their respective responsibilities to said information need. Throughout the design stage (stage 2), the soft landings consultant would potentially act on behalf of the AM team, where the meetings are too regular to justify AM's attendance. This would differ, however, at the point of change-over from design into construction, where AM is required to be included in the conversation to accept the proposed scheme before construction commences.

At the point of handover, it will be the responsibility of the soft landings consultant to be located on site for a fixed period, to aid with the initial aftercare and close any outstanding commissioning issues. This is key for the successful operation of the asset immediately after it is handed to the management team. From then on, the role would include cyclical post-occupancy evaluations, a measure that would ensure that the condition of the asset is allowing for the intended functionality to be continued. The relationship is seen as being long term; at the point of change, the soft landings consultant would then facilitate the preparation of all as-operated information and set of requirements needed for the next cyclical phase of development. By maintaining strong relationships, the transition from one project to the next, or one from phase of a programme to the next, would be eased, whilst ensuring all AM information needs are considered throughout.

It should be noted, however, these are suggested roles, with there being variation depending on the size and scale of project, as well as the appointed contractual environment.

7.3.3 PROCESS

Core processes include the creation of strategies, the itemisation of responsibilities, and the preparation of documentation relating to the development and handover of the asset. The key notion behind the process tab within the framework is to list the minimum tasks that the project team, soft landings consultant and AM representative should include. Most elements that make up the framework have been taken from alternative lifecycles, already used and already discussed in chapter 2 of this thesis. The overriding purpose of including such varying items is to ensure that the full scope of works is pre-empted, planned for and acknowledged. As information is the key consideration throughout this discussion, the consistent use of it to formulate a clear, laid out plan from definition through to change is essential. Only when terminology is agreed, responsibilities identified, and long-term management structures put in place, will the whole-lifecycle perspective for information management be achieved. Processes are key to the successful collaborative effort of an AM-AEC team.

7.3.4 TECHNOLOGY

User acceptance is integral to the successful adoption of whole-lifecycle technologies within the asset management domain, where many of the personnel appear unfamiliar with the more advanced technologies such as virtual reality and augmented reality. It is necessary to quantify not only their existing use of technologies – do they use computers, when are they paper based? – but also their vision for future use. Incorporating a foresighted view of technology will allow the information-centric structures to be translatable, as and when innovation leads to more advanced technical adoption. It must be stated that most participants referred to visualisation as being useful for display but not for daily job completion.

Another consideration when approaching technology adoption is the contractual arrangement for all modelling. If said HE AM requests 3-dimensional models to be created, there needs to be a discussion regarding the ownership of said model at the point of handover.

7.3.5 CHANNELS

Itemisation of the key priorities for exchange is the most important element of the framework. Without a rigid structure for who, what, when and how, the information is at a risk of quickly being misunderstood and mistrusted. Face-to-face instructions and conversations are still deemed vital for all AMs interviewed, and must therefore be continually utilised to reassure, reassess and problem solve.

	0. Define	*1. Plan*	*2. Design*	*3. Construct*	4. Hand-Over	*5. Use*	*6. Change*
PEOPLE	Client. - Hard AM, Soft AM, Cap. Project Lead. Consult. - Soft Landings Rep.	Client. - Information Manager. Consult. - Responsibility Matrix; single proj. set-up.	Client. - Hard AM, Soft AM, Technicians. Consult. - Soft Landings Rep.	Client. - Hard AM, Soft AM. Consult. - Soft Landings Rep., PM.	Client. - Hard AM, Soft AM. Consult. - Soft Landings Rep.	Client. - Hard AM, Soft AM. Consult. - Strat. AM; Soft Landings Rep.	Client. - Hard AM, Soft AM. Consult. - Strat. AM, BS, Soft Landings Rep.
PROCESS	- Collate existing AM register for Strat. AM approach. - 'Model' missing information.	- TOTEX Plan Guidance. - Handover Strategy developed.	- Stage-Review. - Asset Registry. - Incorp. AM Lessons Learned. - Data Mining Opportunities.	- 6Month > 3Month >1Month Walkaround Process. - Commissioning Support.	- As-built Scan Asset Registry. - Asset Acceptance Procedure.	- Initial Aftercare Information Upkeep. - Commissioning Trail. - Whole-Life Costing Analysis.	- Communicating Renewed Asset Requirement; - Change of Need Evaluation.
TECHNOLOGY	- Existing 'model-use' evaluation. - Model Ownership Contract.	- Technology Appropriateness Exploration – comparative study.	- Visualisation Strategy. – 2D-VR Exploration. - CAFM Contract.	- Visualisation Strategy Enabled	- 'Live' Operational Asset Registry – PPM. - Reactive Maintenance Editable Registry.	- Training Programme – tier-staged training.	- Updated 'Scan' of proposed change. - Visualisation Strategy.
CHANNELS	- Priorities for exchange – stage-gate process. - Info. Longevity Plan.	- Face-to-face Consultations. - Lessons Learned Communication.	- Higher Education Community Consultation. - Lessons Learned Communication.	- Time-Staged Walkaround Communication. - AM Registry Communication.	- Expectation vs. Reality Consultation – all levels of HEI.	- Post Occupancy Evaluation Consultation. - Lessons Learned Communication.	- Face-to-face Consultations.

Figure 7.2 PPTC Lifecycle Framework

7.4 PRACTICAL APPLICATION

The intention for the PPTC Lifecycle Framework is to simplify the process of project development, enabling non-specialist personnel (such as maintenance technicians) to view and understand the core responsibilities and subsequent activities. It's not meant to act as a standalone framework but amplify existing practices by adding detail to the phases of the lifecycle where practices pertaining to the management of asset information is lacking.

Intended User

When applied to the project environment, the intention is for the framework to be used as a guide for those in the project management role, or in a role that facilitates the project team in the successful completion of their specific role-related tasks. The project could be managed by an independent stakeholder, or indeed a member of the asset management team rather than necessarily by a member of a construction consultancy or design house. They should be capable of understanding that at the core of the framework is the accepted premise that asset information is key, and the development of said information needs to be consistently pushed as a core delivery for each and every associated project phase.

The framework offers the opportunity of developing the role of the Soft Landings consultant, a role that at present is not found in many UK construction consultancies, and especially lacking when considering infrastructure assets. The introduction of said role would boost the connectivity between AEC and AM industries, as well as connecting those parties that have a mutual interest, such as the lead designer and the employer or client house. Future work has the potential for developing this role further into a facilitator of information management and data mining, enhancing the pre-existence of asset information repositories to make longitudinal predictions about asset use within the HE sector.

Intended Application and Lifecycle Phase

The theory behind the development of the PPTC Lifecycle Framework has stemmed from an investigation into the HE sector. But most construction projects that are delivering an asset(s) to be managed and maintained by an organisation, for an extended period, would be able to utilise the guidance from the framework.

One benefit of this framework is its adaptability to any project size and scale. It is also proposed that it can be applied flexibly for refurbishments and new builds alike. Most projects begin with a problem case, either stemming from a lack of facility or a need to change existing asset capabilities, which in terms of the lifecycle would be stage 6, ‘change’. Yet its use is not bound to when a project commences; there is also potential for it to be adapted to cases where works have already begun. The intention, as a guidance document, is to provide the means to complete projects, with the impetus always remaining about the creation, use, and management of asset information throughout the complete lifecycle.

A secondary, but equally as important, constant about the framework, is its emphasis on cyclical collection, collation and referral of experiential knowledge. Historically, frameworks used within the construction industry have been linear, restricting the ability for one to look bi-directionally across projects and wider programmes. Yet, the PPTC Lifecycle Framework aims to instil a new emphasis on the forward progression on information development, whilst equally emphasising the necessity for backwards-looking review and reflection. It is the intention for mechanisms to be put in place that allow project teams to learn from both positive and negative activities from each lifecycle phase, capturing said valuable insights in a manner that would enable wider audiences to learn from, grow and progress, hence making innovation more prevalent in the construction project context.

Consultancy Feedback

As a means of conducting rudimentary analysis as to the potential success of adopting the PPTC Lifecycle Framework, a consultancy meeting was organised with members of the sponsoring company, Faithful+Gould. It was arranged that representatives from all the work streams would attend: project management, cost consultancy, strategic asset management, and building surveying, ensuring that each role would be given equal opportunity to feedback. A presentation was given followed by discussion surrounding the key findings and thoughts relating to the framework. The informal environment allowed for free flow of ideas with no work stream deemed more involved or important than others.

A main response was to the realisation of the Soft Landings consultant role – the strength of said individual at maintaining the information relationships throughout the lifecycle, whilst working concurrently with the AEC project manager. Dual mechanism of communicating with both the AEC professionals and the AM professionals provided a sense of clarity that would otherwise be unattainable in the traditional project team set up. It was felt that more should be done to develop this role commercially, as it offered the industry a chance to alter existing habits, drive collaboration and enhance future opportunities.

As a final thought, it was suggested that the framework be used to instruct and educate other members of the consultancy environment. If this research were to be continued it would be the intention of the researcher further to explore the consultancy reaction as a means of developing the PPTC Lifecycle Framework to be applied to all industries and all project schemes.

7.5 SUMMARY

This chapter has introduced the PPTC Lifecycle Framework, firstly grounding the practical framework in the theoretical understanding gained in chapters 5 and 6, whilst developing the potential commercial offering. The handover stage was emphasised as being critical to successful transition from CAPEX into OPEX, where staged access to the asset would enable smoother handover of both the physical and the digital. A brief exploration into the potential applicability of the framework in a commercial construction consultancy was conducted, with the need for further communications to fully quantify the use of the framework outside the bounds of the HE sector being identified.

CHAPTER 8 DISCUSSION AND CONCLUSIONS

8.1 INTRODUCTION

This final chapter revisits the original aims and objectives first stated in chapter 1 to summarise the main conclusions and recommendations that draw this thesis to a close. Highlighting specific themes from the literature and findings from the qualitative study, the implications of the thesis for both whole-lifecycle asset management, and the PPTC-framework in both practice and theory are then discussed. Finally, the limitations of the study are explored in more depth that those first mentioned in chapters 3 and 4, proposing potential applications of the research and future research trajectories.

8.2 KEY CONCLUSIONS

The aim of this study was to examine the use of information management strategies for the ongoing operation and maintenance of built assets, exploring how the conditions of information creation influenced the multi-stakeholder use during the in-use phase of the asset's lifecycle. The central idea is that asset managers remain a disparate and secondary stakeholder group, whose ideals and focus for information management is overlooked in terms of contribution towards a development scheme. Literature has shown that when an inclusive effort is made to incorporate the users in the innovation process, the resultant scheme is deemed as holding greater value for said user. The purpose of this research was to assess whether the same runs true for the incorporation and inclusion of asset managers, acknowledging their primary business-needs as a means of enhancing the creational flow of project information.

The thesis addresses the aim in two phases: first, through the identification and knowledge capture of an exploratory study, as well as review of existing practices within the AEC and AM industries; and, secondly, through the in-depth review of multiple higher education cases, collating qualitative data from participants at varying organisational levels as a route to dissecting the current patterns of information flow during operation.

The representation of current inclusive processes and subsequent interpretation of the impact of these processes on the successful handover of an asset at practical completion, clearly identifies the lacking collaborative effort between AEC stakeholder teams and those in AM. There remains great potential for the two-directional guidance and support as a means of pragmatically approaching whole-lifecycle solutions to maintaining a portfolio of assets. Three objectives were formulated to fulfil the research aim and were address as follows.

8.2.1 INFORMATION WASTE

Objective 1 aimed *to understand where waste occurs in the existing model of information transfer*.

The thesis reviewed the contextual relationship of the asset manager's business-as-usual case, focusing specifically on the asset manager's narrative as a means of contextualising what information is needed and how that information is used on a daily basis. The collected data provided an honest narrative to be captured and understood, allowing for varying perspectives to be investigated simultaneously. The data was used to identify issues with the current practice – such as the waste identified by roles, through timeliness, missing information, duplication and inaccurate information. These dimensions were then used to develop new patterns for development in terms of the people, the processes, technologies and the channels of information flow, benefiting not only the HE AM teams, but also the wider project environment.

8.2.2 APPROPRIATE INFORMATION TRANSFER

Objective 2 aimed *to investigate how asset managers may benefit from better methods of transfer*. A picture of the successes and failures in how information is passed from the AEC stakeholders onto the asset managers was created, i.e. handing over from capital into operation. Understanding that inconsistent handover strategies - both in the manner of physically handing over the information but also the timeliness of said exchange - contributed significantly towards frustration, delayed work and costly changes within the project environment. This is, all vastly inconvenient for the time-pressured context of a university. The handover phase was developed in terms of preparing for and successfully managing through the process, introducing the idea of periodical walk-arounds and asset registry coordination, lending towards better structuring of all asset information for ongoing management.

8.2.3 CAPTURING LESSONS LEARNED

Objective 3 aimed *to evaluate how lessons learned can be best captured*. It has been understood that there is an existing perception of using thoughts and lessons for the benefit of future works within the AM industry. However, it is more commonly utilised to capture negative lessons, and hence is seen as an overarchingly negative activity. A cyclical pattern of feedback is proposed, offering the AM a chance to capture and communicate their good news stories as well as learning from failures.

Successful implementation of said cyclical feedback would alter the perception of lessons learned, encouraging the wider project and programme management to continuously feed-back and develop towards the future lifetime cost reduction targets.

8.3 MAIN CONTRIBUTIONS

As well as directly responding to the three itemised objectives, a purpose of this thesis – as successfully fulfilling the demands of the Engineering Doctorate programme, is to contribute to both the theoretical and commercial knowledge base. These main contributions will now be discussed.

8.3.1 THEORETICAL CONTRIBUTION

Original research within this field traditionally commented on the state of interactions between capital project teams and the wider project environment, with many focusing on the premise that technological innovations will aid the move from disparate stakeholder entities, towards a wider accepted digital economy. Theory relating to the smart-city drive and the development of data-rich repositories that would enable better awareness of our built cities, have made motions to highlight the necessity of a single source of information, where interoperability issues had been negated. However, each of these core research pieces have failed to investigate the situation, with respect to the longitudinal management of these assets, and the importance of whole-life management of our asset information. This research contributes to knowledge by evaluating how asset managers interact with information and better understanding: their patterns of use; the potential existing waste patterns; methods of preparation and storage; and suitability of information with regards to completing operational activities.

Analysing data from several HEIs allows for greater understanding of the social need for information; more specifically breaking down the theory into four dimensions of classification: people; process; technology and channels, building upon the original triad of people, process and technology. Each classification challenges the social perspectives of specific stakeholders with regards to their individual information needs; identifying the variance across roles and across university types. The introduction of the 'channels' dimension further illustrates the gap in existing knowledge relating to how technologies are used as a means of communicating and exchanging information. Although inherently entwined with the other three dimensions, 'channels' offers greater clarity over the 'how', a factor that will become ever more essential in the move towards smart cities. Only by breaking down each project environment into the relative people-centric, process-centric, technology-centric, and channels-centric requirements, will complex projects truly be able to manage ‘big data’, and our asset’s lifespans realistically be extended; a factor that all members of the construction management domain should this instant be considering.

A final thought of theoretical guidance offered by this research, is to reiterate and highlight the ever-important need for strategic knowledge capture. When considering the migration from ‘analogue’ practices within the asset management industry (the use of document repositories, supplemented with physical filing systems), across to computer-aided, single repositories, that may or may not include the 3-dimensional information model, there must be a consideration for how experiential knowledge may also be transitioned. The data collected in this research has categorically proven the desire and need for members of AM teams to be included in project environments from earlier stages, where knowledge gained from years of experience may be influential in the successful development of part of complete proposed schemes. There therefore needs to be a mechanism put in place, that allows the cyclical codification and sharing of lessons, at each key lifecycle phase. Instilling a free-flowing transference of knowledge across all stakeholder parties, so that each may feedback and learn from the rest, a principle of construction management that has yet to be successfully adopted.

The theoretical deliverables of this research aimed to provide a cross comparison of the demands for successful whole-life, asset information management, and guidance for how these demands may be transferred into business goals for stakeholders operating within both the capital and operational phases of an asset’s lifecycle.

8.3.2 COMMERCIAL CONTRIBUTION

A major contribution of this research is to provide a guided method to capture client / users’ information needs within the HE sector, presenting them so that members of the AEC industry – more specifically those working within construction consultancies – may better prepare for the whole-life management of asset information. The HE sector offers an opportunity to cross-compare portfolio cases (i.e. campus versus city) in a way that will be applicable to other sectors.

The research has developed a standardised approach to delivering an asset management strategy, so that members of the Design and Construction team can fully understand the ongoing requirements for asset information management. The commercial contribution of the research refers also to the technical structuring of as-built models in preparation for strategic asset management solutions. By fully understanding the users' information needs – both technically and socially – a whole-life approach to information management may be successfully achieved.

The research also presented a collated project lifecycle, combining each of the demands of the construction consultancies' work streams into a single lifecycle, leading towards the holistic delivery of projects. The construction lifecycle is broken down into seven stages, from initial definition of the project's need, through planning, design, construction, handover and into use, with the final stage critical for when a change in need or function occurs. The presented 'PPTC Lifecycle Framework' provides guidance at each stage of a construction consultancy's project lifecycle as to the key considerations for people, process, technology and channels; aiding the development of a project with a soft-landing, whilst continually highlighting the information-centric progression. Even though the revised lifecycle follows the work stream structure of Faithful+Gould, the intention is for it to be adoptable by all other multi-disciplinary consultancies working in the construction sector.

8.4 INDUSTRIAL RELEVANCE

This research holds substantial relevance to the AM industry, not only in the context of the HE sector, but also in terms of their outlook and approach to collaborative working environments. Following is a brief discussion pertaining to this.

8.4.1 AEC-AM CONFLICT

History has shown a very disparate nature to the methods by which the two industries work. Even though they are both working in response to a brief, driving business goals and longitudinal structures, there still remains great conflict between the AEC and AM stakeholder groups. Through the adoption of the suggested framework, there lies great potential for enhancing the communication flow between the two opposing parties, removing the silo effect and delivering a holistic offering to design, construction and operation. By frequent and regular interactions as suggested within the framework, conflicting languages will soon be more free-flowing, with the individual project needs being more easily obtainable.

8.4.2 THE 'SOFT LANDING' APPROACH

Highlighting the handover stage as an independent review stage develops this relationship further. Bringing forward key decisions pertaining to the post-handover operation would not only make the

AM teams become more visible, it would enhance the learning capability of each AEC stakeholder team. So, too, would the opportunity to cyclically learn at each key lifecycle stage, capturing the successes and failures as seen from all parties – AM included – amounting to a continuous repository for knowledge transfer. Only with the introduction and continual use of said learning cycles, will industries such as construction be able to innovate.

8.5 LIMITATIONS

This research was limited to the investigation of a small number of HE institutions. Whilst this provided an opportunity closely to examine their internal practices noting that commonalities are found across both campus-based and city-based universities, it would have been interesting to follow the universities through the end-to-end process of asset development. Moreover, observing their practices throughout each key stage-gate of a construction project would enable greater understanding pertaining to their interactions, inclusions, and separations from other AEC stakeholder teams. It would have been of particular interest to have opportunistically used one of the university cases to test out the PPTC framework, introducing the soft-landings guidance role as a measure of asset management involvement.

There are always inherent limitations when conducting research, especially when conducting qualitative research, which is reflective on the singular view of the researcher in terms of their perception of what is observed and witnessed. The grounded theory approach adopted required the continual collection, deduction, verification, and iteration of data, whilst a concurrent inductive approach to theory creation was attempted. Although the theory offers the opportunity to fully explore a phenomenon, it does however demand vast volumes of data to be captured so that a theory may be developed. A limitation also lies in the method by which data is collected (i.e. the interview process). Being aware that different voices and influences exist for each participant, is part of the process of engaging with the data and extracting meaning from the data. A level of self-awareness is required from the researcher with respect to the distance they allow between themselves and the participant, to ensure the data may remain neutral, yet it must be commented that although great efforts were taken to ensure neutrality, qualitative data sets must always be treated as having an element of bias.

In terms of the sample size, each university case was accessed through an opportunistic approach via the sponsoring company. Although this offered direct access to several key stakeholders within the AM team – especially important to the access of those in managerial positions – it did limit the range in terms of variability. Ethically speaking, the choice of case subject was governed by a pre-existing relationship, which may be deemed restrictive to the derived theory. If the research were conducted again, a greater number of universities would be approached as potential for inclusion within such a study, affording lowered influence from governing sources, opening the study to the wider HE audience.

Transferability of the findings, specifically the theoretical PPTC framework, holds great potential. Universities are bespoke in terms of their location, size and aged built asset portfolio, yet this is not unique to the higher education industry. Government has already shown its awareness of managing its built assets as a single portfolio offering, whilst the examples within healthcare also offer opportunities for further transferring the theoretical ideals of the PPTC framework into standard project practice. Although further investigation would need to be conducted in order to quantify if indeed these sectors would benefit from the application.

8.6 FURTHER RESEARCH OPPORTUNITIES

In this respect, a potential for future research would be to conduct a longitudinal study set within an action research methodology, to closely follow the interactive implementation process using the PPTC framework, to capture the inclusive process and cyclical learning for wider industry benefit.

In addition, there is potential for adding key performance indicator data to the process recommendations made using the framework, i.e. specific models or structures of information creation could be assessed against previous project success factors to align the future needs of operation within project outset.

Finally, this study establishes the positive contribution that the AM industry can provide to the whole-lifecycle management of assets. AM organisations hold the skill, drive and desire to achieve along with the adaptability in culture that is required to deliver AM within differing information models. Ultimately, if given the opportunity, AM would provide invaluable insight and reasoning to any construction project, enhancing the quality of the product and ensuring it continues to hold status for the remainder of its operational life.

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APPENDICES

APPENDIX A – PRJOECT INFORMATION SHEET: EXPLORATORY STUDY

Information Modelling for the ongoing Life-cycle Management of Assets

Project Information Sheet

Research Engineer: Victoria Fillingham

Introduction:

The Case Study Information Sheet has been prepared to define the strategy for investigating the successful implementation of Information Modelling within the developmental process of the Birmingham City University project.

The objective of this Information Sheet is to set out the key research aims; outlining the structure of data collection and the overall strategy by which this case study shall be managed.

Case Study Background:

Building Information Modelling (BIM) is a tool that enables a holistic approach to the design, construction and management of the facilities used in the built environment.

At present, the focus for implementation of BIM within a project is the construction phase, with design and engineering teams utilising three-dimensional, real-time modelling software to analyse geometry, spatial relationships, geographical information and properties of building components. There is, however, the potential to incorporate operational information within the model from the earliest stages of design, allowing end users to maintain an asset through a singular, centralised database. This would mean building management would be taken as a realistic consideration throughout the complete process of construction, and not in the latter stages before handover.

Building Information Modelling will assist building operators in making existing asset management processes and data collection more efficient, having the conclusive effect of improving maintenance procedures and whole-life costing evaluations.

This case study will focus specifically on the Birmingham City University development, researching not only the necessary levels of detail at each stage of the project lifecycle, but also the supply chain's adaptive journey of collaborating within a BIM-environment.

Case Study Objectives:

Review of Client Requirement Criteria:

In order for the findings gathered from the evaluation of this case study to be scalable, the first objective will be to identify those requirements set by the client within the initial stages of the project. The Employer's Information Requirements will be reviewed alongside the project brief to gain an understanding of the foundation given to BIM-processes.

Tender Documentation:

An assessment of the procurement process undertaken for Phase 1 will be carried out, specifically focusing on the tender evaluation criteria and those questionnaires distributed to potential members of the supply chain. How has BIM-capability been incorporated into the plain language of the tender procedure? From here it may be possible to assess the challenges set out to each constructor with regards to complying with the exchange of information defined within the initial briefing documentation.

Information Management Protocol:

The project's Information Management Protocol will be reviewed; assessing the outlined proposed stages of the project, the defined deliverables and the levels of description required, and by whom they were undertaken. Each member of the supply chain's requirements will be justified against the original Employer's Information Requirements, assessing also the skill-set of each member of the project undertaking work.

The assessment with focus primarily on the method to which the standards for practical and efficient application of BIM have been adapted, comparing them to the main objectives of a standardised BIM-protocol, which are as follows:

- Maximise production efficiency through adopting a coordinated approach to working with BIM, consistent throughout the project's lifecycle.
- Define the standards, settings and best practices to be adopted, ensuring delivery of high-quality data to a uniform output.
- Ensure all digital BIM files are constructed correctly, enabling efficient information sharing whilst working in a collaborative environment, both internally and in external BIM teams.

Definitions of communicative rights, rights of ownership over the data and then the information model, will be evaluated at each stage of the project, focussing specifically on the level of comprehension of the data at points of exchange and the structure formatting the set data outputs.

Operational Management Prioritisation:

Identify priorities for the management of the facility for the period of operation, post hand-over. Focusing specifically on the intended use of the information gathered throughout the project developmental stage, and the manipulation of said information to align with the Autodesk BIM 360 Field software.

Facility Management Preparation:

The extent at which additional training was required for the University's Estate Management team. More specifically the level of training each technician undertook – or will undertake – to enable successful maintenance of the facility.

Soft-Landings Period of Aftercare:

To evaluate whether there has been an intended plan of work for an agreed period of aftercare, allowing for the continual monitoring and assessment of the systems operating within the facility. Identifying the year on year structure that will provide the footprint for Post Occupancy Evaluation. To assess the intended protocol for take-over after the fixed beta period, identifying the roles and responsibilities for the remainder of the facility's life.

Phase 2 Preparation and Standardisation:

Identify to what extent the individual members of the supply chain have standardised procedures for future projects, including object standardisation for the use, if any, within Phase 2 of the Birmingham City University development.

Case Study Details:

Project Team:

Management Sponsor: Adrian Malone; Head of BIM and Knowledge Management, Faithful+Gould
Adrian.Malone@fgould.com

Research Engineer: Victoria Fillingham; Engineering Doctorate Researcher, University of Reading
v.l.fillingham@pgr.reading.ac.uk

Interview Structure:

Collection of data will be in the format of an interview, structured for the purpose of gaining personal insight into each member of the supply chain's journey. A set of standard questions relating to the objectives set out above will be distributed prior to the organised date, with the intention of providing an opportunity for final queries to be answered before said interview. A recording of the session will be taken in order for a full account to be successfully documented, with the intention of post-interview analysis to be undertaken. All data collected within the recordings will remain anonymous and will be protected under the Data Protection Act.

Case Study Close Out:

The key deliverable from this Case Study will be a published profile on Phase 1 of the Birmingham City University development project, commenting on the value of information modelling within the successes of the project delivery and the experiences working within a collaborative, BIM-environment.

A secondary function of the data analysis from this study will form a part of the doctoral thesis completed by the Research Engineer; taking example from the project to expose the capability of Building Information Modelling as a tool for the optimisation of strategic asset management.

Comments from the Research Engineer:

The intention of this Information Sheet was to detail the reasoning and key intentions behind the Case Study entitled "The supply chain's adoption of BIM and experiences working within a BIM environment". If there are any further questions surrounding the purpose of the study, or the resulting publication, please contact me on v.l.fillingham@pgr.reading.ac.uk.

APPENDIX B – INTERVIEW PROTOCOL: EXPLORATORY STUDY

University of Reading
Birmingham City University - Case Study Preparation
Stakeholder Adoption of BIM and Experiences Working Together in a BIM Environment
15 August 2013

INTERVIEW SCHEDULE

The following schedule of questions will be suggestive of that used within the formal interview setting.

Initial Introduction

- **What was your role within the Birmingham City University project?**

  Please could you explain your direct relationship to the client; briefly summarising your responsibilities within the project team?

  Before this project began, what was your understanding of Information Management?

  Would you have considered your team to have had skills in Information Management prior to the BCU project?

  How capable a team were you regarding overall knowledge of platform capabilities?

Design Appraisal

- **To your knowledge, when was the project first conceived?**

  Who was the governing force over the design brief?

  What were the overriding priorities for the project taking place?

  Did the need for new facilities come from a board of principles, members of the teaching staff or from the student body?

  How was the briefing document created?

- **How was the tender process approached?**

  Was there an element of the questionnaire that evaluated the BIM-readiness of a team – especially for the stakeholders further down the chain?

- **Which design protocols were used to govern progression?**
- **What was the driving force behind utilising digital technologies for the delivery of the project?**

1

Client led? What were the expectations at the start of the process?

Do you feel it hindered the process in the beginning?

- **Was there any digital exchange protocol discussed and created prior to the D+C stage?**

  How were software standards decided upon?

  How was the structure of the data organised?

  Who was the overriding authority for detailing and referencing the model – signing it off for progression?

  Manipulation of Data - What were the priorities from each of the key players? Did the architects have different priorities to the client?

  BIM protocols development – employers information requirements – execution plan – information delivery plan – roles and responsibilities matrix...

- **At what point was the intention for fully integrated 4D modelling realised?**

  Was it the initial intention of the client? Or was it recommended as an advantage of Information Modelling?

<u>Design</u>

- **Which software was used by each design team?**

  Do you think it was the right decision to use that software?

  Was there any point in the process that you felt an alternative platform would have been more suitable?

- **How was the information shared between the project team?**

  Did each discipline have a local database of objects?

  Was there a single shared store of project information?

  Was cloud technology used?

- **Design information exchanges – who governed how they would be organised?**

  Were they scheduled as per review meetings? How frequently did they occur?

Who created the schedule of works during the design stage?

Access to the model – who had overriding ownership over the content?

Do you feel the exchange of data was an efficient process?

- **What was the Level of Detail at each deliverable stage – for the model and any subsequent take offs?**

Who championed and audited the exchange of data?

- **As the project is within the public domain – was there a requirement for community consultations?**

How did the design team ensure the scheme was going to meet the needs of the staff and student body?

How was the model used as a tool for informative discussions with the user?

On these occasions - what format was the model in?

Were simple 3D perspective take-offs used or was there live interrogation of the model?

Looking back – was there any point where the model could have been utilised more during design consultations?

How would you define the success of the model as a tool for stakeholder management?

- **Were open format standards such as COBie and IFC used?**

If not when were they decided against and for what reason?

- **How were the multiple energy standards [Performance A Rating & BREEAM Excellence] controlled and met through information management?**

Did the specialist teams utilise information modelling that could be read, shared and used by the key design team members?

Pre-Construction

- **Was the model utilised to govern the management of resources i.e. man power as well as material consumption etc?**

  Could this have been better utilised within the process?

- **What was the procedure for scheduling events on site – project construction planning and risk management?**

  Were these tools used advantageously?

- **How was data from product-specialist consultants managed?**

  Was there a detailed specification they had to adhere to?

  Was there a protocol for converting 2D paper data into 3d-ready objects fit for purpose within the model?

- **SME's were said to be used within the construction process – during pre-construction tendering, was their Information Modelling capability examined?**

  Do you feel SME's were at a disadvantage at any point in the process due to lack of BIM experience?

  Was any support given to SME's regarding software and information exchange?

Construction

- **Was the model taken forward into construction and used as a live tool on site by the construction task force?**

  Was additional training required in order for this to successfully happen?

  Who organised the use of the model?

  Was health and safety ever combated through model interrogation?

- **At what point in the construction process was the entire asset list collected, coordinated and converted into the single source for post-practical completion?**

  What was the procedure?

  Was there a set list of characteristics for the entire asset list or was it adaptable?

Do you feel this was a successful process?

For Phase 2 – how are you going to alter this process to make it more efficient?

- **What was the protocol for governing which assets to take forward for management and maintenance?**

  Cost of maintenance for planned life space? Was there lifecycle costing analysis done for the project?

  How was this coordinated with the model?

- **Were the BCU FM team critical in the decision-making process at this point?**

  Had they been consulted before this stage?

<u>**Handover & Operation**</u>

- **Was soft landings used as a procedure for handover?**

  Has there been any documentation to guide the construction and facilities management teams to aid the handover process?

  How were you able to quantify time vs cost?

- **Who was responsible for the auditing and archiving of the information recorded over the period of design and construction?**

  How were paper elements considered – for the longevity and storage of paper-based information?

  Was the commissioning of the systems recorded within the model?

- **Why was Autodesk BIM 360 chosen for operation?**

  Could you sum up the qualities that make it a preferential platform?

  Has there been a beta period for using the software?

- **How were the FM team prepared for the hand-over of the facility?**

  Training for the entire technical maintenance team or is it being rolled out over a set period of time?

  Ensuring they can fully read, navigate, interrogate and understand the software, its use and what is stored within it.

Conclusion

- Please could summarise the key successes which you feel have stemmed from the use of Information Modelling.

  Were these as predicted from the start of the process?

- Do you feel the process benefitted from BIM?
- Do you feel you have benefitted from the learning process of this project?
- Was there any point in the process that you feel could benefit greater from the use of Information Modelling?
- If you could value your experience out of 10, thinking about personal gain and investment, how would you rate it?
- If you could give one piece of advice to someone beginning their BIM-journey, what would it be?

Thank you for your time today.

APPENDIX C – PROJECT INFORMATION SHEET: CORE INTERVIEWS

Information Modelling for the ongoing Life-cycle Management of Assets

Project Information Sheet

Research Engineer: Victoria Fillingham

Introduction:

The Case Study Information Sheet has been prepared to define the strategy for investigating the successful implementation of Information Modelling within the Operational period of built assets. The objective of this Information Sheet is to set out the key research aims; outlining the structure of data collection and the overall strategy by which this case study shall be managed.

Case Study Background:

The UK Government has for many years publicised the inefficiencies and negative traits of the construction industry. Information Modelling has been stated that it will assist building operators in making existing asset management processes and data collection more efficient, having the conclusive effect of improving maintenance procedures and whole-life operation. As a client, the UK Government has defined a series of strategies that highlights the importance of information; information that is created within the earliest stages of design, through to the point of occupation. If the construction industry can work more collaboratively together, utilising common procedures and data-sets to aid the development of ideas, the UK Government have stated that a reduction in 33% of overriding project costs can be achieved by the year 2025. Yet, through all the discussions currently had surrounding collaborative approaches to construction, there has been less emphasis on the existing principles and practices of those within the Asset Management sector.

To understand how information modelling can enable the advancement of asset management, this project has been designed to reverse the lifecycle – starting with the end in mind – highlighting the needs and the requirements of those working within Asset Management departments.

Project Objectives:

- *Business as Usual:*

In order for the findings to be categorised against existing activities within University Asset Management departments, a picture of 'business as usual' shall be captured. Understanding the day-to-day roles of each of the participants, in terms of the key activities they complete, the timescales they operate within, and the surrounding web of stakeholders that they interact with. The findings from the research will be given some grounding based on actuals, providing realistic results applicable to the wider Higher Education Asset Management sector.

- *Review of Existing Information Strategies:*

The department's strategy for Operation and Maintenance will be discussed; identifying the protocols that aid everyday tasks and functions, as well as the methodologies by which these protocols are kept to. The assessment will focus on the importance put on information, more specifically with regards to how it is created and the purpose for its creation. Gaining an understanding into the patterns of use and how function dictates the types and quality of information, will aid a bi-directional view of the complete life-cycle of an asset. Each member of the Asset Management department's daily requirements will be aligned to the overriding management practices in place, assessing also that which is critical for individual roles to complete work effectively and efficiently.

- *Operational Management Prioritisation:*

To identify the specific priorities of the University for the ongoing management of assets, for the 'set' period of operation as defined at handover of the capital works. Focusing specifically on the intended use of the information gathered throughout the project developmental stage, and the manipulation of said information to align with existing management practices, each participant will be asked to comment on areas of success and those of potential change.

- *At the Point of Handover:*

Understanding how information is handed over to the Asset Management department, and subsequently fed down through the chain of stakeholders for its daily use, will enable a long-term perspective to be identified. Critical interactions between those within the Asset Management department, and those partaking in the capital works shall be analysed in terms of the channels of information flow, and the guidance given to each individual stakeholder with regards to information creation. Applying reason to the common challenges at handover may lead to clearer identification, earlier on in the developmental stage of projects.

- *Capturing Lessons Learned:*

Assessing whether lessons learned are ever captured within the Asset Management department; specifically, what priority they are given in terms of the subject matter, contextual relationship and intended audience. Offering the opportunity to communicate experience and knowledge within the department itself, and externally to a wider audience will lead to more efficient methods of management for all.

Case Study Details:

Interview Structure:

Collection of data will be in the format of an interview, structured for the purpose of gaining personal insight into each member of the estate department's day-to-day role, and interaction with information. A recording of the session will be taken in order for a full account to be successfully documented, with the intention of post-interview analysis to be undertaken. All data collected within the recordings will remain anonymous and will be protected under the Data Protection Act.

Project Close Out:

The key deliverable of the project will be the creation of a written doctoral thesis, completed by the Research Engineer. Taking findings from the data analysis to expose how information modelling can be used as a tool for the ongoing life-cycle management of assets, guidance shall be given informing the reader of methods to improve the effectiveness and efficiency of information.

If there are any further questions surrounding the purpose of the study, or the resulting publication, please contact me on ***v.l.fillingham@pgr.reading.ac.uk****, or Dr Dragana Nikolic on* ***d.nikolic@reading.ac.uk*****.**

APPENDIX D – PROJECT CONSENT FORM: CORE INTERVIEWS

Information Modelling for the ongoing Life-cycle Management of Assets

Project Consent Form

Research Engineer: Victoria Fillingham

Participant Consent Form:

Please complete the following form if you are happy to take part in this study.

1. I confirm that I have read and understand the Research Information Sheet for the above study. ☐

2. I confirm that I have communicated with the above researcher and understand that my involvement will consist of being interviewed at an agreed time and place and have had the opportunity to ask questions. ☐

3. I understand that my participation is voluntary and that I am free to withdraw at any time, without my legal rights being affected. ☐

4. I understand both the above researcher from the Technologies for Sustainable Built Environments Centre, University of Reading, and the supervising academic Dr D. Nikolic from The School of Built Environment, University of Reading, will have access to my personal details. ☐

5. I understand that any data or information used within any publications that may arise from this study, will remain anonymous, unless otherwise agreed with the researcher. ☐

6. I understand that all data will be stored securely and is covered by the data protection act. ☐

I confirm that I am happy to take part in the above study.

Name of Participant:

Contact Details:

Signature: **Date:**

APPENDIX E – INTERVIEW SCHEDULE: CORE INTERVIEWS

Information Modelling for the ongoing Life-cycle Management of Assets	
Interview Protocol	
Research Engineer: Victoria Fillingham	

OBJECTIVE 1 – Where does waste occur in the existing model of information transfer?

- **What is your role within the University?**

People	Please could you summarise your position in terms of the overall University hierarchy?
	Who do you directly work with on a daily basis?
	Who do you report to?
Process	What are your typical daily tasks?
	Could you explain how you go about completing XXX task?
	What is the output of XXX task, in terms of work delivered and handed over?
	How do you confirm that a task is complete?
Technology	What tools do you use to complete your daily tasks?
	Do these tools help or hinder you to complete your tasks? Why?
Channel	How do you log your daily completed tasks with your superiors?
	How do you share your successes and failures for each task?

- **Thinking about the existing management practices of your department, could you explain to me when they were first introduced?**

People	Who was influential in their creation?
Process	What were the original requirements for use?
Technology	What tools were prioritised as being important, why?
Channel	Did the introduction change the way the department shared information, how?

- **Can you explain how you use these management practices?**

People	Who issues you work?
	Who monitors whether you are meeting the requirements of the practice?
	Who ensures that the information is accurate?
	Do others use the information that you have created?
	Wo maintains the information once you have completed it?
Process	What are the existing 'protocols' (rules, standards etc) for creating information?
	Are there different rules for different activities?
	Do you use the process differently, depending on who you're working with?
	Is there a cycle for how often you must complete specific activities?
	Do you have to use information created in a previous activity? Completed by you?
	Do these specific practices sit within other University practices?

	Has there been a case where you've had to adapt your process to suit the demands of a task?
Technology	In what format do you create your information?
	Does this format enable your activity?
	Are there any issues with creating information in this format? If yes, is there an example?
	Which format do you store the information that you create?
	How long is the information kept for?
	Can you complete your work using different tools?
Channel	Is there more than one method for distributing your work? Do you have a preference?
	Are there rules in place for how you share information?
	Rules for sharing between users?
	Rules for sharing between 'technologies'?
	What security measures are in place to keep the information 'safe'?

- **What are the main successes of the existing practices, as they are currently used?**

People	Do they offer you opportunity to work with many of your peers?
Process	Do they make your role easier?
	Do they mean you have a greater awareness of other University activities?
Technology	Is the format one that can be easily understood? By all?
	Is there a need for further training and development?
Channel	Can you easily share and receive work from others?

- **If you could identify areas that cause frustration, what would they be?**

People	Are you ever excluded by the existing practices?
Process	What signs are there that the practices are not performing as expected?
	How do these issues effect your day-to-day role?
	Are you always given the exact information that you need to complete your task?
	Does access to information ever restrict your work?
	Can you give an example of when your work was delayed by missing information?
Technology	Are these issues from the type of information or the tool that's used to create the information?
	Are there occasions when you can't understand the information?
	Is the information always 'complete'? As you expected?
Channel	Is information ever lost when being shared between users?
	Is information ever lost between tools?
	Do you feel like you can openly share your information with others?

- **When there are issues, are you given the opportunity to feedback?**

People	Who would you report these issues to?
	Are these reports open or confidential?
Process	Can you explain how you would report an issue?
	Is reporting encouraged?
Technology	Is it easier to report back using a computer-based tool?

OBJECTIVE 2 – What would need to happen for Asset Managers to benefit?

- **In terms of the whole-life perspective, can you explain where your role sits?**

People Do you ever interact with stakeholders on capital projects?
Do you ever interact with designers or engineers?
Do you ever interact with the users of the building?

Process Are you ever included in conversations during the development of capital projects?
At the point of handover, what do you receive?
Do you have any influence over what is requested from D&C? Offer guidance and or standards?
Are there any occasions when you hand information forward to designers or contractors?
Are there any occasions where you have to request further information from D&C?
Is the information given to you at the right time? If not, then when?

Technology Is the information given to you by designers enable you to complete your daily role?
Can you use the information immediately? If not, why not?
Can you use the information after a long period of storage?
How is the information stored?

Channel How do you receive information from D&C?
Is the way you are given information an efficient one?
Are there occasions where information gets 'lost'?

- **If you were to be asked to detail your ideal solution to how you create and use information, what would that be?**

People Who would be responsible for creating the information?
Who would be responsible for maintaining the information?

Process How would you use the solution differently to the existing?
How long would the solution be used for, before changes were needed?

Technology Would the information be a single type of format?
Would the solution mean that information could be stored and accessed remotely?

Channel Would the solution mean you can be given information remotely?

- **Does the existing solution enable you to work effectively?**

People Are you able to interact with others quickly?

Process Does it act as an aid in your daily role?
Does it mean you can complete tasks quickly? If not, why not?

Technology Is there any 'waiting' time?
Is the information ready to use?
Is the 'language' common for all users?

Channel Do you have to pre-empt the sending or receiving of information? Or is it automatic?

- **Does the structure of the existing solution mean that you can manage your day-to-day tasks efficiently?**

People	Do you ever create information that could also be created by others?
	Is there any cross-over with your work and others?
Process	How is the information categorised?
	What priority is given to the creation of information? Does this change per task?
	What information is critical to each task?
Technology	Are there different information requirements for each task (Inputs and Outputs)?
	Do the different requirements lead to difficulties?
	Is the information appropriate to each task?
Channel	Can you access the information quickly and easily?
	Are you required to use any password or log-on?

- **If you could offer changes to make your days more efficient, what would they be?**

People	Would your changes affect anyone else?
	Would the changes mean you could interact with others differently?
Process	Is the structure of the solution too challenging?
	Are you given enough support to complete your role?
Technology	Would the information be grouped differently?
	Would the information be 'written' differently?
	Would the information be visualised differently?
Channel	Would you be given greater access to information?

OBJECTIVE 3 – How can lessons learned best be captured?

- **Are you asked to capture the successes and failures in your day-to-day role?**

People	Who requests feedback?
	Who do you speak to/inform of the successes and failures? Does the person differ?
	Do the successes affect anyone else (immediately or long-term)? Failures?
Process	Do you actively record the pros and cons of a task or activity?
	What would you deem a success? Example?
	What would you deem a failure? Example?
Channel	How would you go about sharing your experience?

- **Should there be an opportunity to feedback to others?**

People	Is communicating your experiences with others in your department easy?
	Can you communicate your experiences with others at the University about your role?
	Can you communicate your experiences easily with external stakeholders
Process	Are you included in the development of practices or solutions within your department?
Technology	How would you suggest that you share your experiences with others?
	Would you want to share results to the wider university audience? External arenas?
Channel	If the way in which you gave feedback was secure, would you be more obliged to do so?

- **Are you included in projects?**

People	Do architects/engineers ever ask for your advice or knowledge?
	Are you ever approached by members outside your department to give advice on projects?
	Do you have an example?
Process	Are you ever included in discussions at the beginning of capital projects?
	Are you ever included during construction?
	Are you ever required to offer support during handover of capital projects? How?
Technology	What sort of information do you give to others? (Experiences/knowledge) Example?
	What would you see as 'useful' knowledge?

- **If you were to offer a lesson or thought to others outside your role, about the work you do, what would it be?**