Project-based innovation learning mechanisms in the built environment

Prompt Udomdech

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Abstract

Built environment organisations innovate or adopt innovation to address complexity and uncertainty that emerge in project operations. Amongst various built environment innovations, Building Information Modelling (BIM) is prominently chosen by the built environment organisations. This innovation presents a great challenge for Small- and Medium-sized Enterprises (SMEs). It renders existing working paradigms obsolete and digitally transforms built environment businesses. The lack of individuals with adequate BIM competence is a major problem. Project-Based Learning (PBL) is a potential solution. This research aims to investigate BIM learning in projects in the built environment SMEs. The study examines knowledge practices used in projects and how they are exercised together in forming a project-based learning mechanism of BIM. 31 designers and engineers from the British and the Thai design and engineering SME consultancies are interviewed. Knowledge practices are identified based on their significance, while associations between them are analysed. Informal meeting, Knowledge team creation, and Standardisation play a crucial role in BIM learning in projects. Informal meeting and Knowledge team creation relate to tacit knowledge learning and exploration. Standardisation encourages explicit knowledge learning and exploitation. A project-based learning mechanism of BIM is formed through an interconnected system of knowledge practices. The connections among knowledge practices are found as assistive and correlative. The project-based learning mechanisms of BIM identified within this research are ambidextrous through the variety of knowledge practices being exercised together. Additionally, they can be further categorised as Exploitative, Ambidextrous, and Explorative. Practical suggestions are provided for BIM managers to increase attention towards the employment of certain knowledge practices and the creation of project-based learning mechanisms of BIM. Informal meeting, Knowledge team creation, and Standardisation are recommended for managers of BIM and other innovations. Innovation managers can balance ambidexterity by utilising an array of knowledge practices to encourage both exploitation and exploration. Proactive and tangible support such as the implementation of guidelines and protocols from the public sector in developing countries will promote BIM learning in organisations and encourage industry-wide adoption.

Keywords: Ambidexterity, Building Information Modelling (BIM), innovation learning, knowledge practice, and Project-Based Learning (PBL).

Impact statement

This research investigates how project actors within built environment organisations learn and comprehend innovation. It specifically examines the challenge of BIM adoption in built environment SMEs. BIM is a current global trend amongst the built environment organisations in both developed and developing industries. The built environment SMEs make the majority of organisations within built environment sectors. The study examines how knowledge practices are utilised by designers and engineers from design and engineering SME consultancies in forming a project-based learning mechanism of BIM. Investigations are performed in the British and the Thai built environment sectors.

There are limited studies on knowledge practices and innovation learning. The field of study, especially within the built environment is recent. The exploration and examination into project-based learning mechanisms of BIM introduce a new perspective to help understand innovation adoption in built environment organisations. It offers an alternative viewpoint for scholars and builds on current studies on knowledge practice, PBL, and innovation adoption. Additionally, it contributes to current debates within ambidexterity literature by utilising ambidexterity theory to understand the project-based learning mechanisms of BIM.

At an individual level, this research puts forward suggestions for managers of BIM and other innovations in improving the project-based innovation learning mechanisms to advance innovation adoption. At an industry level, the study points out current problems within the built environment sector of developing countries and proposes recommendations to help forward the digital transformation of BIM in built environment industries. Improving the adoption of BIM in built environment SMEs directly increases the performance of the entire sector. Furthermore, the theoretical framework of this research can be utilised to assess the learning and adoption of other innovations that might replace BIM in the future. Organisations from other sectors can exercise the framework to review and strengthen their project-based innovation learning mechanisms and sustain their competitive position in the fast-changing market environment.

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List of abbreviations

2D	Two dimensional
3D	Three dimensional
ARCOM	Association of Researchers in Construction Management
BIM	Building Information Modelling
BEP	BIM Execution Plan
CAD	Computer Aided Design
COVID-19	Coronavirus Disease 2019
EPOC	Engineering Project Organization Conference
ESRC	Economic and Social Research Council
GDPR	General Data Protection Regulation
IDP	Information Delivery Plan
IRNOP	International Research Network on Organizing by Projects
ISO	International Organization for Standardization
IT	Information Technology
KBV	Knowledge-Based View
MEP	Mechanical, Electrical, and Plumbing
OL	Organisational Learning
PBL	Project-Based Learning
R&D	Research and Development
RBV	Resource-Based View
SLR	Systematic Literature Review
SME	Small- and Medium-sized Enterprise
SMEs	Small- and Medium-sized Enterprises

Syllk	Systematic lessons learned knowledge model
UCL	University College London

Chapter 1 Introduction

1.1 Research background

Built environment is mainly project-based (Navimipour and Charband, 2016; Tatum, 1987). Projects are temporary organisations, comprised of a team of functional members (Davies and Brady, 2016; Kivrak et al., 2008; Oesterreich and Teuteberg, 2016). Within the built environment industry, these functional members include project parties such as client, architect, designer, engineer, and contractor (Davis et al., 2016; Yun et al., 2011). Actors from each project party collaborate as a project team and dismember after every project completion (Kivrak et al., 2008; Loosemore, 2015). This discontinuity of project actors leads to fragmentation of work and interruption of organisational learning (Sakhrani et al., 2017; Vakola and Rezgui, 2000). Furthermore, each project is unique, complex, and accustomed to uncertainty (Aouad et al., 2010; Polesie et al., 2009). Altogether, they render built environment operation uneconomical and pressure organisations to constantly innovate (Slaughter, 2000;

Tatum, 1989). Amongst various built environment innovations such as augmented reality, robotics, and machine learning, Building Information Modelling (BIM) is a common denomination being adopted by organisations (Dainty et al., 2017; Lindblad and Vass, 2015; Miettinen and Paavola, 2014).

BIM is a socio-technical platform that integrates geometric and functional properties of facilities for all project members to access throughout a building lifecycle (Bryde et al., 2013; Miettinen and Paavola, 2014; Puolitaival and Forsythe, 2016). BIM introduces technological, procedural, and political changes to operations within the built environment sector (Santos et al., 2017; Wu et al., 2018). Design and engineering consultancies are early adopters of BIM (Eadie et al., 2015; Ghaffarianhoseini et al., 2017). A successful integration of BIM in projects and organisations fosters substantial benefits (Aouad et al., 2010; Bryde et al., 2013; Dainty et al., 2017). However, BIM adoption forwards many complications for organisations to overcome (Allen and Shakantu, 2016; Migilinskas et al., 2013).

The adoption of BIM requires organisations to drastically modify their current practice, invest in additional resources, and guide organisational members through change (Miettinen and Paavola, 2014; Tulenheimo, 2015). These challenges are greater for Small- and Medium-sized Enterprises (SMEs) (Dainty et al., 2017; Murguia et al., 2017; Shibeika and Harty, 2015). Instead of organisational growth, SMEs innovate only to survive and counter immediate problems (Chang and Hughes, 2012; Loosemore, 2015). Built environment SMEs account for the majority of organisations within built environment sector (Dainty et al., 2017; Davis et al., 2016). An insufficient utilisation of BIM potentially forces built environment SMEs out of a competitive market, creates a digital divide, and decreases efficiency of the entire built environment industry (Allen and Shakantu, 2016; Migilinskas et al., 2013).

1.2 Problem statement

Lack of *individual BIM competence* (Succar and Sher, 2014; Uhm et al., 2017) in project actors is the major constituent to inept BIM adoption in built environment SMEs (Bryde et al., 2013; Ding et al., 2015; Eadie et al., 2013). BIM competence refers to the personal traits, professional knowledge, and technical abilities of project actors in executing BIM-related tasks and delivering BIM-related outcomes (Miettinen and Paavola, 2014; Succar and Sher, 2014). Individual BIM competence can be increased by improving *BIM learning* of project team members (Succar and Sher, 2014).

BIM learning concerns how project actors acquire BIM-related knowledge and gain adequate competences to perform essential and job-specific tasks of BIM (Bosch-Sijtsema et al., 2019; Uhm et al., 2017). Learning within the built environment is prolific in a project setting (Duffield and Whitty, 2015; Hartmann and Dorée, 2015). BIM learning in projects supports BIM adoption in organisations.

BIM learning in projects relates predominantly to Project-Based Learning (PBL). PBL provides that the performance of an organisation relies on how project team members learn from projects (Bakker et al., 2011; Hartmann and Dorée, 2015). It implies how organisations comprehend innovations by acquiring their embedded knowledge (Gopalakrishnan et al., 1999; Vial, 2019) through the utilisation of *knowledge practices* in projects (De Toni and Pessot, 2020; Hartmann and Dorée, 2015). Knowledge practice refers to mediums exercised for knowledge transfer and learning (Ashok et al., 2016; Hartmann and Dorée, 2015) and entails artefacts and activities chosen by project team members to learn (De Toni and Pessot, 2020; Mueller, 2015). Studies on knowledge practices used for BIM learning in projects are limited (De Toni and Pessot, 2020; Van Waveren et al., 2017). Project teams and organisations employ knowledge practices collectively, where a system of knowledge practices to comprehend BIM in projects refers to a *project-based learning mechanism of BIM.* The study accounts project-based learning mechanism of BIM as process innovation developed primarily within each built environment organisation. A project-based learning mechanism of BIM is an innovative mechanism developed mainly within each organisation to capture, transfer, assimilate, and absorb BIM-related knowledge from projects.

1.3 Aim and objectives

Corresponding to the established problem, the research aim is *to investigate into BIM learning in projects in built environment SMEs*. The research has the following objectives:

a) To explore knowledge practices used in projects for BIM learning;
b) To examine how project teams utilise knowledge practices and formulate project-based learning mechanisms of BIM;
c) To analyse how project-based learning mechanisms of BIM assist built environment SMEs in BIM learning; and
d) To generate recommendations in advancing BIM adoption within built environment SMEs.

1.4 Research questions and sub-questions

With the stated aim, the research question is *'How, and to what extend does BIM learning occur in projects in built environment SMEs?'*. The research sub-questions, corresponding to the objectives are:

a) What are knowledge practices exercised in projects for BIM learning?
b) How do project teams utilise knowledge practices and formulate project-based learning mechanism of BIM?
c) How does each project-based learning mechanism of BIM assist built environment SMEs in BIM learning?
d) How can built environment SMEs improve their BIM adoption through BIM learning?

1.5 Research methodology

The research upholds constructivist ontology and interpretivism epistemology research philosophies. BIM learning in projects is organic, socially formed, and influenced by its context. This demands a qualitative inquiry (Crossan, 2003). Through deductive reasoning approach, the examination sets to generate a greater understanding of BIM learning in projects and achieve a plausible explanation of how project-based learning mechanisms of BIM serve built environment SMEs in BIM learning and adoption.

The inquiry contains 31 interviews of designers and engineers from design and engineering SME consultancies. Designers and engineers are project actors that work actively with BIM (Barison and Santos, 2019; Tulenheimo, 2015). Additionally, the study focused on actors with a BIM managerial role. Design and engineering consultancies are early adopters of BIM in built environment industries (Dainty et al., 2017; Murguia et al., 2017). Interviewees are from two contexts of the British and the Thai built environment sectors. The prior represents a developed industry, while the latter depicts a developing industry. Both have different cultural settings.

The data collection method is through semi-structured interviews. The study breaks down into three stages which are: a) pilot interviews in Thailand; b) the British data collection; and c) the Thai data collection. Interviews are recorded, transcribed, translate (for Thai interviews), and imported into NVivo qualitative analysis software. The analysis method chosen is qualitative content analysis. The research complies with the University College London (UCL) Code of

Conduct for Research, the Economic and Social Research Council (ESRC) Framework for Research Ethics 2015, and the Data Protection Act 1998.

1.6 Research justification

Theoretically, this investigation bridges and builds upon *BIM competence* and *knowledge practice in learning* studies. BIM competence is a concept within *built environment innovation* literature. The built environment innovation literature also relates to knowledge bodies of *digital transformation*, *digital divide*, and *innovation*. Knowledge practice in learning nests in *PBL* and *Knowledge-Based View (KBV) of organisations*. Additionally, BIM learning in projects relates further to theoretical bodies of *ambidexterity* and *knowledge* literature.

Whereas studies on BIM adoption are gaining their common ground, specific investigations on project-based learning mechanisms of BIM are still in infancy. Studies on BIM learning and adoption in built environment SMEs are limited. This research generates a deeper understanding of how BIM-related knowledge is captured, transferred, and learned by project team members and updated into the organisational process. It explains how knowledge practices are utilised in projects and how project-based learning mechanisms are formed to support the innovation of BIM.

In addition, this research reflects upon built environment innovation and digital transformation studies by recognising BIM as a system innovation (Slaughter, 2000) that triggers digital transformation in the built environment sector. The investigation into project-based learning mechanisms of BIM contributes to current debates within ambidexterity literature. BIM learning in projects is integrative, dynamic, and contextual.

Practically, this research produces propositions that assist built environment SMEs in the learning and adoption of BIM. Successful BIM adoption is crucial for built environment SMEs in sustaining their competitive position in the market. With SMEs being the majority of organisations within the built environment sector, improved BIM adoption potentially increases the overall performance of the industry. A greater understanding of project-based learning mechanisms of BIM can bring transferable knowledge about the adoption of other innovations. Additionally, organisations can utilise the theoretical framework of this study to evaluate their *project-based innovation learning mechanisms* to advance future adoption of other innovations.

1.7 Scope and delimitation

Project-based learning mechanisms of BIM in built environment organisations are the innovation being examined in this research. The study omits the learning of other built environment innovations as they are not in the spotlight for most built environment organisations. The investigation compares a project-based learning mechanism of BIM from each built environment SMEs. The research identifies organisations with 10 to 249 members as SMEs (Dainty et al., 2017; European Commission, 2009). The adoption of BIM brings a greater challenge to the built environment SMEs than large organisations (Dainty et al., 2017; Murguia et al., 2017; Shibeika and Harty, 2015). Interviewees within this research are designers or engineers as they are project actors who work hands-on with BIM (Barison and Santos, 2019; Tulenheimo, 2015). Designers and engineers include project roles which are architect, designers, civil engineer, and mechanical engineer. Design and engineering consultancies are early adopters of BIM in the built environment industry (Shibeika and Harty, 2015; Zhang et al., 2018). Design and engineering SME consultancies are from the British or the Thai built environment industries. Both contexts represent developed and developing sectors. The total number of interviewees from each context corresponds to when data collected has reached its saturation period.

1.8 Research outline

Chapter 2 Literature review – Chapter 2 presents a comprehensive literature review of this research. The first part of the chapter covers organisation innovation, built environment innovation, BIM, and BIM competence studies. The second part includes knowledge, knowledge management, learning, PBL, and ambidexterity literature. The last part introduces the theoretical framework that assists in the exploration of project-based learning mechanisms of BIM in design and engineering SME consultancies.

Chapter 3 Research methodology – Chapter 3 clarifies the research methodology. First, it starts with the rationale of this research which entails research context and research paradigm. Second, it explains research methods which include methods of data collection and analysis, as well as information of interviewees and research stages. The chapter ends with ethics and data protection consideration.

Chapter 4 Data presentation and structure – Chapter 4 displays and organises the data collected. It begins with a re-statement of the research question. Subsequently, project-based learning mechanisms of BIM identified from both contexts are categorised based on their dominant traits.

Chapter 5 **Data analysis and interpretation –** Chapter 5 presents the analysis and interpretation of all project-based learning mechanisms of BIM within the study. The deconstruction and evaluation of each project-based learning mechanism of BIM yield research findings.

Chapter 6 **Discussion** – Chapter 6 puts forward the discussion of research findings. Main findings are critically examined to past literature and relevant theories. The discussion chapter is organised concerning research sub-questions posed.

Chapter 7 **Conclusion** – Chapter 7 marks the end of this doctoral thesis. It synthesises the findings discovered within this research and forwards additional insights for framing the research problem based on the results of this study.

Chapter 2 Literature review

This chapter presents an extensive review of relevant literature and theoretical bodies. Chapter 2 comprises of three parts. The first part covers related literature of built environment innovation and BIM. The second part includes reviews of associated studies on knowledge and PBL. The last part of the Literature review chapter introduces the theoretical framework of this research.

2.1 Innovation

2.1.1 Innovation in organisations

Innovation is crucial for organisations to compete in the current market environment, where development and growth are mandatory for businesses to survive (Băjenescu, 2017; Crossan and Apaydin, 2010; Hidalgo and Albors, 2008). Innovation refers to the generation and implementation of a new idea, behaviour, product, procedure, and marketing method (Băjenescu, 2017; Hidalgo and Albors, 2008). Innovation can be *internally* produced and/or *externally* sourced (Băjenescu, 2017). The former view defines innovation as a creation, a development, or a re-combination of new knowledge or ideas within an organisation to facilitate novel business outcome, improve operations and structure, and create market-driven product or service (Băjenescu, 2017; du Plessis, 2007). It is a process in which organisations locate problems and actively produce new knowledge to solve them (Seidler de Alwis and Hartmann, 2008). Innovation within this perspective involves a change in routines and a development of new operations, material, forms of an organisation, and markets (Bygballe and Ingemansson, 2014). The latter notion interprets innovation as successful introduction and adoption of a new product, a production method, a market, a source of supply, or business management processes to an organisation (Hidalgo and Albors, 2008; Pichlak, 2016).

Innovation is a *process*, as much as an *outcome* (Crossan and Apaydin, 2010). It can be broadly classified into two types which are *technical* and *organisational* (Băjenescu, 2017; Gopalakrishnan et al., 1999). On one hand, technical innovation addresses new technologies, products, and services (Crossan and Apaydin, 2010). On the other hand, organisational innovation involves managerial aspects such as the utilisation of a contemporary business practice, procedure, policy, and organisational form (Sohn et al., 2009). Organisational innovation often refers to *administrative* innovation (Băjenescu, 2017). Moreover, organisational innovation comes in three forms which are: a) *product or service innovation*, relates to state-of-the-art products being proposed and implemented in an organisation; b) *process innovation*, concerns new production methods and management approaches (Cooper, 1998; Papinniemi, 1999); and c) *business model innovation*, involves how an organisation creates, sells, and delivers value to customers (Crossan and Apaydin, 2010). Table 2.1 summarises different categorisations of organisational innovation.

Table 2.1: Different categorisations of organisational innovation.

Different categorisations	**Explanation**
Internal	Innovation entails a creation, development, or re-combination of new knowledge or idea. It includes a change in routines to development of new operations, material, forms of an organisation, and markets.
External	Innovation refers to successful introduction and adoption of a new product, production method, market, source of supply, or business management procedure.
Technical	Innovation refers to new technologies, products, or services.
Organisational (administrative)	Innovation involves managerial aspects such as a utilisation of a new business practice, procedure, policy, and organisational form.
Product or service	Innovation includes state-of-the-art products being proposed and implemented in an organisation

Process	Innovation incorporates new production methods and management approaches.
Business model	Innovation encompasses how an organisation creates, sells, and delivers value to customers.

2.1.2 Innovating and adopting innovation

Organisational innovation contains three main elements which are: a) *practitioner*, organisational members or agents who innovate or perform activities that affect organisational innovation; b) *practice*, theories that guide innovation-related activities; and c) *praxis*, actions, activities, or theories-in-use that constitute to the fabric of innovation (Crossan and Apaydin, 2010). Organisations or entities that are early and responsive to implement an innovation or innovate are *leaders*, while late adopters or inventors are *followers* or *latecomers* (Abramovitz, 2006; Hobday, 2005). Followers can decrease the innovative gap through *catching up* (Abramovitz, 2006; Sohn et al., 2009). Catching up concerns two main processes of *imitation* and *innovation* (Hobday, 2005; Iwai, 2000).

Imitation means successful exploitation of organisational resources and existing knowledge in mirroring how leaders innovate (Iwai, 2000). This can occur through both formal and informal modes of knowledge transfer and learning (Hobday, 2005). However, the learning of explicit and codified knowledge is more beneficial as it can be easily absorbed and understood (Sohn et al., 2009). Innovation involves exploring and creating new knowledge, method, or processes based on the internal capability of an organisation (Kim, 1998; Sohn et al., 2009). This process is critical for followers to drastically catch up with leaders. Followers need to come up with a fresh strategy and business model to correspond to the advantages that leaders have from being early adopters (Abramovitz, 2006; Hobday, 2005). The rapid advancement of followers refers to *leapfrogging* (Sohn et al., 2009).

2.1.3 Innovation and standardisation

Organisations innovate and/or adopt innovation differently (Caetano, 2017). This depends on their business practice, drivers of innovation, and innovations being implemented (Crossan and Apaydin, 2010; Pichlak, 2016). Despite the same innovation being adopted, organisation innovation is unique as organisations develop their absorbing mechanism at their distinguish pace and style to suits their businesses (Plesner and Horst, 2013; Warner and Wäger, 2019). The differentiation presents tremendous complications for industries that require extensive coordination such as healthcare, entertainment, and built environment (Blind et al., 2020). This leads to the *standardisation* of tools, processes, and policies as an attempt to foster seamless collaboration between organisations (Jakobs et al., 2001).

Standardisation refers to the development of specifications based on consensus amongst interested parties (Blind et al., 2020). It represents a voluntarily drawn set of rules which imply similarity, uniformity, and continuity of behaviour, actions, and/or beliefs (Wright et al., 2012). Standardisation, while being both technical and organisational entails standards, manuals, and guidelines (Caetano, 2017; Wright et al., 2012). On one hand, standardisation acts as a potential driver for innovation (Caetano, 2017) and an *invincible structure* that binds disciplines together (Maradza et al., 2013). It can enhance organisational capabilities in aligning with national and international best practices, as well as to develop internal competence, routine, and process that can leverage an innovation journey by diffusing knowledge throughout an organisation (Caetano, 2017; Jakobs et al., 2001). On the other hand, standardisation can also hinder innovation in organisations (Polesie et al., 2009). Standardisation provides a certain level of structure and bureaucracy to an organisation which undermines the creation of new ideas and restricts organisation to only perform within certain procedures (Wright et al., 2012). Research on innovation and standardisation is limited, especially on the role of the latter in organisational learning and knowledge transfer for innovation (Caetano, 2017; Maradza et al., 2013).

2.1.4 Views on innovation research

Studies on organisational innovation separate into two directions of *innovation process* and *innovation variance* (Hameed et al., 2012; Pichlak, 2016). Innovation process research examines processes of diffusion of innovation and innovativeness of organisations (Hameed et al., 2012). Innovation variance research focuses on understanding and examining organisational determinants of innovation adoption and effects of innovation adoption on organisational performance (Crossan and Apaydin, 2010; Hameed et al., 2012; Pichlak, 2016).

There are three perspectives on innovation research, namely: a) *individualist perspective*, pays attention to attitudes of organisational members as the major source of any innovative change; b) *structuralist perspective*, assumes that context and structure of an organisation play a crucial role in determining organisational innovation; and c) *interactive process perspective*, undertakes the holistic view where organisation innovation is dynamic and is mutually influenced by context, structure, and members of an organisation (Pichlak, 2016).

2.2 Built environment innovation

2.2.1 Nature of the built environment

Businesses within the built environment industry are partially manufacturing and service providing (Aouad et al., 2010). Works within the sector are project-based (Tatum, 1989). A project contains: a) specific objective to be completed within certain performance specifications; b) limited resources; c) defined start and end dates; d) knowledge needs; and e) a project manager and a project team responsible for project objectives (Gann and Salter, 2000; Koskinen, 2012; Landaeta, 2008).

A project team comprises of a group of people with complementary skills working collaboratively together (Kivrak et al., 2008; Navimipour and Charband, 2016). After every project completion, this collective group of project actors dismembers. This highly fragmented delivery structure besets the performance of organisations and industries (Dainty et al., 2017). Moreover, built environment projects are large, complicate, and long-lasting (Slaughter, 2000). The temporariness nature of the built environment work, together with the complexity of projects result in non-productive work, contractual dispute, adversarial working relationship, unsafe practice, slow delivery, costs overrun, and needs for built environment organisations to innovate (Dainty et al., 2017; Slaughter, 2000; Tatum, 1987).

2.2.2 Innovation in projects

Innovation in built environment organisations generates three areas of benefits which are: a) social benefits, as construction costs reduced, facilities then become more affordable and accessible to greater population; b) technical benefits, as organisations innovate or adopt innovation, projects that may appear to be beyond current technological frontier then turn possible; and c) competitive benefits, as organisations innovate, they improve their performance, reputation, survival, and growth, as well as attract recruits (Aouad et al., 2010; Slaughter, 2000; Tatum, 1987).

Innovation in the built environment can occur at all levels from an individual, a project, an organisation, to an industry (Bygballe and Ingemansson, 2014; Davies and Brady, 2016). However, much of it is hidden and co-developed at a project level (Aouad et al., 2010; Brady and Davies, 2004; Bresnen et al., 2005). Built environment organisations innovate mainly at the project level because work is always unique and delivered to bespoke design (Ozorhon, 2013). Projects are an innovative environment where different project actors come together with various skills and specialities to solve specific problems within a determined timeframe (Davies and Brady, 2016). There are five levels of innovation in the built environment based on complexity of innovation, changes it brings, and links it creates to other systems within an organisation (Slaughter, 2000). The categories are: a) *incremental innovation*; b) *architectural innovation*; c) *modular innovation*; d) *system innovation*; and e) *radical innovation* (Ashok et al., 2016; Slaughter, 2000). Figure 2.1 displays categories of built environment innovation in comparison to one another.

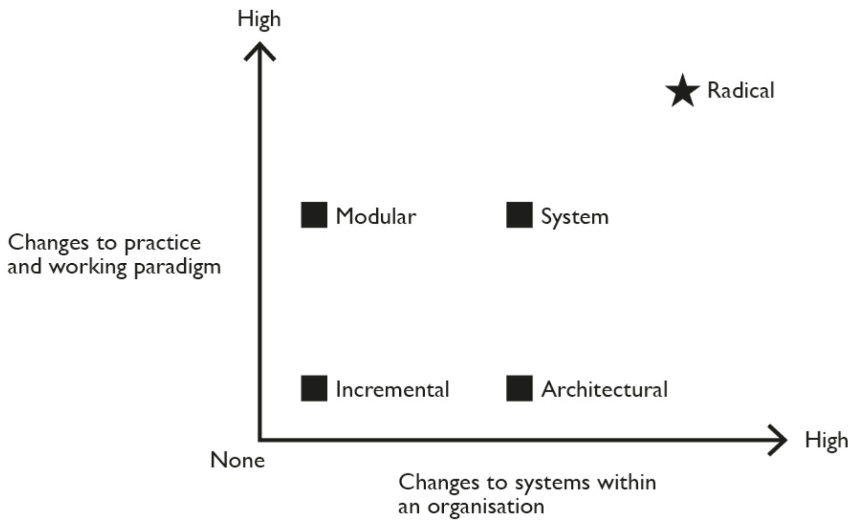

Figure 2.1: Categories of built environment innovation in organisations (Slaughter, 2000).

Referring to Slaughter (2000), incremental innovation refers to innovation adoption that generates small changes in current practices with minimum impacts on other organisational components. Architectural innovation implies innovation with small alterations to current business operations but requires significant modifications in other parts of an organisation in order for the innovation to function properly. Modular innovation is the opposite of architectural innovation. The innovation includes those with substantial impacts on businesses but instructs fewer changes in the organisational system. System innovation is a set of complementary innovations which work together to provide new attributes or functions. Together, they significantly advance the state of practices within an organisation. Radical innovation represents a completely new concept or approach that renders the previous working paradigm obsolete. While system innovation requires coordination from all project team members, radical innovation demands top management from all involved organisations to participate (Dainty et al., 2017; Papadonikolaki, 2017).

Currently, there are numerous innovations being adopted by built environment organisations such as robotics, machine learning, augmented reality, or drones. However, BIM is the prevalent denomination (Bryde et al., 2013; Santos et al., 2017; Zhang et al., 2018). The innovation functions as a platform for project actors to collaborate and introduces a digitally new way of how buildings are designed, documented, constructed, and managed (Dainty et al., 2017; Lindblad and Vass, 2015; Miettinen and Paavola, 2014).

2.2.3 BIM as an innovation

Many practitioners treat BIM as an advanced evolution of CAD (Computer-Aided Design) software (Bryde et al., 2013; Ghaffarianhoseini et al., 2017; Migilinskas et al., 2013). BIM provides an innovative way of approaching built environment projects (Bryde et al., 2013; Ding et al., 2014) by offering a digital platform for project team members to collaborate and for a representation of physical and functional characteristics of a facility (Miettinen and Paavola, 2014; Santos et al., 2017). BIM presents a set of integrated policies, processes, and technologies to improve efficiency and effectiveness of delivering a project from inception to completion (Bryde et al., 2013; Ding et al., 2019). Additionally, BIM is considered as *construction informatics* (Li et al., 2017) and *digital construction tool* (Migilinskas et al., 2013).

Main functions of BIM are to: a) develop a strategy of project design, construction, and management based on a computer-aided modelling and simulation technologies of objects and their development process; b) ensure a unified management of graphical and information flow, combined with descriptions of processes under an integrated digital environment; c) transform individual executor into teams by integrating tasks into processes; and d) perform a more efficient lifecycle operation of a built environment project with lower costs and transparency (Ding et al., 2014; Migilinskas et al., 2013). BIM is different from the traditional 3D (three dimensional) CAD as 3D CAD model only describes a facility with independent 3D views such as plans, sections, and elevations (Ding et al., 2014). Furthermore, data on this traditional paradigm only encompasses graphical entities such as lines, arcs, and polygons (Ding et al., 2014; Li et al., 2017) without further intelligence about the asset represented.

BIM contains a *core area* which holds technical structure and information management processes and a *support area* which carries knowledge transfer, training, and education (Li et al., 2017). Respectively, these areas represent *surface* and *deep structures* of the innovation (Chen et al., 2017). On one hand, the surface structure of BIM considers the innovation as a system or a set of systems enabling users to generate, use, integrate, and reuse building information throughout a project lifecycle. On the other hand, the deep structure of BIM includes the s*tructural feature* such as specific types of rules and offers by the innovation; and the *spirit feature* which is the general intent with regards to values and goals underlying a given set of structural features (Chen et al., 2017).

2.2.4 BIM adoption

Organisations perceive BIM as a suitable countermeasure for the temporariness nature of built environment business and the complexity of built environment projects (Bryde et al., 2013; Puolitaival and Forsythe, 2016). The innovation is routinely exercised throughout the design phase, followed by detailed design and tendering, construction, and management phases of a project respectively (Eadie et al., 2013; Ghaffarianhoseini et al., 2017). Architects and engineers are the most active participant of BIM (Ding et al., 2019; Tulenheimo, 2015).

While BIM is a common technology and process used in built environment projects, it also introduces a revolutionary change to the current working paradigm of organisations (Allen and Shakantu, 2016; Puolitaival and Forsythe, 2016). BIM requires development of new processes and operations, implementation of new technology, and inspired project actors with a new working culture (Alazmeh et al., 2018). Scholars consider BIM as an agent of change that brings *digital transformation* upon the built environment industry (Papadonikolaki, 2020; Plesner and Horst, 2013; Vial, 2019). Digital transformation refers to the application of digital technology to all aspects of the industry through combinations of information, computing, communication, and connectivity (Headrick, 2017; Vial, 2019). Design and engineering consultancies are early adopters to BIM (Eadie et al., 2015; Ghaffarianhoseini et al., 2017).

There are various factors affecting the adoption of BIM in organisations. Through the perspective of innovation catching up (Abramovitz, 2006; Hobday, 2005), enabling and hindering factors of BIM adoption can be classified into four main dimensions of *motivation*, *skills*, *material*, and *usage* (Dainty et al., 2017). First, the motivation dimension refers to a drive of each project actor to adopt, acquire, learn, and use the innovation (Dainty et al., 2017; Ding et al., 2015). Motivation may be straightforward or complex. The prior includes reasons such as the lack of interests, time, and money, while the latter involves reasons like technophobia and the lack of self-confidence (Dainty et al., 2017). Second, the skills dimension entails competences or efforts to be made to operate and use BIM. Project actors acquire skills through formal education such as courses or operation manuals, and/or informal education such as learning through practice, trials and errors, or by asking other skilled project actors (Ding et al., 2015; Eadie et al., 2013). Third, the dimension of material is a physical access to hardware, software, and related services of BIM. Forth, the usage dimension incorporates economic, social, cultural, and political factors (Dainty et al., 2017; van Deursen and van Dijk, 2014). Project actors can develop bias towards BIM as the innovation might favour their particular interests, languages, working culture, or even digital background (Dainty et al., 2017; Ghaffarianhoseini et al., 2017).

The skills dimension, specifically the lack of sufficient BIM expertise in project team members and organisations is the major barrier to successful adoption of BIM (Bosch-Sijtsema et al., 2019; Bryde et al., 2013; Eadie et al., 2013). The lack of BIM expertise relates directly to the issue of inadequate *BIM competence of individuals* within a project team (Bosch-Sijtsema et al., 2019; Ding et al., 2015; Eadie et al., 2015).

2.2.5 Individual BIM competence

The term competence derives from the Latin word *competens*, which translates as: a) a general ability of an individual to be successful in their job; b) a standard to select the best candidates from the average or below average person; and c) a guideline to develop the organisational performance (Uhm et al., 2017). Individual BIM competence refers to personal traits, professional knowledge, and technical abilities required to perform and deliver BIM-related activities and outcomes (Abel, 2008; Succar et al., 2013). *BIM competence* relates to the *competency-based approach* (Lawler, 1994) and *learning* (Kushwaha and Rao, 2015), where skills and capabilities of individuals are the central foci of an organisational development. BIM competence of an individual is the aggregate sum of: a) conceptual or theoretical knowledge; b) skills, procedural, or applied knowledge; and c) personal traits (Succar and Sher, 2014). *Competency* relates more to a specific set of skills required for a certain job (Uhm et al., 2017).

On competency, Abel (2008) classified it into two types which are a) *hard competency*, relates to knowledge, skills, and abilities of individuals required to perform an activity and b) *soft competency*, corresponds to personal behaviour, traits, and motives in working. Succar et al. (2013) provided that there were four levels of discussions on competency. The levels were: a) *individual competency*, the unit measure of abilities of an individual to conduct an activity and deliver an outcome; b) *group competency*, the arithmetic sum of several individual competencies, but as a measure does not reflect efficiencies gained or lost from such aggregation; c) *team capability*, the unit measure of combined abilities of team members; and d) *organisational capability*, the unit measure of abilities of an organisation and its sub-organisational units (Succar et al., 2013; Succar and Sher, 2014).

In particular, Succar and Sher (2014) broke down individual BIM competence into three tiers which are *core*, *domain*, and *execution tiers*. While the core tier referred to personal abilities of individuals that enable them to conduct a measurable activity or deliver a measurable outcome, the domain tier included the professional abilities of individuals. The domain tier also related to the means they use to perform multi-task activities and methods they employ to deliver outcomes with complex requirements. Independently, the execution tier referenced to the abilities of individuals to use specific tools and techniques. Uhm et al. (2017), however, proposed a different approach in assessing individual BIM competence. Concerning BIM-related jobs, roles, and responsibilities, Uhm et al. (2017) divided BIM competence of individuals into three categories of: a) *essential competence*; b) *common competence*; and c) *job-specific competence*. Uhm et al. (2017) referred essential competence as competencies that were required for all project actors operating on BIM regardless of their specific roles. In addition to the essential competence, common competence related to skills required by the majority of BIM-related roles. Job-specific competence regarded the competencies needed for specific project actors.

The lack of individual BIM competence in project actors places emphasise on learning BIM in organisations (Bosch-Sijtsema et al., 2019; Succar and Sher, 2014). Project actors potentially learn BIM through ways such as formal education, on-the-job training, or informal experience gain (Puolitaival and Forsythe, 2016; Succar and Sher, 2014). However, it requires organisations to invest resources and to have adequate experience in managing BIM-related knowledge (Puolitaival and Forsythe, 2016). BIM learning presents a challenge that is greater for SMEs than large organisations (Loosemore, 2015; Murguia et al., 2017).

2.2.6 BIM and built environment SMEs

SMEs refers to organisations with 20 to 249 members (Dainty et al., 2017; European Commission, 2009). In general, SMEs are in a tight spot when it comes to innovation as they are motivated by factors such as survival and the need to solve immediate problems, rather than growth (Chang and Hughes, 2012; Loosemore, 2015). Most SMEs are technologically weak, poor in investments for learning, and inferior in management experience in coping with regulations and associated compliance costs (Egbu, 2000; Ghaffarianhoseini et al., 2017; Loosemore, 2015).

With the adoption of BIM, Ghaffarianhoseini et al. (2017) and Tulenheimo (2015) stated that built environment SMEs are in an unequal situation compared to large organisations in terms of available resources. Dainty et al. (2017) added that smaller organisations lack the capacity, where those with more resources implemented first since they have more access. However, Tulenheimo (2015) pointed out that smaller organisations can also be in the position of advantage. Sexton and Barrett (2004) further explained that for smaller built environment organisations, innovations or technologies can be absorbed and used more quickly and tangibly if they can be dovetailed into existing organisational capability. Additionally, this argument was raised in Murguia et al. (2017) and Tulenheimo (2015). Notwithstanding, Migilinskas et al. (2013) and Sexton and Barrett (2004) described that any innovation that is far too removed from the comfort zone of SMEs, requires excessive investments, and yields substantial risks would be ignored.

Studies on the organisational side of BIM learning and adoption are limited (Lindblad and Vass, 2015), especially with foci on the built environment SMEs (Dainty et al., 2017; Murguia et al., 2017). Most studies on innovation adoption orient towards large organisations with their own Research and Development (R&D) departments and elaborate divisions of organisational members (Hobday, 2005). SMEs operate more on an informal process (Arendt, 2008; Davis et al., 2016). Differently than large organisations, SMEs are different species that operate in a different market, behave in varying ways to adapt and succeed, and need distinct sources and types of knowledge and technology to remain nourished (Dainty et al., 2017; Tulenheimo, 2015).

Investigations into the learning of BIM in built environment SMEs are necessary for advancing the adoption of BIM in both SMEs and the industry. This research builds on Tulenheimo (2015) and Dainty et al. (2017), by considering *BIM as a system innovation* (Slaughter, 2000). BIM challenges and replaces an existing understanding of how buildings are designed, constructed, and managed. It requires attention from all project team members in an organisation to enforce a proper utilisation. BIM competence of individuals relates to the KBV of organisations, where knowledge is a valuable organisational resource in the successful adoption of innovation (Egbu, 2000; Liyanage et al., 2009)

2.3 KBV of organisations

2.3.1 Knowledge

Knowledge generally refers to individual competencies acquired through the dynamic human process of justifying personal perception towards truths (Nonaka, 1994; Prencipe and

Tell, 2001; Vladimirou and Tsoukas, 2001). Knowledge is context-specific, depending on particular time and space; and dynamic, creating in social interactions amongst individuals and organisations (Seidler de Alwis and Hartmann, 2008). Knowledge consists of truth, belief, perspective, concept, judgement, expectation, and methodology (Egbu, 2000). Often, knowledge is mistaken as *data*, *information*, and *expertise* (Bender and Fish, 2000; Court, 1997).

Data equals to raw numbers, characters, and facts that have not been organised or interpreted (Court, 1997). Information represents a combination of raw data that has been processed by individuals with a certain understanding, meaning, relevance, and purpose (Liyanage et al., 2009). Information becomes knowledge when interpreted and given context through the personal application, value, and belief (Bender and Fish, 2000; Starbuck, 1992). Knowledge is the mental state of ideas, facts, concepts, and techniques that are recorded in the memory of each individual (Bender and Fish, 2000). Expertise corresponds to specialised and deep understanding in a certain field that is far above average (Bender and Fish, 2000; Vakola and Rezgui, 2000). Individuals gain expertise through experience, training, and education (Brauner and Becker, 2006; Starbuck, 1992). They should be able to create novel knowledge and solutions from their field of proficiency (Brauner and Becker, 2006; Vakola and Rezgui, 2000). Figure 2.2 illustrates the hierarchy of data, information, knowledge, and expertise.

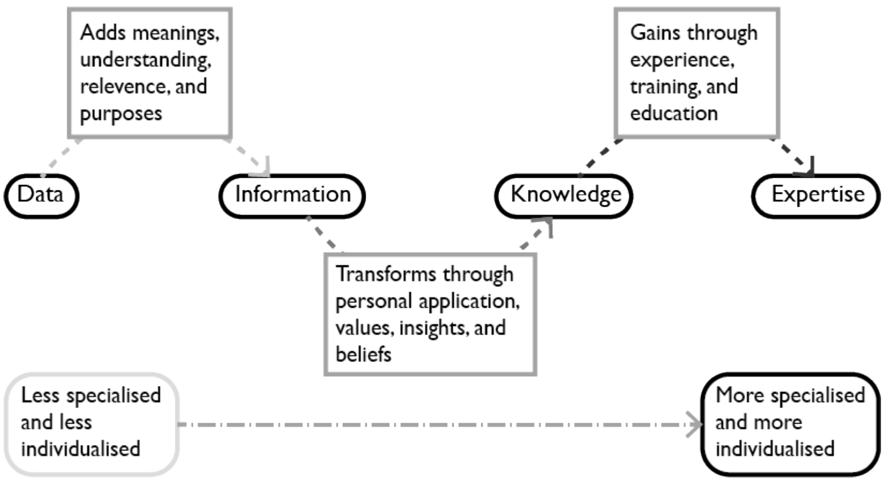

Figure 2.2: Hierarchy of data, information, knowledge, and expertise (Nonaka and von Krogh, 2009; Vakola and Rezgui, 2000).

There are four kinds of knowledge which are: a) *know-what*, accumulation of facts that can be broken down into pieces; b) *know-why*, scientific knowledge that underlies technological development, product, and process advancement; c) *know-how*, skills and competencies to do something, as well as reasons for the formation of industrial networks to enable organisations to share and combine elements of know-how; and d) *know-who*, information about individuals who know what and how to do what (Egbu and Robinson, 1998). Generally, knowledge is classified into two types of *tacit* and *explicit* knowledge (Nonaka and von Krogh, 2009).

Tacit knowledge is personal (Addis, 2014). It has an un-codifiable nature and difficult to articulate (Koskinen et al., 2003; Nonaka, 1994). It resides in individual skills, previous experience from collaboration, and social context (Lindner and Wald, 2011; Seidler de Alwis and Hartmann, 2008). Tacit knowledge expresses itself through human action in forms such as evaluation, attitude, point of view, commitment, and motivation (Koskinen et al., 2003). Tacit knowledge contains two main elements of *technical* and *cognitive* (Seidler de Alwis and Hartmann, 2008). The prior concerns personal know-how and skills of an individual, while the latter involves paradigm, perspective, and cultural belief (Duffield and Whitty, 2015; Seidler de Alwis and Hartmann, 2008). Tacit knowledge is a key source of competitive advantage, a valuable resource for built environment organisations to innovate (Gann and Salter, 2000; Prencipe and Tell, 2001). On the contrary, explicit knowledge is codifiable, structured, and conscious (Egbu, 2004). It includes knowledge that can readily be transcribed in words and numbers, shared in manuals, and distribute to others (Kivrak et al., 2008). Knowledge within an organisation is a mixture of tacit and explicit knowledge (Egbu and Robinson, 1998). Both knowledge types are not in a dichotomous state, but mutually dependent and reinforcing qualities of knowledge (Liyanage et al., 2009).

2.3.2 KBV and built environment innovation

The KBV of organisations sits within the Resource-Based View (RBV) of organisations, which stresses complementary relations of knowledge to organisational performances (Hervas-Oliver et al., 1988; Yusof and Bakar, 2012). The KBV of organisations views knowledge as an everlasting resource (Vakola and Rezgui, 2000), a critical organisational asset to sustain a competitive position (Landaeta, 2008; Lindner and Wald, 2011). The fundamental factor of successful innovation adoption also lies in the abilities of organisations in recognising and utilising knowledge (Na Lim and Peltner, 2011; Yun et al., 2011). The KBV of organisations provides a perspective where organisations perceive innovations through their embedded knowledge (Gopalakrishnan et al., 1999; Woodhead et al., 2018).

In addition to tacit and explicit knowledge, Gopalakrishnan et al. (1999) proposed how organisations and organisational members could comprehend innovations through knowledge dimensions which are *systematic*, *autonomous*, *complex*, and *simple*. Table 2.2 provides a summary of all knowledge dimensions in comprehending innovations.

Table 2.2: Knowledge dimensions in comprehending innovations.

Knowledge dimensions	Descriptions
Tacit	Knowledge that is un-codifiable and resides in each individual.
Explicit	Knowledge that is codifiable and easily articulated through numbers and words.
Systematic	Knowledge that can be implemented only in conjunction with related and complementary innovation.
Autonomous	Knowledge that can be developed and utilised independently.
Complex	Knowledge that is divisible, linked to other systems, sophisticated, and original.
Simple	Knowledge that contains no links, easy to understand, and not new to project team members and an organisation.

Knowledge achieves its optimal potential in innovation adoption if properly managed, transferred, and learned by all project team members and an organisation (Court, 1997; Starbuck, 1992). This emphasises on the management and transfer of knowledge amongst project team members and to an organisation.

2.3.3 Knowledge management and transfer

Knowledge management is the planned and structured approach in capturing, sharing, transferring, and learning of knowledge to enhance abilities, speed, and effectiveness of organisations (du Plessis, 2007; Landaeta, 2008). It entails policies, tools, and processes (Landaeta, 2008) that aim to: a) make knowledge visible and highlight its roles in an organisation; b) build a knowledge infrastructure, both technically and socially; and c) develop a knowledge-intensive culture by encouraging and aggregating knowledge transfer and learning behaviours (Egbu, 2004; Liyanage et al., 2009). Knowledge management contains two distinctive tasks of facilitating creation of new knowledge and managing ways individuals share and apply such knowledge (Seidler de Alwis and Hartmann, 2008).

Specifically, knowledge transfer is an area within the management of knowledge which concerns the movement of knowledge from a source to a receiver (du Plessis, 2007; Liyanage et al., 2009). The source of knowledge ranges from a place, a person, an entity, ownership, or even the receiver through time (Liyanage et al., 2009). There are four modes of knowledge transfer which are: a) *socialisation*; b) *externalisation*; c) *internalisation*; and d) *combination* (Liyanage et al., 2009; Nonaka, 1994).

Socialisation is an informal mode of tacit knowledge transfer through a shared experience between individuals (Nonaka, 1994). Externalisation refers to a transformation of tacit knowledge into an explicit version through analogies and models, while Internalisation is the reverse through individual learning and training (Egbu and Robinson, 1998; Liyanage et al., 2009). Combination is a conversion of codified knowledge into its new form (Liyanage et al., 2009; Nonaka, 1994). Figure 2.3 conceptualises the four modes of knowledge transfer.

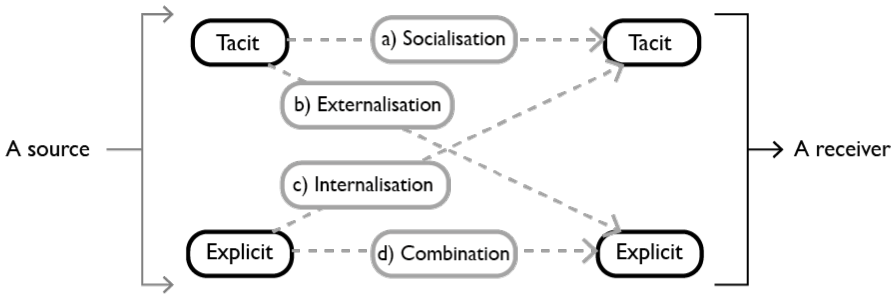

Figure 2.3: Modes of knowledge transfer (Liyanage et al., 2009).

The concept of knowledge management intertwines with *organisation learning* (Hartmann and Dorée, 2015; Na Lim and Peltner, 2011). Knowledge management places greater emphasis on knowledge itself. It acknowledges more on the treatment of knowledge; and projects back to organisational entities such as an individual and a project team. However, within the context of innovation adoption in the built environment, it is necessary to consider both. Individuals should continuously expand their competences. Meanwhile, project teams and an organisation should maximise the absorption of such competence to an organisational routine, practice, and belief (Kim, 1998; Koskinen, 2012; Styhre et al., 2004).

2.4 Organisational learning

2.4.1 Learning

Learning in organisations describes that mere possession of potentially valuable knowledge somewhere within an organisation does not indicate that other parts benefit from that knowledge (Starbuck, 1992; Szulanski, 2000). Learning is the process by which one unit of an organisation, such as a group or a department is affected by the experience of others (Koskinen, 2012; Zhao et al., 2015), as well as from one activity to another (Davies and Brady, 2016; Levinthal and March, 1993). Learning contains two main views of *technical* and *social* (Bartsch et al., 2013). The technical view focuses on processes and response to knowledge, while the social view acknowledges learning as a result of social interaction that assists individuals in making sense of their work experience (Bartsch et al., 2013; Levinthal and March, 1993). Learning contains two main processes of *exploration* and *exploitation* (Eriksson, 2013; Levinthal and March, 1993).

2.4.2 Learning processes and ambidexterity

Exploration involves the pursuit of new knowledge (Levinthal and March, 1993). It is an innovative behaviour of organisations in experimenting with new bids and unfamiliar activities (Brady and Davies, 2004; Diaz-Fernandez et al., 2017). This learning process is more suitable in a changing or unstable environment, where organisations face continuous challenges in testing new alternatives, re-deploying their existing resources, and developing novel capabilities and routines (Brady and Davies, 2004; Bygballe and Ingemansson, 2014).

Exploitation includes routine behaviour to refine, align, and control capabilities of an organisation and improve the performance of an existing operation (Eriksson, 2013). Exploitation is more appropriate in a stable market environment, where there are little interests in learning or making organisational improvement through exploration (Brady and Davies, 2004; Levinthal and March, 1993). There are limited studies on both learning processes with innovation adoption of built environment organisations (Eriksson, 2013; Senaratne and Wang, 2018).

Organisations reach the state of *ambidexterity* or *organisational ambidexterity* when exploration and exploitation are achieved (Eriksson, 2013; Levinthal and March, 1993). Ambidexterity refers to the ability of an organisation to concurrently explore new knowledge and technologies to enhance long-term development; and exploit existing knowledge and technologies for short-term profits (Davies and Brady, 2016; Petro et al., 2019). Organisations must experiment with new alternatives and explore possibilities to avoid stagnation and inertia (Bygballe and Ingemansson, 2014). However, they need to stabilise and routinise new solutions to maximise benefits produced (Raisch et al., 2009; Wei et al., 2014). Ambidexterity can occur at any level within an organisation (Petro et al., 2019; Raisch et al., 2009).

Punctuated equilibrium is the opposite of ambidexterity (Bygballe and Ingemansson, 2014). It refers to the temporal rotation between a long period of exploitation and a short burst of exploration (Wei et al., 2014). In a vibrant environment such as the built environment industry, punctuated equilibrium may delay innovation adoption speed and eliminate opportunities to explore new knowledge in time (Levinthal and March, 1993; Wei et al., 2014).

2.4.3 Views and debates of ambidexterity

Birkinshaw and Gibson (2004) provided that there are two views of ambidexterity: *structural* and *contextual*. Eriksson (2013) and Turner et al. (2016) explained structural ambidexterity as to where exploration and exploitation activities are separated by different organisational units but coordinated by senior management members. Birkinshaw and Gibson (2004) supported this by putting forward that these learning processes are dramatically different that they cannot effectively co-exist. Chang and Hughes (2012) presented that within this view, explorative activity appeared to thrive on an organic organisational structure and limited routines, while exploitative activity flourished from a mechanistic structure with standardised rules, procedures, and routines that exist to coordinate actions of individuals. Turner et al. (2015) referred to this view as *partitional approach*, while Raisch et al. (2009) regarded the view as *differentiation*.

With contextual ambidexterity, Birkinshaw and Gibson (2004) argued that it referred to how individuals have choices between alignment-oriented or adaptation-oriented activities in the context of their day-to-day operation. Turner et al. (2015) added that exploration and exploitation co-exist as orthogonal and complementary dimensions of learning. Awojide et al. (2018) and Chang and Hughes (2012) further highlighted how contextual ambidexterity concerns the creation of a high-performance organisational context, where adaptability and alignment are presented for individuals. Awojide et al. (2018) underlined the social aspect and culture as the central attention of this view. Awojide et al. (2018) acknowledged the contextual ambidexterity as the *behavioural approach*. Raisch et al. (2009) referenced the view as the *integration approach*.

Both views on ambidexterity presented one of the current debates of ambidexterity. Raisch et al. (2009) summarised that there are four main debates of ambidexterity in organisations. The structural ambidexterity and the contextual ambidexterity related to *differentiation vs integration* (Raisch et al., 2009; Wei et al., 2014). Other debates of ambidexterity in Raisch et al. (2009) were *individual vs organisation*; *static vs dynamic*; and *internal vs external.*

Referring to the individual versus organisation debate, Raisch et al. (2009) explained that some studies on ambidexterity claimed that ambidexterity occurs only through an organisational mechanism such as formal structures or a lateral coordination mechanism. Conversely, some competence indicated how ambidexterity rooted in the ability of an individual to explore and exploit. On the static versus dynamic debate, earlier studies suggested exploration and exploitation were static and separated in time, while an organisation moves from one dominant theme to another (Eriksson, 2013; Turner et al., 2015). However, recent investigations such as Davies and Brady (2016) and Petro et al. (2019) argued that it is more ideal for organisations to simultaneously balance exploration and exploitation. With the internal versus external debate, Raisch et al. (2009) pointed out that ambidexterity may depend on the ability of an organisation to comprehend either internal or external knowledge. Table 2.3 placed all debates into comparison.

Table 2.3: Current debates on ambidexterity in organisations.

Ambidexterity debates		Arguments
1	Differentiation (structural)	Exploration and exploitation are detached activities by different organisational unit.
	Integration (contextual)	Ambidexterity is achieved within an organisational unit.
2	Individual	Ambidexterity roots in competence of an individual to explore and exploit.
	Organisation	Organisational mechanisms such as organisational structure and coordination mechanisms allow ambidexterity to occur.
3	Static	Exploration and exploitation are separated in time.
	Dynamic	Organisation must simultaneously balance exploration and exploitation in a fluid manner.
4	Internal	Ambidexterity relies on internal knowledge base within an organisation.
	External	Ambidexterity requires external knowledge agent.

Awojide et al. (2018) explained that there are two research schools of ambidexterity thinking: *activity* and *outcome* research schools. The prior examined into a joint pursuit or seemingly opposing activities within an organisation setting, while the latter looked into the outcome of ambidexterity and concerned about underlying characteristics of the outcome as opposed to consequences for competitiveness and performance (Awojide et al., 2018; Petro et al., 2019; Turner et al., 2016).

Chang and Hughes (2012) and Senaratne and Wang (2018) highlighted how ambidexterity is a challenge for SMEs. Senaratne and Wang (2018) provided how SMEs lack adequate resources, systems to support innovation, hierarchical administrative system, and individuals with adequate competence in navigating ambidexterity. Additionally, Turner et al. (2016) emphasised that there are scarce investigations into ambidexterity at the operational level. With the project setting as an arena for fruitful learning and innovation, investigations into PBL and ambidexterity could offer insights to advance the challenge of innovation adoption in the built environment SMEs.

2.5 Learning in projects

2.5.1 PBL in the built environment

PBL is a key driver for higher innovativeness in the built environment organisations (Bartsch et al., 2013; Prencipe and Tell, 2001). The multidisciplinary nature of a project team allows different opinions to be discussed (Hartmann and Dorée, 2015). Organisations successfully adopt an innovation if knowledge from projects is properly learned (Davies and Brady, 2016). There are six types of project-based knowledge: a) project knowledge that denotes an overview of an organisational landscape; b) intra-project knowledge within a project; c) knowledge between upstream and downstream projects; d) knowledge between parallel projects; e) knowledge between projects and their parent organisations; and f) knowledge between two projects with different completion time (Lindner and Wald, 2011; Zhao et al., 2015). PBL originates from the education literature. Figure 2.4 illustrates all types of project-based knowledge as adapted from (Lindner and Wald, 2011; Zhao et al., 2015).

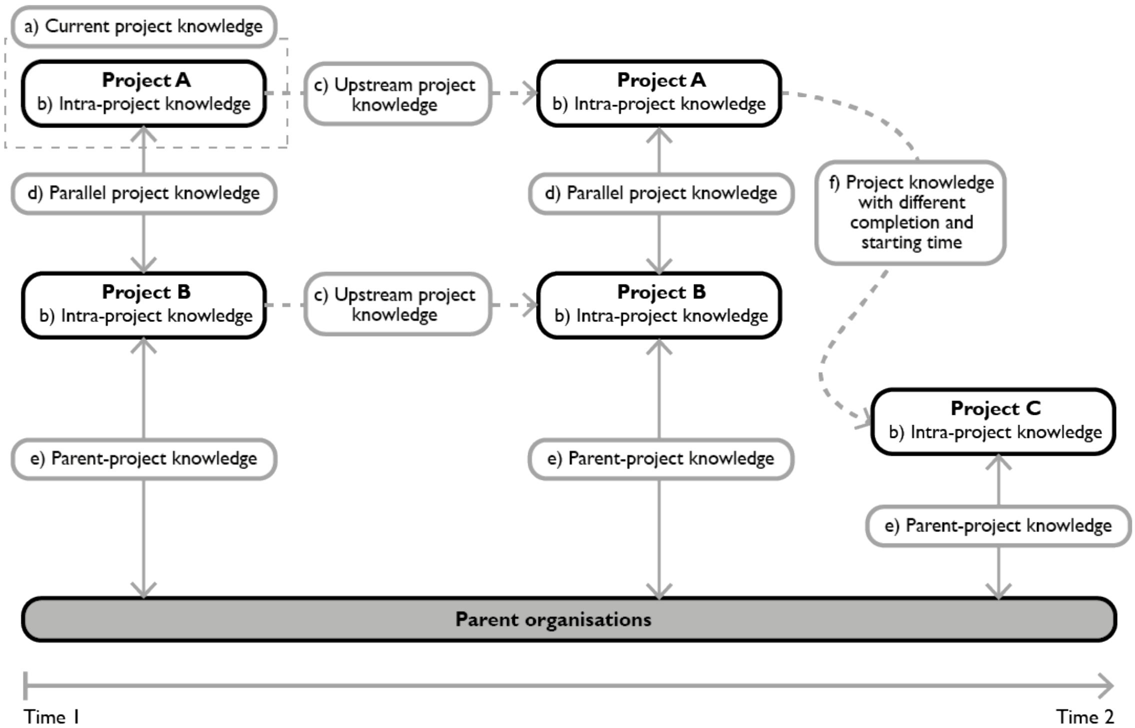

Figure 2.4: Different types of project-based knowledge as adapted from Lindner and Wald (2011) and Zhao et al. (2015).

2.5.2 PBL in education

Within the education literature, PBL is a student-centric form of learning bases on three constructivist principles of: a) learning is context-specific; b) learners are involved actively in the learning process; and c) learners achieve their goal through social interactions; and sharing of knowledge and understanding (Efstratia, 2014; Kokotsaki et al., 2016). The concept of PBL in education lies on how the real-world problem captures the interests of students and provokes serious thinking as students acquire and apply new knowledge in a problem-solving context (Efstratia, 2014). Teachers play the role of a facilitator, working with students to assist with complications and lessons learned (Bell, 2010; Kokotsaki et al., 2016). PBL in education relates to concepts of *scaffolding* and *differentiation* (Bell, 2010; Holmes and Hwang, 2016; Kokotsaki et al., 2016).

In each classroom, the success of PBL lies upon the ability of a teacher to effectively construct learning, as well as support, motivate, and guide students (Kokotsaki et al., 2016). Scaffolding refers to how various technologies or techniques used in learning are carefully selected and exercised together so that they form a system or an infrastructure that aids students (Bell, 2010). A scaffold is temporary. Each component can be removed and altered to support differentiation, where students develop their own interests and pursue deeper learning according to their competence (Bell, 2010; Holmes and Hwang, 2016).

2.5.3 Approaches on PBL and built environment innovation

PBL in the built environment context contains two approaches of the *Sender/receiver* and the *Social learning* approaches (Bresnen et al., 2003; Hartmann and Dorée, 2015). The Sender/receiver approach weights on the storage, retrieval, and transfer processes of explicit knowledge that can be codified and reverted into transmission channels such as electronics and document-based repositories (Hartmann and Dorée, 2015). Equally recognised as the *Cognitive model* (Bresnen et al., 2003), this approach is based on the cognitive learning theory that describes learning as an acquisition of both abstract and general knowledge of an individual through knowledgeable resources or artefacts (Hartmann and Dorée, 2015). The approach also values tacit knowledge learning. However, such knowledge must be converted into an explicit form (Seidler de Alwis and Hartmann, 2008).

The Social learning approach values the social and contextual nature of learning (Hartmann and Dorée, 2015). Referred to as the *Community approach* (Bresnen et al., 2003), this perspective suggests learning to occur through the interaction of individuals during their daily activities and exists as an ongoing social accomplishment (Bartsch et al., 2013; Gasik, 2011). This approach covers similar concepts in learning such as the Community of practice, the Social capital, the Social interaction perspective, and the Social system approach (Bresnen et al., 2005;

Chen and Huang, 2007; Gasik, 2011). This approach circulates around the creation of a *fertile* project or organisation (Szulanski, 2000).

The fertile environment refers to an organisational context that supports and facilitates every learning-related actions (Duffield and Whitty, 2015; Lloyd-Walker et al., 2014). Knowledge learned through the Social learning approach is mostly tacit, intangible, and context-dependent (Bresnen et al., 2003). The Social learning approach breaks down into three streams of: a) *social containment*, where knowledge locates in relationships of individuals who engage in specific learning activities; b) *mutual constitution*, where knowledge and learning activities are two entities that are mutually established; and c) *equivalence perspective*, where knowledge and learning activities are inseparable and knowledge becomes an active process of learning rather than being an object that can be transferred (Hartmann and Dorée, 2015).

PBL approaches in the built environment assist in categorising existing models and frameworks of PBL, knowledge transfer, and innovation adoption. On one hand, models and frameworks within the Sender/receiver approach consider processes, knowledge practices, and contextual factors to learning of individuals in projects through a more explicit form of knowledge. On the other hand, models and frameworks that fall within the Social learning approach prioritise contextual aspects of a project team or an organisation, as well as a promotion of the fertile project where social interaction encourages learning in projects. Models and frameworks within this approach recognise innovation as a collaborative outcome of individuals with different competence, coming together to exchange their opinions and knowledge.

2.5.4 The Sender/receiver models and frameworks

Prencipe and Tell (2001) suggested a learning landscape framework in analysing learning abilities of project-based organisations. Prencipe and Tell (2001) classified learning processes into experience accumulation, knowledge articulation, and knowledge codification; and contained three levels of analysis which were an individual, a group or a project, and an organisation. The framework provided three learning landscapes, which were explorer learning, the navigator learning, and the exploiter learning landscapes. Additionally, Prencipe and Tell (2001) presented knowledge practices used in learning by individuals within each learning process and further highlighted the articulation of codified knowledge.

Liyanage et al. (2009) presented a process model apprehending knowledge transfer from a source to a receiver. The model included knowledge transfer dimensions of: a) processes of awareness, acquisition, transformation, association, and application of knowledge; b) influencing factors to the transfer and each individual such as individual capacities, willingness, and cultural attributes; c) modes of knowledge transfer; and d) performance measurement. Liyanage et al. (2009) described knowledge transfer and learning as actions relating to knowledge communication and translation.

Szulanski (2000) presented a process model of knowledge transfer among individuals and emphasised knowledge transfer barriers of each process. Barriers of learning were regarded as stickiness within Szulanski (2000). The model presented in Szulanski (2000) also recognised individualised factors to learning such as motivation of senders and receivers, as well as absorptive capacity of a receiver to learn. Drawing upon Szulanski (2000), Tan et al. (2006) introduced a live-capturing and sharing of explicit knowledge amongst project members. The model stressed workflow and knowledge practice as major contributors. Additionally, Tan et al. (2006) discussed costs, workloads, legal issues, accuracy, and representation of knowledge as supporting factors to explicit knowledge learning. Tan et al. (2006) elaborated on how knowledge practices chosen by individuals in learning should not generate extra workloads and costs to an organisation, while a certain level of standardisation and validation mechanism is required (Tan et al., 2006).

Knowledge practice was further mentioned in Reich et al. (2012) as a necessary element to the transfer of knowledge and learning. Reich et al. (2012) regarded knowledge practices as activities related to a generation of useable knowledge in both tacit and explicit forms. Knowledge practice assisted organisations in achieving the desired business outcome when aligned with *knowledge stocks* and *enabling environment*. Reich et al. (2012) further explained the knowledge stocks as the total cognitive capacity available in projects at an individual, a group, or an organisation level. The framework of Reich et al. (2012) elaborated the enabling environment as the technological and social aspects of projects to support the use of knowledge practice. Duffield and Whitty (2015) accentuated this by proposing the Systematic lessons learned knowledge (Syllk) model, encouraging alignment of organisation elements such as organisational members, knowledge practices, and cultural enablers. Additionally, Duffield and Whitty (2015) forwarded major influencing factors that facilitate the employment of knowledge practices such as time pressure, culture, poor Information Technology (IT) infrastructure, and social barriers.

2.5.5 The Social learning models and frameworks

Bresnen et al. (2005), from the Social capital theory proposed a framework consisted of dimensions that contribute to learning. The framework entailed: a) *structural dimension*, patterns of ties that connect individuals together; b) *relational dimension*, nature or quality of ties that characterises each relationship; and c) *cognitive dimension*, perceptive similarity between individuals such as shared goals and common interests. Bakker et al. (2011) proposed a similar framework, however, substituted the structural dimension with temporal dimension and later stressed influences that the temporal nature of the built environment has to learning. The framework of Bakker et al. (2011) also highlighted absorptive capacity of individuals as major contributor to successful PBL.

With the cognitive, relational, and temporal dimensions presented in Bakker et al. (2011), Lindner and Wald (2011) posed three supporting attributes of: a) culture and leadership; b) organisation and process; and c) technology system. Specifically, the framework of Lindner and Wald (2011) emphasised culture, top management support, and IT communication system as crucial attributes to successful learning. Bartsch et al. (2013), corresponded to Bresnen et al. (2005), highlighted social capital as the source of continuity that goes against the temporariness nature of projects and bridges critical intra-organisational barriers to learning. Additionally, Hartmann and Dorée (2015) suggested that learning in projects should consider three elements of individual, social, and organisational context together around activities performed in projects. The model of Zhao et al. (2015) re-classified attributes to a fertile project into attributing dimensions which are: a) transfer capabilities of project team members; b) relationships amongst project actors; c) project context; and d) context of tasks assigned to a project team. Zhao et al. (2015) argued in their model that project managers must simultaneously consider multiple attributing dimensions and pay considerable attention to senders and receivers in each project team.

Moreover, Brady and Davies (2004) presented a model describing how a project-based organisation learn as it innovates and moves into a new market base. The model captured three phases of project-based explorative and exploitative learning which are: a) within-project learning; b) project-to-project learning; and c) project-to-organisation learning. Similarly, ambidextrous learning was integrated into the analytical model of Bygballe and Ingemansson (2014). Linking ambidexterity to innovation learning and adoption, Bygballe and Ingemansson (2014) explained how the learning of innovation-related knowledge can transcend forwards from projects to an organisation and an industry, as well as informed backwards from industry to an organisation and projects.

2.5.6 Problem identification of existing models and frameworks

Models and frameworks within the Sender/receiver approach explored heavily into learning processes and knowledge practices used in learning in projects. The approach related to the learning of codifiable knowledge. This included explicit knowledge and tacit knowledge that can be converted into an explicit form. Models and frameworks within this approach also covered contextual aspects of project teams and an organisation with direct influence on individual learning. Differently, models and frameworks within the Social learning approach accentuated on the learning of un-codifiable knowledge and contextual aspects to the fertile projects and organisations. The Social learning models and frameworks highlighted the contextual aspects of projects and organisations such as social capital, structures of an organisation, relationships between individuals, perceptions of individuals, and project deadlines were stated.

The integration of the Sender/receiver and the Social learning approaches provides an alternative viewpoint in assessing how an organisation utilises knowledge in innovation learning and adoption. An investigation into the *knowledge practice* exercised for learning in projects, which is the central focus of the Sender/receiver models and frameworks; and the *contextual attribute* to a fertile project, which is the heart of the Social learning models and frameworks potentially yields greater understanding on how innovation is learned in projects. There is a lack of studies that bridge both approaches of PBL. With BIM as the exemplar innovation, this research puts forwards a theoretical framework in accessing how BIM is learned in projects or the *project-based learning mechanism of BIM* in the built environment SMEs.

2.6 Theoretical framework of the research

2.6.1 Framework construction

The theoretical framework of this research aimed at conceptualising how knowledge practices are utilised in projects for BIM learning, with regards to the contextual attributes of projects. The formulation of this theoretical framework stood on the constructivist ontology and epistemology research paradigms. The framework did not suggest that there is only one way of how knowledge practices are utilised. Instead, it offered an alternative viewpoint in understanding how each organisation exercises their knowledge practices.

The framework was advanced from a Systematic Literature Review (SLR) of PBL, knowledge transfer, and innovation adoption in the built environment studies. The research examined through International Journal of Project Management, Journal of Knowledge Management, Journal of Management Studies, Construction Innovation Journal, Automation in Construction Journal, Building Research & Information Journal, and Proceedings of ARCOM (Association of Researchers in Construction Management). Qualitatively, insights from the literature were synthesised and build upon one another through an inductive approach. The theoretical framework was initially presented and published at the 34th conference and annual general meeting of ARCOM at Queen's University, Belfast from 3rd to 5th September 2018. Comments and suggestions from the conference were integrated to further developed this theoretical framework. The framework included three dimensions to BIM learning in projects which are: a) *Knowledge stocks*; b) *Knowledge practice*; and c) *Contextual attribute*.

2.6.2 Knowledge stocks

Building on Reich et al. (2012), the Knowledge stocks dimension represented individuals within a project team with cognitive capacities and potentials to learn and increase their competence. Individuals within a project team were divided into *a sender* and *a receiver* (Hartmann and Dorée, 2015). The sender referred to individuals that are the source of knowledge who identifies, captures, and transfers BIM-related knowledge (du Plessis, 2007; Liyanage et al., 2009). The receiver entailed individuals who absorb such knowledge (Reich et al., 2012). Referring to Lindner and Wald (2011) and Zhao et al. (2015), the sender and the receiver could be two different individuals within a project, between upstream and downstream projects, amongst parallel projects, between two projects with different starting and completion time, and between a project and the parent organisation. Additionally, receivers could be senders, learning from previous projects they were in. Figure 2.5 illustrated the Knowledge stocks dimension.

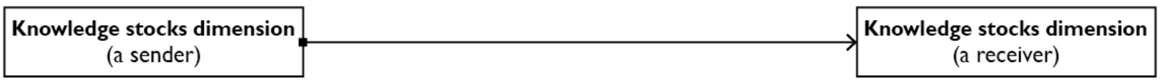

Figure 2.5: Knowledge stocks dimension.

2.6.3 Knowledge practice

The Knowledge practice dimension included all means exercised by individuals for learning BIM in projects. Knowledge practice entailed actions, activities, artefacts, practices, tools, and techniques used in capturing, transferring, and learning BIM-related knowledge

(Reich et al., 2012; Van Waveren et al., 2017). Reich et al. (2012) highlighted knowledge practice as the central concern within the Sender/receiver approach of PBL. It was also referred to as *mechanisms of learning* in De Toni and Pessot (2020), *knowledge transfer and preservation methods* in Terzieva and Morabito (2016), *mechanisms for transferring and embedded knowledge* in Egbu (2004), *learning transfer channels* in Hartmann and Dorée (2015), and *knowledge transfer mechanism* in Van Waveren et al. (2017).

From knowledge management and transfer literature, Egbu (2004) investigated how knowledge is transferred and embedded into the organisational culture. Knowledge practices, as well as enabling and hindering factors of knowledge practice were also presented. Kivrak et al. (2008) acknowledged these knowledge practices as knowledge sources; and ranked them according to preferences of organisational members. Williams (2008) executed a similar investigation. However, Williams (2008) explored knowledge practices through how they capture lessons and presented a comparison between perceptions of organisational members and applications in an organisation. Tan et al. (2006) researched knowledge practices through case studies and categorised them into knowledge management tools and technologies. Additionally, Senaratne and Bacic (2015) looked into experience-based knowledge practices commonly used in tacit knowledge learning.

From PBL literature, Hartmann and Dorée (2015), classified knowledge practices found into the Sender/receiver and the Social learning approaches. De Toni and Pessot (2020) evaluated knowledge practices to organisational learning processes. De Toni and Pessot (2020) divided knowledge practices into three types of: a) experience-based knowledge acquisition; b) knowledge creation; and c) knowledge capture and codification (De Toni and Pessot, 2020). Differently, Terzieva and Morabito (2016) categorised knowledge practices based on explicit and tacit knowledge types. Knowledge practices were also mentioned in various PBL models and frameworks such as in Duffield and Whitty (2015) and Prencipe and Tell (2001). Furthermore, Van Waveren et al. (2017) refined classification of knowledge practices and identified 52 different knowledge practices to learning in projects. Van Waveren et al. (2017) later classified them into five clusters of: a) *formal codification landscape*; b) *training and coaching landscape*; c) *informal person-to-person landscape*; d) *inter-organisational networking landscape*; and e) *intra-organisational communal landscape*. Mueller (2015) examined into formal and informal knowledge practices in projects and their enacted cultural attributes. Mueller (2015) also brought in the concept of transactive knowledge, where a boundary between formal and informal knowledge practices is blurred. The research paper highlighted how the creation of a system of knowledge about knowledge is necessary.

Building upon existing knowledge practice, PBL, and innovation adoption literature, this research provided three landscapes of knowledge practices which were: a) *Codifiable knowledge practice*; b) *Un-codifiable knowledge practice*; and c) *Transactive knowledge practice*. On one end of the spectrum, Codifiable knowledge practice landscape concerned knowledge practices that focus more on the learning of explicit knowledge. Knowledge practices within this landscape could be identified as artefacts that contain knowledge within themselves for project actors to access. They represented a more formal means of learning. Codifiable knowledge practices associated with the exploitative learning process, where knowledge practices contributed directly to the refinement and alignment of project teams and an organisation.

On another end of the spectrum, Un-codifiable knowledge practice landscape included knowledge practices with the core feature of tacit knowledge learning. This landscape related more towards informal means of learning and the Social learning approach, where learning occurs through the interaction of project actors within and across project teams. Knowledge practices within this landscape accounted for explorative learning.

In the middle of the spectrum, Transactive knowledge practice landscape entailed knowledge practices that require both tacit and explicit knowledge. Transactive knowledge practices were knowledge practices that did not contain a clear boundary between formal and informal means of learning. Additionally, learning through knowledge practices within this landscape requires a combination of artefacts and social interactions. Knowledge practices within this landscape assisted in ambidextrous learning within a project team and an organisation.

Similar knowledge practices from past studies were grouped and given a term that best represents the knowledge practice. The theoretical framework acknowledged these subsets of knowledge practice as *instrumentalities*. The term instrumentalities was brought up in Miettinen and Paavola (2014) as various ways of how BIM can be defined and perceived. For example, the ISO (International Organization for Standardisation) standard and British BIM standard were identified as various instrumentalities of Standardisation. Standardisation was further categorised within the Codifiable knowledge practice landscape. Table 2.4 elaborated the Knowledge practice dimension.

Table 2.4: The Knowledge practice dimension.

Landscapes	**Knowledge practices**	**Descriptions and instrumentalities**
Codifiable knowledge practice	External source	External sources of BIM-related knowledge such as BIM forums, online tutorials, and various search engines.
	Project documentation	Physical documents and digital model of previous BIM projects.

	Shared knowledge repository	Digital storage of BIM-related knowledge such as cloud storage or a file storage function within a social media application.
	Standardisation	Established BIM standards and manuals within an organisation or from a govern institution.
Transactive knowledge practice	Assignment of knowledge management personnel	The appointment of project actors to oversee the management of BIM-related knowledge within a project.
	Competence assessment	An individual-, a project team-, or an organisation-wide assessment of individual BIM competence.
	Learning-by-doing	The learning of BIM through working on actual projects.
	Professional networks	A network of BIM experts from within and various organisations. This also includes BIM seminars and symposiums.
	Project review	Project meetings, both after each project stages and after a project completion, were project team members come together to discuss success, failure, and problems encountered.
	Promotion of knowledge sharing culture	Any motivational actions towards promoting the learning of BIM in projects.
	Specialist consultant	An appointment of a BIM-specialist organisation to oversee BIM learning and adoption.
	Training & Workshop	Formal and informal classes or events to enhance BIM competence of project actors.
Un-codifiable knowledge practice	Incentive	Economic, social, and technological rewards to project actors, in relation to BIM learning such as monetary incentive and hardware upgrade.
	Informal meeting	Unscheduled meeting where BIM-related issues are discussed.
	Knowledge team creation	A creation of a group within a project team or an organisation to foster BIM learning and adoption.
	Mentoring	An assignment of a project actor with higher BIM competence to assist other project team members.
	Partnering	A partnership with organisations considered as BIM leaders.
	Recruitment & Reassignment	An acceptance of new project team members with adequate BIM competence and the allocation of BIM experts between project teams.

The Knowledge practice dimension sits between the sender and the receiver in the theoretical framework. It represents how the dimension performs as a mean for the receiver to learn from the sender. Organisations exercise various knowledge practices together in projects for innovation learning and adoption (Terzieva and Morabito, 2016; Van Waveren et al., 2017). Figure 2.6 displays how the Knowledge practice dimension nests in the theoretical framework of this research.

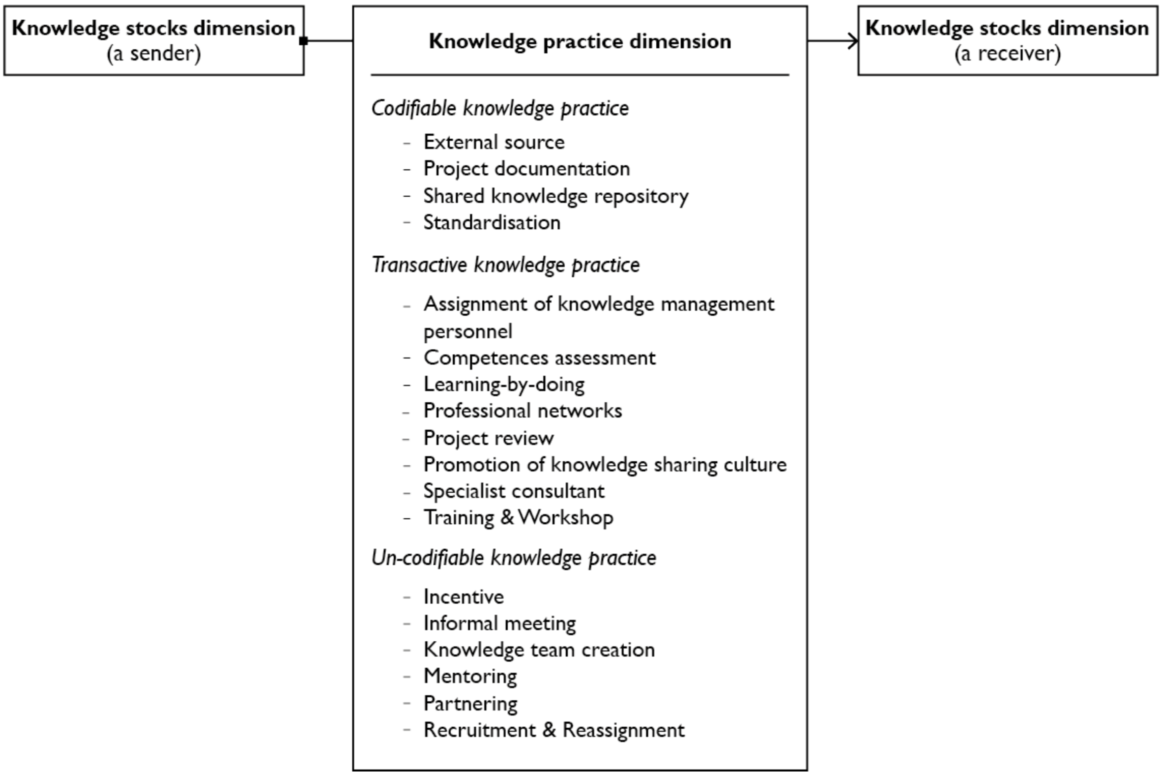

Figure 2.6: The Knowledge practice and Knowledge stocks dimensions.

2.6.4 Contextual attributes

The Contextual attribute dimension incorporated both technological and social aspects of PBL and innovation adoption (Hartmann and Dorée, 2015). Contextual attributes within this dimension included both enabling and hindering factors to a fertile project (Bresnen et al., 2005; Reich et al., 2012). Building on existing models and frameworks from both the Sender/receiver and the Social learning approaches, contextual attributes found from past studies were categorised into five themes of: a) *Quality of a sender*; b) *Quality of a receiver*; c) *Project team relationships*; d) *Project team context*; and e) *Project operational context*. Table 2.5 clarified the Contextual attribute dimension of this theoretical framework.

Table 2.5: The Contextual attribute dimension.

Themes	Contextual attributes	Definitions and supporting attributes
Quality of a sender	Transferring capacity	Existing abilities of an individual to realise value and purposes of BIM-related knowledge, as well as to take opportunity to accurately document, store, and transfer such knowledge.
	Willingness to share	Personal resources such as time in capturing BIM-related knowledge, workloads of a sender, and legal issues associated with BIM-related knowledge captured.
Quality of a receiver	Absorptive capacity	Abilities of an individual to identify value of new BIM-related knowledge, assimilate it, and apply it.

	Knowledge quality	Usefulness, expiration, and fragmentation of captured BIM-related knowledge.
	Motivation to absorb	Personal resources such as time to learn, workloads of a receiver, and legal issues associated with BIM-related knowledge captured.
Project team relationship	Cognitive aspect	Shared representation, interpretation, understanding, and system of meanings amongst project team members. This attribute also applies to shared understanding of BIM and BIM operation.
	Relational aspect	Network ties with current and former project team members based on trust, cooperation, and communication.
	Temporal aspect	Disruptive experience and connection of project team members from previous projects through the temporariness nature of the built environment operation.
Project team context	Project climate	Support from management members, culture of knowledge sharing, and a no-blame culture where social barrier to learning is blurred and learning in projects is structured and encouraged.
	Project resource	Investments made to both directly and indirectly capture, transfer, and learn BIM-related knowledge. This also includes a modification to existing business processes to support BIM learning.
	Project structure	A construction and an arrangement of project team members, as well as formalisation, centralisation, integration, and stratification of roles and responsibilities of project team members.
Project operational context	Project similarity	Similarity between BIM projects, specific tasks, and problems found.
	Time urgency	Difference in timescale of BIM projects, tasks, and urgencies of problems encountered. Additionally, it also accounted for project and task deadlines.

The Quality of a sender and The Quality of a receiver contained contextual attributes that directly influence senders and receivers within the Knowledge stocks dimension (Bresnen et al., 2005; Lloyd-Walker et al., 2014; Zhao et al., 2015). The Project team relationship, the Project team context, and the Project operational context affected the Knowledge practice dimension (Bakker et al., 2011; Egbu, 2004; Lindner and Wald, 2011). Figure 2.7 illustrated the theoretical framework of the research, with inclusion of the Contextual attribute dimension.

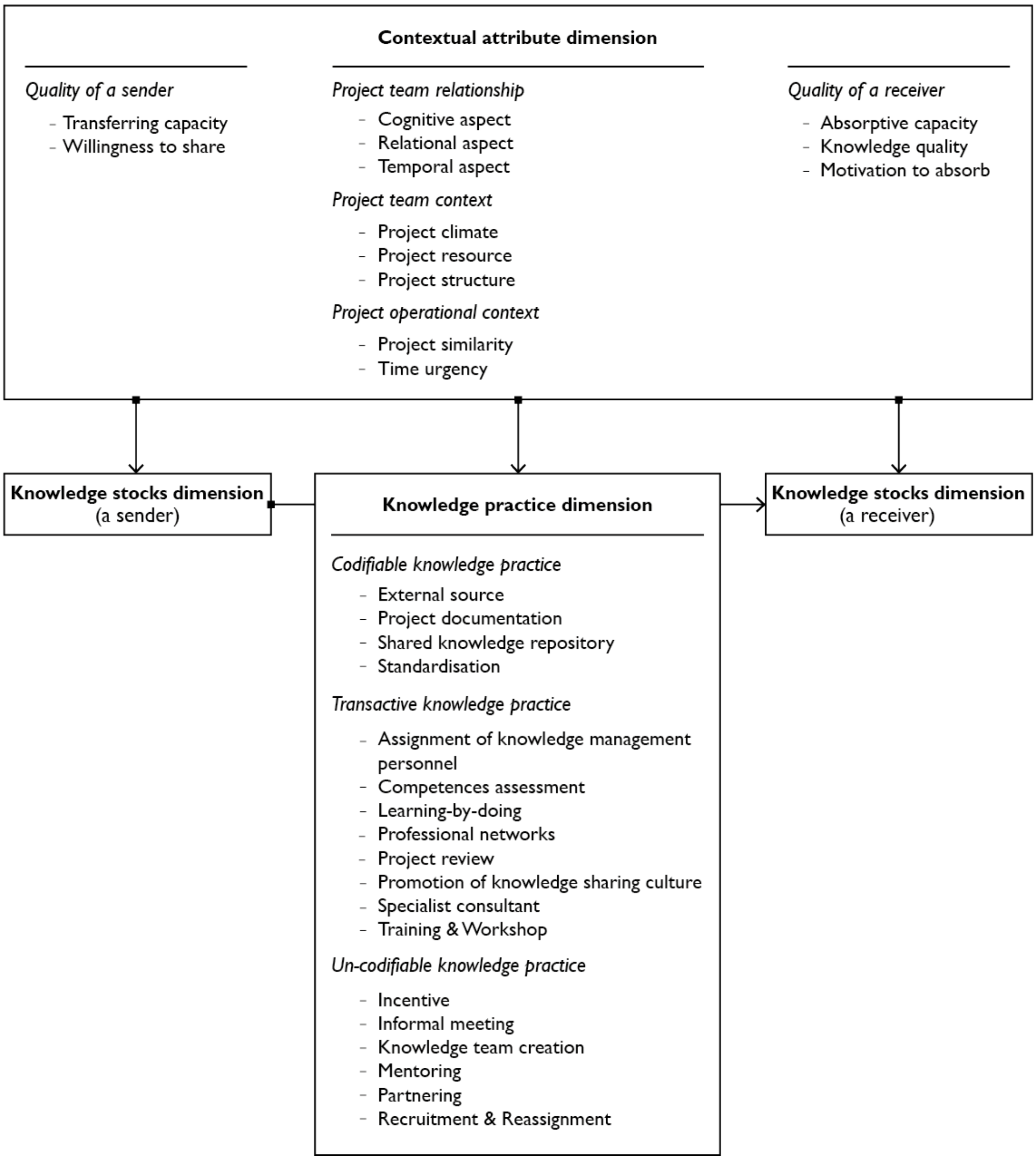

Figure 2.7: The theoretical framework of the research.

The theoretical framework of this study resonates with KBV of organisations and innovation adoption literature, where knowledge and learning are crucial to learning and adopting innovation in organisations. Furthermore, the framework highlights the importance of individual competence and addresses the relation of knowledge practice and contextual attribute to BIM learning in projects. The framework assists this research in understanding project-based learning mechanisms of BIM in built environment SMEs (Udomdech et al., 2018).

2.7 Chapter summary

This chapter laid out the background of this research, provided an extensive review of relevant literature, and introduced the theoretical framework of the study. It was well-established that organisations innovate and/or implement innovation to survive and strive in a highly competitive market. Within the built environment industry, BIM was highlighted as the common denomination amongst organisations to counter the temporariness nature and the complexity of built environment work. BIM was considered as a system innovation. The innovation digitally transformed the built environment sector and rendered traditional built environment operation obsolete. Amongst various issues hindering the successful adoption of BIM in the built environment SMEs, the lack of individuals with adequate BIM competence was highlighted as the major complication. PBL was underlined as the potential key.

PBL dwelled within the RBV and the KBV of organisations theories. Knowledge was acknowledged as a critical organisational resource, where learning in projects directly influenced innovation adoption. Learning contained two processes of exploration and exploitation. Organisations achieved ambidexterity when both learning processes are exercised. PBL contained two approaches of the Sender/receiver and the Social learning approaches. Existing models and frameworks of PBL, knowledge management and transfer, and innovation adoption were reviewed and classified within these two approaches. Furthermore, they were criticised and utilised to formulate the theoretical framework of this research.

The theoretical framework of this study submitted three dimensions in examining the learning of BIM in projects. The dimensions were: a) Knowledge stocks; b) Knowledge practice; and c) Contextual attribute. The Knowledge stocks dimension referred to project actors, recognised as the sender and/or the receiver of BIM-related knowledge. The Knowledge practice dimension included artefacts and activities used by project actors as means to acquired BIM competence. The Contextual attribute dimension related to both technical and organisational factors to the fertile project environment. The theoretical framework allowed this research to examine the learning of BIM in projects or the project-based learning mechanisms of BIM in built environment SMEs.

Chapter 3 Research methodology

This chapter describes the research methodology. It initiates with a re-statement of the research aim and objectives. The following section presents the research rationale, research methods, ethical consideration, and data protection protocol. The chapter also provides how data is collected, processed, and analysed.

3.1 Re-statement of aim and objectives

The research advanced the aim to investigate the *learning of BIM in projects or the project-based learning mechanisms of BIM* in built environment SMEs. The first research objective was to explore knowledge practices exercised in projects for the learning of BIM-related knowledge. The second research objective involved an examination of how knowledge practices are being utilised together, with regards to contextual attributes of projects. The second research objective determined to understand the formulation of a project-based learning mechanism of

BIM. This followed by the next research objective to analyse how each project-based learning mechanism of BIM assist a built environment SME in BIM adoption. The last research objective included a generation of greater understanding of the learning of BIM in projects to help advance BIM adoption within the built environment SMEs.

3.2 Research rationale

3.2.1 Research context

Project-based learning mechanism of BIM as innovation

The research considers project-based learning mechanism of BIM as innovation. It represents an innovative mechanism developed by built environment organisations to capture, transfer, assimilate, and absorb BIM-related knowledge that emerges to and from projects. The project-based learning mechanism of BIM is process innovation (Cooper, 1998; Papinniemi, 1999) that is internally produced (Băjenescu, 2017) and organisational (Gopalakrishnan et al., 1999). Each project-based learning mechanism is mainly developed within each organisation. The innovation alters how built environment organisations operate. It emphasises the aspect of learning to project actors. Each project-based learning mechanism of BIM reflects how BIM is being learned for an entire built environment organisation. The study compares project-based learning mechanism of BIM from different project-based organisations to obtain a greater understanding of how BIM-related knowledge is being learned.

Design and engineering SME consultancies

The research directs towards design and engineering SME consultancies. Design and engineering consultancies are project-based and are considered as leaders in the adoption of BIM, compared to other organisations within the built environment industry (Eadie et al., 2015; Ghaffarianhoseini et al., 2017). The challenge of comprehending BIM is greater in built environment SMEs than large organisations mainly due to the lack of individuals with adequate BIM competence (Dainty et al., 2017; Murguia et al., 2017). Additionally, built environment SMEs account for the majority of organisations within the sector (Dainty et al., 2017; Senaratne and Wang, 2018).

Specifically, the research obtains insights on how individuals learn BIM-related knowledge and acquire BIM competence through how knowledge practices are exercised in projects. The utilisation of knowledge practices is affected by contextual attributes of projects and an organisation. The project level is the operational ground of the built environment that provides a unique arena for learning and innovation (Ayas and Zeniuk, 2001; Bygballe and Ingemansson, 2014; Duffield and Whitty, 2015). Therefore, the research explores into the learning of BIM by designers and engineers from design and engineering SME consultancies.

The British and the Thai built environment industries

The investigation looks into two operational, cultural, and geographical backgrounds of the British and the Thai built environment industries. Both the British and the Thai built environment sectors enclose their own working culture. The prior context is perceived as more formal and developed, whereas the latter context is informal and developing. Each provides a different context of how BIM is being learned and adopted. Generally, built environment organisations within the British built environment industry are leaders in BIM adoption, while organisations from the Thai built environment sector are followers.

The British built environment industry is developed and knowledge-intensive (Eadie et al., 2015; Ganah and John, 2014). The sector comprises of various world-leading design and engineering consultancies (Ganah and John, 2014). The industry contains £113 billion in investment values, while SMEs accounts for 96% of organisations within the sector (Department for Business Innovation & Skills, 2013).

With BIM, most professional bodies, public institutions, and educational establishments in the UK are now actively promoting its adoption (Edirisinghe and London, 2015; Ganah and John, 2014). Publicly procured projects in the UK from 2016 are requiring BIM operation according to the mandate made by the UK government (Edirisinghe and London, 2015; Shibeika and Harty, 2015). In the UK, the process of working on BIM such as file structuring to communication methods have been standardised to promote seamless collaboration between different built environment parties (Alazmeh et al., 2018). Standardisation of BIM refers to how agreed BIM processes, protocols, and policies have been made into standards, manuals, and guidelines (Maradza et al., 2013). This invisible structure uniforms BIM tools and binds project parties together (Edirisinghe and London, 2015; Howard and Björk, 2008).

While many argue that the implementation of standards hinders innovation processes (Polesie et al., 2009), they are constantly re-configured to ease the learning of BIM and become the business-as-usual way of working (Alazmeh et al., 2018; Howard and Björk, 2008). Standardisation of BIM plays a critical role in the adoption of BIM for the entire British built environment sector (Alazmeh et al., 2018). Despite the sector being one of the world leaders in terms of BIM adoption, built environment SMEs within the industry are still facing the challenge of the lack of individuals BIM competence (Dainty et al., 2017; Eadie et al., 2015).

The Thai built environment industry is a developing sector. The working paradigm of Thai built environment organisations holds a direct relation to the Chinese working culture of family ties, connections, and *guanxi* (Pheng and Leong, 2001). Guanxi refers to a system of social networks and influential relationships that facilitate business (Virulrak, 2015). Business within the sector is lifelong employment, where seniority plays an important role in learning and innovating (Teerajetgul and Chareonngam, 2008). 99% of organisations within the industry are SMEs. The built environment sector is the main contributor to the development of the country (CIT, 2015), which holds the amount of £22 billion in investment values. Trailing after the British built environment industry, BIM is the current trend being adopted that can improve the overall performance of the Thai built environment sector (Ngowtanasawan, 2017).

The concept of BIM in Thailand was initially discussed amongst high-level academics in the early 2000s (Virulrak, 2015). However, it was the late 2000s that the platform was utilised in projects. Architects and civil engineers were the project actors to first transit into BIM (Virulrak, 2015). The lack of individuals with appropriate competence and understanding of BIM had always been the main complication of BIM adoption within the Thai built environment sector (Ngowtanasawan, 2017; Virulrak, 2015). Moreover, studies on BIM in the context of Thailand were limited. Table 3.1 brought the British and the Thai built environment industries into comparison.

Table 3.1: Comparison between the British and the Thai built environment industries.

British built environment industry	Thai built environment industry
Developed sector	Developing sector
SMEs are accounted for 99% of organisations within the industry.	SMEs are accounted for 96% of organisations within the industry.
£113 billion in investment values	£22 billion in investment values
Knowledge-driven and knowledge-intensive	Seniority and guanxi
From 2016, all public projects must be executed with BIM.	BIM have just been used in projects in the late 2000s.

The British built environment industry represents a leader in BIM adoption, while the Thai built environment sector depicts a follower. Additionally, the adoption of BIM in the British context is more refined. It accompanies by official standards and supports from various public institutions. Insights from both contexts allow a more comprehensive understanding of the learning of BIM in projects to be generated.

3.2.2 Research paradigm

Research philosophy

This research follows Saunders research onion (Saunders et al., 2009) as a framework for explaining the research paradigm. The ontological and the epistemological positions of this research challenge the positivist assumption of a single reality that is dependent on the human perspective (Golafshani, 2003; Mukherjee et al., 2002). The learning of BIM relies heavily on social and cultural aspects such as human perception, personal sense-making, experience, history, and social interaction (Ghaffarianhoseini et al., 2017; Puolitaival and Forsythe, 2016). The reality of learning BIM is constructed in the minds of project actors.

The study employs constructivist ontology and interpretivism epistemology. The study supports that the learning of BIM cannot exist without project actors and varies between individuals, projects, and organisations. The learning of BIM depends on the knowledge practices used by project actors and the contextual attributes of projects and an organisation.

Research approach

This research occupies deductive reasoning as the primary research approach. The main function of deductive reasoning is to offer an explanation or an understanding of an event or a phenomenon (Graneheim et al., 2017). Deductive reasoning or deduction uses a general idea in reaching a specific conclusion (Forman and Damschroder, 2007). Often known as a *top-down* approach, it starts from a theory, derives hypotheses from it, tests the hypotheses, and revises the theory (Woiceshyn and Daellenbach, 2018).

This research starts with the development of a theoretical framework entailing various knowledge practices and contextual attributes of projects. The framework provides a general idea of how knowledge practices are utilised for BIM learning in project-based organisations. Analyses of project-based learning mechanisms of BIM from both built environment contexts confirms or rejects the theory. They later allow for a specific understanding of BIM learning to emerge and a revision of the theoretical framework of the research to take place.

Research methodological approach

The exploration into the learning of BIM by project actors appeals for the qualitative methodological approach. It requires in-depth, complex, and detailed information on how BIM is learned by project actors in organisations. This includes, but not limited to how project actors experience BIM learning in their life, how individuals and/or groups behave, how an organisation operates, and how interactions between entities shape relations between knowledge practices and the unique reality of BIM learning between built environment organisations (Dale and Volpe, 2008; Graneheim et al., 2017). *Interview research* is a strategic research choice selected. This research is practice-oriented (Flick, 2014).

3.3 Research methods

3.3.1 Interview research

Interview research involves a presentation of oral-verbal stimuli and reply (Kothari, 2004). It requires a person known as the interviewer asking questions generally in face-to-face contact with another person or a group of people (DiCicco-Bloom and Crabtree, 2006). Interview research can be categorised into three types which are *structured*, *unstructured*, and *semi-structured* (DiCicco-Bloom and Crabtree, 2006; Qu and Dumay, 2011).

On one end, the structured interview involves the use of pre-determined questions with highly standardised techniques and recording and analysis data (Kothari, 2004). The interviewer follows a rigid procedure and asks questions in prescribed form and order (Qu and Dumay, 2011). On the other end, the unstructured interview is characterised as flexible and fluid. It does not follow any pre-determined questioning structure and it entirely explorative in nature (DiCicco-Bloom and Crabtree, 2006). In the middle, the semi-structured interview allows the interviewer to decide on manger and sequence in which questions are asked. Additionally, the interviewer has the freedom to explore any emergent discovery. The semi-structured interview is the most common qualitative research method (Qu and Dumay, 2011). It offers sufficient flexibility to approach different informants, while covers a similar area of data collection (Mohd Noor, 2008). This research exercises the semi-structured interview method.

The inquiry stands on the *romanticism view* of interview research. Within this view, an interview is a human encounter between interviewer and interviewee. An interviewer is an empathetic listener that explores the inner world of interviewees, while an interviewee is a participant to reveal real-life experience and their complex social reality (Qu and Dumay, 2011).

3.3.2 Sampling criteria

Built environment SMEs with design tasks

Interviewees of this research are from design and engineering SME consultancies. Organisations containing between 10 to 49 organisational members are considered small-sized, while organisations with 50 to 249 project actors are regarded as medium-sized (European Commission, 2009). Design and engineering consultancy involves organisations that work on any design aspects of a built environment project. Design aspects of a built environment project range from conceptual design and architectural design, to structural design and MEP (Mechanical, Electrical, and Plumbing) design. Design and engineering consultancies are early adopters of BIM in the built environment industry (Santos et al., 2017; Virulrak, 2015). Design and engineering SME consultancies of interviewees must be operating directly with BIM. The research disregards the sizes of projects taken by organisations.

Designers and engineers

Designers and engineers refer to roles within an organisation that assist or directly take part in designing a project. They include project actors such as architect, designer, civil engineer, and mechanical engineer. Designers and engineers are project roles that work hands-on with BIM. To increase the validity of data selected designers and engineers must also hold a BIM managerial role such as BIM manager or BIM coordinator. Furthermore, the selection of an interviewee does not include factors of working experience or the familiarity with BIM.

3.3.3 Data collection

The British interviewees recruitment strategy

Potential interviewees from the British built environment industry were located from their publicly available information on the website of their organisations. The recruitment strategy was Convenience sampling. The majority of design and engineering SMEs consultancies adopting BIM within this study were identified from multiple BIM level 2 accreditation websites. The initial communication medium in contacting potential interviewees was email. Each email was attached with the Invitation to research document. Afterwards, phone calls were made to explain the research in detail and to schedule the interview date. This followed by a confirmation email which included the Consent form and the Participant information sheet. The Participant information sheet provided the research background and purpose. All documents were approved by the UCL Research Ethics Committee. Appendix 1 presented an example of the initial email sent to the potential interviewees from the British built environment sector. Appendix 3 displayed the Invitation to research document. Appendix 5 and Appendix 7 provided the Consent form and the Participant information sheet, respectively.

The Thai interviewees recruitment strategy

Recruiting interviewees from the Thai built environment sector required a different approach. With a limited number of BIM adopting design and engineering SMEs consultancies in Thailand, the Snowball sampling strategy was utilised. The first interviewee was a well-known architect and BIM manager in Thailand. With the benefit of a greater understanding of how BIM is learned amongst Thai built environment organisations, the first interviewee agreed to recruit more designers and engineers working on BIM to participate in the research. Phone call was the primary mode of communication in contacting potential interviewees and scheduling interviews. A follow-up email with the Invitation to research document, Consent form, and Participant information sheet was later sent to the potential interviewee. All documents, which were approved by the UCL Research Ethics Committee were translated into Thai by the researcher. The language of communication was Thai since English is not the official language. The researcher did not use any official translation service. Appendix 2 provided an example of emails sent to the potential interviewees in Thailand. Appendix 4 put forward the Invitation to research document. Appendix 6 presented the Consent form and Appendix 8 displayed the Participant information sheet.

Interview strategy

At the beginning of every interview, the research background, aim, and objectives were informed in detail to the interviewees. The briefing also covered information on ethics and GDPR (General Data Protection Regulation). The interviews would not proceed unless the consent form was signed within any additional issues. The theoretical framework of this research was utilised as the interview guideline. Information required in the research were broadly categorised into four areas which were: a) *general information of an interviewee*; b) *general information of BIM projects and an organisation*; c) *knowledge practices used in project teams for learning BIM*; and d) *relations between knowledge practices and contextual attributes of projects*. The areas of information required provided the interview structure, while the interview questions were based on the information required. Moreover, the interviews explored any emergent discoveries that were relevant to the learning of BIM. Table 3.2 elaborated on areas of information required in the interviews.

Table 3.2: Areas of information required in the interviews.

Areas of information required	Information required
General information of an interviewee	Roles of interviewees

	Responsibilities in a project team and an organisation of interviewees
General information of BIM projects and an organisation	BIM adoption year of an organisation
	Project types of an organisation
	Driver to BIM adoption in an organisation
Knowledge practices used in project teams for learning BIM	Knowledge practices used by project teams to learn BIM
	Efficiency of knowledge practices utilised
	How each knowledge practice was exercised
	The most effective knowledge practices in each organisation
	Obsolete knowledge practices in each organisation
	How knowledge practices used contribute to the learning of BIM
Relations between knowledge practices and contextual attributes of projects	How knowledge practices utilised were influenced by contextual attributes of projects
	Influences that each contextual attribute has over knowledge practices exercised
	The most influential contextual attribute to the learning of BIM in projects

Each interview lasted between 45 minutes to one hour and a half. The interviews of Thai designers and engineers were in Thai as English is not the official language. The interviews were recorded, translated, transcribed, and imported into NVivo qualitative data analysis software for further analysis. An interview was a unit of analysis within this research. The chosen research method for analysing the data was *qualitative content analysis*.

3.3.4 Qualitative content analysis

Overview of the qualitative content analysis

Qualitative content analysis refers to a research method for systematically describing the meaning of qualitative data (Schreier, 2014). The goal of the method is to understand a phenomenon, rather than to make generalisations from data collected (Forman and Damschroder, 2007). It focuses on both the subject and the context (Graneheim et al., 2017), and emphasises on variations such as similarities and differences between parts of the data (Bazeley, 2013; Mayring, 2000). Qualitative content analysis is descriptive in nature (Bazeley, 2013; Schreier, 2014).

Schreier (2014) explained the qualitative content analysis to contain three main features. The first feature referred to a *reduction* of data. The qualitative content analysis allowed and required the researcher to focus on specific aspects of the data that are relevant to the overall research (Forman and Damschroder, 2007). The second feature related to how the research method provided a *systematic* approach, where the treatment of data demands a certain sequence

(Bazeley, 2013; Mayring, 2000). The third feature presented the *flexibility* of the research method, where data analysis could be *concept-* or *theory-driven*, as well as *data-driven* (Graneheim et al., 2017; Schreier, 2014).

Forman and Damschroder (2007) provided a framework for approaching qualitative content analysis. The framework contained three phases which were: a) *data immersion*, entails how the researcher engages and obtain a sense of the data; b) *data reduction*, involves how the researcher develops a systematic approach to the data; and c) *data interpretation*, implies how the researcher identifies patterns, re-assembles data, displays key findings, and verifies the conclusion. The framework of Forman and Damschroder (2007) was utilised within this research.

Data immersion

Audio recordings of the interviews were listened to and transcribed. The process was straight forward for the interviews from the British built environment sector. However, for the Thai built environment interviews, the procedure was longer as translations were needed. The interviews were transcribed solely by the researcher into Microsoft Word. The transcription did not employ any assistive software. The audio recording of each interview was eliminated immediately after the transcription to comply with the GDPR instilled by the UCL Research Ethics Committee. Transcriptions were read thoroughly by the researcher and imported into NVivo qualitative analysis software for data reduction.

Data reduction

The goal of the data reduction phase was to: a) reduce the amount of raw data that is irrelevant to answering the research question; b) break down the data into themes and thematic segments; and c) re-organise the data into categories that address the research question and sub-questions (Forman and Damschroder, 2007). A coding scheme was developed to assist in the reduction of data.

Coding provided a systematic approach to manage, locate, identify, and sort data (Bazeley, 2013). It created a critical link between data collection and its explanation of meaning (Saldaña, 2015). Coding represented topics, concepts, or categories of events, processes, or belief (Forman and Damschroder, 2007). Data could be coded as *categories* or *themes* (Graneheim et al., 2017; Saldaña, 2015). Categories included things, opinions, attitudes, perceptions, and experiences (Graneheim et al., 2017). A theme described a unifying *red thread* that runs through several categories that brings meaning to a topic or experience (Saldaña, 2015). Forman and Damschroder (2007) explained how the development of a coding scheme could be *deductive* or *inductive*. On one hand, deductive codes existed a priori and were constructed from a source such as a theoretical framework or a relevant empirical work (Forman and Damschroder, 2007; Saldaña, 2015). It resonated with the idea of concept- or theory-driven that was evident in Schreier (2014). On the other hand, inductive codes came from the data itself (Forman and Damschroder, 2007; Saldaña, 2015). It could be associated with data-driven analysis approach as presented in Schreier (2014). Additionally, Forman and Damschroder (2007) elaborated that a development of a coding scheme under the qualitative content analysis usually employs a combination of both approaches. The coding scheme of the research contained four levels of nodes which were *primary*, *secondary*, *tertiary*, and *quaternary*. Table 3.3 presented the coding scheme of the research.

Table 3.3: The coding scheme of the research.

Primary nodes	Secondary nodes	Tertiary nodes	Quaternary nodes
General information	Basic information of an interviewee	Role within a project team	Architect
			Designer
			Engineer
		Roles in relation to BIM	BIM manager
			BIM coordinator
	Basic information of an organisation	Organisation sizes	Small
			Medium
		Project types	Residential
			Office
			Renovation
			Infrastructure
			High-rise residential
			Commercial
			Well-being
		BIM adoption year	-
		Driver to BIM adoption	External (pressure from client, the government, or other organisations)
			Internal (to improve production)
Knowledge practices in projects	Codifiable knowledge practices	External source	-
		Project documentary	Project document
			Past models
			BIM library
		Standardisation	BIM standard
			BIM manual
			Internal BIM standard
			Internal BIM manual
			Social media application

		Shared knowledge repository	Cloud storage
			Internal folder
	Transactive knowledge practices	Assignment of knowledge management personnel	-
		Competences assessment	BIM matrix
			Internal assessment
		Learning-by-doing	-
		Professional networks	BIM seminar
			BIM specialist meeting
		Project review	Project meeting
			Post Project Review
		Promotion of knowledge sharing culture	-
		Specialist consultant	-
		Training & Workshop	Internal BIM training
			Internal BIM workshop
			External BIM course
			Tailored BIM course
	Un-codifiable knowledge practices	Incentive	Social incentive
			Economic incentive
		Informal meeting	-
		Knowledge team creation	Creation of a BIM specialist team
			Internal BIM learning group
		Mentoring	-
		Partnering	-
		Recruitment & Reassignment	Recruiting BIM expert
			Personnel allocation
			Work allocation
Contextual attributes	Project team relationship	Cognitive aspect	Shared BIM adoption goal
			Shared interpretation of BIM
			Shared understanding of BIM benefits
		Relational aspect	Network ties with former project team members
			Relationship with current project team members
			Trust towards other project actors
			Communication between project team members
			Communication to former project team members
		Temporal aspect	Disruptive connection between project team members

			Disruptive experience of working together
	Project team context	Project climate	Management support
			Knowledge sharing culture
			No-blame culture
		Project resources	Investments on hardware and software
			Investments on learning BIM-related knowledge
		Project structure	Formalisation
			Centralisation
			Integration
			Stratification
	Project operational context	Project similarity	Similarity on project type
			Similarity on tasks
			Similarity on issues encountered
		Time urgency	Task deadline
			Project deadline
			Urgency of issues found

**The inductive codes were highlighted in grey*

Deductively, the coding scheme of this research utilised the theoretical framework and the areas of information required presented in the previous chapter. The Knowledge practice dimension and the Contextual attribute dimension of the framework depicted a primary node in the coding scheme. The primary node also included the general information of an interviewee and the general information of BIM projects and an organisation. These primary nodes represented three main themes of the data, which were: a) *general information*; b) *knowledge practices in projects*; and c) *contextual attributes*.

The secondary node was a breakdown of the general information theme from the primary node to themes of the *basic information of an interviewee* and the *basic information of an organisation*. This correlated with the established areas of information required. Referring to the theoretical framework of the research, the knowledge practices in projects theme collapsed into themes within the secondary node of: a) *codifiable knowledge practices*; b) *transactive knowledge practices*; and c) *un-codifiable knowledge practices*. Similarly, the contextual attributes theme included secondary nodes of: a) *project team relationship*; b) *project team context*; and c) *project operational context*.

The tertiary node within the general information theme reflected the information required stated in Table 3.2. Furthermore, the tertiary node within the knowledge practices in projects theme were various knowledge practices mentioned in the theoretical framework. The contextual attributes to the fertile projects and an organisation from the theoretical framework were underlined as the tertiary node within the contextual attributes theme.

The quaternary node was deductive and inductive. It reflected more as categories of data, rather than themes (Forman and Damschroder, 2007). Displayed in Table 3.3, categories that emerged from the data were highlighted in grey. They represented codes that were data-driven and inductively collected. All quaternary nodes within the general information were data-driven. A large number of nodes within the knowledge practices in projects section were inductive. They extended current studies of knowledge practices within the built environment. There were no inductive nodes within the contextual attributes theme.

The data reduction phase utilised NVivo qualitative analysis software in the coding. The four nodes within the coding scheme were applied the software to generate a coding framework (Bazeley, 2013). Appendix 9 provided the coding framework as displayed in NVivo. The interview transcriptions were imported and coded in NVivo separately after the completion of each interview. The coding framework was constantly updated after each interview transcription was coded. This was to incorporate any emergent categories. The coding did not only highlight keywords but also passages to include the context of each node. Appendix 10 showed how the keywords and passages of the data were coded in NVivo.

In addition, relationships between each node were inductively discovered. The relationships identified were between a) different tertiary nodes within the knowledge practices in projects theme and b) various tertiary nodes of the knowledge practices in projects and the contextual attributes themes. The coding of relationships between nodes was supported by the *Relationships function* in NVivo. Passages of the data that reflected connections between nodes were coded. There were three types of relationships which were *causality*, *facilitated by*, and *correlational*. Causality referred to an assistive relationship between one node to another. Facilitated by related to how a node encouraged or promoted another. Correlational described a bi-directional relationship where both nodes supported the existence or the performance of one another. Appendix 11 provided an example of the coding of relationships between nodes within the relationship function of NVivo. Each interview contained its own distinctive set of relationships. Therefore, it was impossible to create a framework of relationships to apply to every interview.

The topic of knowledge practices was further examined in the research. The interviewees classified the knowledge practices used according to their significance to the learning of BIM in projects. Knowledge practices were labelled as *primary*, *secondary*, and *inefficient*. Primary applied to knowledge practices that were used extensively in the learning of BIM in projects. They were knowledge practices that played a key role in the adoption of BIM in an organisation. Secondary implied to supporting knowledge practices or knowledge practices that were not utilised by most of the project team members. Inefficient indicated knowledge practices that were inactive or unnecessary to the learning and adoption of BIM. NVivo did not contain a function that can incorporate these additional nodes. Accordingly, a table in Microsoft Excel was created. Appendix 12 displayed how primary, secondary, and inefficient knowledge practices were recorded in Microsoft Excel. Primary, secondary, and inefficient were converted into *major*, *minor*, and *obsolete* later in the Data presentation and structure chapter.

NVivo and Microsoft Excel were used within this research to increase the effectiveness and efficiency of the data reduction phase. While there were arguments on how computer-aided coding supplant the time-honoured ways of learning from data (Bazeley, 2013), both software allowed the data to be handled subjectively.

Data interpretation

The data interpretation phase involved the use of codes to re-assemble the data in a coherent manner (Forman and Damschroder, 2007). This process allowed the researcher to identify patterns, validate any preliminary conclusions, attach significance to particular results, and place them within and against an analytical framework (Graneheim et al., 2017; Saldaña, 2015). The common way to interpret data included methods such as re-organising or writing descriptive and interpretive summaries (Forman and Damschroder, 2007). However, *qualitative modelling* method was employed primarily within this research.

Forbus (2008) explained qualitative modelling to concern the representation and reasoning about continuous aspects of entities and systems in a symbolic and a human-like manner. It provided a certain level of abstraction and interpretation that best represent relationships between various entities (Forbus, 2008; Richards, 2009). The first step of qualitative modelling was to construct a scenario or a preliminary model of a system from the data (Forbus, 2008). The maps function within NVivo was exercised in creating a scenario of each interview. Appendix 13 displayed an example of a scenario generated by NVivo. Each scenario depicted a project-based learning mechanism of BIM or how various knowledge practices were utilised together. The scenarios were developed and re-visualised further to be displayed in the Data presentation and structure chapter. Additionally, it eased the comparison of different project-based learning mechanisms of BIM.

3.3.5 Research stages

Stage 1: The pilot interviews

Five pilot interviews were conducted in September 2018. The pilot interviews were towards Thai designers and engineers from design and engineering SME consultancies. They were necessary in refining the design of the data collection. The pilot interviews also assisted into the development of the theoretical framework of the research.

The five interviewees included three architects and two civil engineers. The first two architects were from design consultancies, while the rest were from engineering consultancies. During the first two interviews, the conversations were often stopped for additional explanation on various terms used. There were misalignments between the terms used in academia and practical setting. For example, Post Project Review was casually referred to as meeting by the interviewees. Additionally, both interviewees asked frequently of where they were in the discussions and repeated regularly of things mentioned. It was difficult for the interviews to be fluid. Therefore, a guideline was mandatory as the backbone of each interview. The initial theoretical framework of the research, which was formulated and published in Udomdech et al. (2018) was exercised in the remaining pilot interviews.

Interview questions were constantly developed after the completion of each pilot interview. Originally, the questions derived from the areas of information required stated in Table 3.2. Each interview was unique and did not contain a certain structure. The development of the interview questions allowed the researcher to be more precise and flexible. Table 3.4 presented a comparison between pre-pilot and post-pilot interview questions.

Table 3.4: The comparison of the pre-pilot and the post-pilot interview questions.

Pre-pilot interview questions	Post-pilot interview questions
Could you please provide me some basic information about yourself?	Could you please provide me with some basic information about yourself?
How long has the organisation use BIM?	What kind of roles and responsibility do you have in projects and in an organisation?
Could you please describe the types of projects the organisation normally took?	Can you please tell me the year that BIM was first adopted within this organisation?
What knowledge practices do you typically employ in learning BIM in projects?	Can you please describe types of projects your organisation normally took?
Which knowledge practices used are the most effective in learning BIM and why?	Can you please elaborate further on how BIM was introduced to this organisation?
How are knowledge practices used affected by contextual attributes of projects?	Can you please tell me what knowledge practices you and your team use in learning BIM?

	Can you please elaborate on how the knowledge practice you mentioned was utilised by project team members?
	Amongst all knowledge practices that you have mentioned, which of them do you consider as more effective?
	Can you please rank the knowledge practices that you have mentioned in terms of their significance?
	On the contrary, which knowledge practices do you think are inefficient to the learning of BIM?
	How do you think these knowledge practices were influenced by contextual aspects of project teams?
	In your opinion, which contextual attribute is the most influential to the learning of BIM and why?

The interview questions mentioned in Table 3.4 represented principal questions of the semi-structured interview. Each question was accompanied by probing questions such as *'Could you please say something more about that?'*, *'Can you please provide more detail on it?'*, and *'Do you have further examples of this?'* for further clarification and interpreting questions such as *'You then mean that …, am I right?'* and *'Is it correct that … ?'* (Qu and Dumay, 2011). All interviews ended with throw away questions such as *'Do you have anything else you would like to add about BIM learning in projects?'* and *'Do you have any question or are there anything that you think I need to know about BIM learning?'* (Kothari, 2004; Qu and Dumay, 2011).

The pilot interviews resulted in the revision of the research methods and the theoretical framework of the study. Comments received from the ARCOM conference 2018, where the initial version of the theoretical framework of the study was presented also contributed to the improvement of the theoretical framework. Additionally, training courses provided by UCL on conducting interviews were attended by the researcher. *Data saturation* criteria were developed after the completion of the pilot interviews.

The data saturation referred to a point in the data collection where no new categories or themes emerged (DiCicco-Bloom and Crabtree, 2006; Fusch and Ness, 2015). The data saturation was important in determining the adequate sample size of the research (Francis et al., 2010; Mason, 2010). Guest et al. (2006) underlined how most studies achieve data saturation after 12 interviews. Eight to 10 interviews were the initial analysis sample of the research. The stopping criterion was when three further interviews did not yield any additional knowledge practices used for BIM learning in projects.

Stage 2: the British data collection

The data collection period in the British built environment industry lasted four months from February 2019 to May 2019. 12 project actors were interviewed. Nine interviewees were designers, while the rests were engineers. Nine organisations of the project actors were architectural design consultancies, while another three were engineering consultancies. Project types undertaken by organisations varied. Four organisations were medium-sized. The first organisation to adopt BIM was a small-sized engineering consultancy, where BIM was implemented in 2003. Half of the design and engineering SME consultancies within this research were BIM level 2 accredited. Table 3.5 provided information about the interviewees from the British built environment sector.

Table 3.5: Information of the British interviewees.

Code	Project roles	Project type	Organisation type	Organisation size	BIM adoption year
UK01	Engineer and BIM manager	Commercial and offices	Mechanical engineering	Medium	2005
UK02	Project architect, partner, and BIM manager	Housing and educational	Architectural design	Small	2007**
UK03	Architect and BIM manager	Offices	Architectural design	Small	2018*
UK04	Mechanical engineer and BIM manager	Mixed-uses, residential, and master planning	Mechanical engineering	Medium	2012**
UK05	Architect and BIM manager	Residential and offices	Architectural design	Small	2018*
UK06	Architect and BIM manager	Offices and refurbishment	Architectural design	Small	2017*
UK07	Project architect and BIM manager	Residential and educational	Architectural design	Medium	2016**
UK08	Project architect and BIM manager	Leisure and well-being	Architectural design	Small	2015
UK09	Architect, partner, and BIM manager	Educational and residential	Architectural design	Small	2012**
UK10	Project engineer and BIM manager	Residential and commercial	Engineering	Small	2003**
UK11	Architect and BIM manager	All types	Architectural design	Medium	2018
UK12	Project architect and BIM manager	Educational, residential, and mixed-uses	Architectural design	Small	2012**

**Signifies organisations aiming for BIM level 2 accreditation*
***Signifies organisations with BIM level 2 accreditation*

Each interviewee was assigned a code of *UK*, followed by a number. BIM level 2 accreditation corresponded with the mandate made by the UK government (Eadie et al., 2015). Data analysis was performed concurrently with the data collection. Initial findings from the first three interviewees were published and presented at the EPOC (Engineering Project Organization Conference) 2019. Comments and suggestions from the conference further developed the research.

Stage 3: The Thai data collection

The data collection within the Thai built environment industry was from June 2019 to September 2019. 19 project actors were interviewed. 11 interviewees were designers. 11 interviewees were from design consultancies, while the rests were from engineering consultancies. Eight organisations were small-sized. Similar to the British data collection, the project types of organisations varied. The first organisation to adopt BIM was a medium-sized engineering consultancy with the BIM adoption year of 2009. It was the only organisation that implemented BIM before the year 2010. The BIM adoption year in the Thai built environment sector appeared to be later than stated in Virulrak (2015). Table 3.6 displayed information about the interviewees from the Thai built environment sector.

Table 3.6: Information of the Thai interviewees.

Code	Project roles	Project type	Organisation type	Organisation size	BIM adoption year
TH01	Interior designer and BIM coordinator	Commercial, residential, and well-being	Interior and architectural design	Medium	2014
TH02	Project architect and BIM manager	Commercial	Architectural design	Medium	2014
TH03	Project engineer and BIM manager	High-rise residential and commercial	Mechanical engineer and construction management	Medium	2018
TH04	Project engineer, partner, and BIM manager	High-rise residential and commercial	Civil engineering	Small	2017
TH05	Architect and BIM manager	High-rise residential and commercial	Architectural design	Medium	2016
TH06	Architect and BIM manager	High-rise residential and commercial	Architectural design	Medium	2014
TH07	Manging director, architect, and BIM manager	Residential and commercial	Architectural design	Small	2017

TH08	Project manager, lead designer, and BIM manager	Landscape	Landscape design	Small	2017
TH09	Project engineer and BIM manager	High-rise residential	Civil engineering	Medium	2019
TH10	Project engineer and BIM manager	High-rise residential and commercial	Mechanical engineer	Medium	2016
TH11	Project architect and BIM manager	Public infrastructure	Architectural design	Small	2019
TH12	Managing director, project architect, and BIM manager	High-rise residential	Architectural design	Small	2016
TH13	Project architect and BIM manager	Residential and commercial	Architectural design	Medium	2015
TH14	Associate, project architect, and BIM manager	Mixed-uses, commercial, and residential	Architectural design	Small	2012
TH15	Project architect and BIM manager	Residential and commercial	Architectural design	Small	2007
TH16	Project engineer and BIM manager	Residential and commercial	Civil engineering	Small	2015
TH17	Project engineer, partner, and BIM manager	Residential and well-being	Civil engineering	Medium	2014
TH18	Project engineer and BIM manager	Residential and commercial	Civil engineering	Medium	2014
TH19	Associates, project engineer, and BIM manager	Commercial and infrastructure	Engineering	Medium	2009

Corresponding to the British data collection, interviewees from the Thai built environment sector were assigned a code of TH, followed by a number. Additional findings from the interviews within the Thai context were analysed and submitted to the IRNOP (International Research Network on Organizing by Projects) 2020 conference. However, due to the emergent circumstance of COVID-19 (Corona Virus Disease 2019), the conference was cancelled.

During the write-up stage of the research, the world was going through COVID-19 pandemic. It was catastrophic to lives around the world. The pandemic caused severe impacts on organisations, especially towards SMEs. Many built environment SMEs were pressure to lower their organisational number, while some were forced out of a market. Therefore, it was impossible to reach out to some interviewees for data validation. All interviewees performed in the British and the Thai built environment industries were approved by the UCL Research Ethics Committee.

3.4 Ethics and data protection considerations

3.4.1 Ethical consideration

Informed consent

The research adhered to the UCL Code of Conduct for Research and the ESRC (Economic and Social Research Council) framework for research ethics 2015. The research ensured that all interviewees were fully informed about their participation and their rights. Interviewees were made aware of: a) research background; b) purpose of the study; c) overseeing institution of this research; d) how data is used; e) potential adverse impacts in their contribution to this study; and f) other individuals who have access to data obtained.

Additional information was provided if that interviewees became distressed during their participation. Interviewees were briefed about the interviewing process such as the duration of an interview and what their participation leads to. Information provided before each interview within the Thai context were translated into Thai by the researcher. The data collection in the British and the Thai contexts was approved by the UCL Research Ethics Committee. The British data collection was registered with the UCL Research Ethics Committee under a project ID of 14079/002. Whereas the project ID for the Thai data collection was 14079/003.

Voluntary participation

It was ensured that all interviewees were free from coercion. Project actors were informed that they could withdraw their involvement in the research at any time without any negative impact. No pressure was placed on project actors who chose not to participate or withdraw. Any personal information of interviewees would remain anonymous and the subject of withdrawal would not be mentioned in any form.

Do no harm

This research confirmed that there were no physical and psychological harms to the interviewees. In terms of the physical harm, it was made sure that the interview locations were secured, private, and well speculated with no risks to any physical harm. No physical contact that would cause any physical harm was made between the researcher and interviewees. In the aspect of the psychological harm, it was ascertained that involvement of informants would cause no harm before, during, and after the completion of the research. Involvement of interviewees would be kept secret to avoid any pressure, anxiety, or any invasion of privacy.

Any data or information given by interviewees would not be made public unless anonymised, even to the overseeing institution.

Confidentiality and anonymity

Any personal information of interviewees would be anonymised and would not be made available to or accessed by anyone but the researcher unless anonymised. Any information that could be used in tracking the interviewees would be excluded from any published document or would be coded in ways that could not be identified. Any personal information mentioned during the interviews would be made generic. There would be no discussion of any personal information of the interviewees to any external agent to this research.

Only access relevant component

The investigation only access components that were of relevance to the research aim and objectives. In cases that other topics outside BIM learning in projects which could be considered as irrelevant to the research emerged, the interviews would be re-directed from such components. The irrelevant topics would not be included in any published documents.

3.4.2 Data protection consideration

Data Protection Act

Referring to the Data Protection Act 1998, personal data obtained were: a) fairly and lawfully processed; b) processed for limited purposes; c) adequate, relevant, and not excessive; d) accurate and up-to-date; e) not kept for longer than is necessary; f) processed in line with your rights; g) secure; and h) not transferred to other countries without adequate protection.

Personal data collected within this research were: a) names; b) familiarity of interviewees with BIM; and c) opinions on how BIM is being learned in projects. It was ensured that all data was processed with caution and only for this research inquiry. Only relevant data would be processed and not kept for longer than four weeks after the study is completed with no further amendments. Full consent must be obtained from the interviewees only in using their personal information in the research, where all personal data would be anonymised.

Data sharing and storage

Raw data obtained would only be accessible by the researcher and would only be used for this study. Data could potentially be published or made public in journals, conference papers, and this research. All data was securely stored following the UCL Code of Conduct. The storage was password-protected and fully encrypted, where the researcher would be the only individual with an access. Any copy made were stored in approved storage spaces. They were password-protected and fully encrypted.

3.5 Chapter summary

This chapter explained and elaborated the research methodology. The chapter contained three parts which were the research rationale, the research methods, and the ethics and data protection considerations. Project-based learning mechanisms of BIM in organisations were regarded as process innovation. The context of the research entailed investigations into the project-based learning mechanisms of BIM in design and engineering SME consultancies from the British and the Thai built environment industries. Both organisational types were leaders in BIM adoption. The challenge of BIM adoption was greater for SMEs than large organisations. The British environment industry represented a developed sector, while the Thai built environment industry depicted a developing sector. Both contexts presented two settings that were culturally different. The comparison of BIM learning in projects between the British and the Thai design and engineering SME consultancies potentially shed light on the learning and adoption of BIM in projects by organisations.

The research correlated to constructivist ontology and interpretivism epistemology research paradigms. BIM learning in projects for individuals was personal and socially constructed. Deductive reasoning was the primary research approach. Qualitatively, the interview research method was exercised. The interviews were semi-structured. Information required in answering the research question was categorised into four areas of: a) general information of an interviewee; b) general information of BIM projects and an organisation; c) knowledge practices used in project teams for learning BIM; and d) relations between knowledge practices and contextual attributes of projects. The study employed qualitative content analysis as the research method for data analysis.

The qualitative content analysis entailed three phases of data immersion, data reduction, and data interpretation. In the data immersion phase, the audio recordings of the interviews were listened to, translated, transcribed, and read before imported into NVivo qualitative analysis software. In the data reduction phase, a coding scheme was developed through both deductive and inductive approaches. Data was realised as categories or themes. The coding scheme of the research contained four levels of nodes which were primary, secondary, tertiary, and quaternary nodes. The first three levels of nodes were deductively formulated from the theoretical framework of the research and the areas of information required. The quaternary node was deductive and inductive as some nodes were data-driven. Relationships between nodes were inductive and coded additionally. The significance of knowledge practices was coded separately in Microsoft Excel. In the data interpretation phase, qualitative modelling was the primary method used.

The research was divided into three stages. The first stage referred to the pilot interviews of Thai designers and engineers. The pilot interviews assisted in developing the interview techniques, the interview questions, and the theoretical framework of the study. The second stage related to the data collection in the British built environment industry, where 12 designers and engineers were interviewed. The third stage entailed interviews with Thai designers and engineers. 19 interviews from the Thai built environment industry were executed. The data collection was approved by the UCL Research Ethics Committee and adhere to the UCL Code of Conduct for Research, the ESRC, and the Data Protection Act 1998.

Chapter 4 Data presentation and structure

This chapter displays the data of the research. The data comprises of 31 interviews of designers and engineers from the British and the Thai design and engineering SME consultancies. Each project actor provides a project-based learning mechanism of BIM. The presentation of the project-based learning mechanisms of BIM from the interviews are structured based on their associated learning processes.

4.1 Overview of the project-based learning mechanisms of BIM

The data collection contained 31 interviews of the designers and engineers from British and Thai design and engineering SME consultancies. Each interviewee provided a project-based learning mechanism of BIM within their organisation. The project-based learning mechanisms of BIM were unique. They were categorised into three types according to the learning process they contribute to. The types were: a) *Exploitative*; b) *Ambidextrous*; and c) *Explorative*.

On one end, the Exploitative type included project-based learning mechanisms of BIM that all major knowledge practices utilised were listed within the Codifiable knowledge practice landscape of the theoretical framework of the research. On the other end, the Explorative type entailed project-based learning mechanisms of BIM with all major knowledge practices stated as the Un-codifiable knowledge practice. In between, the Ambidextrous type covered project-based learning mechanisms of BIM that contain major knowledge practices from the Transactive knowledge practice landscape or more than one landscapes of knowledge practice. Table 4.1 presented the categorisation of the project-based learning mechanisms of BIM.

Table 4.1: Types of the project-based learning mechanisms of BIM within the research.

Types of learning mechanisms	Interviewees
Exploitative	UK06
Ambidextrous	UK01, UK02, UK03, UK04, UK05, UK07, UK09, UK10, UK11, UK12, TH01, TH02, TH03, TH05, TH06, TH07, TH09, TH10, TH12, TH13, TH14, TH15, TH16, TH18, and TH19
Explorative	UK08, TH04, TH08, TH11, and TH17

4.2 Exploitative type

From all project-based learning mechanisms of BIM within the research, UK06 was the only interview within this Exploitative type.

UK06 was an architect and a BIM manager from a small-sized architectural design consultancy. The organisation normally took on office and refurbishment projects. The organisation of UK06 adopted BIM in 2017 and was aiming to obtain BIM level 2 accreditation. Table 4.2 displayed basic information of UK06. Whereas further detail of the interviewee could be located in Table 3.5.

Table 4.2: Basic information of the interviewee within the Exploitative type.

Code	Project roles	Organisation type	BIM adoption year
UK06	Architect and BIM manager	Architectural design	2017*
**Signifies organisations aiming for BIM level 2 accreditation*			

The project-based learning mechanism of BIM provided by UK06 contained nine knowledge practices. Shared knowledge repository and Standardisation were regarded as major, while the rests were acknowledged as minor. UK06 did not highlight any knowledge practices as obsolete. Table 4.3 displayed the major and minor knowledge practices in the project-based learning mechanism of BIM described by UK06.

Table 4.3: Major (MA), minor (MI), and obsolete (OB) knowledge practices from the project-based learning mechanism of BIM within the Exploitative type.

Landscapes	Knowledge practices	UK06
Codifiable knowledge practice	External source	-
	Project documentation	MI
	Shared knowledge repository	MA
	Standardisation	MA
Transactive knowledge practice	Assignment of knowledge management personnel	MI
	Competences assessment	-
	Learning-by-doing	MI
	Professional networks	MI
	Project review	MI
	Promotion of knowledge sharing culture	MI
	Specialist consultant	-
	Training & Workshop	-
Un-codifiable knowledge practice	Incentive	-
	Informal meeting	MI
	Knowledge team creation	-
	Mentoring	-
	Partnering	-
	Recruitment & Reassignment	-

UK06

UK06 identified Shared knowledge repository and Standardisation as major. The project actor did not underline any obsolete knowledge practice. Figure 4.1 provided an illustration of the project-based learning mechanism of BIM from UK06.

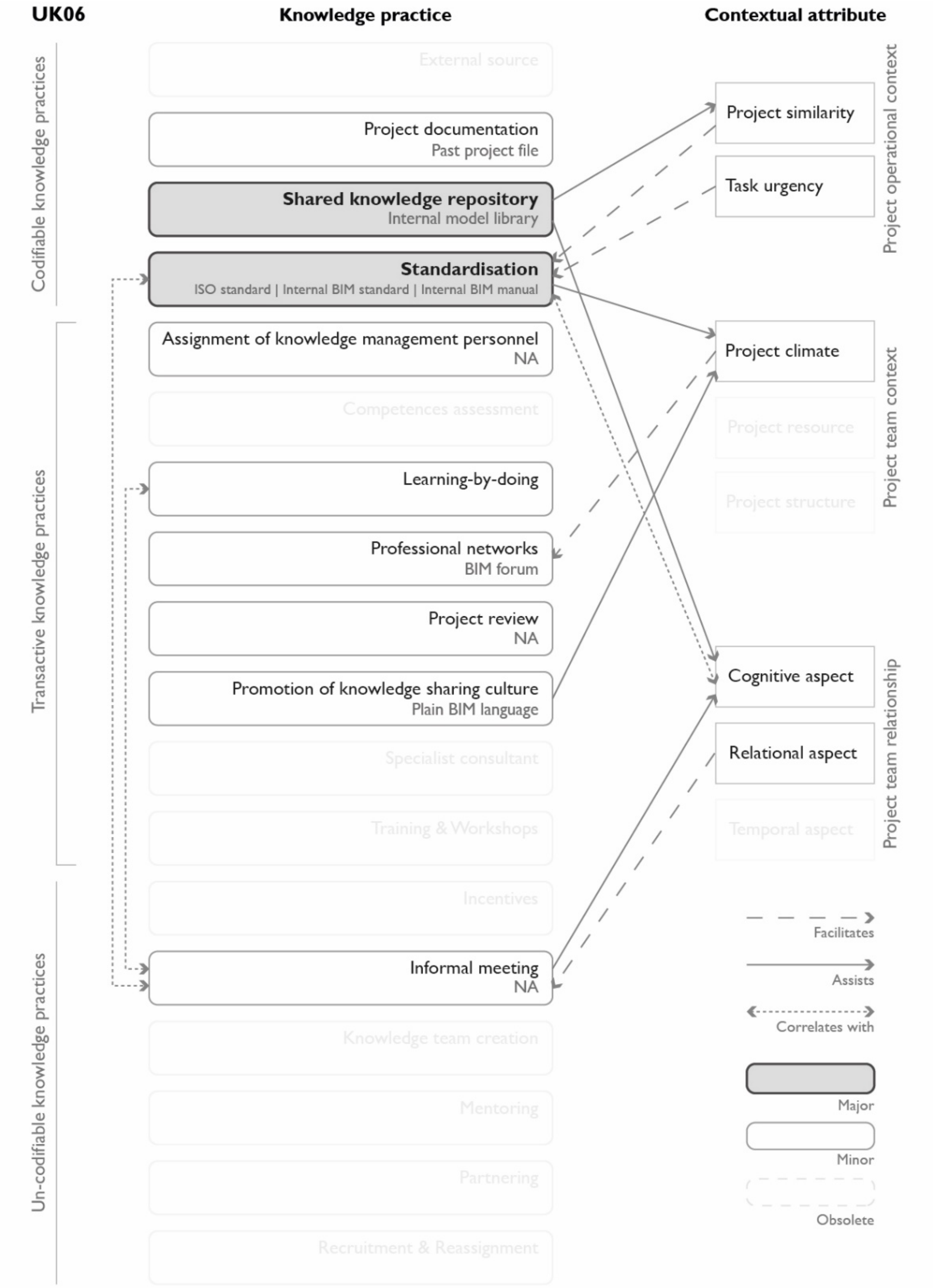

Figure 4.1: Project-based learning mechanism of BIM from UK06.

UK06 described Shared knowledge repository as a reference point for project actors. Internal model library was the instrumentality of this knowledge practice. It assisted the Cognitive aspect and was facilitated by Project similarity. With the prior, UK06 highlighted *"There are eight to nine documents to that … people know where they are and they can refer to them when they are working."*. With the latter, UK06 interviewee responded *"Definitely, it is quite helpful ... since we are doing a lot of offices, the library has been built up for years, the specifications, standards for floors, and etc. I think that it is efficient."*.

The project actors explained Standardisation to include modes of ISO standard, Internal BIM standard, and Internal BIM manual. Standardisation assisted Cognitive aspect and Project climate as it helped align understanding of project actors on BIM operation. Additionally, it also created a BIM environment for project actors within the organisation. UK06 described, *"That explains the whole process of how you set up, how you make the sheet, how you draw it, … and also explain how these ties into the very basic concept of BIM."*. It was facilitated by Task urgency and Project similarity. UK06 further elaborated, *"I try to have the time for at least once a month to add anything from all feedbacks. It doesn't really work out that well all the time from pressures of project deadlines … this 108-page document that focuses on specific scenarios which are the very typical jobs that we do, office projects."*. It also correlated with Informal meeting as BIM managers personally explained various standards to project team members.

4.3 Ambidextrous type

The Ambidextrous type of project-based learning mechanisms of BIM contained most of the interviews within the research. The Ambidextrous type was discussed with the interviewees UK01, UK02, UK03, UK04, UK05, UK07, UK09, UK10, UK11, UK12, TH01, TH02, TH03, TH05, TH06, TH07, TH09, TH10, TH12, TH13, TH14, TH15, TH16, TH18, and TH19.

The organisation of UK10 was the earliest to implement BIM. The organisation started to use BIM in 2003. This followed by the organisation of UK01 in 2007 and the organisation of UK02 in 2007. The organisations of UK02, UK04, UK07, UK09, UK10, and UK12 were BIM level 2 accredited. The organisation of TH19 was the earliest within this learning mechanism type to adopt BIM from the Thai built environment industry. The organisation utilised BIM in 2009. 14 out of 25 organisations within the Ambidextrous type were medium-sized. 15 organisations were design consultancies. Table 4.4 provided basic information of the interviewees within this learning mechanism type. Further information of the project actors was displayed in Table 3.5 and Table 3.6.

Table 4.4: Basic information of the interviewees within the Ambidextrous type.

Code	Project roles	Organisation type	BIM adoption year
UK01	Engineer and BIM manager	Mechanical engineering	2005
UK02	Project architect, partner, and BIM manager	Architectural design	2007**
UK03	Architect and BIM manager	Architectural design	2018*
UK04	Mechanical engineer and BIM manager	Mechanical engineering	2012**
UK05	Architect and BIM manager	Architectural design	2018*
UK07	Project architect and BIM manager	Architectural design	2016**
UK09	Architect, partner, and BIM manager	Architectural design	2012**
UK10	Project engineer and BIM manager	Engineering	2003**
UK11	Architect and BIM manager	Architectural design	2018
UK12	Project architect and BIM manager	Architectural design	2012**
TH01	Interior designer and BIM coordinator	Interior and architectural design	2014
TH02	Project architect and BIM manager	Architectural design	2014
TH03	Project engineer and BIM manager	Mechanical engineer and construction management	2018
TH05	Architect and BIM manager	Architectural design	2016
TH06	Architect and BIM manager	Architectural design	2014
TH07	Manging director, architect, and BIM manager	Architectural design	2017
TH09	Project engineer and BIM manager	Civil engineering	2019
TH10	Project engineer and BIM manager	Mechanical engineer	2016
TH12	Managing director, project architect, and BIM manager	Architectural design	2016
TH13	Project architect and BIM manager	Architectural design	2015
TH14	Project architect, associate, and BIM manager	Architectural design	2012
TH15	Project architect and BIM manager	Architectural design	2007
TH16	Project engineer and BIM manager	Civil engineering	2015
TH18	Project engineer and BIM manager	Civil engineering	2014
TH19	Associates, project engineer, and BIM manager	Engineering	2009

**Signifies organisations aiming for BIM level 2 accreditation*
***Signifies organisations with BIM level 2 accreditation*

The project-based learning mechanism of BIM from UK12 contained the highest number of knowledge practices. The learning mechanism included 14 knowledge practices, where three were regarded as major. On the contrary, the project-based learning mechanism of BIM from TH16 included the least number of knowledge practices. The learning mechanism comprised of four knowledge practices, where two were major. The project-based learning mechanism of BIM from UK10 entailed the highest number of knowledge practices highlighted as major. UK10 highlighted five knowledge practices in the learning of BIM in projects as major. Differently, TH03 underlined one major knowledge practice.

Standardisation, Project review, and Knowledge team creation were mentioned the most by the project actors as major. Each knowledge practice was listed by eight project actors. However, Project review was underlined mostly by project actors from the British design and engineering SME consultancies. Training & Workshop was regarded the most as obsolete by four project actors. This followed by External source, which was identified as obsolete by three project actors. It could be observed that knowledge practices from the Un-codifiable knowledge practice landscape were more preferable amongst the Thai design and engineering SME consultancies. The Transactive knowledge practices were more favoured in the British context.

In addition, project-based learning mechanisms of BIM within the Ambidextrous type could be further divided into five groups. The group was based on the knowledge practice landscapes of highlighted major knowledge practices. The five groups were: a) *Codifiable, transactive, and un-codifiable*; b) *Codifiable and un-codifiable*; c) *Codifiable and transactive*; d) *Transactive*; and e) *Transactive and un-codifiable*. Table 4.5 and Table 4.6 provided details of the major, minor, and obsolete knowledge practices of project-based learning mechanisms of BIM within the Ambidextrous type.

Table 4.5: Major (MA), minor (MI), and obsolete (OB) knowledge practices of project-based learning mechanisms of BIM within the Ambidextrous type (Part 1 of 2).

Landscapes	Knowledge practices	Codifiable, transactive, and un-codifiable				Codifiable and un-codifiable				Codifiable and transactive			
		UK07	**UK11**	**TH05**	**TH06**	**TH01**	**TH02**	**TH12**	**TH19**	**UK02**	**UK04**	**UK12**	**TH10**
Codifiable knowledge practice	External source	-	MI	MI	MI	*OB*	*OB*	MI	-	MI	MI	MI	-
	Project documentation	-	**MA**	**MA**	MI	-	**MA**	MI	-	-	-	**MA**	-
	Shared knowledge repository	-	MI	MI	**MA**	**MA**	MI	**MA**	**MA**	-	**MA**	MI	-
	Standardisation	**MA**	**MA**	**MA**	MI	-	MI	MI	**MA**	**MA**	**MA**	MI	**MA**
Transactive knowledge practice	Assignment of knowledge management personnel	MI	-	-	-	-	-	-	-	-	-	-	-
	Competences assessment	-	MI	MI	MI	-	-	-	-	MI	MI	-	-
	Learning-by-doing	-	MI	MI	MI	MI	MI	MI	-	MI	**MA**	MI	MA
	Professional networks	-	-	-	-	-	-	-	MI	MI	-	MI	-
	Project review	**MA**	MI	MI	MI	-	MI	-	-	**MA**	MI	**MA**	-
	Promotion of knowledge sharing culture	-	-	-	-	-	-	MI	MI	MI	-	MI	MI
	Specialist consultant	-	-	-	MI	-	MI	-	-	-	-	**MA**	MI
	Training & Workshop	**MA***	**MA**	**MA***	**MA**	MI*	MI	-	-	MI	**MA***	*OB*	MI
Un-codifiable knowledge practice	Incentive	-	-	-	-	*OB*	-	**MA**	-	-	-	-	-
	Informal meeting	MI	MI	MI	MI	MI	MI	**MA**	MI	MI	MI	MI	MI
	Knowledge team creation	**MA**	**MA**	**MA**	**MA**	MI	**MA**	-	-	-	-	MI	-
	Mentoring	-	MI	MI	MI	-	**MA**	-	**MA**	-	-	-	-
	Partnering	MI	MI	MI	-	-	-	-	-	-	-	MI	MI
	Recruitment & Reassignment	-	-	-	MI	**MA**	-	**MA**	MI	-	-	MI	-

**Signifies knowledge practices with a mode that was highlighted as obsolete.*

Table 4.6: Major (MA), minor (MI), and obsolete (OB) knowledge practices of project-based learning mechanisms of BIM within the Ambidextrous type (Part 2 of 2).

Landscapes	Knowledge practices	Transactive			Transactive and un-codifiable									
		UK01	**TH03**	**TH15**	**UK03**	**UK05**	**UK09**	**UK10**	**TH07**	**TH09**	**TH13**	**TH14**	**TH16**	**TH18**
Codifiable knowledge practice	External source	*OB*	-	-	-	MI	MI	-	MI	-	MI	-	-	MI
	Project documentation	-	MI	-	MI	MI	MI	-	-	-	MI	-	-	-
	Shared knowledge repository	MI	-	-	MI	-	-	-	-	-	-	-	-	-
	Standardisation	MI	MI	MI	MI	MI	MI	MI	MI	-	MI	MI	-	MI
Transactive knowledge practice	Assignment of knowledge management personnel	-	-	-	-	-	MI	-	-	-	-	-	-	-
	Competences assessment	MI	-	-	-	-	-	-	-	-	-	-	-	-
	Learning-by-doing	**MA**	MI	MI	MI	MI	MI	-	-	-	MI	MA	MI	MI
	Professional networks	-	-	-	-	MI	-	MI	-	-	-	-	-	-
	Project review	**MA**	MI	-	**MA**	**MA**	**MA**	**MA**	-	-	-	-	-	MI
	Promotion of knowledge sharing culture	MI	-	**MA**	-	-	-	-	MI	-	-	MI	**MA**	**MA**
	Specialist consultant	-	**MA**	**MA**	-	-	-	**MA**	**MA**	-	**MA**	-	-	-
	Training & Workshop	*OB*	*OB*	**MA***	MI	MI	MI	MI	MI	**MA**	MI	MI	*OB*	MI
Un-codifiable knowledge practice	Incentive	-	-	-	-	-	-	MI	-	MI	MI	-	-	-
	Informal meeting	-	-	MI	**MA**	**MA***	MI	**MA**	MI	**MA**	**MA**	**MA**	**MA**	MI
	Knowledge team creation	-	-	-	-	MI	-	MI	**MA**	**MA**	-	**MA**	-	**MA**
	Mentoring	-	-	-	-	-	-	MI	-	-	-	-	-	**MA**
	Partnering	-	-	-	MI	-	**MA**	-	-	MI	-	-	-	-
	Recruitment & Reassignment	MI	-	MI	MI	-	-	MI	-	MI	MI	MI	-	-

**Signifies knowledge practices with a mode that was highlighted as obsolete.*

4.3.1 Codifiable, transactive, and un-codifiable

The Codifiable, transactive, and un-codifiable group contained the project-based learning mechanisms of BIM with major knowledge practices coming from all knowledge practice landscapes of the theoretical framework of the research. The group comprised of the project-based learning mechanisms of BIM from UK07, UK11, TH05, and TH06. Standardisation was the most highlighted major knowledge practice from the Codifiable knowledge practice landscape, while Training & Workshop and Knowledge team creation were regarded the most as major from the Transactive and the Un-codifiable knowledge practice landscapes respectively. UK07, UK11, and TH05 underlined Standardisation as major. UK07, UK11, TH05, and TH06 identified Training & Workshop and Knowledge team creation as major.

The project learning mechanism of BIM from TH06 possessed the highest amount of knowledge practices but included the lowest number of major knowledge practices. TH06 discussed 13 knowledge practices used in the learning of BIM. However, only three were regarded as major which were Shared knowledge repository, Training & Workshop, and Knowledge team creation. On the contrary, the project-based learning mechanism of BIM as provided by UK07 borne seven knowledge practices in the learning of BIM, where four were major knowledge practices. UK07 explained Standardisation, Project review, Training & Workshop, and Knowledge team creation as major.

The project-based learning mechanisms of BIM of UK11 and TH05 were similar in terms of the knowledge practices exercised. Both project-based learning mechanisms of BIM contained an equal amount of knowledge practices utilised. UK11 and TH05 described Project documentation, Standardisation, Training & Workshop, and Knowledge team creation as major. The following section presented the project-based learning mechanism of BIM of TH05 as an example of the project-based learning mechanisms of BIM within this group. The project-based learning mechanisms of BIM provided by UK07, UK11, and TH06 could be located in Appendix 14.

TH05

Project-based learning mechanism of BIM from TH05 included Project documentation, Standardisation, Training & Workshop, and Knowledge team creation as major. It did not contain any obsolete knowledge practice. Figure 4.2 illustrated the project-based learning mechanism of BIM from TH05.

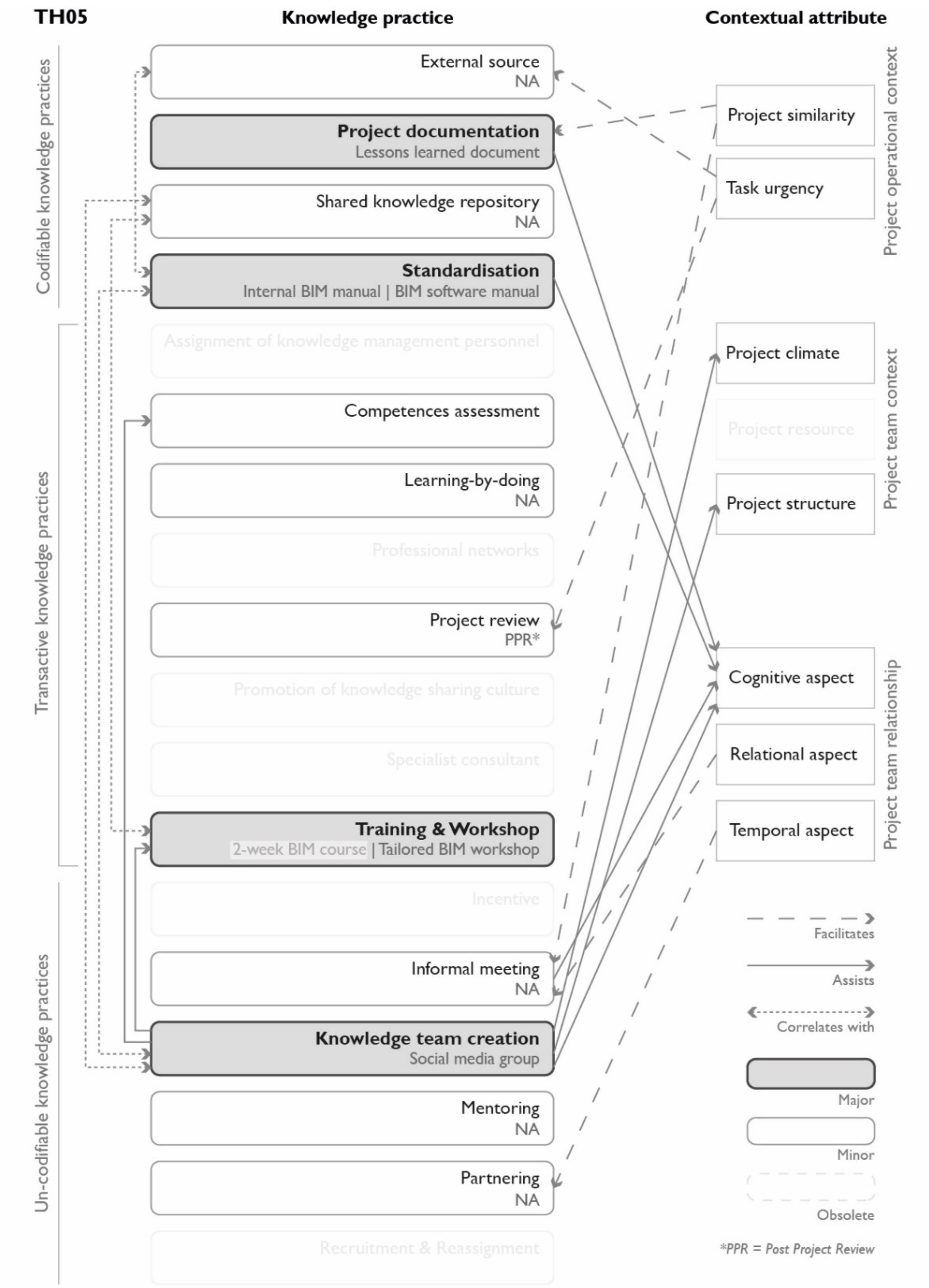

Figure 4.2: Project-based learning mechanism of BIM from TH05.

Project documentation included an instrumentality of Lessons learned document. BIM-related knowledge would be documented and shared across projects through Lessons learned document. This provided how the knowledge practice assisted Cognitive aspect of project teams. TH05 explained, *"Documents are really good for basics … we would be telling them to go back to the documents so that they know how to solve those themselves."*. Project documentation was facilitated by Project similarity. TH05 described Lessons learned documentation as the most suitable knowledge practice as the organisation normally took on a similar kind of project repetitively.

Standardisation contained instrumentalities of Internal BIM manual and BIM software manual. Standardisation correlated with External source and Knowledge team creation. The knowledge practice also assisted Cognitive aspect of project teams. Both instrumentalities of knowledge practice were formulated by referencing publicly available BIM standard. They were initially given to project actors when they join the organisation.

Training & Workshop entailed two instrumentalities of 2-week BIM course and Tailored BIM workshop. While the prior mode was stated as generic, the latter was labelled as major as it was more specific towards works in project teams. TH05 commented that Tailored BIM workshop was run by BIM managers and varied, depending on current projects and competence of project actors. TH05 added, *"It is my job to make sure that the training is tailored towards the situation."*.

Knowledge team creation held an instrumentality of Social media group. This knowledge practice assisted Project climate, Project structure, and Cognitive aspect. TH05 explained, *"We also have a social media group where they can just ask anything there and we would be trying to answer them through there. This group is tailored towards BIM."*. Regarding Project structure, TH05 added, *"What is so great about this social media group is that, it eliminates the presence of hierarchy within the office or projects. It allows things to be less formal which means that one personnel with a problem or a question can communicate with others easier."*.

4.3.2 Codifiable and un-codifiable

The Codifiable and un-codifiable group included project-based learning mechanisms of BIM with major knowledge practices from the Codifiable and the Un-codifiable knowledge practice landscapes. The group entailed the project-based learning mechanisms of BIM from TH01, TH02, TH12, and TH19. Shared knowledge repository was underlined the most as major from the Codifiable knowledge practice landscape. Mentoring and Recruitment & Reassignment were highlighted the most from the Un-codifiable knowledge practice landscape. TH01, TH12, and TH19 regarded Shared knowledge repository as major. TH01 and TH12 explained Recruitment & Reassignment as major, while the other two interviewees underlined Mentoring as major.

The project-based learning mechanism of BIM from TH12 entailed the highest number of major knowledge practice. TH12 recognised Shared knowledge repository, Incentive, Informal meeting, and Recruitment & Reassignment as significant to the learning of BIM in projects. On the contrary, the project-based learning mechanism of BIM from TH01 only included two major knowledge practices. TH01 described Shared knowledge repository and Recruitment & Reassignment as major. Incentive, which was regarded by TH12 as major knowledge practice was perceived as obsolete by TH01.

The project-based learning mechanisms of BIM from TH02 and TH19 each possessed three major knowledge practices. TH02 identified Project documentation, Knowledge team creation, and Mentoring, Whereas, TH19 covered Shared knowledge repository, Standardisation, and Mentoring as major. The following section put forward the project-based learning mechanism of BIM from TH12 as an example that represent the Codifiable and un-codifiable group within the Ambidextrous type as it contained the highest number of major knowledge practices. The project-based learning mechanisms of BIM from TH01, TH12, and TH19 were presented in Appendix 15.

TH12

Project-based learning mechanism of BIM from TH12 concluded Shared knowledge repository, Incentive, Informal meeting, and Recruitment & Reassignment as major. TH12 did not provide any obsolete knowledge practice. Figure 4.3 visualised the project-based learning mechanism of BIM from TH12.

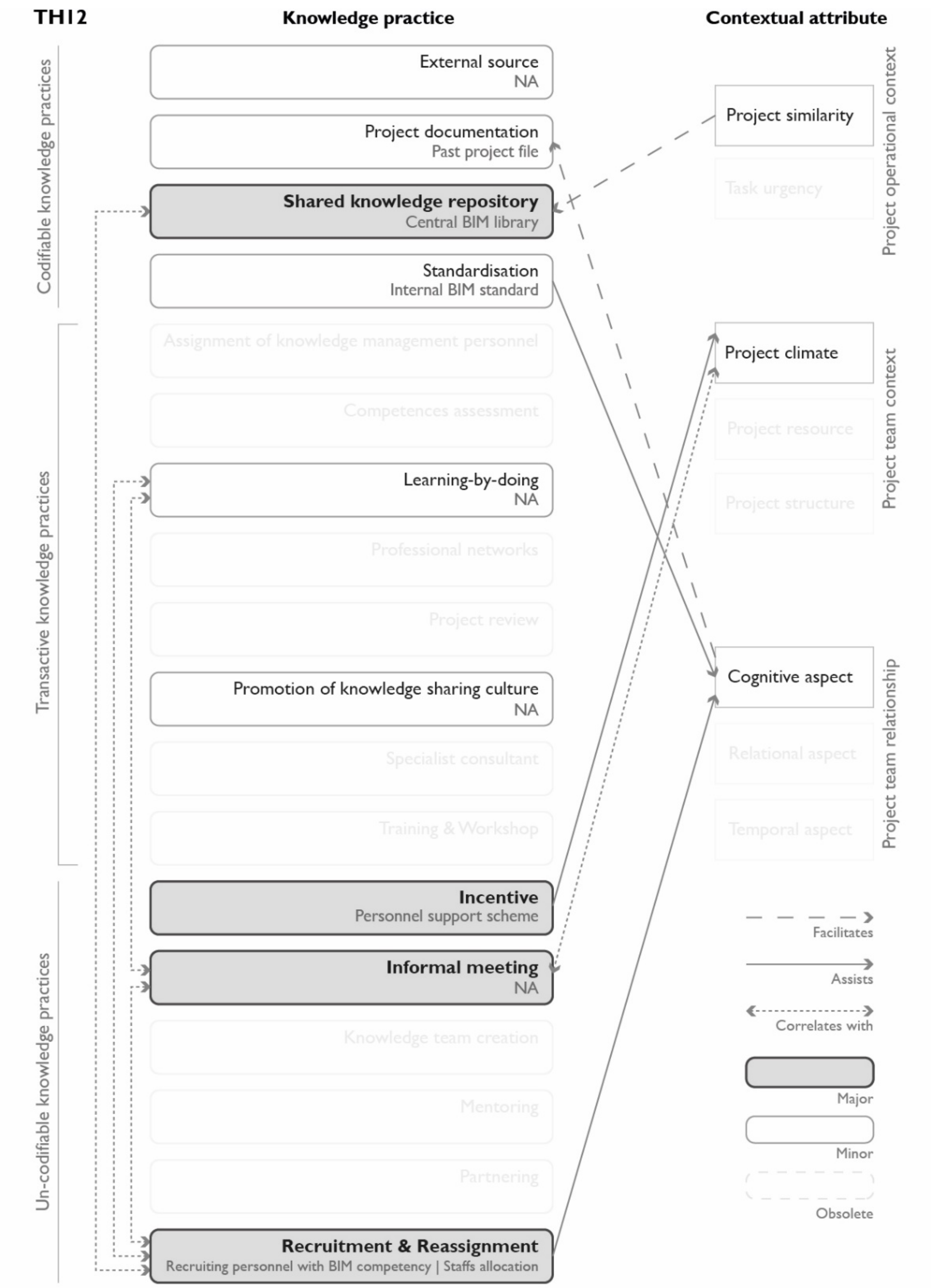

Figure 4.3: Project-based learning mechanism of BIM from TH12.

Recruitment & Reassignment was highlighted as the most significant knowledge practice. It contained similar instrumentalities of knowledge practice to the project-based learning mechanism of BIM from TH01. Recruiting project actors with BIM competence was the initial mode to introduce BIM into project team members. Staffs allocation allowed BIM to be dispersed rapidly throughout the organisation. TH12 furthered, *"If I got a project, and let's say that the project has 8 buildings. I wouldn't be assigning 1 building to 1 or 2 people. I would be making everyone model all 8 building at the same time. Walls, everyone does walls. Floors, everyone does floors. We all go through tasks at the same time."*. Recruitment & Reassignment assisted Cognitive aspect by allowing BIM understanding to be learned equally throughout an organisation. Additionally, Staffs allocation correlated with Shared knowledge repository, Learning-by-doing, and Informal meeting.

Shared knowledge repository contained an instrumentality of Central BIM library. TH12 provided, *"We have this central file. Not an actual file, but it is a file that contains all door types, window types, and etc., that we have modelled or used before in previous projects."*. This was facilitated by Project similarity. Taking on similar type of projects allowed operations to be repetitive. Therefore, it was easier for project actors to utilise knowledge from previous projects. TH12 explained, *"..., our projects are mainly condominium after all. Works are quite repetitive ... another reason that makes the library works is that we normally take on projects from not many developers in Thailand ... you have settings for working with all of them, everything is a lot easier."*.

Incentive included an instrumentality of Personnel support scheme. Project actors within an organisation were supported in every way that reduces frustration. This entailed insurances, holidays, office trips, BIM classes, and external BIM workshops. Personnel support scheme also covered a pension scheme, where the income of project actors is partially invested to generate guaranteed additional profits when they decide to leave the organisation.

Informal meeting was provided to mainly correlated with Recruitment & Reassignment. TH12 commented, *"What was really great about this was that, each one will encounter different problems, but from similar source. This also allowed discussions to occur."* Informal meeting also correlated with Project climate. TH12 added, *"The company is just too small that every time someone is having a problem, the rests would hear what is going on and they could walk and see how it is done."*.

4.3.3 Codifiable and transactive

The Codifiable and transactive group entailed the project-based learning mechanisms of BIM with major knowledge practices from the Codifiable and the Transactive knowledge practice landscapes. The group contained UK02, UK04, UK12, and TH10. Standardisation was the regarded the most as major. It was located as major in UK02, UK04, and TH10.

The project-based learning mechanism of BIM from UK04 included the highest number of major knowledge practices. UK04 explained Shared knowledge repository, Standardisation, Learning-by-doing, and Training & Workshop as major. This followed by the project-based learning mechanism of BIM from UK12 with three major knowledge practices of Project documentation, Project review, and Specialist consultant. UK02 put forward two major knowledge practices of Standardisation and Project review. The project-based learning mechanism of BIM from TH10 contained only one major knowledge practice which was Standardisation. The following section presented the project-based learning mechanism of BIM from UK04 as an example of project-based learning mechanisms of BIM within this group. The project-based learning mechanisms of BIM from UK02, UK12, and TH10 were elaborated in Appendix 16.

UK04

Project-based learning mechanism of BIM from UK04 encompassed Shared knowledge repository, Standardisation, Learning-by-doing, and Training & Workshop as major knowledge practices. Figure 4.4 portrayed the project-based learning mechanism of BIM from UK04.

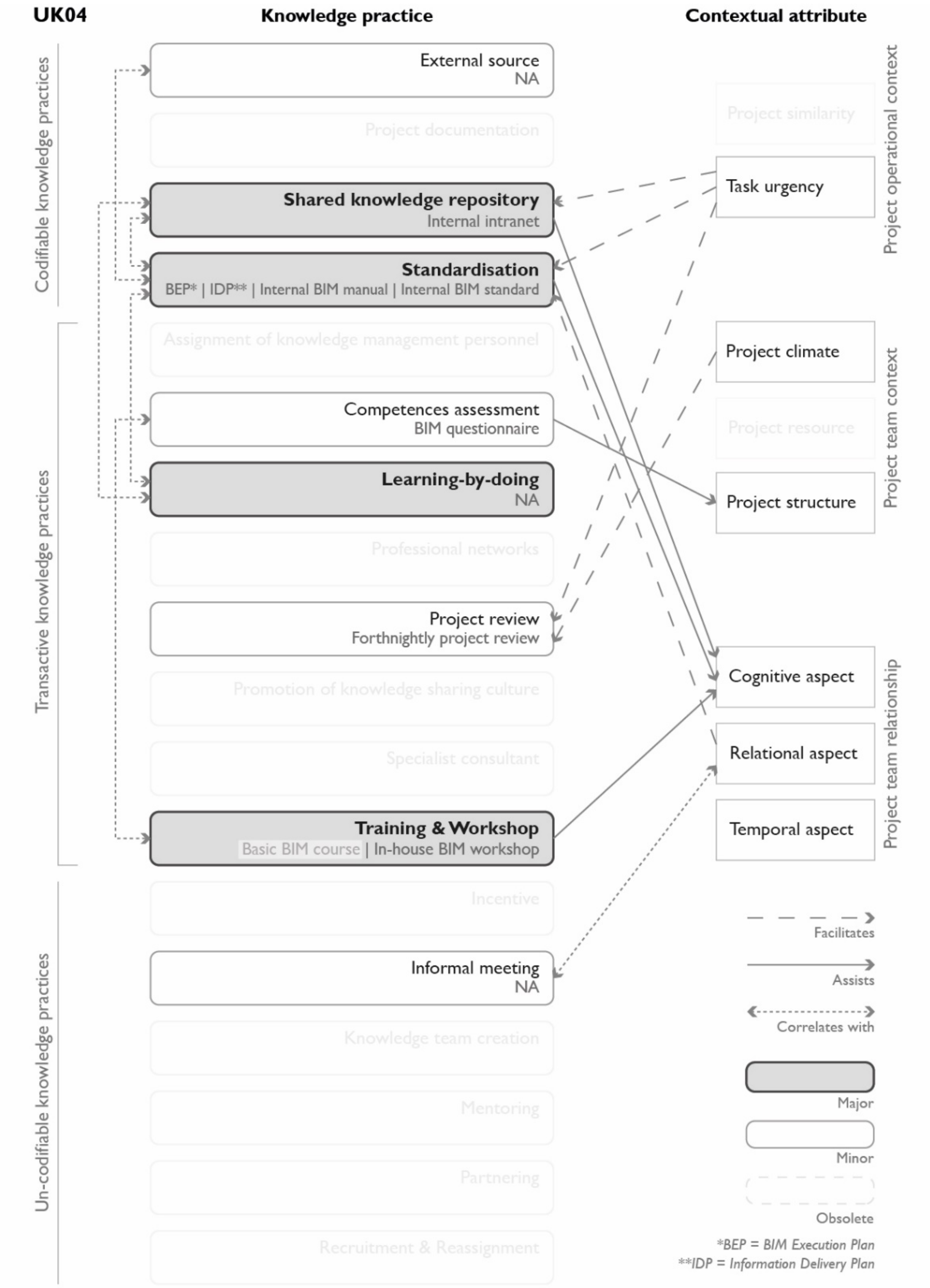

Figure 4.4: Project-based learning mechanism of BIM from UK04.

Similar to the project-based learning mechanism of BIM from UK02, Standardisation was highlighted as major. The knowledge practice included instrumentalities of BEP, IDP (Information Delivery Plan), Internal BIM manual, and Internal BIM standard. Standardisation was utilised to provide a reference point for project actors while operating on BIM. UK04 elaborated, *"All of them have notes of this is what we do and how we do. So, if you are new, you can pick it up and know a bit about BIM … there is a lot of real-world example that we uses as well. You can open it up and go over it step-by-step."*. Standardisation was described to correlated with External source, Shared knowledge repository, and Learning-by-Doing. It was facilitated by Task urgency and Relational aspect. Project deadlines influenced the amount of time project actors were accessing Standardisation. With Relational aspect, a good relationship between BIM managers and project actors was necessary to persuade project actors to comply to various standards.

Shared knowledge repository correlated with Standardisation as it played as an alternative route to access a more informal version of BIM-related knowledge. UK04 commented, *"…, because of the language, the acronyms, I think that they are a massive barrier for people … it is the language side of it that kills the implementation for a lot of people."*. It provided a translation of more formal terminologies to project actors. The knowledge practice contributed to Cognitive aspect of project teams.

Learning-by-doing was underlined as the most significant knowledge practice within this learning mechanism. However, UK04 commented that it would not be significant unless exercised with Standardisation and Shared knowledge repository. Both project knowledge practices performed as a reference point for project actors while operating with BIM.

Training & Workshop contained two instrumentalities of Basic BIM course and In-house BIM workshop. The prior mode was identified as obsolete. It was provided by BIM software provider. The course was generic for project actors. UK04 commented, *"…, with the trainings and seminars, … you never utilise stuffs that you just learned, and that will just disappear … it needs to be something practical, that is why we are assessing everyone."*. Therefore, it was more preferable for BIM education to be done internally by BIM managers. This allowed a more specific understanding of BIM to be learned. In-house BIM workshop correlated with Competences assessment. Competences assessment was done in order to understand the level of BIM competence within projects and the organisation.

4.3.4 Transactive

The Transactive group included the project-based learning mechanisms of BIM with major knowledge practices coming from the Transactive knowledge practice landscape. The group contained three learning mechanisms which were UK01, TH03, and TH15.

UK01 forwarded Learning-by-doing and Project review as major knowledge practices. The interviewee further described External source and Training & Workshop as obsolete. TH03 highlighted Specialist consultant as the sole major knowledge practice. Similar to UK01, TH03 elaborated Training & Workshop as obsolete. Project-based learning mechanism of BIM from TH03 did not utilise any knowledge practice from the Un-codifiable knowledge practice landscape. The project-based learning mechanism of BIM from TH15 possessed the highest number of major knowledge practices. TH15 described three knowledge practices as major. The following section provided a presentation of the project-based learning mechanism of BIM from TH15 as an example of project-based learning mechanisms of BIM within this Transactive group. The project-based learning mechanism of BIM from UK01 and TH03 could be located in Appendix 17.

TH15

Project-based learning mechanism of BIM from TH15 provided Promotion of knowledge sharing culture, Specialist consultant, and Training & Workshop as major knowledge practices. TH15 did not state any obsolete knowledge practice. Figure 4.5 displayed the project-based learning mechanism of BIM from TH15.

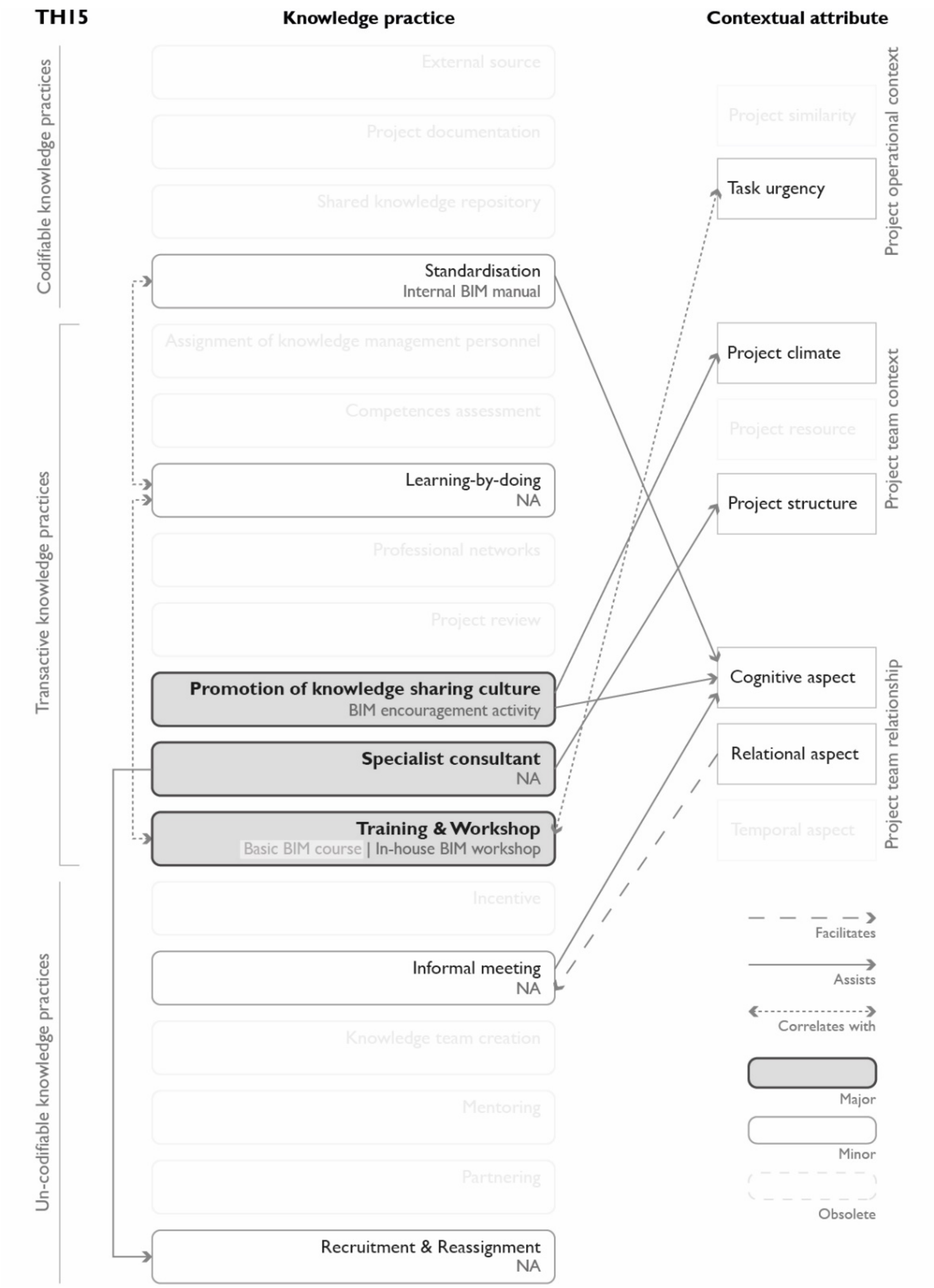

Figure 4.5: Project-based learning mechanism of BIM from TH15.

Promotion of knowledge sharing culture contained an instrumentality of BIM encouragement activity. This assisted directly to Project climate, as well as Cognitive aspect of project teams. Regarding BIM encouragement activity within this learning mechanism, TH15 explained, *"We have a projector projecting BIM works all day long within the office. The projector would be displaying the actual BIM project that the adopting team is doing for the rest of the firm to see. We realised that by increasing the awareness that BIM is a big thing, people tend to learn faster."*. The interviewee further added, *"Another message that was delivered with having the projector is about collaboration. Everyone could see that they are working on the same file and that changes made by then are being updated in real-time for everyone in the team."*.

Specialist consultant was employed to ease with any frustration of project actors while operating with BIM. It assisted Project structure as BIM specialists were appointed to work alongside project actors on actual projects. TH15 commented, *"BIM workflow is really complicated. There are problems all the time. Bringing these people in would help the staffs a lot so that they won't get too frustrated with BIM learning."*.

Training & Workshop contained two instrumentalities of Basic BIM course and In-house BIM workshop. Similar to other interviewees that mentioned Basic BIM course, Basic BIM course was viewed as generic and obsolete. However, In-house BIM workshop was perceived as valuable as it provided more specific BIM-related knowledge alongside actual projects. This correlated Training & Workshop to Learning-by-doing.

4.3.5 Transactive and un-codifiable

The Transactive and un-codifiable group entailed the project-based learning mechanisms of BIM with major knowledge practices from the Transactive and the Un-codifiable knowledge practice landscapes. The group encompassed most of the project-based learning mechanisms of BIM within the Ambidextrous type. The Transactive and un-codifiable group included 10 interviews which were UK03, UK05, UK09, UK10, TH07, TH09, TH13, TH14, TH16, and TH18.

Informal meeting was highlighted the most by interviewees within this group as major knowledge practice. The knowledge practice was identified as major by seven interviewees which were UK03, UK05, UK10, TH09, TH13, TH14, and TH16. This followed by Project review and Knowledge team creation. Both were underlined as major in four project-based learning mechanisms of BIM. UK03, UK05, UK09, and UK10 described Project review as major, while TH07, TH09, TH14, and TH18 located Knowledge team creation as major.

Project-based learning mechanisms of BIM within this group each contained around two to three major knowledge practices. The project-based learning mechanisms of BIM from TH09 and TH18 included three, while the rests encompassed two. TH09 explained Training & Workshop, Informal meeting, and Knowledge team creation as major. TH18 identified Promotion of knowledge sharing culture, Knowledge team creation, and Mentoring as major. The following section presented the project-based learning mechanism of BIM from TH18 as an example of learning mechanisms within this Transactive and un-codifiable group. Appendix 18 provided other project-based learning mechanisms of BIM within this group.

TH18

Project-based learning mechanism of BIM from TH18 included Promotion of knowledge sharing culture, Knowledge team creation, and Mentoring as major knowledge practices. TH18 did not bring up any obsolete knowledge practice. Figure 4.6 displayed the project-based learning mechanism of BIM from TH18.

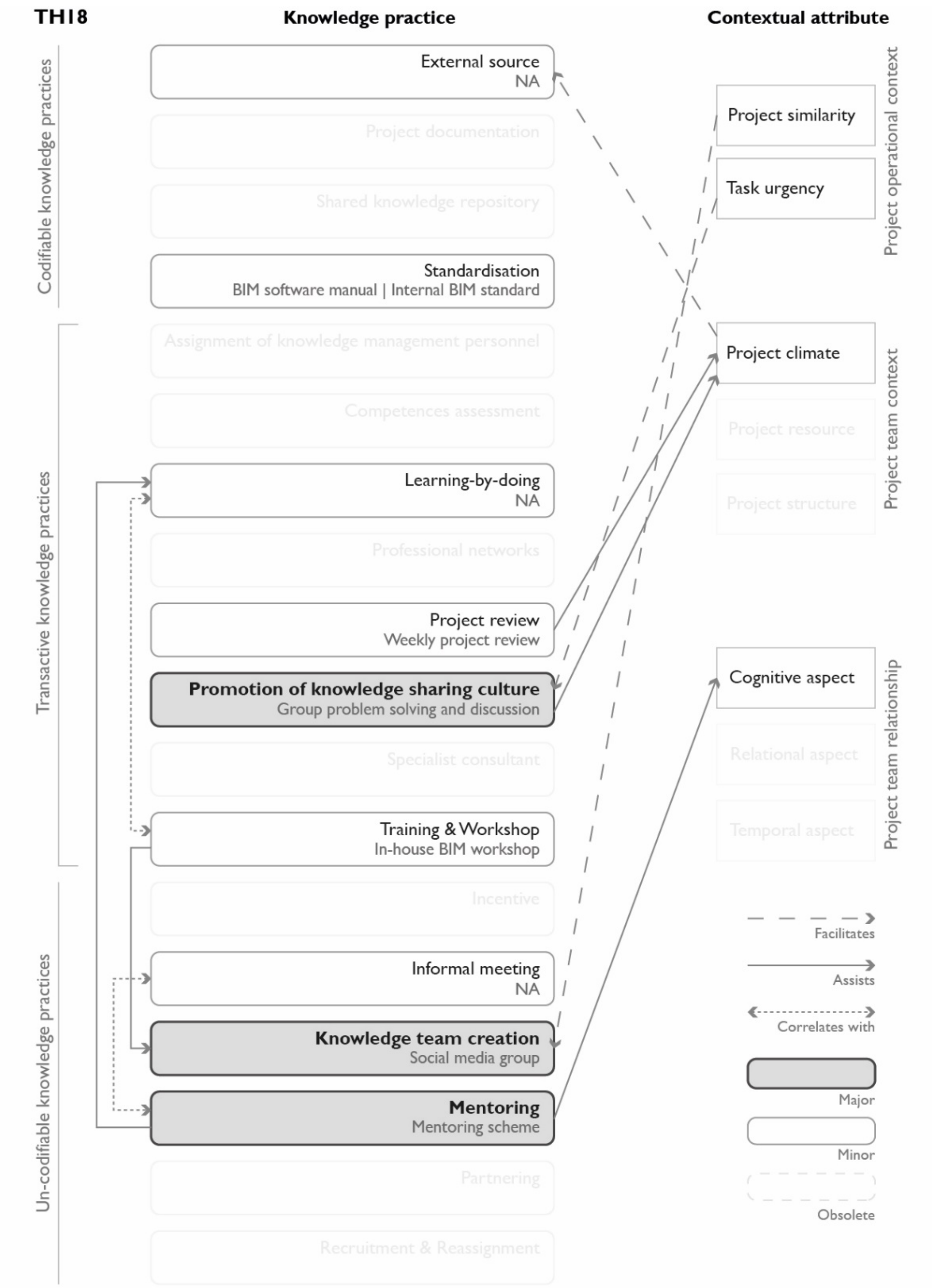

Figure 4.6: Project-based learning mechanism of BIM from TH18.

TH18 described Promotion of knowledge sharing culture to be important for project actors to figure out how to navigate through BIM on their own. However, suggestions would be given for project actors to experiment with the platform. TH18 explained, *"I think that people learn quicker if they figure things out themselves. So, I would be suggesting ways for my staffs to overcome problems found on BIM … I also think that this method would open up my staffs' mind the most to BIM."*. However, it was facilitated by Task urgency as project actors were always pressured by project deadlines.

Knowledge team creation contained an instrumentality of Social media group. Within the organisation, a social media group for BIM learning was created, where BIM-related knowledge was constantly shared. TH18 provided, *"For example, a new way that we can all work faster, if I found that, I would then send messages to the group and let everyone knows that, hey, this is the new way that I think we should be working on."*. This assisted Cognitive aspect as it allowed BIM understanding to be shared amongst project actors. It was facilitated by Project similarity. The fact that projects were repetitive eased the learning of BIM through Social media group.

According to the interviewee, Mentoring scheme was created to maximise BIM learning of project actors. Works were divided into parts, where project actors would be going through them with close supervision from the BIM manager. TH18 described, *"I found that, once they get a hold of the first object, they can progress further by themselves. With the columns that I mentioned, after my staffs finished with the first column, they can then work on the next one by themselves. They can then work through other kind of columns that are different than the first one."*. This provided how Mentoring correlated with Informal meeting and assisted Learning-by-doing as both knowledge practices were mandatory for the success of Mentoring.

4.4 Explorative type

The Explorative type included the project-based learning mechanisms of BIM with major knowledge practices from the Un-codifiable knowledge practice landscape of the theoretical framework of the research. The type contained UK08, TH04, TH08, TH11, and TH17.

Most interviewees within this Explorative type were from the small-sized design and engineering SME consultancies. TH17 was the only interviewee from a medium-sized organisation. UK08 was the sole interviewee from the British built environment industry. UK08, TH08, and TH11 were from the architectural design consultancies. TH04 and TH17 were from the civil engineering consultancies. Table 4.7 provided basic information about the interviewees within this Explorative type. Further detail of interviewees could be identified in Table 3.5 and Table 3.6.

Table 4.7: Basic information of the interviewees within the Explorative type.

Code	Project roles	Organisation type	BIM adoption year
UK08	Project architect and BIM manager	Architectural design	2015
TH04	Project engineer, partner, and BIM manager	Civil engineering	2017
TH08	Project designer and BIM manager	Architectural design	2017
TH11	Project architect and BIM manager	Architectural	2019
TH17	Project engineer, partner, and BIM manager	Civil engineering	2014

Project-based learning mechanism of BIM from TH17 contained the highest number of knowledge practices. With 10 knowledge practices stated, TH17 explained Knowledge team creation and Mentoring as major. On the contrary, project-based learning mechanism of BIM from TH11 included five knowledge practices. TH11 underlined Mentoring as the sole major knowledge practice.

Informal meeting was referred to the most as major, while Training & Workshop was underlined the most as obsolete. UK08, TH04 and TH08 located Informal meeting as major. TH08, TH11, and TH17 identified Training & Workshop as obsolete.

Table 4.8: Major (MA), minor (MI), and obsolete (OB) knowledge practices of project-based learning mechanisms of BIM within the Explorative type.

Landscapes	Knowledge practices	UK08	TH04	TH08	TH11	TH17
Codifiable knowledge practice	External source	MI	-	*OB*	MI	MI
	Project documentation	-	-	-	-	MI
	Shared knowledge repository	-	MI	-	-	-
	Standardisation	MI	-	MI	-	-
Transactive knowledge practice	Assignment of knowledge management personnel	MI	-	-	-	-
	Competences assessment	-	-	-	-	-
	Learning-by-doing	-	-	MI	-	MI
	Professional networks	-	-	MI	-	MI
	Project review	-	MI	MI	-	MI
	Promotion of knowledge sharing culture	-	-	-	-	-
	Specialist consultant	-	MI	-	MI	MI
	Training & Workshop	MI	MI	*OB*	*OB*	*OB*
Un-codifiable knowledge practice	Incentive	-	-	-	-	-
	Informal meeting	**MA**	**MA**	**MA**	MI	MI
	Knowledge team creation	-	**MA**	-	-	**MA**

Mentoring	MI	-	-	**MA**	**MA**
Partnering	-	-	-	-	-
Recruitment & Reassignment	**MA**	-	MI	-	-

UK08

Project-based learning mechanism of BIM from UK08 contained major knowledge practices of Informal meeting and Recruitment & Reassignment. UK08 did not identify any obsolete knowledge practice. Figure 4.7 displayed the project-based learning mechanism of BIM from UK08.

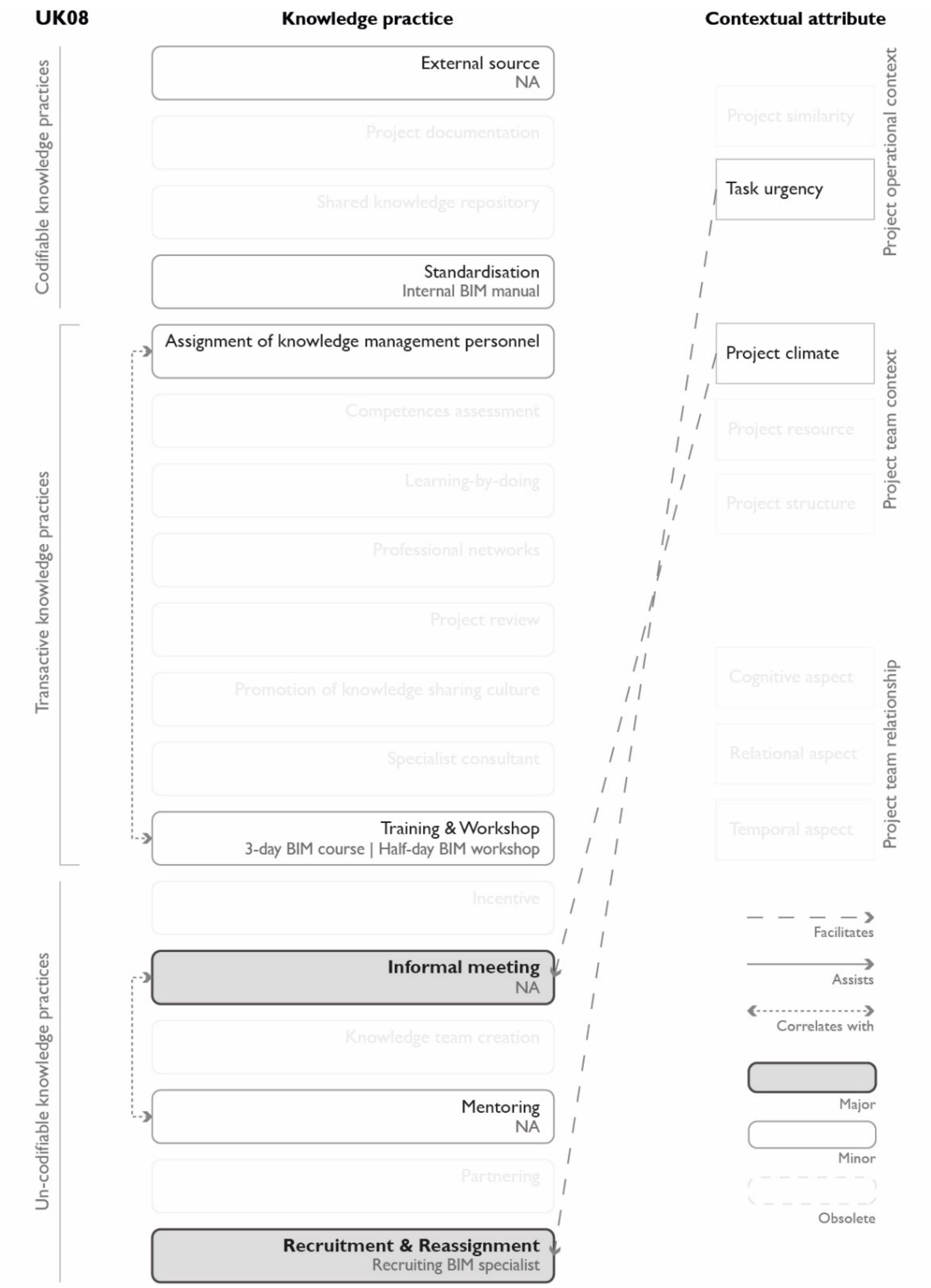

Figure 4.7: Project-based learning mechanism of BIM from UK08.

Informal meeting was facilitated by Project climate. UK08 explained, *"…, this firm is very laidback kind of firm. We tend to just do things together, shout out if we have problems and anyone will come to you to help you out with it."*. The interviewee added that the working environment within projects was a *helping environment*, where project actors would be assisting one another regularly. Informal meeting correlated with Mentoring as BIM managers and BIM specialists would be monitoring BIM learning processes of project actors.

Recruitment & Reassignment was mentioned as the more significant knowledge practice. BIM specialists were recruited to assist existing project actors with BIM operations and to help with any BIM complications. The knowledge practice was facilitated by Task urgency. UK08 elaborated, *"We were quite worried about committing to BIM, getting stuck, having deadlines, and not being able to meet the deadline because people didn't know how to get out of the software, or what needs to be done to be out of it."*.

TH04

Project-based learning mechanism of BIM from TH04 included Informal meeting and Knowledge team creation as major. It did not encompass any obsolete knowledge practices. Figure 4.7 provided the project-based learning mechanism of BIM from TH04.

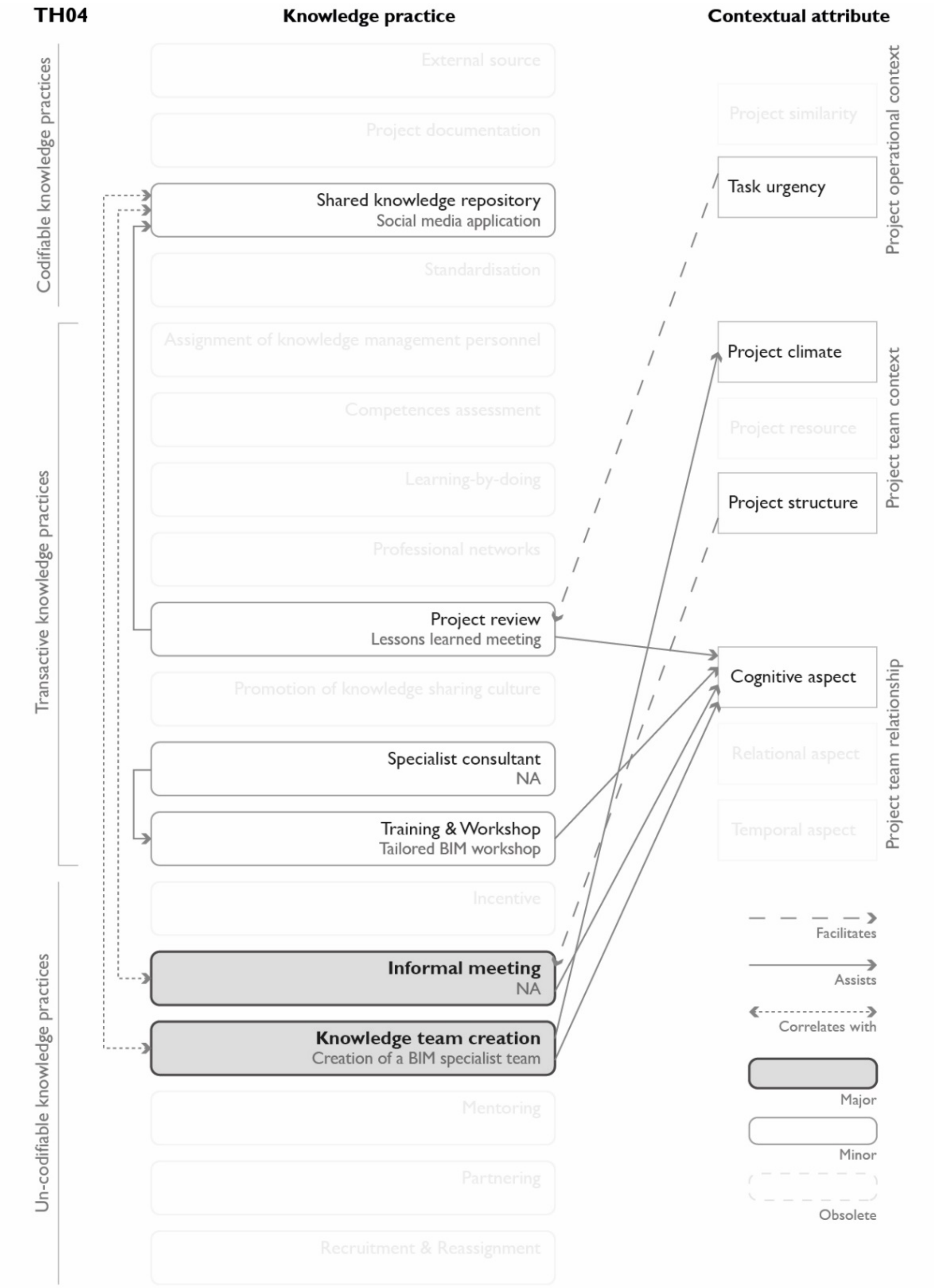

Figure 4.8: Project-based learning mechanism of BIM from TH04.

Informal meeting was described as major due to the fact that most BIM problems were mitigated through informal conversations between project actors and BIM managers. It correlated with Shared knowledge repository as BIM-related knowledge found would be uploaded into a storage within a social media application that all project team members operate on. TH04 commented, *"… I would be summarising that in the social media group saying that the problem has been addressed by this method and by this person ... this social media group is like a backbone of how BIM is learned and managed within the firm."*. TH04 elaborated the knowledge practice to assist Cognitive aspect of project teams.

With Knowledge team creation, TH04 described, *"We started with creating an informal group that will deal with BIM problems and keeping everyone on track."*. Similar with Informal meeting, Knowledge team creation correlated with Shared knowledge repository as the specialist team was utilising the social media application as a medium to manage BIM knowledge from projects. This presented how the knowledge practice assisted both Project climate and Cognitive aspect of project teams.

TH08

Project-based learning mechanism of BIM from TH08 provided Informal meeting as the only major knowledge practice. TH08 brought up External source and Training & Workshop as obsolete. Figure 4.9 visualised the project-based learning mechanism of BIM from TH08.

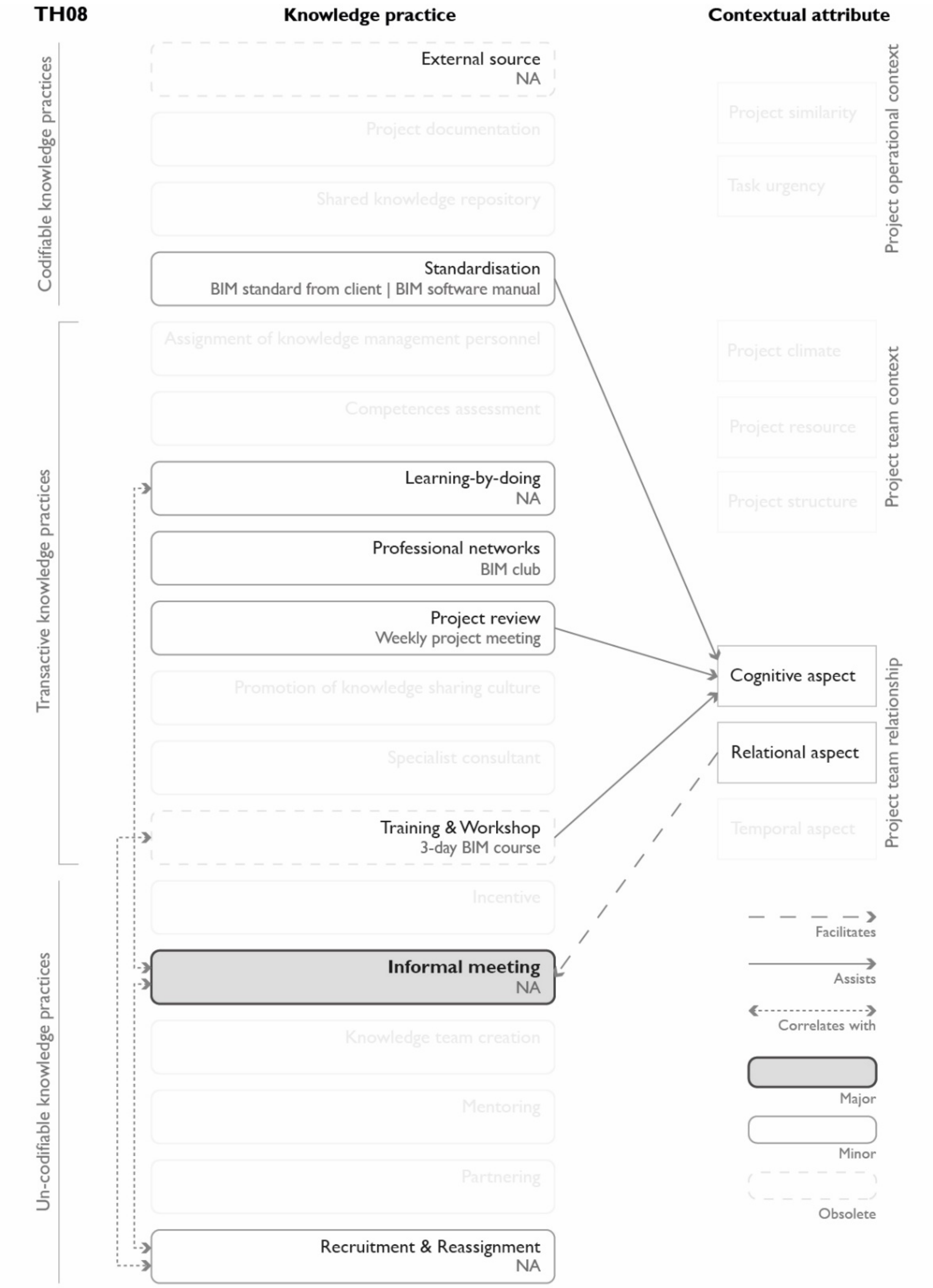

Figure 4.9: Project-based learning mechanism of BIM from TH08.

Informal meeting was facilitated by Relational aspect. TH08 explained, *"I definitely talk more to those I am quite familiar with … being really close really helps with going through those frustration and making sure that no feelings are harmed."*. It correlated with Learning-by-doing and Recruitment & Reassignment. With Learning-by-doing, TH08 added, *"…, it was me sitting with all of them and teach them every step … I think working side-by-side and teach them on-the-go is so much faster than having to set up a meeting and train everyone …"*. With Recruitment & Reassignment, project actors were assigned according to BIM tasks so that it was more convenient for BIM manager to go through BIM complication together with project actors.

External source and Training & Workshop were obsolete. With External source, the interviewee described that it was due to the fact that most online tutorials were in English. Therefore, it was too difficult for project actors with no English competence. For Training & Workshop, 3-day BIM course was found to be generic. Knowledge gained from the course was lost immediately if not use practically or if project actors were not assisted by someone with higher BIM competence.

TH11

TH11 described Mentoring as the only major knowledge practice. TH11 highlighted Training & Workshop as obsolete. Figure 4.10 showed project-based learning mechanism of BIM from TH11.

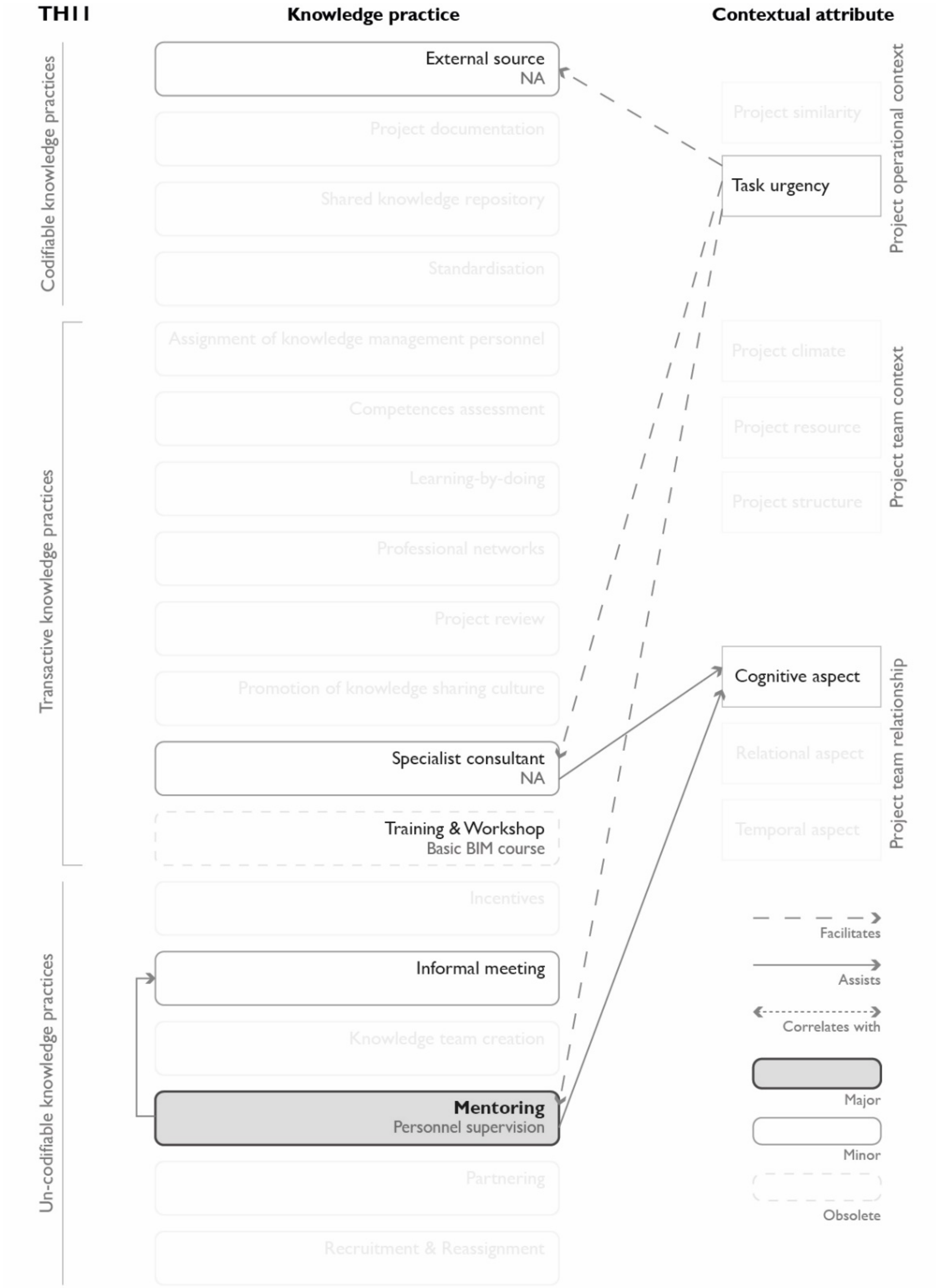

Figure 4.10: Project-based learning mechanism of BIM from TH11.

Mentoring was facilitated by Task urgency as it was exercised to comprehend pressures from project deadlines. TH11 explained, *"This is due to the fact that our deadlines are quite hectic. It is necessary for me to sit next to others so that when they have problems, I can just assist them right away and make sure that all works are done to the quality required."*. This also provided how Mentoring assisted Informal meeting.

Training & Workshop contained an instrumentality of Basic BIM course. TH11 commented, *"The course was expensive and only taught general BIM knowledge and commands which made it really hard to work on the actual project."*. Although, the course provided basic BIM knowledge and understanding, which were beneficial initially, it gave out wrong impression of BIM. TH11 added, *"All beginners within the firm then started with wrong conception of BIM that it is easy … I feel like the firm was tricked by the software company of what BIM can potentially deliver. With BIM, the picture was painted in such a way that made works so easy."*.

TH17

Project-based learning mechanism of BIM from TH17 entailed Knowledge team creation and Mentoring as major knowledge practices. TH17 regarded Training & Workshop as obsolete. Figure 4.11 illustrated the project-based learning mechanism of BIM from TH17.

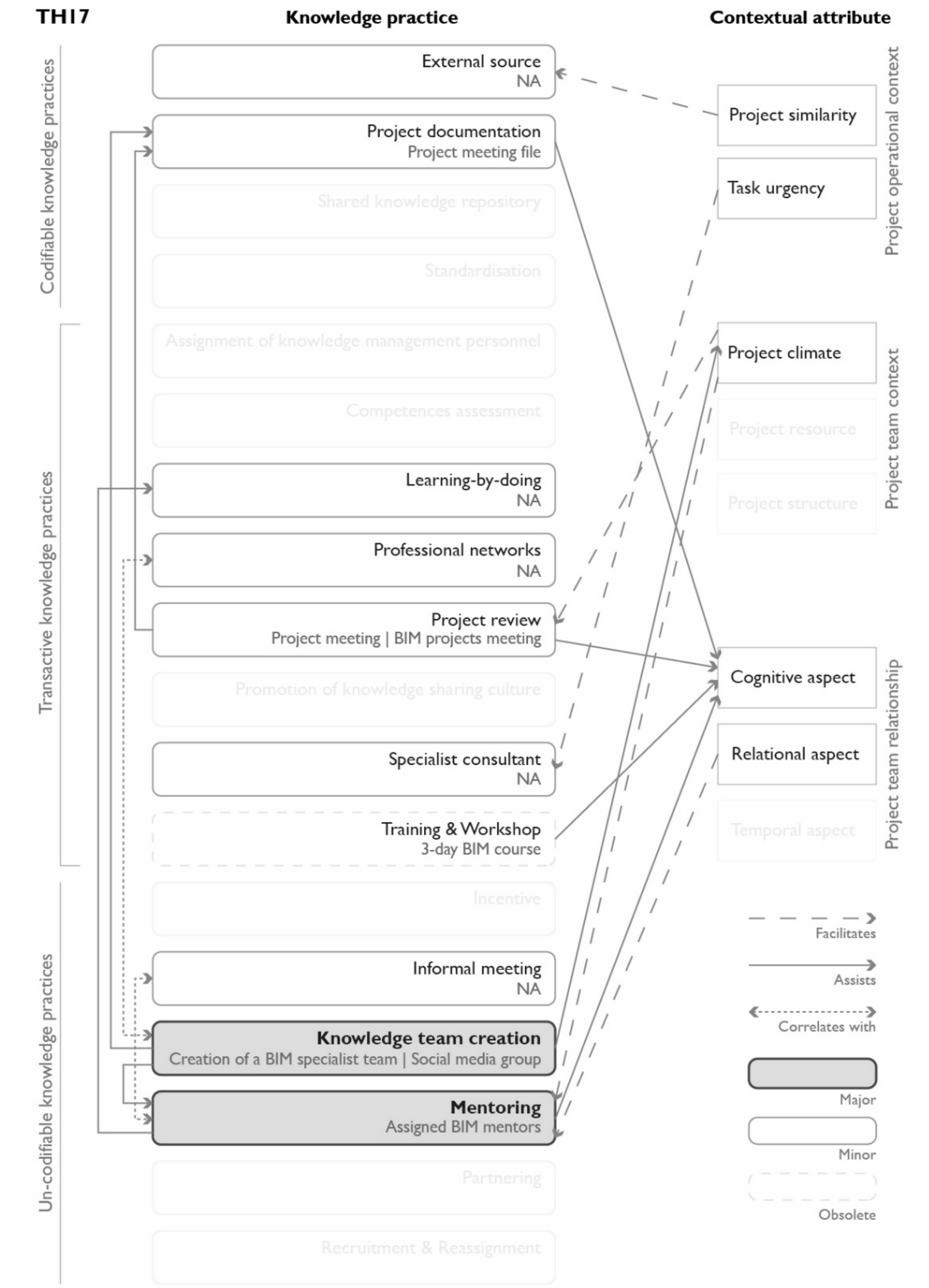

Figure 4.11: Project-based learning mechanism of BIM from TH17.

Knowledge team creation entailed instrumentalities of Creation of a BIM specialist team and Social media group. The knowledge practice assisted Project documentation, Mentoring, and Project climate. With the BIM specialist team, TH17 explained, *"We now have our central team that is in charge of BIM adoption and learning for the entire firm. They are now looking over in terms of how BIM is."*. Creation of a BIM specialist team was crucial in making sure that knowledge gain by a project actor is shared and implemented in the organisation. Social media group was created to respond to how project actors were active on social media. This special workspace allowed BIM discussions to be made and corrected. TH17 elaborated, *"We would be overlooking the group to make sure that the conversations are limited to the sharing of BIM knowledge or problems found … This workspace allows people to post questions or topics that people can engage with or answer."*. The group was also utilised to broadcast tailored BIM lessons from the BIM manager. TH17 provided, *"For example, last week I was broadcasting live on how to combine models together. So, I invited people to join the live session and they would be asking questions which creates discussions. It was very useful for people and me as well."*.

Mentoring was exercised as a more specific mean to keep close supervision on BIM competence of each project team member. Project actors would be regularly supervised and paired up with the BIM specialists. TH17 elaborated, *"So, by sitting next to a specialist, they can just describe how they would want the actual outcome to be like. The specialist can teach them how to achieve that."* Mentoring was facilitated by Relational aspect. Project actors tended to learn in a faster fashion with other project team members they are comfortable with. TH17 explained, *"I think that for each pair, if the specialist is way older than the newcomer or the learner, I found that the learner won't be asking much questions … There are cases as well with people coming from the same region of Thailand and they got together really fast."*.

Training & Workshop included an instrumentality of 3-day BIM course. It was regarded as obsolete. TH17 explained Training & Workshop as to only provide basic BIM knowledge and demand additional revision while working on actual projects.

4.5 Chapter summary

This chapter presented and structured the data collected within this research. The interviews from the British and the Thai design and engineering SME consultancies provided 31 project-based learning mechanisms of BIM. Project-based learning mechanisms of BIM were classified into three types of Exploitative, Ambidextrous, and Explorative. Each type was categorised based on the major knowledge practices highlighted by the interviewees. The

Exploitative type entailed project-based learning mechanisms of BIM with all major knowledge practices from the Codifiable knowledge practice landscape of the theoretical framework of this research. The type only included one project-based learning mechanism of BIM which was from UK06.

The Ambidextrous type covered project-based learning mechanisms of BIM with all major knowledge practices from the Transactive knowledge practice landscape, as well as from more than one knowledge practice landscape. This further divided project-based learning mechanisms of BIM within this type into five groups. The groups were: a) Codifiable, transactive, and un-codifiable; b) Codifiable and un-codifiable; c) Codifiable and transactive; d) Transactive; and e) Transactive and un-codifiable. The Ambidextrous type contained the majority of the interviewees which were UK01, UK02, UK03, UK04, UK05, UK07, UK09, UK10, UK11, UK12, TH01, TH02, TH03, TH05, TH06, TH07, TH09, TH10, TH12, TH13, TH14, TH15, TH16, TH18, and TH19.

The Explorative type encompassed project-based learning mechanisms of BIM with all major knowledge practices from the Un-codifiable knowledge practice landscape. The project-based learning mechanisms of BIM from UK08, TH04 TH08, TH11, and TH17 were regarded within this type. The majority of interviews within this Explorative were from the Thai built environment sector.

Chapter 5 Data analysis

This chapter provides an analysis of the project-based learning mechanisms of BIM. It starts with a re-statement of the research questions and follows by an assessment of knowledge practices used in the learning of BIM and the project-based learning mechanisms of BIM.

5.1 Re-statement of the research questions

This research revolves around the central research question of *'How, and to what extend does BIM learning occur in projects in built environment SMEs?'*. The research question introduced four research sub-questions. The first research sub-question was: *'What are knowledge practices exercised in projects for BIM learning?'*. The second research sub-question was: *'How do project teams utilise knowledge practices and formulate project-based learning mechanisms of BIM?'*. The third research sub-question was: *'How does each project-based learning mechanism of BIM assist built environment SMEs* *in BIM learning?'*. The last research sub-question was: *'How can built environment SMEs improve their BIM adoption through BIM learning?'*.

5.2 Knowledge practice

From all possible project-based learning mechanisms of BIM, the research identified 18 knowledge practices used in the learning of BIM in projects. The knowledge practices located in learning mechanisms correlated with the knowledge practices stated in the theoretical framework of the research.

The Data presentation and structure chapter provided how the interviewees categorised knowledge practices into the major, minor, and obsolete. The interviewees from both research contexts considered major knowledge practices to knowledge practices that played a significant role or exercised regularly in the learning of BIM-related knowledge in projects. Designers and engineers recognised minor knowledge practices as supporting knowledge practices. The interviewed project actors regarded obsolete knowledge practices to knowledge practices that were inefficient and did not contribute much to the learning and adoption of BIM in projects and organisations. They also referred the obsolete knowledge practices to those that had been replaced. Table 5.1 presented the occurrences of major, minor, and obsolete knowledge practices in the research.

Table 5.1: Occurrences of the major, minor, and obsolete knowledge practices from all project-based learning mechanisms of BIM.

Landscapes	Knowledge practices	Major	Minor	Obsolete
Codifiable knowledge practice	External source	0	16	3
	Project documentation	3	9	0
	Shared knowledge repository	6	16	1
	Standardisation	9	5	0
Transactive knowledge practice	Assignment of knowledge management personnel	0	5	0
	Competences assessment	0	6	0
	Learning-by-doing	4	**18**	0
	Professional networks	0	8	0
	Project review	8	11	0
	Promotion of knowledge sharing culture	3	10	0
	Specialist consultant	5	7	0
	Training & Workshop	7	17	**7**
Un-codifiable knowledge practice	Incentive	1	3	1
	Informal meeting	**11**	17	0
	Knowledge team creation	10	4	0

Mentoring	5	3	0
Partnering	1	6	0
Recruitment & Reassignment	3	13	0

5.2.1 Major knowledge practices

Informal meeting was mentioned the most as major knowledge practice. This knowledge practice situated within the Un-codifiable knowledge practice landscape. It was followed by Knowledge team creation from the same knowledge practice landscape and Standardisation from the Codifiable knowledge practice landscape.

11 interviewees, which were UK03, UK05, UK08, UK10, TH04, TH08, TH09, TH12, TH13, TH14, and TH16 brought up Informal meeting as major. The interviewees referred to Informal meeting as an impromptu or casual conversation amongst project team members. Project actors utilised Informal meeting to immediately respond to BIM-related complications that were being encountered in the daily operations. Relational aspect and Task urgency facilitated Informal meeting. With Relational aspect, interviewees such as UK03, TH08, and TH09 stated that it was easier for them to sit down and go through BIM issues with project actors whom they were familiar with. TH13 confirmed this by explaining that project actors must be used to one another to a certain extent to allow seamless conversation or discussion. With Task urgency, UK05 and UK10 brought up Informal meeting to be the most effective knowledge practice when there were pressures from the project deadlines. However, it also implied that the senders of BIM-related knowledge would have to cease their current tasks to assist others. Additionally, TH12 put forward the factor of organisational sizes. TH12 elaborated that with a small organisation, it was simpler for Informal meeting to occur. From all interviewees that underlined Informal meeting as major knowledge practice, only UK10, TH09, and TH13 were from medium-sized organisations. The rests were from small-sized design and engineering SME consultancies.

10 interviewees, which included UK07, TH02, TH04, TH05, TH06, TH07, TH09, TH14, TH17, and TH18 highlighted Knowledge team creation as major. Project actors recognised Knowledge team creation as the creation of an additional BIM group within an organisation or the formulation of a BIM specialist team. UK07, TH05, TH07, TH17, and TH18 related Knowledge team creation to the creation of an additional group within an organisation. Conversations within this group were mainly BIM-related such as how to overcome certain BIM problems or interesting BIM insights. This instrumentality of Knowledge team creation provided how the knowledge practice assisted Cognitive aspect and Project climate. It helped

in leveraging BIM understanding amongst project actors and in setting up a BIM environment within an organisation. Specifically, the creation of a BIM group within the project-based learning mechanisms of BIM from TH05, TH07, TH17, and TH18 was based on a social media application widely used by project actors. The project-based learning mechanisms of BIM from TH02, TH04, TH06, TH09, TH14, and TH17 put forward the formulation of a BIM specialist team within an organisation. Within these learning mechanisms, BIM specialist teams were formulated to assist in every aspect of BIM learning and adoption. TH02 and TH04 explained tasks of this team ranged from assisting project actors through BIM problems, managing standards and manuals, to hosting an in-house BIM workshop.

Nine interviewees, which encompassed UK02, UK04, UK06, UK07, UK10, UK11, TH05, TH10, and TH19 listed Standardisation as major. The interviewed designers and engineers elaborated Standardisation as the reference point for project actors. Standardisation acted as a guideline for project actors to follow while working with BIM. Specifically, TH05 and TH10 used Standardisation as a way to internally refine BIM operations within their organisations. BIM-related knowledge emerged from project works would be updated constantly into their employed standards. Furthermore, designers and engineers from the British built environment industry perceived Standardisation as significant as it related to achieving BIM level 2 accreditation. The organisation of UK02 was aiming to received BIM level 2 accreditation, while the organisations of UK04, UK06, UK07, and UK10 were accredited. The organisation of UK11 was the only one that did not acquire such award. However, UK11 realised Standardisation as a necessity as BIM level 2 was often demanded by the clients. The case was similar with the organisation of TH19, where the organisation normally took on international projects.

5.2.2 Minor knowledge practices

Learning-by-doing was highlighted the most as minor knowledge practices. The knowledge practices nested within the Transactive knowledge practice landscape. Training & Workshop and Informal meeting were second. Similar to Learning-by-doing, Training & Workshop was from the Transactive knowledge practice landscape. Informal meeting was from the Un-codifiable knowledge practice landscape.

18 interviewees regarded Learning-by-doing as minor knowledge practices. The interviewees were UK02, UK03, UK05, UK06, UK09, UK11, UK12, TH01, TH02, TH03, TH06, TH08, TH12, TH13, TH15, TH16, TH17, and TH18. The interviewees described Learning-by-doing

as an accompanying knowledge practice for major knowledge practices to perform effectively. For example, UK05, UK11, and TH08 explained how the use of Informal meeting was more efficient if exercised together with Learning-by-doing. It was more convenient for project actors to discuss any BIM-related issues by using an actual project as an example. UK09 provided how the partnered office utilised ongoing projects to set up a BIM workflow to meet the required standard by clients. TH03 and TH13 elaborated how the specialist consultants exploited current projects as the learning material. This allowed BIM learning to occur simultaneously with actual project works of the project actors. The event was similar in the project-based learning mechanisms of BIM from TH06, TH15, TH17, and TH18. Learning-by-doing encouraged Knowledge team creation in the project-based learning mechanism of BIM from TH06, the project-based learning mechanism of BIM from TH15 in Training & Workshop, and the project-based learning mechanisms of BIM from TH17 and TH18 in Mentoring.

17 interviewees highlighted Training & Workshop as minor knowledge practices. The interviewees were UK01, UK02, UK03, UK05, UK07, UK08, UK09, UK10, UK12, TH01, TH02, TH04, TH05, TH07, TH10, TH14, and TH18. Similarly with Learning-by-doing, the interviewees explained Training & Workshop as a contributing knowledge practice to other major knowledge practice. For instance, UK09 provided how an In-house BIM workshop was hosted by the project actors from a partnering organisation. UK10 and TH07 described how Training & Workshop assisted Specialist consultant in leveraging BIM-related knowledge to other projects within an organisation. TH02 and TH14 discussed how the BIM specialist teams regularly host In-house BIM workshop for project actors.

While Informal meeting was highlighted as major in 11 interviews, it was also identified as minor by 17 designers and engineers. The interviewees were UK02, UK04, UK06, UK07, UK09, UK12, TH01, TH02, TH05, TH06, TH07, TH10, TH11, TH15, TH17, TH18, and TH19. As presented in Sub-section 5.2.1, Informal meeting referred to casual conversation between project actors. The knowledge practice was mentioned to support various knowledge practices. For example, TH17 and TH18 described Informal meeting to increase the effectiveness of Mentoring by allowing further discussions on BIM to be made. Specifically, TH17 elaborated how Informal meeting enabled project actors to express their personality and become more familiar with other project actors. Moreover, Informal meeting was exercised to ease the use of a more complicated knowledge practice. As seen in the project-based learning mechanism of BIM from UK06, Informal meeting was employed in correlation with Standardisation as project actors occasionally require verbal explanations.

5.2.3 Obsolete knowledge practices

Training & Workshop had been highlighted the most by designers and engineers as an obsolete knowledge practice. This knowledge practice dwelled in the Transactive knowledge practice landscape and was followed by External source. External source was categorised within the Codifiable knowledge practice landscape.

Seven interviewees regarded Training & Workshop as an obsolete knowledge practice. The interviewees were UK01, UK12, TH03, TH08, TH11, TH16, and TH17. The main reason was due to the fact some instrumentalities of Training & Workshop such as Basic BIM course only provided generic BIM-related knowledge for project actors. BIM-related knowledge learned from such course inapplicable on a practical setting, where tasks were more complex. TH08 added to this argument that project actors still had to be supervised by BIM managers or other project actors with higher BIM competence on real projects. TH11 further pointed out that Training & Workshop could also plant a wrong conception of BIM in project actors. Project actors from the organisation of TH11 attended a Basic BIM course and arrived in conclusion that BIM is only an alternative modelling software. Notwithstanding, it was necessary to underline how Training & Workshop was also stated as major by seven other interviewees. This was due to how different organisations utilise various instrumentalities of Training & Workshop that are available.

Three interviewees mentioned External source as obsolete. The interviewees were TH01, TH02, and TH08. External source was identified as obsolete only by the designers and engineers from the Thai context as most publicly available knowledge of BIM is in English. English was not the official language of Thailand. Therefore, accessing External source for some project actors was realise as a challenge.

5.3 Instrumentalities of knowledge practice

There were 80 different instrumentalities of knowledge practices uncovered within this research. Various instrumentalities of knowledge practices represented specific means of each knowledge practice that were employed by project teams and organisations in capturing, transferring, and learning BIM-related knowledge. The instrumentalities of knowledge practice submitted how each project team and organisation perceived and internalised each knowledge practice.

Promotion of knowledge sharing culture contained the highest number of instrumentalities. Interviewees included 10 instrumentalities of knowledge practice within Promotion of knowledge sharing culture. This was followed by Standardisation, Project review, and Training & Workshop with nine instrumentalities of knowledge practice each. External source, Assignment of knowledge management personnel, Learning-by-doing, Specialist consultant, and Informal meeting did not contain any instrumentalities. Table 5.2 displayed different instrumentalities of knowledge practices within the research.

Table 5.2: Different instrumentalities of knowledge practices within the research.

Landscapes	Knowledge practices	Instrumentalities of knowledge practices	Usage
Codifiable knowledge practice	External source	NA	-
	Project documentation	1. Past project file	8
		2. Project meeting file	1
		3. Model archiving	1
		4. Weekly project recap	1
		5. Lessons learned document	1
	Standardisation	1. ISO BIM standard	2
		2. Internal BIM standard	14
		3. Internal BIM manual	14
		4. British BIM standard	5
		5. BEP (BIM Execution Plan)	5
		6. IDP (Information Delivery Plan)	1
		7. BIM standard from client	1
		8. BIM software manual	3
		9. BIM guideline	1
	Shared knowledge repository	1. Central BIM knowledge pool	3
		2. Internal model library	2
		3. Internal intranet	1
		4. BIM could server	1
		5. BIM model library	1
		6. Storage function within social media applications	1
		7. Internal knowledge folder	1
Transactive knowledge practices	Assignment of knowledge management personnel	NA	-
	Competences assessment	1. BIM questionnaire	2
		2. BIM skills matrix	1
		3. Self-assessment form	1
		4. BIM survey	1
	Learning-by-doing	NA	-
	Professional networks	1. BIM forum	1
		2. BIM conference	2

		3. BIM user group	1
		4. BIM club	1
		5. Public seminar	1
	Project review	1. Post Project Review	3
		2. Lessons learned meeting	2
		3. Weekly project meeting	7
		4. Fortnightly project review	1
		5. Project meeting	2
		6. BIM project meeting	1
		7. Monthly or bi-monthly project review	1
		8. Project team meeting	1
		9. Bi-weekly project meeting	1
	Promotion of knowledge sharing culture	1. Plain BIM language	1
		2. BIM share point	1
		3. Open-plan office	3
		4. Using other project parties as incentive	1
		5. Encouraging members to attend BIM-related event	1
		6. BIM awareness	1
		7. Setting up BIM environment through BIM360	1
		8. Group problem-solving and discussion	1
		9. Making people sit together	1
		10. BIM encouragement activity	1
	Specialist consultant	NA	-
	Training & Workshop	1. Basic BIM course	7
		2. In-house BIM workshop	10
		3. Tailored BIM workshop	5
		4. 3-day BIM course	2
		5. 1-week BIM course	1
		6. 5-day BIM course	1
		7. 1-on-1 training	1
		8. 2-week BIM course	1
		9. E-learning subscription	1
Un-codifiable knowledge practices	Incentive	1. Work allocation for self-learning	1
		2. Personnel support scheme	1
		3. Reward	1
		4. Roles upgrade	1
		5. Monetary incentive	1
	Informal meeting	NA	-
	Knowledge team creation	1. Creation of BIM specialist team	5
		2. Social media group	4
		3. BIM work group	1
		4. BIM learning group	1

	5. Internal R&D team	1
Mentoring	1. Mentoring scheme	4
	2. Skills development scheme	1
	3. Close supervision from BIM manager	1
Partnering	1. Working with other BIM parties	3
	2. BIM drawing office	1
	3. Partner with a software provider	1
Recruitment & Reassignment	1. Recruiting BIM manager	1
	2. Recruiting personnel with BIM competence	9
	3. Staffs allocation based on their BIM competence	5
	4. Recruiting personnel with digital familiarity	1
	5. Allocating BIM tasks to project actors	1
	6. Personnel categorisation	1

5.3.1 Knowledge practices with a high number of instrumentalities

Standardisation, Project review, Promotion of knowledge sharing culture, and Training & Workshop were knowledge practices with a high number of instrumentalities. Promotion of knowledge sharing culture entailed the highest number of instrumentalities. There were 10 instrumentalities of the knowledge practice. This followed by Standardisation, Project review, and Training & Workshop. Each included nine instrumentalities of knowledge practice.

Promotion of knowledge sharing culture contained instrumentalities which were Plain BIM language, BIM share point, Open-plan office, Using other project parties as incentive, Encouraging members to attend BIM-related events, BIM awareness, Setting up BIM environment through BIM360, Group problem-solving and discussion, Making people sit together, and BIM encouragement activity. Amongst various instrumentalities of knowledge practice, Open-plan office was mentioned the most by designers and engineers. The instrumentality was highlighted by three interviewees. UK02, UK11, and TH14 referred to Open-plan office as to how room partitions were removed or how offices were redesigned to promote communication and collaboration. Other instrumentalities of Promotion of knowledge sharing culture only occurred once in all project-based learning mechanisms of BIM. Promotion of knowledge sharing culture was from the Transactive knowledge practice landscape.

Similarly, Project review and Training & Workshop were from the Transactive knowledge practice landscape. Project review included instrumentalities which were Post project review, Lessons learned meeting, Weekly project meeting, Fortnightly project review, Project meeting, BIM project meeting, Monthly or bi-monthly project review, Project team meeting, and Bi-weekly project meeting. From all instrumentalities of Project review, Weekly project meeting was stated the most. Seven interviewees utilised Weekly project meeting in their project-based learning mechanisms of BIM. The instrumentality of knowledge practice was referred to by interviewees such as UK02 and UK03 as a project meeting that occurs every week to evaluate project progresses.

The nine instrumentalities of Training & Workshop within this research were Basic BIM course, In-house BIM workshop, Tailored BIM workshop, 3-day BIM course, 1-week BIM course, 5-day BIM course, 1-on-1 training, 2-week BIM course, and E-learning subscription. In-house BIM workshop was exercised the most by interviewees. UK05, UK07, and TH15 described In-house BIM workshop as BIM-related workshops or classes that were hosted internally within an organisation by the BIM managers or specialist teams. UK04, UK07, and TH15 specifically emphasised In-house BIM workshop as major. Basic BIM course was generally acknowledged by interviewees as minor or obsolete.

Standardisation positioned within the Codifiable knowledge practice landscape. There were nine instrumentalities of Standardisation. The instrumentalities were ISO BIM standard, Internal BIM standard, Internal BIM manual, British BIM standard, BEP, IDP, BIM standard from client., BIM software manual, and BIM guideline. Amongst various instrumentalities of Standardisation, Internal BIM standard and Internal BIM manual were the most common. Each mode was highlighted in 14 project-based learning mechanisms of BIM. Internal BIM standard referred to a set of documents that explain processes and procedures of BIM operations in projects and an organisation. Interviewees described Internal BIM manual as another set of documents that provide instructions on how to maneuverer BIM software. Different project teams and organisations possessed their own version of Internal BIM standard and Internal BIM manual according to their working environment and project types.

5.3.2 Knowledge practice with context-specific instrumentalities

All knowledge practices were mentioned by designers and engineers from both the British and the Thai built environment industries. However, British BIM standard, which was an instrumentality of Standardisation was specific to the British context. Interviewees from the British design and engineering SME consultancies regarded British BIM standard as an instrumentality of knowledge practice that directs organisations towards BIM level 2 accreditation. It was referred to by five interviewees which were UK02, UK03, UK09, UK11, and UK12. There was no context-specific instrumentality of knowledge practice from the Thai context.

5.4 System of knowledge practices

5.4.1 Relationships between knowledge practices

Interviewees within the research described how various knowledge practices were utilised together in the learning of BIM in projects. Different knowledge practices contained distinct relationships to one another that formulate into an interconnected system. This interconnected system of major and minor knowledge practices was recognised within this research as a project-based learning mechanism of BIM. There were two types of relationships between knowledge practices. The relationships were *assistive* and *correlative*.

Assistive relationship implied how a knowledge practice is supporting or upholding other knowledge practices. The relationship was unidirectional. Without the assistive knowledge practices, the supported knowledge practices would be less effective or would not function entirely. With the project-based learning mechanism of BIM from UK10 as an example, UK10 mentioned Specialist consultant to assist Standardisation. UK10 stated,

> *"…, we are employing an external consultant, but not someone just to come and do trainings, but a company who is going to come in and help us, basically pull together a set of templates, manuals, and resources from what we already have." (See Appendix 17 – UK10 for a full presentation of UK10).*

The organisation of UK10 employed a BIM specialist team to help develop BIM standard and BIM software manual of the organisation. The BIM specialist team also assisted in constantly updating both instrumentalities of Standardisation. This provided how Standardisation became fully functional by being assisted by Specialist consultant.

Correlative relationship referred to how two knowledge practices are promoting one another. Interviewees underlined correlative relationship as bidirectional. The relationship represented how two knowledge practices increase their effectiveness by assisting one another. With the project-based learning mechanism of BIM from TH14 as an example, TH14 identified Learning-by-doing as being correlated to Standardisation. BIM-related knowledge acquired by project actors from working on actual projects was constantly revised and updated into Internal BIM standard of the organisation. Standardisation was then performed as a reference point for project actors. TH14 described, *"I would have then have them work on some pilot projects, and at the same time, setting up standards. This is so that they don't forget skills that they have learned from projects." (See Appendix 18 – TH14 for a full presentation of TH14).*

In addition, a knowledge practice potentially assisted or correlated with multiple knowledge practices within a project-based learning mechanism of BIM. As seen in the project-based learning mechanism of BIM from TH06, TH06 described Knowledge team creation to assist Standardisation, Learning-by-doing, and Training & Workshop. Within the organisation of TH06, an Internal BIM R&D team was formulated to develop BIM standard, assist project actors on projects, and host BIM workshops. TH06 stated:

"Our R&D department would be helping us with what we learned and help us distribute that knowledge across." (See Appendix 14 – TH06 for a full presentation of TH06).

Each knowledge practice could be both assistive and correlative to other knowledge practices. However, some knowledge practices were more inclined to dominantly contain one type of relationship. Table 5.3 provided the occurrences of assistive and correlative relationships of all knowledge practices.

Table 5.3: Occurrences of assistive and correlative relationships of all knowledge practices.

Landscapes	Knowledge practices	Relationships	Occurrences
Codifiable knowledge practice	External source	Assistive	0
		Correlative	3
	Project documentation	Assistive	1
		Correlative	2
	Shared knowledge repository	Assistive	0
		Correlative	6
	Standardisation	Assistive	0
		Correlative	8
Transactive knowledge practice	Assignment of knowledge management personnel	Assistive	0
		Correlative	3
	Competences assessment	Assistive	2
		Correlative	1
	Learning-by-doing	Assistive	1
		Correlative	12
	Professional networks	Assistive	0
		Correlative	2
	Project review	Assistive	3
		Correlative	4

	Promotion of knowledge sharing culture	Assistive	0
		Correlative	5
	Specialist consultant	**Assistive**	**8**
		Correlative	1
	Training & Workshop	Assistive	2
		Correlative	10
Un-codifiable knowledge practice	**Incentive**	**Assistive**	**0**
		Correlative	**0**
	Informal meeting	Assistive	1
		Correlative	**16**
	Knowledge team creation	Assistive	7
		Correlative	5
	Mentoring	Assistive	3
		Correlative	4
	Partnering	Assistive	0
		Correlative	3
	Recruitment & Reassignment	Assistive	3
		Correlative	4

5.4.2 High connectivity knowledge practice

Specialist consultant was highly assistive. Specialist consultant was employed the most in project-based learning mechanisms of BIM in assisting other knowledge practices. The knowledge practice was described as being assistive by eight interviewees which were UK10, TH02, TH04, TH07, TH10, TH13, and TH15. This was followed by Knowledge team creation. Knowledge team creation was exercised in seven project-based learning mechanisms of BIM to assist other knowledge practices. The project-based learning mechanisms of BIM were from TH01, TH02, TH05, TH06, TH09, TH14, and TH17. The majority of interviewees who stated Specialist consultant and Knowledge team creation were from the Thai design and engineering SME consultancies.

Informal meeting was highly correlative. Informal meeting was utilised the most in correlation to other knowledge practices. 16 interviewees highlighted Informal meeting as correlative. The interviewees were UK02, UK03, UK05, UK06, UK07, UK08, UK09, UK11, TH04, TH06, TH08, TH12, TH14, TH16, TH17, and TH18. This was followed by Learning-by-doing, Training & Workshop, and Standardisation. The knowledge practices correlated to other knowledge practices in 12, 10, and 8 project-based learning mechanisms of BIM respectively.

Specialist consultant, Knowledge team creation, Informal meeting, Learning-by-doing, Training & Workshop, and Standardisation could be regarded as *high connectivity knowledge* *practice*. Specialist consultant, Learning-by-doing, and Training & Workshop were from the Transactive knowledge practice landscape. Knowledge team creation and Informal meeting were from the Un-codifiable knowledge practice landscape. Standardisation was the only knowledge practice from the Codifiable knowledge practice landscape.

5.4.3 Low connectivity knowledge practice

Incentive could be categorised as *low connectivity knowledge practice*. Incentive was not exercised in any project-based learning mechanisms of BIM in assisting or correlating to other knowledge practices. Incentive was from the Un-codifiable knowledge practice landscape.

5.4.4 The individualisation of project-based learning mechanisms of BIM

Project-based learning mechanisms of BIM within the research were unique from one another. Different relationships that knowledge practices can contain and various instrumentalities of knowledge practices that can be utilised by project teams and organisations resulted in how each project-based learning mechanism of BIM was individualised to each organisation. Although, there were some resemblances between the project-based learning mechanisms of BIM from UK03 and UK05, as well as the project-based learning mechanisms of BIM from UK11 and TH05 in terms of the major knowledge practices highlighted. These learning mechanisms of BIM were different from one another from the instrumentalities of knowledge practices employed and how knowledge practices connected diversely.

5.5 Knowledge practices and the contextual attributes of projects

Knowledge practices were utilised in assisting the contextual attributes of projects. Cognitive aspect of project teams was assisted the most. Training & Workshop was employed within the highest number of project-based learning mechanisms of BIM in assisting Cognitive aspect of project teams. This was followed by Project review and Standardisation. Table 5.4 displayed the occurrences of knowledge practices exercised in assisting the contextual aspects of projects.

Table 5.4: Occurrences of knowledge practices assisting the contextual attributes of projects.

Landscapes	Knowledge practices	Contextual attributes	Occurrences
	External source	Cognitive aspect	1
	Project documentation	Project climate	1

Codifiable knowledge practices		Cognitive aspect	6
	Shared knowledge repository	Project climate	2
		Cognitive aspect	6
	Standardisation	Project climate	2
		Cognitive aspect	12
		Relational aspect	1
Transactive knowledge practices	Assignment of knowledge management personnel	Project climate	1
		Cognitive aspect	1
	Competences assessment	Project climate	1
		Project structure	1
	Learning-by-doing	Cognitive aspect	1
	Professional networks	Project climate	2
	Project review	Project climate	4
		Cognitive aspect	13
	Promotion of knowledge sharing culture	Project climate	7
		Cognitive aspect	2
		Relational aspect	1
	Specialist consultant	Project climate	3
		Cognitive aspect	2
		Project structure	2
	Training & Workshop	**Cognitive aspect**	**14**
Un-codifiable knowledge practices	Incentive	Project climate	2
	Informal meeting	Cognitive aspect	9
	Knowledge team creation	Project climate	5
		Cognitive aspect	4
		Project structure	1
	Mentoring	Cognitive aspect	3
	Partnering	Project climate	1
		Cognitive aspect	1
		Project structure	1
	Recruitment & Reassignment	Project climate	1
		Cognitive aspect	2
		Project structure	2

Interviewees within the research referred the Cognitive aspect of project teams mainly to the shared understanding of BIM between project actors. This included the awareness of project actors on how to manoeuvre BIM software, as well as knowledge of project actors on BIM-related policies and processes. Majority of knowledge practices were exercised in assisting the Cognitive aspect of project teams. From all 18 knowledge practices, Competences assessment and Incentive were the only two knowledge practices that did not support Cognitive aspect. Other knowledge practices were identified in at least one project-based learning mechanisms of BIM in assisting the Cognitive aspect of project teams.

Training & Workshop was mentioned the most to assist Cognitive aspect. There were 14 project-based learning mechanisms of BIM where the knowledge practice assisted the Cognitive aspect of project teams. The project-based learning mechanisms of BIM were from UK03, UK03, UK04, UK07, UK09, TH01, TH04, TH06, TH07, TH08, TH09, TH13, TH16, and TH17. This was followed by Project review and Standardisation. Project review was utilised to assist Cognitive aspect in 13 project-based learning mechanisms of BIM. 12 interviewees underlined Standardisation as supporting the Cognitive aspect of project teams.

5.6 Chapter summary

This chapter provided the analysis of project-based learning mechanisms of BIM within this research. There were 18 knowledge practices in the learning of BIM in projects. Interviewees identified the knowledge practices into major, minor, and obsolete. The categorisation referenced the significance of knowledge practices in the learning of BIM. Informal meeting was regarded the most as major. The knowledge practice situated within the Un-codifiable knowledge practice landscape of the theoretical framework of the research. It was followed by Knowledge team creation from the same knowledge practice landscape and Standardisation from the Codifiable knowledge practice landscape. Training & Workshop was underlined the most as obsolete.

From the identified knowledge practices, the interviewees further pointed out 80 instrumentalities of knowledge practices. Promotion of knowledge sharing culture contained the highest number of instrumentalities. This was followed by Project review, Training & Workshop, and Standardisation at second place. External source, Assignment of knowledge management personnel, Learning-by-doing, Specialist consultant, and Informal meeting did not contain any instrumentalities. British BIM standard, which was an instrumentality of Standardisation was context-specific to the British built environment industry.

An interconnected system of major and minor knowledge practices formed a project-based learning mechanism of BIM. There were two types of relationships between knowledge practices. The types were assistive and correlative. The assistive relationship referred to how one knowledge practice was utilised in supporting other knowledge practices. The correlative relationship signified a bidirectional connection, where two knowledge practices promote one another. Specialist consultant, Knowledge team creation, Informal meeting, Learning-by-doing, Training & Workshop, and Standardisation were regarded as high connectivity knowledge practices. These knowledge practices were exercised within various project-based learning mechanisms of BIM in assisting or correlating other knowledge practices. On the contrary, Incentive was listed as a low connectivity knowledge practice. The knowledge practice did not assist or correlate with any knowledge practices.

Different types of relationship that knowledge practices can have and various instrumentalities of knowledge practices that project teams and organisations potentially employed together resulted in the uniqueness of each project-based learning mechanism of BIM. They individualised each project-based learning mechanism of BIM to be specific to an organisation. Additionally, the utilisation of knowledge practices in project-based learning mechanisms of BIM provided how Cognitive aspect was the most important contextual attribute of projects. The majority of knowledge practices were exploited in at least one project-based learning mechanism of BIM in assisting the Cognitive aspect of project teams. Training & Workshop primarily assisted the Cognitive aspect of project teams. The knowledge practice was followed by Project review and Standardisation.

Chapter 6 Discussion

This chapter provides a discussion of results and findings of the research. The insights from all project-based learning mechanisms of BIM are critically evaluated to past studies and theories. The discourse responds to the research sub-questions stated. Additionally, the chapter ends with the theoretical and practical implications, research limitations, and future recommendations.

6.1 Knowledge practices exercised for BIM learning in projects

6.1.1 Explanation of knowledge practices

The first research sub-question addressed knowledge practices utilised in projects for BIM learning. From 31 project-based learning mechanisms of BIM, 18 knowledge practices were identified. The interviewees classified knowledge practices into major, minor, and obsolete. The categorisation based on the significance of knowledge practices to the learning of BIM in projects. The designers and engineers interviewed underlined Informal meeting the most as major knowledge practice. This followed by Knowledge team creation and Standardisation. Learning-by-doing was listed the most as minor within the research. Training & Workshop and Informal meeting were mentioned as minor knowledge practice. Additionally, Training & Workshop was regarded by most project actors as an obsolete knowledge practice.

The interviewees within the research identified 80 instrumentalities of knowledge practices. They were specific artefacts and activities to learn BIM that rest within each knowledge practice. Standardisation, Project review, Promotion of knowledge sharing culture, and Training & Workshop were recognised as knowledge practices with a high number of instrumentalities. External source, Assignment of knowledge management personnel, Learning-by-doing, Specialist consultant, and Informal meeting did not contain any instrumentalities. British BIM standard, one of the instrumentalities of Standardisation was context-specific to the British built environment organisations.

6.1.2 Discussion of knowledge practices

Knowledge practices and the theoretical framework of the research

The identification of 18 knowledge practices within this research correlates with the theoretical framework of the research (as presented in Figure 2.7 in Sub-section 2.6.4). Each knowledge practice from the framework is mentioned in at least one project-based learning mechanism of BIM. Also, the designers and engineers interviewed did not mention any additional knowledge practice to the theoretical framework. As presented in Table 3.3 in Sub-section 3.3.4, there were no inductive nodes generated to the existing Tertiary nodes of the coding scheme. This supports Udomdech et al. (2018), where the theoretical framework of the study was built upon. It also builds on the knowledge management literature such as Hidalgo and Albors (2008) and Williams (2008) and the knowledge management in the built environment literature such as Duffield and Whitty (2015), Egbu (2004), and Reich et al. (2012). Knowledge management tools and techniques from the general management studies are applicable in the project setting of the built environment.

Furthermore, this finding extends current knowledge practice literature by providing a contemporary set of knowledge practices from a setting that has not been explored before. Current studies on knowledge practices such as De Toni and Pessot (2020), Terzieva and Morabito (2016), and Van Waveren et al. (2017) have only examined knowledge practices from the general perspective of knowledge and PBL. However, the focus of this research is into knowledge practices in the context of built environment innovation learning, where BIM is the evincing system innovation. This provides originality to the research and urges for more investigations into other system innovations within the built environment industry. The relationship between knowledge and innovation adoption also resonates with Gopalakrishnan et al. (1999) and other KBV of organisations literature such as Na Lim and Peltner (2011), Starbuck (1992), and Yusof and Bakar (2012). It confirms how innovation adoption in organisations is relative to the learning of embedded knowledge of such innovation.

The research forwards a categorisation of knowledge practices into three landscapes of the Codifiable, Transactive, and Un-codifiable. The classification goes beyond Terzieva and Morabito (2016) where only tacit and explicit knowledge are presented and provides an additional view of the knowledge process that is more pragmatic. However, it adds to Van Waveren et al. (2017) by building on how knowledge practices can be organised. Referring to Van Waveren et al. (2017), knowledge practices can be divided into five groups of: a) formal codification landscape; b) training and coaching landscape; c) informal person-to-person landscape; d) inter-organisational networking landscape; and e) intra-organisational communal landscape. The three knowledge practice landscapes provide more depths to the formal codification landscape of Van Waveren et al. (2017) by presenting how knowledge practices can be further appropriated.

Knowledge practices and their significance to BIM learning in projects

Informal meeting and Knowledge team creation are the top two of the most stated major knowledge practices. Both knowledge practices nest within the Un-codifiable knowledge practice landscape. This signifies how it is preferable for project actors to obtain individual BIM competence through tacit knowledge learning. This research finding aligns with the Social learning approach of PBL (Bresnen et al., 2005). It supports Bartsch et al., 2013) and Gasik (2011) on how learning occurs more through the interactions of individuals. Moreover, it reflects upon the connection between the Un-codifiable knowledge practices and the explorative learning process (Eriksson, 2013). The research finding provides new knowledge on how project actors are more inclined towards tacit knowledge learning when they are experimenting or working in an unfamiliar environment or innovation (Brady and Davies, 2004; Bygballe and Ingemansson, 2014). This point is supported further as Informal meeting was also highlighted by the interviewees as one of the most used minor knowledge practices.

Standardisation is also underlined by project actors as significant. Contrary to Informal meeting and Knowledge team creation, Standardisation rests within the Codifiable knowledge practice landscape and relates more towards explicit knowledge learning. This supports the Sender/receiver approach of PBL by accentuating on the storage of BIM-related knowledge to effective BIM learning (Hartmann and Dorée, 2015). The research finding enhances the necessity of BIM-related knowledge to be archived and refined into the organisational process. This strengthens the connection between Standardisation and other knowledge practices within the Codifiable knowledge practice landscape to the exploitative learning process (Brady and Davies, 2004; Levinthal and March, 1993). Furthermore, the finding agrees with Blind et al. (2020) and Jakobs et al. (2001) on how standardisation is crucial for organisations to innovate or adopt an innovation. This supports Caetano (2017) by providing how standardisation acts as a driver to innovation by assisting organisations in refining and developing processes and routines to promote innovation learning. The research finding also conforms with Maradza et al. (2013) who described standardisation as an invincible structure that leverages an understanding of innovation and connects project actors together.

Training & Workshop is recognised the most as an obsolete knowledge practice. This contradicts current BIM learning literature such as Puolitaival and Forsythe (2016) and Succar and Sher (2014). Formal education is described as valuable in obtaining BIM competence. However, this research finding presents that BIM-related knowledge gain through Training & Workshop is often generic. Project actors require a more job-specific competence of BIM that varies between project actors, projects, and organisations. This agrees with Uhm et al. (2017) on how different project actors demand a specific set of BIM competence. The uses of Training & Workshop in some project-based learning mechanisms of BIM are underlined as major when they are more tailored towards project works within organisations, as well as organised specifically by the BIM managers or the in-house teams.

Instrumentalities of knowledge practice and BIM learning in projects

The interviewees within the research locate 80 instrumentalities of knowledge practices. The instrumentalities of knowledge practice represent the specific means of how each knowledge practice is exercised by project teams and organisations. The instrumentalities of knowledge practice allow: a) different dimensions of BIM-related knowledge to be learned (Gopalakrishnan et al., 1999); b) organisations to respond to various types of PBL (Lindner and Wald, 2011; Zhao et al., 2015); and c) project actors to specifically grasp BIM-related knowledge that is applicable to their roles (Uhm et al., 2017).

Instrumentalities of knowledge practice are utilised in project-based learning mechanisms of BIM to comprehend different dimensions of BIM-related knowledge. This resonates with

Gopalakrishnan et al. (1999) on the KBV of organisations and innovation adoption. Innovation-related knowledge is classified in Gopalakrishnan et al. (1999) into tacit, explicit, systematic, autonomous, complex, and simple. Various instrumentalities of knowledge practice provide options for project teams and organisations in choosing the most suitable artefacts or activities in learning BIM. For example, in the project-based learning mechanism of BIM from TH17 (see Sub-section 4.4 – TH17), the learning mechanism of BIM contains Creation of a BIM specialist team and Social media group as instrumentalities of Knowledge team creation. Social media group is utilised by the BIM manager and project actors to respond to a more autonomous and simple knowledge of BIM such as specific modelling techniques or problems found. However, Creation of a BIM specialist team is conducted for a more systematic and complex BIM-related knowledge that should be shared across projects or updated in Project documentation for other project actors in the organisation.

Different types of PBL can be achieved through the employment of various instrumentalities of knowledge practice. The research summarises six types of project-based knowledge and learning according to Lindner and Wald (2011) and Zhao et al. (2015) . The types are a) project knowledge that denotes an overview of an organisational landscape; b) intra-project knowledge within a project; c) knowledge between upstream and downstream projects; d) knowledge between parallel projects; e) knowledge between projects and their parent organisations; and f) knowledge between two projects with different completion time (see Figure 2.4). The majority of instrumentalities of knowledge practice are capable for mainly one type of PBL. For example, in the project-based learning mechanism of BIM described by TH12 (see Sub-section 4.3.2 – TH12), Recruitment & Reassignment contains instrumentalities of Recruiting personnel with BIM competency and Staffs allocation. Recruiting personnel with BIM competency is provided as an appropriate instrumentality for stimulating intra-project knowledge and upstream project knowledge learning. Staffs allocation, however, enables the learning of BIM-related knowledge between parallel projects and to the parent organisation.

Each instrumentality of knowledge practice allows the compartmentalisation of BIM-related knowledge to fit certain BIM roles. This builds on Uhm et al. (2017), where each BIM project role is requiring a different set of BIM competences. Every instrumentality of knowledge practice is compatible to transfer specific BIM competences. With the project-based learning mechanism of BIM from TH18 as an example (see Sub-section 4.3.5 – TH18), Standardisation entails instrumentalities which are BIM software manual and Internal BIM standard. While both instrumentalities of Standardisation store BIM-related knowledge that applies to all BIM project actors, Internal BIM standard holds a more tailored BIM-related knowledge for BIM technician and BIM managers. Another example is the project-based learning mechanism of BIM from TH17 (see Sub-section 4.4 – TH17) The formulation of Social media group in the project-based learning mechanism of BIM from TH17 is for all organisational members. Whereas the Creation of a BIM specialist team is customised for BIM operational members such as designers and engineers.

Standardisation, Project review, Promotion of knowledge sharing culture, and Training & Workshop are identified within this research as knowledge practices with a high number of instrumentalities. This implies how these knowledge practices are more flexible for project teams and organisations to exercise. The choice of project teams and organisations to utilise certain instrumentalities of knowledge practice can also depend on factors outside this research such as the personal preferences of BIM managers or investments required. This brings forth the complexity of BIM learning and demands for more investigations to be performed.

External source, Assignment of knowledge management personnel, Learning-by-doing, Specialist consultant, and Informal meeting do not possess any instrumentalities at the project level. This might be because these knowledge practices are also available at the individual and the organisational level. It depicts how the boundary of BIM learning in projects can be blurred through the uses of these knowledge practices. This research finding builds on Succar et al. (2013), where BIM learning and competence is clearly divided into the individual, group, project team, and organisational levels. The research finding asks for further examinations on how BIM learning can transition seamlessly between different organisational levels.

6.2 Formulation of project-based learning mechanisms of BIM

6.2.1 Explanation of project-based learning mechanisms of BIM

The second research sub-question addressed how knowledge practices are being utilised and formulated the project-based learning mechanisms of BIM. Major and minor knowledge practices were described by the interviewees to be exercised together in an interconnected system. The system of knowledge practices was referred to within the research as a project-based learning mechanism of BIM. Every project-based learning mechanism of BIM was unique and individualised to an organisation. There were two types of relationships between knowledge practices. The relationships were assistive and correlative. Specialist consultant and Informal meeting were identified as high connectivity knowledge practices. Incentive was recognised as a low connectivity knowledge practice.

6.2.2 Discussion of project-based learning mechanisms of BIM

The research finding of how knowledge practices are deployed together extends greatly the current knowledge practice and PBL studies. The relationships and connections between knowledge practices are rarely explored in literature. This contributes to current knowledge practice studies such as De Toni and Pessot (2020) and Van Waveren et al. (2017) or PBL studies such as Duffield and Whitty (2015) and Hartmann and Dorée (2015) on how knowledge practices promote one another. This research finding introduces an interesting research area, where more studies potentially shed new light into PBL literature.

The formulation of project-based learning mechanisms of BIM resonates with Szulanski (2000) on how creating a fertile environment is recommended for organisations. Project-based learning mechanisms of BIM act as a learning environment or an organisational context for project actors and provides learning options for project actors to choose. This also conforms with Bartsch et al. (2013) and Bresnen et al. (2005) on how project actors learn differently and upholds upon the underlying concept of the Social learning approach of PBL, where learning in projects is fluid. It also supports the concept of mutual constitution as explained in Hartmann and Dorée (2015). Knowledge practices such as Standardisation and Shared knowledge repository represent the knowledge entity, while Informal meeting and Knowledge team creation depict learning activities. The connections between the two within a project-based learning mechanism of BIM signify how both entities are mutually established and connected.

Moreover, this research finding appeals to PBL in education studies such as Bell (2010) and Holmes and Hwang (2016) on the concepts of scaffolding and differentiation. Scaffolding refers to how various teaching material is utilised by the teacher in a classroom to maximise the learning of students (Kokotsaki et al., 2016). Similarly, knowledge practices are attentively chosen to form a scaffolding that assists project actors in the learning of BIM in projects. Knowledge practices in a scaffolding or a project-based learning mechanism of BIM can be removed or added to modify the learning mechanism to support differentiation (Bell, 2010), where project actors pursue the learning of BIM to their required competence.

The relationships between knowledge practices propose a new research territory to the knowledge practice and PBL literature. It builds on Van Waveren et al. (2017) by offering an alternative approach in looking into knowledge practices. Knowledge practices can be examined and categorised based on their relationships, connections, and interactions to one another. This also exemplifies the importance of knowledge practices with high connectivity which are Specialist consultant, Informal meeting, Knowledge team creation, Learning-by-doing, and Standardisation.

6.3 BIM learning in built environment SMEs

6.3.1 Explanation of BIM learning

The third research sub-question focused on how project-based learning mechanisms of BIM assist the built environment SMEs in BIM learning. Project-based learning mechanisms of BIM were classified within this research into three types of Exploitative, Ambidextrous, and Explorative. The Ambidextrous type contained most of the project-based learning mechanisms of BIM. The Cognitive aspect of project teams was the most significant contextual attributes of projects.

6.3.2 Discussion of BIM learning

Project-based learning mechanisms of BIM and ambidexterity

Project-based learning mechanisms of BIM within this research are classified into Exploitative, Ambidextrous, and Explorative types based on the major knowledge practices utilised and the organisational learning processes they contribute to. This categorisation bridges together PBL and ambidexterity studies by providing how certain knowledge practices contribute to a particular learning process. The Exploitative type, representing the more structured and rigid end of the learning spectrum (Bygballe and Ingemansson, 2014; Petro et al., 2019) entails project-based learning mechanisms of BIM with all major knowledge practices from the Codifiable knowledge practice landscape. The Explorative type, depicting the more unstructured and fluid end of the learning spectrum includes the learning mechanisms with all major knowledge practices from the Un-codifiable knowledge practice landscape. The Ambidextrous type, situating in the middle of the learning spectrum contains project-based learning mechanisms of BIM with all major knowledge practices from the Transactive knowledge practice landscape or more than one knowledge practice landscapes.

Every project-based learning mechanism of BIM contains a certain level of ambidexterity. It is due to how knowledge practices from more than one knowledge practice landscapes are exercised in all project-based learning mechanisms of BIM. This adds to studies on ambidexterity such as Eriksson (2013) and Levinthal and March (1993) by presenting how ambidexterity at the project level becomes a common state in comprehending a system innovation in the built environment organisations. The deployment of knowledge practices from more than one knowledge practice landscapes directly leads to ambidexterity. The project-based learning mechanisms of BIM from UK06 provides an outstanding example.

The project-based learning mechanism of BIM provided by UK06 (see Sub-section 4.2 – UK06) is classified as Exploitative. However, the learning mechanism also includes knowledge practices from the Transactive and the Un-codifiable knowledge practice landscapes. While Shared knowledge repository and Standardisation, which are from the Codifiable knowledge practice landscape are highlighted as major within the project-based learning mechanism of BIM from UK06, the latter knowledge practice is described to be correlated with Informal meeting, which is underlined as minor knowledge practice from the Un-codifiable knowledge practice landscape. It is explained by UK06 that informal conversations are needed for the clarification of standards to project actors.

Adding to the ambidexterity debates

The identification of project-based learning mechanisms of BIM in organisations supports the contextual view of ambidexterity in the structural and contextual debate (Birkinshaw and Gibson, 2004; Turner et al., 2016). The contextual view of ambidexterity argues that both exploitative and explorative learning activities co-exist in an organisation and are available as choices for individuals (Awojide et al., 2018; Chang and Hughes, 2012). Within this research, a project-based learning mechanism of BIM is highlighted to encompass a certain level of ambidexterity through various knowledge practices within. Each knowledge practice contributes to different learning processes.

This research finding also resonates with Davies and Brady (2016) and Petro et al. (2019) on the modern ambidexterity studies, where organisational ambidexterity is dynamic. In the dynamic versus static debate, the dynamic view of ambidexterity refers to how organisations pursuing ambidexterity are required to simultaneously and continuously balance exploitation and exploration. Various knowledge practices deployed in a project-based learning mechanism of BIM are described by the interviewees to co-exist concurrently and connected fluidly to one another.

Furthermore, the existence of project-based learning mechanisms of BIM contends with Raisch et al. (2009) on how ambidexterity can only occur at either the individual or the organisational levels. A project-based learning mechanism of BIM involves all levels within an organisation. It allows project actors to explore BIM-related knowledge through knowledge practices such as Informal meeting and Recruitment & Reassignment and enables organisations to refine and align their operations through exploitative knowledge practices such as Standardisation and Shared knowledge repository. The research does not contribute to the internal and external debate of organisational ambidexterity as mentioned in Raisch et al. (2009).

Project-based learning mechanism of BIM and the contextual attributes of projects

Knowledge practices within each project-based learning mechanism of BIM are mentioned to assist multiple contextual attributes of projects. Each knowledge practice is also capable to influence various contextual attributes of projects. This research finding contradicts to the general understanding of enabling and hindering factors to learning in projects and organisations (Bresnen et al., 2005; Reich et al., 2012). Contextual attributes of projects are described in the literature to facilitate learning (Bartsch et al., 2013; Duffield and Whitty, 2015). However, it is discerned within the research that the connection between knowledge practices and contextual attributes of projects is bidirectional. The knowledge practices employed in projects potentially impact the contextual fabric of projects.

Most knowledge practices are described by the interviewees to assist the Cognitive aspect of project teams. This conforms with Bakker et al. (2011) and Bresnen et al. (2005) on the importance of shared understanding between project actors to BIM learning. It also highlights the shared understanding of BIM operations amongst project actors as the initial focus that is mandatory for BIM adoption in any organisations.

6.4 Chapter summary

The chapter offered a discussion of results and findings within this research. Findings on knowledge practices were referenced back to past studies on knowledge practices, PBL, innovation adoption, and KBV of organisations. The chapter answered the first three research sub-questions. The identification of knowledge practices and their instrumentalities in comprehending system innovation of BIM extended greatly to PBL and knowledge practice literature. The formulation of project-based learning mechanisms of BIM was broken down and evaluated against different approaches of PBL. The identification of project-based learning mechanisms of BIM supported the concept of a fertile environment within the Social learning approach of PBL and related to the concept of scaffolding and differentiation from the PBL in education literature.

Project-based learning mechanisms of BIM were evaluated through ambidexterity. The ambidexterity theory offered a pragmatic lens in understanding the learning processes of BIM in built environment SMEs. It assisted in explaining the contribution of project-based learning mechanisms of BIM to BIM learning in organisations. The discussion of project-based learning mechanisms of BIM and ambidexterity argued that ambidexterity in projects is contextual, dynamic, and situates in every organisational level.

Chapter 7 Conclusion

This chapter concludes this doctoral thesis. It encompasses a research summary, theoretical contribution, practical recommendation, limitation, and future direction of the research.

7.1 Research summary

With the research aim to investigate the learning of BIM in built environment SMEs, this research examines knowledge practices exercised in projects and how they are utilised together in forming the project-based learning mechanisms of BIM in organisations. BIM is a system innovation being implemented by organisations in the built environment. The adoption of BIM presents a greater challenge for the built environment SMEs than large organisations. The lack of individuals with adequate BIM competence is the main barrier. The theoretical framework of the research is developed from literature to assist in evaluating how knowledge practices are being exercised in projects. There are 18 knowledge practices, where they can be classified into the Codifiable, Transactive, and Un-codifiable landscapes.

Knowledge practices from the Un-codifiable landscape are most preferred by designers and engineers. They are knowledge practices with the capability to foster tacit knowledge learning. Informal meeting and Knowledge team creation, which are knowledge practices from the Un-codifiable landscape are mentioned the most as significant to the learning of BIM in projects. The emphasis on both knowledge practices correlates with the Social learning approach of PBL. Interactions among project actors and explorative learning are crucial in comprehending an unfamiliar innovation. Additionally, Standardisation from the Codifiable landscape is also recognised as significant to the learning of BIM in projects. Designers and engineers regard Standardisation more as an artefact that allows explicit knowledge learning, as well as exploitative learning.

The utilisation of knowledge practices varies across organisations. Specific uses of knowledge practices are referred to within this research as instrumentalities of knowledge practices. 80 instrumentalities of knowledge practices are identified. Knowledge practices with a high number of instrumentalities which are Standardisation, Project review, Promotion of knowledge sharing culture, and Training & Workshop allow project teams and organisations to be flexible in comprehending BIM. Instrumentalities of knowledge practice contain three main functions of: a) enabling designers and engineers to obtain BIM-related knowledge through its various dimensions; b) supporting the built environment SMEs to respond to different types of PBL; and c) permitting the project actors to grasp BIM-related knowledge that is more applicable to their roles. These functions relate to the KBV of organisations, PBL, and BIM competence literature. They explain how these research areas are connected and can be employed together in assessing innovation learning. The research also uncovers knowledge practices with no instrumentality. These represent how the boundaries of BIM learning between all organisational levels can be blurred and provide an interesting faucet for future exploration.

A project-based learning mechanism of BIM refers to how knowledge practices are exercised together in an interconnected system. Knowledge practices are connected through two types of relationships which are assistive and correlative. The formulation of project-based learning mechanisms of BIM in organisations has been referred to the concept of fertile environment in the Social learning approach of PBL, as well as the notions of scaffolding and differentiation in PBL in education literature. The connections between knowledge practices and various instrumentalities of knowledge practices allow each project-based learning mechanism of BIM to be unique and individualised. Through ambidexterity, the project-based learning mechanisms of BIM have been classified as Exploitative, Ambidextrous, and Explorative. The research argues that each project-based learning mechanism of BIM contains a certain degree of ambidexterity. This research finding supports the contextual view of ambidexterity, agrees on the modern ambidexterity research that organisational ambidexterity is dynamic, and concludes that ambidexterity requires participation from all organisational levels.

7.2 Theoretical contribution of the research

There are three main contributions to knowledge within this research. The first contribution relates to knowledge practices and their instrumentalities presented. It extends greatly to current knowledge practice and PBL literature. The second contribution involves how the identification of project-based learning mechanism of BIM adds to ambidexterity theory. The last contribution is towards innovation research. It provides how process innovation in built environment organisation can be examined through project-based innovation learning mechanism.

7.2.1 Contribution to knowledge practice and PBL literature

This investigation provides a contemporary research area for knowledge practice and PBL literature. The identification of knowledge practices in project-based learning mechanisms of BIM within this research offers an alternative set of knowledge practices that supports system innovation learning in built environment organisations. The relationship between knowledge practice and innovation learning in project-based organisations is unexplored in both knowledge practice and PBL literature. The research uncovers how the utilisation of knowledge practices and their instrumentalities permits different dimensions of BIM-related knowledge to be learned (Gopalakrishnan et al., 1999), organisations to respond to various types of PBL (Lindner and Wald, 2011; Zhao et al., 2015), and project actors to specifically grasp BIM-related knowledge that is suitable to their roles (Bosch-Sijtsema et al., 2019; Uhm et al., 2017).

The inquiry into major and minor knowledge practices in BIM learning forwards a more holistic and pragmatic view to PBL research. Factors of project-actor, knowledge practice, contextual attribute of projects, and knowledge types are all significant to system innovation learning in project-based organisations. This highlights how the Sender/receiver and the Social learning approaches of PBL should be examined together (Bresnen et al., 2005; Hartmann and Dorée, 2015). The research also brings to light how each built environment organisation developed its own project-based innovation learning mechanism by creating an integrated system of major and minor knowledge practices. This discovery is original to knowledge practice and PBL in built environment literature. It relates to the prominent concept of scaffolding from the knowledge body of PBL in education (Bell, 2010).

7.2.2 Contribution to ambidexterity literature

This research adds to ambidexterity literature by providing how system innovation learning in built environment organisations is ambidextrous. Every project-based learning mechanism of BIM examined is ambidextrous as it contains knowledge practices from more than one landscapes of Codifiable, Un-codifiable, and Transactive. This forwards a remark, where ambidexterity in projects and project-based organisations is a common state in comprehending system innovation (Eriksson, 2013; Levinthal and March, 1993).

In addition, the study contributes to three of the four current debates within ambidexterity research (Raisch et al., 2009). To the structural versus contextual debate, the research agrees with the latter. The utilisation of various knowledge practices in a project-based learning mechanism of BIM allows both exploitative and explorative learning processes to co-exist and available as choices in an organisation for project actors (Birkinshaw and Gibson, 2004). To the static versus dynamic debate, the investigation argues that system innovation learning in built environment organisations is dynamically ambidextrous. Exploitation and exploration are simultaneous for project actors in learning BIM through various knowledge practices exercised (Turner et al., 2015). To the individual versus organisation debate, the inquiry supports both arguments. While the decision to engage in either exploitation or exploration depends on project actors, a mechanism to allow both learning processes must be in place at an organisational level (Davies and Brady, 2016; Petro et al., 2019). This directly refers to the project-based learning mechanism of BIM. The analysis of project-based learning mechanisms of BIM does not generate any assertion to the internal versus external debate.

7.2.3 Contribution to innovation literature

This study contributes to innovation literature by forwarding that a project-based learning mechanism of BIM is a process innovation (Crossan and Apaydin, 2010) that is internally produced in organisations (Hidalgo and Albors, 2008; Pichlak, 2016). A project-based learning mechanism of BIM developed by each built environment SMEs reflects how they calibrate their business practice and operation in comprehending the system innovation of BIM. Investigations into project-based learning mechanism of BIM generate a greater understanding of procedural changes in SMEs going through innovation adoption. The concept of project-based learning mechanism also echoes the element of praxis in the theoretical body of innovation adoption.

The examination into the project-based learning mechanism of BIM conforms this research into the direction of innovation process research (Hameed et al., 2012) and the interactive process perspective of innovation adoption (Pichlak, 2016). The notion of innovation adoption in built environment organisation can be further understood by looking into the process of innovation learning or the project-based innovation learning mechanism.

7.3 Practical recommendations

There are three sets of practical recommendation. The first set directs toward BIM managers in built environment organisations. The second set extends from the first set of recommendation and converses to innovation managers in other project-based organisations. The third set of recommendation refers to lessons that the British and the Thai built environment industries can learn from one another. This section answers the last research sub-question.

7.3.1 Recommendations to BIM managers

Foremost, BIM managers must acknowledge the impacts and challenges that come with BIM adoption. Studies on BIM adoption have highlighted how BIM influences the current working paradigm of the built environment and requires organisations, especially SMEs to quickly adapt. Investigations into various project-based learning mechanisms of BIM underline how the learning of BIM requires participation from organisational members of all levels. Project actors from different roles and responsibilities are required to obtain specific sets of BIM competence (Bosch-Sijtsema et al., 2019; Uhm et al., 2017).

This research suggests BIM managers to explore Informal meeting, Knowledge team creation, and Standardisation as viable knowledge practices to be included in a project-based learning mechanism of BIM. These knowledge practices are recognised within this study as significant to the learning of BIM in projects. Informal meeting and Knowledge team creation are recommended for BIM managers in organisations that are recent in the adoption of BIM. Both knowledge practices contribute directly to explorative learning. Exploration is necessary for project actors when experimenting or working in an unfamiliar environment (Eriksson, 2013). On the contrary, Standardisation is applicable for built environment organisations that have implemented BIM for a certain period. It associates with exploitative learning. Standardisation allows BIM-related knowledge learned by project actors to be refined, aligned, and updated into the organisation.

Specialist consultant and Training & Workshop should also be within considerations of BIM managers. Both knowledge practices are referred to within this study as high connectivity knowledge practice. Specialist consultant and Training & Workshop contain a capability in assisting or correlating with other knowledge practices. Additionally, close attention to the utilisation of each knowledge practice is vital. Each knowledge practice entails multiple instrumentalities, where certain instrumentalities might be more suitable for specific project teams and organisations.

Furthermore, this research advises BIM managers to be rigorous towards the formulation of a project-based learning mechanism of BIM. BIM managers are recommended to constantly monitor the uses of knowledge practices from more than one knowledge practice landscapes to ensure a fluid balance between exploitation and exploration. A project-based learning mechanism of BIM that contains a diverse group of knowledge practices from the Codifiable, Transactive, and Un-codifiable knowledge practice landscapes is more beneficial to BIM learning than the ones that include knowledge practices only from one knowledge practice landscape. Knowledge practices should also be subtracted and added according to the maturity level of BIM adoption in an organisation. The utilisation of knowledge practices should also acknowledge the importance of the Cognitive aspect of projects. Specifically, knowledge practices are to be exercised to leverage BIM understanding between project actors.

7.3.2 Recommendations to innovation managers

The recommendations provided for BIM managers extend towards innovation managers working in other project-based environments. This research regards BIM only as one of the system innovations being implemented within the built environment industry. There are also other system innovations being adopted in other project-based industries. While further research on specific knowledge practices and innovation learning in other project-based industries is necessary to generate a fruitful conclusion, innovation managers are advised to pay close attention in balancing explorative and exploitative learning processes through the utilisation of knowledge practices. Informal meeting, Knowledge team creation, and Standardisation are recommended for innovation managers as viable knowledge practices to effective innovation learning.

In addition, the theoretical framework of the research can be exploited as an analytical tool by innovation managers in assessing the *project-based innovation learning mechanism* and measure ambidexterity in organisations. The framework allows innovation managers to gain an in-depth understanding of how an adopting innovation is being learned by organisational members in order to modify their learning mechanisms to suit an innovation being adopted.

7.3.3 Recommendations to industries

Lessons for the Thai built environment industry

Attention is required from the Thai public sector towards the learning of BIM in the built environment SMEs. Compared to the UK, the research confirms how BIM is more supported in the British built environment industry (Eadie et al., 2013). Built environment organisations in the UK are more pressured and motivated to implement BIM in achieving BIM level 2 accreditation. However, by looking specifically into the learning of BIM and the employment of knowledge practices, there is no significant difference between the British and the Thai built environment organisations. Informal meeting is equally underlined as major knowledge practices by designers and engineers from both contexts. Similarly, Training & Workshop is considered evenly in both industries as obsolete.

In addition, there is a minor difference revolving Knowledge team creation and Standardisation. Knowledge team creation is more regarded as major by Thai project actors. However, Standardisation is greatly preferred by British project actors. This variance in the utilisation of Knowledge team creation and Standardisation depicts how the learning of BIM is influenced by actions from the public sector. For built environment organisations within the UK to participate in publicly procured projects, BIM level 2 accreditation is required (Dainty et al., 2017). This reflects how Standardisation is exercised and perceived as major knowledge practice by British designers and engineers. This also echoes how the adoption of BIM in the UK is more structured. Moreover, the mandate from the UK government (Eadie et al., 2015) on BIM also results in an extra instrumentality of knowledge practice that is context-specific. As highlighted in Sub-section 5.3.2, British BIM standard is identified as local to the British built environment sector. Further investigation on the context-specific instrumentality potentially yields insightful knowledge on the differences between BIM adoption in the British and the Thai built environment industries.

The Thai built environment SMEs can be used to represent SMEs in other developing countries. Referring to innovation catch-up literature (Hobday, 2005; Sohn et al., 2009), this research categorises these built environment organisations as followers in BIM adoption. The majority of SMEs in developing countries are being left behind in the adoption of BIM by large organisations within the country and internationally. The development of a digital infrastructure within the built environment sector to support innovation learning conceivably improves the adoption of BIM and other innovations amongst SMEs in developing countries. Protocols, guidelines, standards must be developed and enforced by the government institutions to encourage industry-wide learning and foster leapfrogging in organisations.

Lessons for the British built environment industry

While BIM protocols, guidelines, and standards have been in place for built environment organisations in the UK and other developed countries, it is important for organisations and the public sector to be aware of how fast the business environment changes. There is no guarantee of the arrival time of the next scene-changing innovation that will replace BIM. Innovation can emerge in the near future and completely renders BIM working paradigm obsolete. Organisations that rely too much on Standardisation from the government in learning BIM will face tremendous costs of change when they have to re-calibrate their project-based learning mechanisms of BIM (Caetano, 2017). Corresponding with the previous recommendation, the study proposes for a more organisation-centric approach from the public sector of developed industries. This refers to the creation of an infrastructure that enables organisations to advance their mechanisms of learning that rely less on public mandates and standardisation (Blind et al., 2020; Jakobs et al., 2001).

Learning from the Thai built environment organisations, this research suggests a slight modification in project-based innovation learning mechanisms of organisations from the UK and other developed industries. While remaining ambidextrous, the development of project-based innovation learning mechanisms should remain more explorative than exploitative. This can be executed by employing a higher number of major knowledge practices from the Un-codifiable landscape, compared to knowledge practices from the Codifiable landscape. Project-based innovation learning mechanisms with a greater inclination towards exploration allow organisations to be more adaptive to innovation. They permit a rapid dispersion of new knowledge amongst project actors. Knowledge practices from the Un-codifiable landscape enable assimilation of personal experience. They also allow learning between project actors to occur in their most comfortable manner. For example, the uses of local dialects and informal languages between project actors from the same region of hometown. This strengthens ties between project actors and promotes learning after project completion.

7.4 Limitation and direction for future research

This research subjects to several limitations. First, there are limited studies on the learning of BIM in projects and knowledge practice that can provide a solid ground for the study. Studies on knowledge practices and innovation learning are recent in PBL and innovation adoption literature. There is also a considerably smaller number of investigations on SMEs than large organisations. Therefore, this research lacks prior investigations that can offer a direct theoretical foundation. This limitation is addressed by integrating relevant concepts such as knowledge management, organisational learning, and innovation adoption in the formulation of the theoretical framework of the research. Future studies on knowledge practice and innovation learning potentially validate the theoretical framework of this research and shed light on how innovations are learned and adopted in organisations, especially SMEs.

Second, the time constraint plays a significant role in the chosen research method. This research is explorative. It immerses into project-based learning mechanisms of BIM in the attempt to generate a greater understanding of BIM learning in different project-based organisations. A cross-sectional study is performed to identify and compare various project-based learning mechanisms of BIM, as well as to comply with the given timeframe of a doctoral degree. However, it is also necessary to acknowledge that learning can evolve and change through time. This urges for a longitudinal study of how BIM is learned in organisations.

Third, the geographical background of the researcher affects greatly the selection of built environment industries. The research examines the design and engineering SMEs consultancies from the British and the Thai built environment sectors. While both contexts represent the developed and developing industries respectively, they are familiar research settings for the researcher. This results in the exclusion of other contexts. For example, countries such as Vietnam and Malaysia are similar to Thailand in terms of being a follower in BIM adoption. Whereas countries such as Germany and the Netherlands are considered leaders alongside the UK. Further expeditions into project-based learning mechanisms of BIM in other contexts possibly offer a more wholesome view. Additionally, knowledge practices and their connections to innovation learning can be evaluated in other project-based industries such as pharmaceutical or aeronautics.

7.5 Closing remarks

The innovation being addressed within this research is the project-based innovation learning mechanism developed by built environment SMEs to comprehend BIM. BIM is a system innovation that is a puzzling situation in the built environment, where there is no established best practice. A project-based innovation learning mechanism functions as a backbone of an organisation to quickly learn from projects and adapt to the fast-changing market environment. A well-structured and ambidextrous project-based innovation learning mechanism represents a competitive advantage of an organisation by allowing innovations and their embedded knowledge to be quickly learned by project actors and refined in the organisation.

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Appendix

Appendix 1 – An example of the Invitation to research email sent to the British designers and engineers.

BIM research invitation_the Bartlett, UCL

Udomdech, Prompt <prompt.udomdech.14@ucl.ac.uk>

[redacted]

[redacted]

[redacted]

My name is Prompt Udomdech. I am a PhD student from the Bartlett School of Construction and Project Management, UCL. I am writing to seek permission to interview [redacted] within your firm for my research project on BIM innovation learning in project teams.

I am researching on how learning from projects can assist SMEs in BIM adoption.
The interview will last no more than 1 hour.

Please find attached the Invitation to research document that will provide more details of my research.

Look forwards to be hearing from you soon.

Regards,
Prompt U

Prompt Udomdech, BSc MSc
PhD Candidate
The Bartlett School of Construction and Project Management
Faculty of the Built Environment, University College London (UCL)

1-19 Torrington Place
London WC1E 7HB
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Appendix 2 – An example of the Invitation to research email sent to the Thai designers and engineers.

เอกสารยินยอม และประกอบการเข้าร่วมงานวิจัยการใช้ BIM_พร้อม อุดมเดช

Udomdech, Prompt <prompt.udomdech.14@ucl.ac.uk>

[redacted]

[redacted]

[redacted]

ผมชื่อพร้อมนะครับ ที่เมื่อสักครู่ได้คุยกันไปทางโทรศัพท์เกี่ยวกับการขอสัมภาษณ์เรื่องการเรียนรู้ และประยุกข์ใช้ BIM
ผมขออนุญาตนำส่งเอกสารประกอบการวิจัย และเอกสารยินยอมเข้าร่วมการวิจัยครับ

ทั้งนี้ ผมขอยืนยันการสัมภาษณ์เป็นพรุ่งนี้ (วันพุธที่ 18 กันยายน) เวลา 14.00 ที่ [redacted]
ครับพี่

ขอแสดงความนับถือ
พร้อม อุดมเดช

Prompt Udomdech, BSc MSc
PhD Candidate
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Appendix 3 – The Invitation to research document for the British designers and engineers.

The Bartlett School of Construction and Project Management

UCL

INVITATION TO RESEARCH FOR DESIGNERS AND ENGINEERS WORKING ON BIM-OPERATING PROJECTS[1], THE UK BUILT ENVIRONMENT STUDIES

[1]Projects where BIM innovation is the main operating platform.

Title of study: Project-Based Learning to advance Building Information Modelling innovation adoption in the built environment SMEs, the UK built environment study.
Name and contact details of the principle researcher: Prompt Udomdech, prompt.udomdech.14@ucl.ac.uk, Room 232 1-19 Torrington Place London WC1E 7HB

Building Information Modelling (BIM) innovation is the current denomination chosen by majority of built environment organisations to counter various complications found. The adoption of BIM innovation, however, is a radical challenge for SMEs as it renders previous practices obsolete. SMEs contain insufficient personnel with adequate BIM competences. BIM competences are personal and professional abilities of individuals in performing and delivering BIM-related tasks and outcomes. BIM competences can be developed by improving the learning of BIM innovation in project teams, paying attention to the Project-Based Learning (PBL) to BIM innovation. This research asks **"How, and to what extent does BIM learning occur in projects in built environment SMEs?"**

To respond to the research question, the study establishes objectives which are to:

- Explore knowledge practices exercised for BIM learning in project teams;
- Investigate relationships between knowledge practices exerted and each contextual aspect of BIM-operating project teams;
- Examine possibilities of improving mechanism of BIM learning in project teams to improve individual BIM competences; and
- Formulate propositions to explain BIM learning mechanisms of project teams and help in advancing BIM innovation adoption of the built environment SMEs.

You have been invited to this research as you are a designer and/or an engineer within design and engineering SMEs consultancies operating on BIM innovation. You will be interviewed by the researcher. You will be asked to provide information regarding your roles within the project and opinions of how BIM innovation is learned within the project team. The interview will last no more than 1 hour.

**Thank you for your interests in the research. The researcher hopes to be hearing back from you.*

Prompt Udomdech
Room 232, 1-19 Torrington Place, London WC1E 7HB
Tel: +44 (0)75 9638 6156 prompt.udomdech.14@ucl.ac.uk

Appendix 4 – The Invitation to research document for the Thai designers and engineers.

The Bartlett School of Construction and Project Management

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เอกสารขอความอนุเคราะห์ข้อมูล

๒๔ กันยายน ๒๕๖๑

เรื่อง ขอความอนุเคราะห์ข้อมูล

เรียน [redacted]

ข้าพเจ้านายพร้อม อุดมเดช นักศึกษาปรัชญามหาดุษฎีบัณฑิตจาก The Bartlett School of Construction and Project Management, Faculty of the Built Environment, University College London (UCL) [redacted] โดยการสัมภาษณ์สถาปนิก และ/หรือ วิศวกรเพื่อใช้เป็นส่วนหนึ่งในการทำวิทยานิพนธ์ โดยมีรายละเอียด ดังต่อไปนี้

[redacted] Building Information Modelling learning mechanism in Thai construction SMEs" และ มีเป้าหมายการวิจัยเพื่อ:

[redacted] ที่ทางนักศึกษาได้สร้างขึ้นเพื่อทำความเข้าใจเกี่ยวกับการเรียนรู้นวัตกรรม Building Information Modelling (BIM) ของแต่ละบุคคลในโครงการก่อสร้าง และ

[redacted]

การวิจัยนี้จะสอบถามเกี่ยวกับวิธีปฏิบัติเพื่อการเรียนรู้ (knowledge practices) และ สภาพแวดล้อมของโครงการ (project influential attributes) ที่ใช้ BIM [redacted] ระหว่างบริษัทในอังกฤษ และ ไทยเพื่อนำมาใช้ในการหาวิธีพัฒนาการเรียนรู้ และ ปรับใช้ BIM ที่ดีขึ้นในอนาคต โดยจะไม่มีการเปิดเผยข้อมูลส่วนตัวใด ๆ ของทั้งบริษัท และ พนักงานแก่สาธารณะ

จึงเรียนมาเพื่อโปรดพิจารณา และ ขอความอนุเคราะห์

[redacted]

(นายพร้อม อุดมเดช)

นักศึกษาปรัชญาดุษฎีบัณฑิต

Prompt Udomdech BSc., MSc.
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Appendix 5 – The Consent form for the British designers and engineers.

The Bartlett School of Construction and Project Management

UCL

CONSENT FORM IN RESEARCH STUDIES FOR DESIGNERS AND ENGINEERS[1] WITHIN BIM-OPERATING PROJECT TEAMS

[1]Designers and engineers within design and engineering SMEs consultancy

Please complete this form after you have read the Participant Information Sheet and/or listened to an explanation about the research.

Title of study: Project-Based Learning to advance Building Information Modelling innovation adoption in the built environment SMEs, the UK built environment study.

Department: The Bartlett School of Construction and Project Management, Faculty of the Built Environment, University College London (UCL).

Name and contact of the researcher: Prompt Udomdech, prompt.udomdech.14@ucl.ac.uk, 1-19 Torrington Place London WC1E 7HB

Name and contact of the researcher's supervisor: Dr Eleni Papadonikolaki, e.papadonikolaki@ucl.ac.uk, 1-19 Torrington Place London WC1E 7HB

Thank you for considering taking part in this research. The person organising the research must explain the project to you before you agree to take part. If you have any questions arising from the Participant information sheet or explanation already given, please ask the researcher before you decide whether to join in. You will be given a copy of this consent form to keep and refer to at any time.

I confirm that I understand that by ticking/initialling each box below I am consenting to this element of the study. I understand that it will be assumed that unticked/initialled boxes mean that I DO NOT consent to that part of the study. I understand that by not giving consent for any one element that I may be deemed ineligible for the study.

No#	Descriptions	Tick box
1	I confirm that I have read and understood the Participant information sheet for the above study. I have had an opportunity to consider the information and what will be expected of me. I have also had the opportunity to ask questions which have been answered to my satisfaction and would like to take part in an individual interview for the above-mentioned research.	

University College London, Gower Street, London WC1E 6BT
Tel: +44 (0)20 7679 2000

2	I understand that I will be able to withdraw my data at any time until the results are analysed and published.	
3	I consent to the processing of my personal information for the purpose explained to me which are: - My roles within the organisation; - Main project type of the organisation (residential, commercial, etc.); - Organisational period in adopting BIM innovation; - Types of projects I am working on; - Knowledge practices used within the project to transfer, capture, and learn BIM innovation; and - Relationships between the knowledge practices used and the contextual aspects of the project team to innovation learning. I understand that the research does not collect my name, and the name of the organisation, as well as the name of projects I am working on. I also understand that such information will be handled in accordance with all applicable data protection legislation.	
4	I understand that I will be interviewed through a semi-structured interview approach. Each interview lasts no more than one hour and is recorded with a recording device. Each interview is analysed back to the theoretical framework of the research and between other interview from the same organisation. Each organisation represents one case study. The research aims to interview between one to three informants per organisation; and between eight to twelve cases. Interviews gathered will be transcribed and imported into NVivo qualitative analysis software. Recordings of interviews will be destroyed after transcription is completed per interview. I understand that all personal information will remain confidential and that all efforts will be made to ensure my organisation and I cannot be identified; unless I state otherwise. I also acknowledged that my audio recording will be transcribed into an anonymised transcription, where then my audio recording will be destroyed immediately after the transcription is completed. I understand that my data gathered in this study will be stored anonymously and securely. It will not be possible to identify my organisation or me in any publications. My comments and participation will be presented anonymously with no mention of my role and affiliation.	
5	I understand that my anonymised information may be subjected to review by responsible individuals from the university for monitoring and audit purposes	
6	I understand that my raw information will only be access by the principle researcher. My anonymised research data may be accessed by others for future research.	
7	I understand that my participation is completely voluntary and that I am free to withdraw at any time without giving a reason. If I decide to withdraw, any personal data I have provide up to that point will be deleted unless I agree otherwise.	
8	I understand potential risks of participating and the support that will be available to me should I become distressed during the course of the research.	
9	I understand the indirect benefits of participating.	

University College London, Gower Street, London WC1E 6BT
Tel: +44 (0)20 7679 2000

10	I understand that I will not benefit financially from this study or from any possible outcome it may result in the future	
11	I understand that the data will not be made available to any commercial organisations but is solely the responsibility of the researcher undertaking this study.	
12	I understand that I will not be compensated for the portion of time spent in the study.	
13	I understand that the information I have submitted will be published as a report, a thesis, and/or a journal paper and I wish to receive a copy of it. **Please circle around your preference choice.*	Yes/No
14	I consent to my interview being audio recorded and understand that the recording will be destroyed immediately after being transcribed into an anonymised transcript. **If you do not want your participation audio recorded, you can still take part in the study. Please inform the researcher of your preference.*	
15	I hereby confirm that I understand the inclusion criteria as detailed in the participant information sheet and explained to me by the researcher.	
16	I hereby confirm that: - I understand the exclusion criteria as detailed in the participant information sheet and explained to me by the researcher; and - I do not fall under the exclusion criteria.	
17	I have informed the researcher of any other research in which I am currently involved or have been involved in during the past 12 months.	
18	I am aware of who I should contact if I wish to lodge a complaint.	
19	I voluntarily agree to take part in this study.	
20	Data collected will be used mainly towards a thesis completion of the researcher. Your anonymised personal data will be processed only for this research. Your interview will be anonymously transcribed. Your recorded audio will be destroyed after transcription is complete and only the researcher can access the storage of your data. The recording will be stored in an external hard-drive, accessible only by the researcher. The anonymised transcriptions will be stored in the laptop of the researcher and the external hard-drive. Both storage spaces will be encrypted and password-protected. I would be happy for the data I provide to be archived at the secured external hard-drive and the laptop of the researcher. I understand that the other authenticated researchers will only have access to my anonymised data.	
21	I understand that my personal data will be stored in an external hard-drive and the laptop of the researcher; and the following safeguards will be put in place: - Deletion of the audio recordings that contains personal information; - Anonymisation of any personal information; - Encrypted storage; and - Password-protected access.	

_______________________ _______________ ____________________

Name of participant Date Signature

University College London, Gower Street, London WC1E 6BT

Tel: +44 (0)20 7679 2000

Appendix 6 – The Consent form for the Thai designers and engineers.

The Bartlett School of Construction and Project Management

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เอกสารแสดงความยินยอมเข้าร่วมการวิจัย
สำหรับนักออกแบบ และวิศวกร[1] ในโครงการที่ใช้ระบบ BIM (Building Information Modelling) ในประเทศไทย

[1]นักออกแบบ และวิศวกรในบริษัทขนาดกลาง และขนาดย่อม (SMEs)

กรุณากรอกแบบฟอร์มนี้หลังจากที่ได้อ่านเอกสารข้อมูลสำหรับผู้เข้าร่วมการวิจัย และ/หรือ ได้ฟังคำอธิบายเกี่ยวกับงานวิจัยแล้วเท่านั้น

หัวข้องานวิจัย: การศึกษา และวิจัยเพื่อพัฒนาการประยุกต์ใช้ Building Information Modelling (BIM) ในบริษัทขนาดกลาง และขนาดย่อมในประเทศไทย

คณะ/ภาควิชา: The Bartlett School of Construction and Project Management, Faculty of the Built Environment, University College London (UCL)

ชื่อ และข้อมูลติดต่อผู้ทำการวิจัย: นายพร้อม อุดมเดช, prompt.udomdech.14@ucl.ac.uk, ห้อง 338, 1-19 Torrington Place, London WC1E 7HB

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ทางภาควิชาขอกราบขอบคุณผู้เข้าร่วมการวิจัยทุกท่าน ทั้งนี้ทางผู้ทำการวิจัยจะต้องอธิบายรายละเอียดของงานวิจัยให้ท่านทราบก่อนการเริ่มวิจัยทุกครั้ง หากท่านมีข้อสงสัย หรือคำถามใด ๆ ในเอกสารข้อมูลสำหรับผู้เข้าร่วมวิจัย หรือในรายละเอียดที่ได้รับการอธิบาย ได้โปรดสอบถาม กับทางผู้ทำการวิจัยก่อนการตัดสินใจเข้าร่วม ผู้เข้าร่วมการวิจัยจะได้รับสำเนาเอกสารแสดงความยินยอมเข้าร่วมการวิจัยนี้เพื่อใช้เป็นเอกสารอ้างอิง

ข้าพเจ้าเข้าใจว่าการทำเครื่องหมายในแต่ละช่องด้านล่างนั้น เป็นการยอมรับในข้อกำหนดนั้น ๆ ในการวิจัยในครั้งนี้ การไม่ทำเครื่องหมายในแต่ละช่องจึงหมายความว่าข้าพเจ้านั้นไม่เห็นด้วยกับข้อกำหนดข้อนั้น และการวิจัยครั้งนี้ถูกยกเลิก

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ข้อ	คำอธิบาย	ช่องเครื่องหมาย
1	ข้าพเจ้ายืนยันว่าได้อ่าน และทำความเข้าใจในเอกสารข้อมูลสำหรับผู้เข้าร่วมการวิจัยของการทำวิจัยในครั้งนี้แล้ว ข้าพเจ้าได้มีโอกาสในการคำนึงถึงข้อมูลที่เกี่ยวข้องทั้งหมด และได้มีโอกาสในการถามคำถามซึ่งได้รับคำตอบที่น่าพอใจแล้วจึงได้ทำการตกลงเข้าร่วมงานวิจัยนี้	
2	ข้าพเจ้ารับทราบว่าสามารถถอนตัว และข้อมูลจากงานวิจัยเมื่อไหร่ก็ได้จนกว่าข้อมูลจะได้รับการวิเคราะห์ และตีพิมพ์	
3	ข้าพเจ้ายอมรับในการนำข้อมูลส่วนตัวของข้าพเจ้าไปใช้ โดยข้อมูลดังกล่าวมีดังนี้: - บทบาทของข้าพเจ้าในบริษัท - ลักษณะของโครงการที่บริษัทรับผิดชอบ - ระยะเวลาในการประยุกข์ใช้ BIM ในบริษัท - ลักษณะของโครงการที่ข้าพเจ้ารับผิดชอบ - วิถีปฏิบัติเพื่อการเรียนรู้ในโครงการเพื่อถ่ายโอน เก็บเกี่ยว และเรียนรู้ BIM - ความสัมพันธ์ระหว่างวิถีปฏิบัติเพื่อการเรียนรู้ในโครงการ และบริบทบรรยากาศของตัวโครงการในการเรียนรู้นวัตกรรม ข้าพเจ้ารับทราบว่างานวิจัยนี้จะไม่ทำการบันทึกชื่อของข้าพเจ้า บริษัท และโครงการที่อยู่ในการดูแลของข้าพเจ้า ข้าพเจ้ารับทราบว่าข้อมูลดังกล่าวจะถูกปฏิบัติตามข้อกำหนดทางกฎหมายทุกประการ	
4	ข้าพเจ้ารับทราบว่าจะถูกสัมภาษณ์แบบกึ่งโครงสร้าง (semi-structured interview) แต่ละการสัมภาษณ์จะไม่เกิน 1 ชั่วโมง และจะถูกบันทึกโดยเครื่องบันทึกเสียง แต่ละการสัมภาษณ์จะถูกนำไปวิเคราะห์กับทฤษฎีพื้นฐานของงานวิจัย และกับบทสัมภาษณ์จากบริษัทอื่น ๆ แต่ละบริษัทจะเทียบเท่า กับ 1 กรณีศึกษา (case study) งานวิจัยนี้ตั้งเป้าหมายที่จะสัมภาษณ์ผู้เข้าร่วมวิจัย 1 ถึง 3 คนต่อบริษัท และประมาณ 8 ถึง 12 บริษัท บทสัมภาษณ์จะถูกนำไปถอดความ และวิเคราะห์ในโปรแกรม NVivo บทสัมภาษณ์จะถูกลบทิ้งหลังจากถูกถอดความแล้ว ข้าพเจ้ารับทราบว่าข้อมูลส่วนตัว และข้อมูลเกี่ยวกับบริษัททั้งหมดจะถูกเก็บเป็นความลับ และทำให้ไม่สามารถระบุตัวตนได้ ข้าพเจ้ารับทราบว่าบทสัมภาษณ์ของข้าพเจ้าจะถูกถอดความแบบไม่ระบุชื่อ และตัวบทสัมภาษณ์จะถูกลบทิ้งหลังจากถอดความแล้ว ข้าพเจ้ารับทราบว่าข้อมูลของข้าพเจ้าจะถูกเก็บบันทึกไว้อย่างปลอดภัยโดยข้อมูลนี้จะไม่สามารถระบุตัวตน และบริษัทของข้าพเจ้าได้ บทสัมภาษณ์ของข้าพเจ้านั้นจะถูกนำไปใช้โดยไม่ได้พูดถึงบทบาทใด ๆ ของข้าพเจ้าในบริษัท	
5	ข้าพเจ้ารับทราบว่าบทสัมภาษณ์ของข้าพเจ้าอาจจะถูกตรวจสอบโดยคณะกรรมการจากมหาวิทยาลัยเพื่อตรวจสอบความถูกต้องของการทำวิจัย	
6	ข้าพเจ้ารับทราบว่าข้อมูลของข้าพเจ้าจะสามารถเข้าถึงได้โดยแค่ผู้ทำวิจัยหลักเท่านั้น บุคคลอื่นนั้นสามารถเข้าถึงได้แค่ข้อมูลที่ทำการลบ และแก้ไขข้อมูลส่วนตัวออกไปแล้วเท่านั้น	
7	ข้าพเจ้ารับทราบว่าการเข้าร่วมงานวิจัยนี้เป็นไปด้วยความสมัครใจ และสามารถถอนตัวได้ทุกเมื่อโดยไม่ต้องให้เหตุผลประกอบ	

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	หากข้าพเจ้าถอนตัว ข้อมูลทั้งหมดของข้าพเจ้าจะถูกลบทิ้งออกทั้งหมด ยกเว้นว่าข้าพเจ้าจะมีความต้องการอื่น ๆ	
8	ข้าพเจ้ารับทราบถึงความเสี่ยงทั้งหมดที่อาจจะเกิดขึ้นได้จากการเข้าร่วมงานวิจัยนี้ และข้าพเจ้าสามารถเข้าถึงการช่วยเหลือหากข้าพเจ้ามีความกังวลใจใด ๆ ระหว่างที่เข้าร่วมงานวิจัยนี้	
9	ข้าพเจ้ารับทราบถึงผลประโยชน์ทางอ้อมทั้งหมดในการเข้าร่วมงานวิจัยนี้	
10	ข้าพเจ้ารับทราบว่าข้าพเจ้าจะไม่ได้รับผลประโยชน์โดยตรงใด ๆ จากงานวิจัยในครั้งนี้ และจากผลลัพธ์ของงานวิจัยนี้	
11	ข้าพเจ้ารับทราบว่าข้อมูลของข้าพเจ้านั้นจะไม่ถูกนำไปใช้เพื่อการโฆษณา หรือเพื่อผลประโยชน์ของบริษัทใด ๆ การนำข้อมูลของข้าพเจ้าไปใช้เป็นความรับผิดชอบของผู้ทำการวิจัยแต่เพียงผู้เดียว	
12	ข้าพเจ้ารับทราบว่าข้าพเจ้าจะไม่ได้รับการชดเชยโดยตรงใด ๆ ต่อเวลาที่ใช้ไปในการเข้าร่วมวิจัย	
13	ข้าพเจ้ารับทราบว่าข้อมูลที่ได้ให้ไปจะถูกนำไปตีพิมพ์ในรายงาน วิทยานิพนธ์ และ/หรือวารสาร ข้าพเจ้ารับทราบว่าถ้าข้าพเจ้านั้นอยากเข้าถึงการตีพิมพ์นี้ ข้าพเจ้าจะต้องติดต่อตัวผู้ทำการวิจัยด้วยตัวเอง	
14	ข้าพเจ้ายอมรับให้บทสัมภาษณ์ถูกบันทึกด้วยเครื่องบันทึกเสียง และรับทราบว่าเสียงที่ถูกบันทึกจะถูกลบทิ้งทันทีที่ถูกถอดความแบบไม่ระบุตัวตนแล้ว **กรุณาแจ้งผู้ทำการวิจัยหากท่านไม่อยากให้มีการบันทึกเสียง ท่านยังสามารถเข้าร่วมการวิจัยนี้ได้*	
15	ข้าพเจ้ารับทราบถึงข้อกำหนดในการเลือกผู้เข้าร่วมงานวิจัยนี้ที่ได้ระบุไว้ในเอกสารข้อมูลสำหรับผู้เข้าร่วมการวิจัย และ/หรือได้อธิบายให้ข้าพเจ้าได้รับฟัง	
16	ข้าพเจ้ายืนยันว่า: - ข้าพเจ้ารับทราบถึงข้อกำหนดอื่น ๆ ที่อาจจะทำให้ข้าพเจ้าไม่เกี่ยวข้องกับงานวิจัยนี้ - ข้อกำหนดอื่น ๆ ที่อาจจะทำให้ข้าพเจ้าไม่เกี่ยวข้องกับงานวิจัยนี้ไม่มีผลเกี่ยวข้องใด ๆ กับตัวข้าพเจ้า	
17	ข้าพเจ้าได้แจ้งแก่ผู้ทำการวิจัยถึงงานวิจัยอื่น ๆ ที่ข้าพเจ้ามีส่วนร่วมในช่วง 12 เดือนที่ผ่านมา	
18	ข้าพเจ้ารับทราบถึงผู้ที่สามารถติดต่อได้ หากมีข้อไม่พอใจ	
19	ข้าพเจ้าสมัครใจในการเข้าร่วมงานวิจัยนี้	
20	ข้อมูลแบบไม่ระบุตัวตนทั้งหมดจะถูกนำไปใช้ในการทำวิทยานิพนธ์ของผู้ทำการวิจัยเป็นหลัก บทสัมภาษณ์จะถูกนำไปถอดความแบบไม่ระบุตัวตน และจะถูกลบทิ้งทันทีหลังจากถอดความแล้ว มีแค่ผู้ทำวิจัยเท่านั้นที่สามารถเข้าถึงข้อมูลนี้ได้ บทสัมภาษณ์จะถูกบันทึกไว้ใน external hard-drive ที่สามารถเข้าถึงได้แต่ผู้ทำการวิจัยเท่านั้น บทถอดความแบบไม่ระบุตัวตนจะถูกเก็บไว้ในคอมพิวเตอร์ของผู้ทำการวิจัย และใน external hard-drive ที่เก็บข้อมูลทั้งสองที่ได้ถูกเข้ารหัสไว้เพื่อความปลอดภัยของข้อมูล ข้าพเจ้ายินดีที่ข้อมูลของข้าพเจ้าจะได้รับการจัดเก็บในสองที่ ๆ ได้กล่าวมา ข้าพเจ้ารับทราบว่าผู้ร่วมวิจัย และผู้เกี่ยวข้องอื่น ๆ สามารถเข้าถึงข้อมูลแบบไม่ระบุตัวตนของข้าพเจ้าได้เท่านั้น	
21	ข้าพเจ้ายอมรับให้ข้อมูลส่วนตัวของข้าพเจ้าได้รับการจัดเก็บใน external hard-drive และในคอมพิวเตอร์ของผู้ทำการวิจัย งานวิจัยนี้มีปฏิบัติการป้องกันข้อมูลดังต่อไปนี้:	

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	- การลบบทสัมภาษณ์ที่มีข้อมูลส่วนตัวทิ้งทันที - การแปลงข้อมูลให้เป็นแบบไม่ระบุตัวตน - การจัดเก็บที่มีการเข้ารหัส - การตั้งรหัสเพื่อป้องกันการเข้าถึงโดยไม่ได้รับอนุญาต	

_______________________ _______________ ____________________

ชื่อ และนามสกุล **วันที่** **ลายเซ็น**

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Appendix 7 – The Participant information sheet for the British designers and engineers.

The Bartlett School of Construction and Project Management

PARTICIPANT INFORMATION SHEET FOR DESIGNERS AND ENGINEERS WORKING ON BIM-OPERATING PROJECTS IN THE UK BUILT ENVIRONMENT INDUSTRY

You will be given a copy of this information sheet

Title of study: Project-Based Learning to advance Building Information Modelling innovation adoption in the built environment SMEs, the UK built environment study.

Department: The Bartlett School of Construction and Project Management, Faculty of the Built Environment, University College London (UCL).

Name and contact details of the researcher/principle researcher: Prompt Udomdech, prompt.udomdech.14@ucl.ac.uk, 1-19 Torrington Place London WC1E 7HB

1. Invitation paragraph

You are being invited to participate in a research project. Before you decided, it is important for you to understand why the research is being done and what participation will involve. Please take time through the following information carefully and discuss it with others if you wish. You can contact the researcher anytime if questions and concerns arose. The researcher would like to thank you in advance for your attention in participating.

2. Project background information

The temporariness nature of the built environment operation contains various complications. Businesses in this sector predominantly or entirely perform works in projects, where each project is unique from one another. Project teams also dismember after every project completion. This temporariness, together with the complexity of a building project, result in a non-productive work, costs overrun, adversarial working relationship, and the need for organisations to innovate. Building Information Modelling (BIM) innovation is the common denomination chosen by majority of organisations. However, the adoption of BIM innovation is a radical challenge for SMEs as it renders previous practices and working paradigm obsolete, as well as brings tremendous changes to all system of organisations. Built environment SMEs also possess insufficient resources of time, money, and specifically, personnel with adequate competences.

BIM competences are personal traits, professional knowledge, and technical abilities of individuals in performing BIM-related tasks and deliver BIM-related outcomes. BIM competences of an individual can be increased by improving BIM learning in project teams and

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organisations. Projects are a setting where knowledge is usually lost, and innovation is mostly hidden. The research aims to advance BIM innovation adoption of the built environment SMEs with PBL.

To respond to the research aim, the study establishes objectives which are to:

- Explore knowledge practices exercised for BIM learning in project teams;
- Investigate relationships between knowledge practices exerted and each contextual aspect of BIM-operating project teams;
- Examine possibilities of improving mechanisms of BIM learning in project teams to improve individual BIM competences; and
- Formulate propositions to explain BIM learning mechanisms of project teams and help in advancing BIM innovation adoption of the built environment SMEs.

The data collection period of this project last 5 months between February 2019 to June 2019. The data collection is towards a PhD thesis completion in September 2020.

3. Participants selection

Participants of this research are BIM designers and/or engineers within design and engineering SMEs consultancies in the UK built environment industry. This includes roles such as architects, designers, civil engineers, and mechanical engineers. They are those who operates BIM innovation in a more hands-on basis in BIM-operating project teams. Participants must be working on BIM-operating projects. The research does not take BIM innovation proficiency into account in selecting participants. This research interviews between 25 to 35 informants.

You have been invited based on your BIM-related profession and roles, as well as your involvement in BIM-operating projects within a design and engineering SMEs consultancy.

4. Participation decision

Your decision to participate in this research is entirely voluntary. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a consent form. You are free to withdraw at any time without giving a reason. There is no consequence of your withdrawal or refusal to participate in this research. If you decide to withdraw, you will be asked what you wish to happen to the data you have provided up to that point. Any personal information is anonymised.

5. Participants involvement in the research

Participants will be interviewed by the researcher. Each interview will last no more than one hour. All participants will be given an interview guideline beforehand to familiarise themselves with terms and the framework used. There will be one interview per participant. The researcher will be making sure to minimise any travel expenses of the participants.

The interview will be semi-structured. Questions used in this semi-structured interview will concern knowledge practices used in BIM-operating project teams to capture, transfer, and

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learn BIM-related knowledge; and contextual aspects influencing BIM innovation learning within BIM-operating project teams.

6. Data collection and processing protocols

Interviews are recorded with a recording device. Audio records will be transcribed, anonymised, destroyed, and used only for analysis and presentation in the PhD thesis, conference presentations, and journal publications. No other uses will be made of them without your written permission, and no one outside the project will be allowed access to the original recordings. Recorded audios are transcribed and imported to NVivo qualitative data analysis software for analysation. Your recording audios will be stored in an external hard-drive that only the principle researcher can access. They will be immediately destroyed after transcription is completed of each recording. The anonymised transcriptions will be stored in both the external hard-drive and the laptop of the principle researcher. Both storage spaces are password-protected and encrypted. Only the principle researcher can access these storage locales.

7. Possible disadvantages and risks of taking part

Physically, participants of this research might be exposed to physical risks if the interviewing location is in a high-risk locale such as your office within a construction site. The researcher will make sure that interviewing locations do not present participants of any physical risks. Additionally, meeting rooms within the institution of the researcher or external meeting rooms can be booked.

Psychologically, participants might be subjected to psychological discomforts as the research collects personal opinions of projects that the participants are working on. The collected information not only display the condition of projects but also reflect the image of the organisation. The researcher will make sure that interviews obtained are enclosed only to the researcher unless anonymised. Published information that is considered personal information (can be traced back to an individual or an organisation) will also be anonymised.

8. Possible benefits of taking part

Whilst there are no immediate benefits for those people participating in this research project, the completion of this research yields both practical and theoretical benefits. Practically, the research assists in advancing BIM innovation adoption for the built environment SMEs. The research aims to suggest propositions for practitioners in improving project mechanisms in learning BIM innovation to advance its adoption. Theoretically, the study consolidates theoretical bodies of BIM innovation, innovation adoption in the built environment, and PBL. The research also generates deeper understanding of how knowledge of BIM innovation can be captured, transferred, and learned; and contributes to the theoretical debate of how organisation should effectively learn innovation.

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9. The occurrence of serious adverse event

In the case where serious adverse event occurs and complaints must be made, participants file a complaint or report to the supervisor of the researcher. The contact detail is Dr Eleni Papadonikolaki, 1-19 Torrington Place WC1E 7HB, e.papadonikolaki@ucl.ac.uk. However, if you feel that your complaint has not been handled to your satisfaction, you can contact the Bartlett School of Construction and Project Management Research Ethics Committee officer

10. Ethics and the protection of personal data

All information collected about you during the course of the research will be kept strictly confidential. The research won't be collecting your name, as well as the name of your organisation. Any personal information made public will be anonymised. You will not be able to be identified in any ensuing reports or publications, unless you wish your involvement to be made public. The research will adhere to the UCL Code of Conducting Researches and the ESRC Framework for Research Ethics 2015 in terms of the ethical considerations. It will also follow the Data Protection Act 1998 in the aspect of the personal data protection. The research cannot proceed unless approved by the UCL Research Ethics and Data Protection committees.

For privacy and confidentiality of informants, any personal information will be anonymised. This includes information of informants, organisations, and any other third-party that might come up during the interview. The researcher will ensure that the audio recordings of interviews will be destroyed immediately after transcriptions are completed. Your participation will be completely confidential. There won't be any discussion of un-anonymised information.

11. Results of the research project

The research is due to be completed in September 2020. The results are likely to be publish around this completion time. You can obtain a copy of the published result by directly contact the researcher. Your contribution and information will not be identified in any report or publication. Data collected during the course of the project might be used for additional researches and publications. However, your information and contribution will remain anonymised.

12. Local Data Protection privacy notice

The controller of this project will be UCL. The UCL Data Protection Officer provides oversight of UCL activities involving the processing of personal data and can be contacted at data-protection@ucl.ac.uk

This 'local' privacy notice sets out the information that applies to this particular study. Further information on how UCL uses participant information can be found in our 'general' privacy notice: https://www.ucl.ac.uk/legal-services/privacy/ucl-general-research-participant-privacy-notice

Personal data required from the participants are:

- Roles of the participants within the project team and the organisation;
- Main project types of the organisation;
- Organisation period of adopting BIM innovation;
- Types of projects the participants are working on;
- Knowledge practices used within the project to transfer, capture, and learn BIM innovation; and
- Relationships between the knowledge practices used and the contextual aspects of the project team to innovation learning.

The lawful basis that would be used to process your personal data will be performance of a task in the public interest. Your personal data will be anonymised before being processed so long as it is required for the research project, which is until its expected due date in September 2020. Any personal information will be anonymised. Your anonymised information may be processed by other researchers in the future. The researcher will inform all participants of any future use of information for consents.

If you are concerned about how your personal data is being processed, or if you would like to contact us about your rights, please contact UCL in the first instance at data-protection@ucl.ac.uk

13. Contact for further information

For further information, you can contact directly to the researcher: Mr Prompt Udomdech, prompt.udomdech.14@ucl.ac.uk, 1-19 Torrington Place WC1E 7HB. You will be given a copy of the information sheet and a signed consent form to keep.

Thank you for reading this information sheet and for considering participating in this research study.

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Figure A7: The Participant information sheet for the British designers and engineers.

Appendix 8 – The Participant information sheet for the Thai designers and engineers.

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เอกสารข้อมูลสำหรับผู้เข้าร่วมการวิจัยสำหรับนักออกแบบ และวิศวกรในบริษัทสิ่งปลูกสร้างขนาดกลาง และขนาดย่อมในโครงการที่ใช้ระบบ BIM (Building Information Modelling) ในประเทศไทย

ท่านจะได้รับสำเนาของเอกสารนี้

หัวข้องานวิจัย: การศึกษา และวิจัยเพื่อพัฒนาการประยุกต์ใช้ Building Information Modelling (BIM) ในบริษัทขนาดกลาง และขนาดย่อมในประเทศไทย

คณะ/ภาควิชา: The Bartlett School of Construction and Project Management, Faculty of the Built Environment, University College London (UCL)

ชื่อ และข้อมูลติดต่อผู้ทำการวิจัย: นายพร้อม อุดมเดช, prompt.udomdech.14@ucl.ac.uk, ห้อง 338, 1-19 Torrington Place, London WC1E 7HB

1. **เกริ่นนำ**

ท่านกำลังได้รับเชิญให้เข้าร่วมการวิจัย ก่อนการตัดสินใจเข้าร่วม กรุณาทำความเข้าใจจุดประสงค์ของงานวิจัยนี้ และสิ่งที่ผู้เข้าร่วมวิจัยต้องรับทราบ กรุณาอ่านข้อมูลต่อจากนี้ และสอบถามหากมีข้อสงสัย ท่านสามารถติดต่อสอบถามผู้ทำงานวิจัยได้ตลอดเวลา ผู้ทำการวิจัยต้องขอกราบขอบพระคุณท่านมา ณ ที่นี้

2. **คำอธิบายงานวิจัยโดยสังเขป**

บริบทชั่วคราวของงานก่อสร้าง และโครงการมีความซับซ้อนในระดับสูง บริษัทในอุสาหกรรมนี้จะปฏิบัติงานในรูปแบบของโครงการ ซึ่งในแต่ละโครงการจะมีความแตกต่างกันโดยสิ้นเชิง ผู้ร่วมงานในโครงการต่างแยกย้ายจากกันหลังโครงการสิ้นสุด ความชั่วคราวนี้ กอปรกับความซับซ้อนของงานก่อสร้าง และโครงการนำมาซึ่งงานที่ไม่ได้มาตรฐาน ค่าใช้จ่ายที่เกินงบประมาณ ความสัมพันธ์ที่ไม่แน่นอนระหว่างผู้ร่วมงาน และความต้องการในการเปลี่ยนแปลงปรับใช้นวัตกรรมใหม่ ๆ Building Information Modelling (BIM) เป็นนวัตกรรมที่ถูกนำมาใช้อย่างแพร่หลายในบริษัทต่าง ๆ และการปฏิบัติงานก่อสร้าง หากแต่ว่าการประยุกต์ใช้ BIM นั้นเป็นการเปลี่ยนแปลงในระดับรากฐาน (radical innovation) สำหรับบริษัทขนาดกลาง และย่อมอันเนื่องมาจากการที่ตัว BIM นั้นทำให้เกิดการเปลี่ยนแปลงในรูปแบบการทำงาน และระบบปฏิบัติการทั้งหมดของบริษัท อีกทั้งธุรกิจสิ่งปลูกสร้างขนาดกลาง และย่อมไม่ได้มีทรัพยากรที่มากพอในเรื่องเวลา ทุนทรัพย์ และบุคลากรที่มีความเชี่ยวชาญที่มากพอ

ความเชี่ยวชาญเรื่อง BIM เป็นเรื่องเฉพาะบุคคล และเป็นความรู้ความสามารถทางเทคนิคของแต่ละบุคคลในการปฏิบัติงานที่เกี่ยวกับ BIM ความเชี่ยวชาญเรื่อง BIM สามารถพัฒนาได้ผ่านการพัฒนาการเรียนรู้ BIM ในคณะปฏิบัติงานโครงการ และในบริษัท โครงการเป็นพื้นที่ ๆ ความรู้มักสูญหาย และนวัตกรรมมักถูกซ่อนไว้ งานวิจัยนี้ต้องการพัฒนาการประยุกต์ใช้ BIM ในธุรกิจสิ่งปลูกสร้างขนาดกลาง และย่อมผ่านการเรียนรู้แบบใช้โครงงานเป็นฐาน (Project-Based Learning)

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งานวิจัยมีจุดประสงค์ย่อยดังต่อไปนี้:

- เพื่อสำรวจวิถีปฏิบัติเพื่อการเรียนรู้ในโครงการที่ใช้ในการเรียนรู้ BIM โดยคณะปฏิบัติงานโครงการ
- เพื่อสำรวจความสัมพันธ์ระหว่างวิถีปฏิบัติเพื่อการเรียนรู้ในโครงการ และบริบทของแต่ละคณะปฏิบัติงานโครงการที่ใช้ระบบ BIM
- เพื่อวิเคราะห์ความเป็นไปได้ในการพัฒนากลไกการเรียนรู้ BIM ในคณะปฏิบัติงานโครงการเพื่อพัฒนาความเชี่ยวชาญเรื่อง BIM ในแต่ละบุคคล
- เพื่อหาคำอธิบายทางทฤษฎีของกลไกการเรียนรู้ BIM ในคณะปฏิบัติงานโครงการ และพัฒนาการประยุกต์ใช้ BIM ในธุรกิจสิ่งปลูกสร้างขนาดกลาง และย่อม

การเก็บข้อมูลของงานวิจัยนี้จะเป็นระยะเวลาทั้งสิ้น 3 เดือนตั้งแต่เดือนกรกฎาคม 2662 ถึง กันยายน 2662 การเก็บข้อมูลของงานวิจัยนี้เป็นส่วนหนึ่งของการทำวิทยานิพนธ์ที่มีกำหนดส่งในเดือนกันยายน 2663

3. การเลือกผู้เข้าร่วมงานวิจัย

ผู้เข้าร่วมการวิจัยจะต้องเป็นนักออกแบบ หรือวิศวกรในบริษัทออกแบบ และวิศวกรรมขนาดกลาง และย่อมที่ใช้งาน BIM ในประเทศไทย ผู้เข้าวิจัยนี้รวมวิชาชีพตั้งแต่สถาปนิก นักออกแบบ และวิศวกรที่ใช้ BIM ในการปฏิบัติการ วิชาชีพเหล่านี้ถือว่าเป็นกลุ่มคนแรก ๆ ที่ได้ใช้ BIM ผู้เข้าร่วมงานวิจัยต้องกำลังอยู่ในโครงการที่ใช้ BIM เป็นระบบปฏิบัติการหลัก งานวิจัยนี้ไม่นับรวมความเชี่ยวชาญเฉพะบุคคลเกี่ยวกับ BIM มาเกี่ยวข้องในการเลือกผู้เข้าร่วมงานวิจัย งานวิจัยนี้มีเป้าหมายในการสัมภาษณ์ตั้งแต่ 12 ถึง 36 คน

ท่านได้รับเชิญให้เข้าร่วมงานวิจัยนี้จากความเชี่ยวชาญ และเกี่ยวข้องของท่านในตัว BIM และโครงการที่ใช้ระบบ BIM ในการปฏิบัติการ อีกทั้งท่านยังทำงานในบริษัทออกแบบ และวิศวกรรมที่มีขนาดกลาง หรือย่อม

4. การตัดสินใจของผู้เข้าร่วมการวิจัย

การตัดสินใจเข้าร่วมในงานวิจัยนี้เป็นไปตามความสมัครใจของท่าน หากตัดสินใจเข้าร่วม ท่านจะได้รับเอกสารข้อมูลสำหรับผู้เข้าร่วมการวิจัย และเอกสารยืนยันการเข้าร่วมการวิจัยให้เซ็น ท่านสามารถถอนตัวได้ทุกเวลาโดยไม่จำเป็นจะต้องให้เหตุผลประกอบ การถอนตัว หรือปฏิเสธของท่านจะไม่มีผลกระทบใด ๆ ต่อตัวท่าน ถ้าหากท่านถอนตัว ท่านจะได้รับการถามถึงสิ่งที่ท่านต้องการให้เกิดกับข้อมูลที่ท่านได้ให้สัมภาษณ์จนถึงตอนนั้น ข้อมูลส่วนตัวใด ๆ ของท่านจะถูกลบทิ้ง หรือทำลาย

5. การมีส่วนร่วมของผู้เข้าร่วมการวิจัย

ผู้เข้าร่วมวิจัยจะถูกสัมภาษณ์โดยผู้ทำการวิจัยเท่านั้น แต่ละการสัมภาษณ์จะไม่ยาวเกิน 1 ชั่วโมง ผู้เข้าร่วมการวิจัยทุกคนจะได้รับมอบเอกสารประกอบการสัมภาษณ์ก่อนการเริ่มสัมภาษณ์ ผู้เข้าร่วมการวิจัยจะถูกสัมภาษณ์เพียง 1 ครั้ง ผู้ทำการวิจัยจะพึงระวัง และคอยตรวจสอบให้ผู้เข้าร่วมการวิจัยใช้เวลาเดินทางน้อยที่สุด

การสัมภาษณ์จะเป็นแบบกึ่งโครงสร้าง (semi-structured interview) คำถามในการสัมภาษณ์นี้จะเกี่ยวกับวิถีปฏิบัติเพื่อการเรียนรู้ BIM ในโครงการ และบริบทของคณะปฏิบัติงานโครงการ

6. การเก็บข้อมูล และการปฏิบัติต่อข้อมูลที่ได้มา

บทสัมภาษณ์จะถูกบันทึกโดยเครื่องบันทึกเสียง บทสัมภาษณ์จะถูกถอดความให้ไม่สามารถระบุตัวตนได้ และจะถูกลบทิ้งหลังถอดความเรียบร้อย งานวิจัยนี้จะใช้บทถอดความที่ได้รับการทำให้ระบุตัวตนไม่ได้แล้วเท่านั้นในการวิเคราะห์ และนำเสนอในวิทยานิพนธ์ ตีพิมพ์ในงานสัมนา และวารสารทางวิชาการ จะไม่มีผู้อื่นได้รับอนุญาตให้เข้าถึงข้อมูลนี้ได้โดยปราศจาก

การยืนยันเป็นลายลักษณ์อักษรจากท่านก่อน บทสัมภาษณ์จะได้รับการถอดความ และนำเข้าโปรแกรม NVivo เพื่อใช้ในการวิเคราะห์ บทสัมภาษณ์จะถูกบันทึกไว้ใน external hard-drive ที่มีแต่ผู้ทำการวิจัยเท่านั้นที่เข้าถึงได้ บทสัมภาษณ์จะถูกลบทิ้งทันทีที่ได้ทำการถอดความแล้ว บทถอดความแบบไม่ระบุตัวตนจะถูกบันทึกไว้ใน external hard-drive และคอมพิวเตอร์ของผู้ทำการวิจัย พื้นที่เก็บข้อมูลทั้ง 2 ที่ได้รับการเข้ารหัส และมีการตั้งรหัสไว้เพื่อความปลอดภัยของข้อมูล มีแต่ผู้ทำการวิจัยเท่านั้นที่สามารถเข้าถึงพื้นที่เก็บข้อมูลทั้ง 2 ที่นี้ได้

7. ความเสี่ยงที่เป็นไปได้ในการเข้าร่วมการวิจัย

ทางกายภาพ ผู้เข้าร่วมการวิจัยอาจจะมีความเสี่ยงอันเนื่องมาจากสถานที่ ๆ ได้ทำการสัมภาษณ์ซึ่งอาจจะอยู่บนพื้นที่ ๆ อันตราย อาทิ บริเวณไซต์งานก่อสร้าง ผู้ทำการวิจัยจะทำการตรวจสอบ และระวังในข้อนี้เพื่อป้องกันความเสี่ยงใด ๆ ที่อาจจะเกิดขึ้นได้ ทั้งนี้ ห้องประชุมใกล้ ๆ หรือในบริษัทของผู้เข้าร่วมการวิจัยอาจจะถูกนำไปใช้แทน

ทางจิตวิทยา ผู้เข้าร่วมการวิจัยอาจมีความเสี่ยงต่อความรู้สึกไม่สบายใจอันเนื่องมาจากการเก็บข้อมูลที่เป็นส่วนตัว และเป็นความคิดเห็นที่เกี่ยวกับโครงการที่กำลังดำเนินการอยู่ ความคิดเห็นนี้นอกจากจะสะท้อนถึงภาพลักษณ์ของโครงการแล้วยังสามารถสะท้อนถึงภาพลักษณ์ของบริษัท บทสัมภาษณ์จะสามารถเข้าถึงได้โดยผู้ทำการวิจัยเท่านั้นยกเว้นจะถูกทำให้ระบุตัวตนไม่ได้ ข้อมูลที่ได้รับการตีพิมพ์ที่อาจจะเข้าข่ายเป็นข้อมูลส่วนตัวจะถูกทำให้ระบุตัวตนไม่ได้

8. ผลประโยชน์ที่เป็นไปได้ในการเข้าร่วมการวิจัย

ในขณะที่ผู้เข้าร่วมการวิจัยจะไม่ได้รับผลประโยชน์โดยตรงใด ๆ จากการเข้าร่วมการวิจัยนี้ ตัวงานวิจัยนั้นจะนำไปสู่ผลประโยชน์ในทางปฏิบัติ และทางทฤษฎี ในทางปฏิบัติงานวิจัยนี้จะช่วยในการพัฒนาการประยุกต์ใช้ BIM ในบริษัทสิ่งปลูกสร้างขนาดกลาง และย่อม งานวิจัยนี้จะนำเสนอทฤษฎี หรือแนวทางปฏิบัติที่สามารถนำไปพัฒนากลไลการเรียนรู้ BIM ได้ ในทางทฤษฎีนั้น งานวิจัยนี้จะเป็นการต่อยอดงานวิจัยในปัจจุบันในเรื่องของการประยุกต์ใช้ BIM ในบริษัท การประยุกต์ใช้นวัตกรรมต่าง ๆ ในบริษัท และการเรียนรู้แบบใช้โครงงานเป็นฐาน งานวิจัยนี้ยังทำให้เกิดองค์ความรู้ใหม่ ๆ ในเรื่องของการเรียนรู้ BIM แบบต่าง ๆ ผ่านวิธีการต่าง ๆ และในเรื่องของวิธีการเรียนรู้นวัตกรรมใหม่ ๆ ในบริษัท

9. ในกรณีที่มีเหตุฉุกเฉิน หรือเหตุที่ไม่น่าพอใจ

ในกรณีที่มีเหตุฉุกเฉิน หรือเหตุที่ไม่น่าพอใจผู้เข้าร่วมการวิจัยสามารถแจ้งไปยังอาจารย์ที่ปรึกษาของผู้ทำการวิจัย โดยสามารถติดต่อไปยัง ดร. Eleni Papadonikolaki, ห้อง 251, 1-19 Torrington Place, London WC1E 7HB, e.papadonikolaki@ucl.ac.uk ทั้งนี้หากท่านรู้สึกว่าคำร้องทุกข์ไม่ได้รับการปฏิบัติเท่าที่ควร กรุณาติดต่อไปที่หัวหน้าคณะกรรมการการทำวิจัยของทางภาควิชา the Bartlett School of Construction and Project Management ดร. Niamh Murtagh, n.murtagh@ucl.ac.uk.

10. จริยธรรม และการป้องกันในเรื่องของข้อมูลส่วนตัว

ข้อมูลทั้งหมดเกี่ยวกับตัวท่านจะถูกเก็บเป็นความลับ งานวิจัยนี้จะไม่ทำการบันทึกชื่อของท่าน หรือชื่อของบริษัท ข้อมูลส่วนตัวใด ๆ ที่ได้รับตีพิมพ์จะถูกทำให้ระบุตัวตนไม่ได้ จะไม่มีใครสามารถระบุตัวตนของผู้เข้าร่วมการวิจัยได้ในการตีพิมพ์ต่าง ๆ งานวิจัยนี้จะทำตาม UCL Code of Conducting Research และ ESRC Framework for Research Ethics 2015 ในเรื่องของจริยธรรมในการทำงานวิจัย และยังทำตาม Data Protection Act 2018 ในการคุ้มครองข้อมูลส่วนตัว งานวิจัยนี้ไม่สามารถดำเนินการต่อได้ ถ้าไม่ได้รับการอนุมัติจากคณะกรรมการ UCL Research Ethics และ Data Protection งานวิจัยนี้ได้รับการอนุมัติแล้ว

สำหรับในเรื่องของความเป็นส่วนตัว และการเก็บข้อมูลของผู้เข้าร่วมการวิจัยเป็นความลับ ข้อมูลส่วนตัวทั้งหมดของผู้เข้าร่วมการวิจัยจะถูกทำให้ระบุตัวตนไม่ได้ ทั้งนี้รวมถึงข้อมูลของผู้เข้าร่วมงานวิจัย บริษัท และข้อมูลของบุคคลที่ 3 ที่สามารถมีการพูดถึงได้ในการสัมภาษณ์ บทสัมภาษณ์จะถูกลบทิ้งทันทีหลังจากได้รับการถอดความแบบไม่ระบุตัวตนแล้ว การเข้าร่วมการวิจัยของท่านจะถูกเก็บเป็นความลับ

11. ผลลัพธ์ของงานวิจัย

งานวิจัยนี้มีกำหนดเสร็จสิ้นในเดือนกันยายน 2663 ผู้เข้าร่วมวิจัยสามารถร้องขอสำเนาบทความที่ได้ตีพิมพ์โดยการติดต่อผู้ทำการวิจัยโดยตรง ความร่วมมือของท่านจะถูกพูดถึงในบทความ บทสัมภาษณ์ และข้อมูลที่ได้ทำการบันทึกอาจจะถูกนำไปใช้ในงานวิจัย และการตีพิมพ์นอกเหนือจากวิทยานิพนธ์ของผู้ทำการวิจัย ข้อมูลส่วนตัวทั้งหมดจะถูกทำให้ระบุตัวตนไม่ได้

12. หมายเหตุเกี่ยวกับการป้องกันข้อมูล

ผู้ดูแลความเรียบร้อยโดยรวมของงานวิจัยนี้คือ UCL หน่วยงานการป้องกันข้อมูลของ UCL จะทำการดูแลความเรียบร้อยทั้งหมดเกี่ยวกับการจัดการข้อมูลที่เป็นส่วนตัว และสามารถติดต่อได้ที่ data-protection@ucl.ac.uk

ผู้เข้าร่วมการวิจัยสามารถเข้าไปดูข้อกำหนดอื่น ๆ เกี่ยวกับการจัดการข้อมูส่วนตัวของผู้เข้าร่วมการวิจัยได้ที่ส่วน 'general' ที่ https://www.ucl.ac.uk/legal-services/privacy/ucl-general-research-participant-privacy-notice ข้อมูลส่วนตัวที่ต้องการจากผู้เข้าร่วมการวิจัยครั้งนี้ได้แก่:

- บทบาท และส่วนร่วมของผู้เข้าร่วมการวิจัยในคณะปฏิบัติการโครงการ และบริษัท
- ลักษณะของโครงการหลักที่บริษัทรับผิดชอบ
- ระยะเวลาในการประยุกข์ใช้ BIM ในบริษัท
- ลักษณะของโครงการหลักที่ข้าพเจ้ารับผิดชอบ
- วิถีปฏิบัติเพื่อการเรียนรู้ในโครงการเพื่อถ่ายโอน เก็บเกี่ยว และเรียนรู้ BIM
- ความสัมพันธ์ระหว่างวิถีปฏิบัติเพื่อการเรียนรู้ในโครงการ และบริบทบรรยากาศของตัวโครงการในการเรียนรู้นวัตกรรม

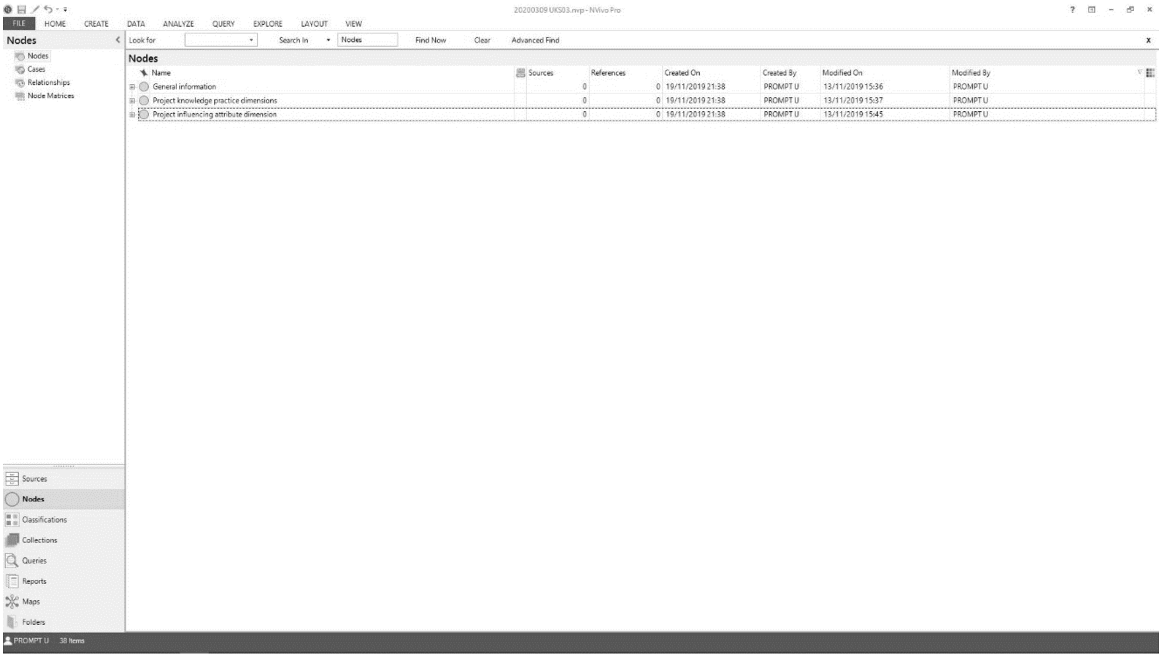
ข้อกฎหมายที่ใช้อ้างอิงในการวิเคราะห์ข้อมูลเป็นข้อกฎหมายที่เป็นที่ยอมรับโดยบุคคลทั่วไป ข้อมูลส่วนตัวของท่านจะถูกทำให้ระบุตัวตนไม่ได้ก่อนจะถูกนำไปวิเคราะห์ ข้อมูลนี้จะถูกใช้งานไปจนกว่าวิทยานิพนธ์นี้จะสำเร็จลุล่วงไปในเดือนกันยายน 2663 ข้อมูลที่ถูกทำให้ระบุตัวตนไม่ได้ของท่านอาจจะถูกวิเคราะห์โดยนักวิจัยอื่น ๆ ในอนาคต ผู้ทำการวิจัยจะแจ้งให้ท่านทราบก่อนการนำไปใช้ที่นอกเหนือจากที่ได้กล่าวไว้ หากท่านมีข้อสงสัยใด ๆ กรุณาแจ้งไปที่ data-protection@ucl.ac.uk

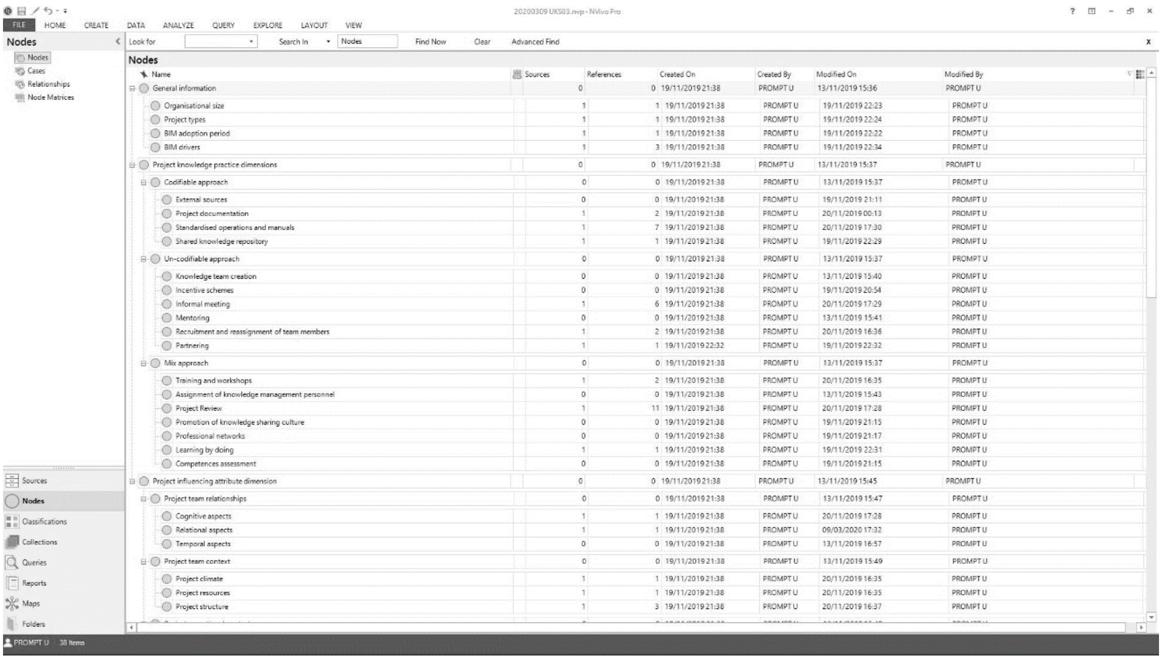
13. การติดต่อเพื่อขอข้อมูลเพิ่มเติม

สำหรับข้อมูลเพิ่มเติม ท่านสามารถติดต่อโดยตรงไปที่ผู้ทำการวิจัย นายพร้อม อุดมเดช prompt.udomdech.14@ucl.ac.uk ห้อง 338, 1-19 Torrington Place, London WC1E 7HB ท่านจะได้รับสำเนาเอกสารข้อมูลสำหรับผู้เข้าร่วมการวิจัยสำหรับนักออกแบบ และเอกสารยืนยันเข้าร่วมงานวิจัย

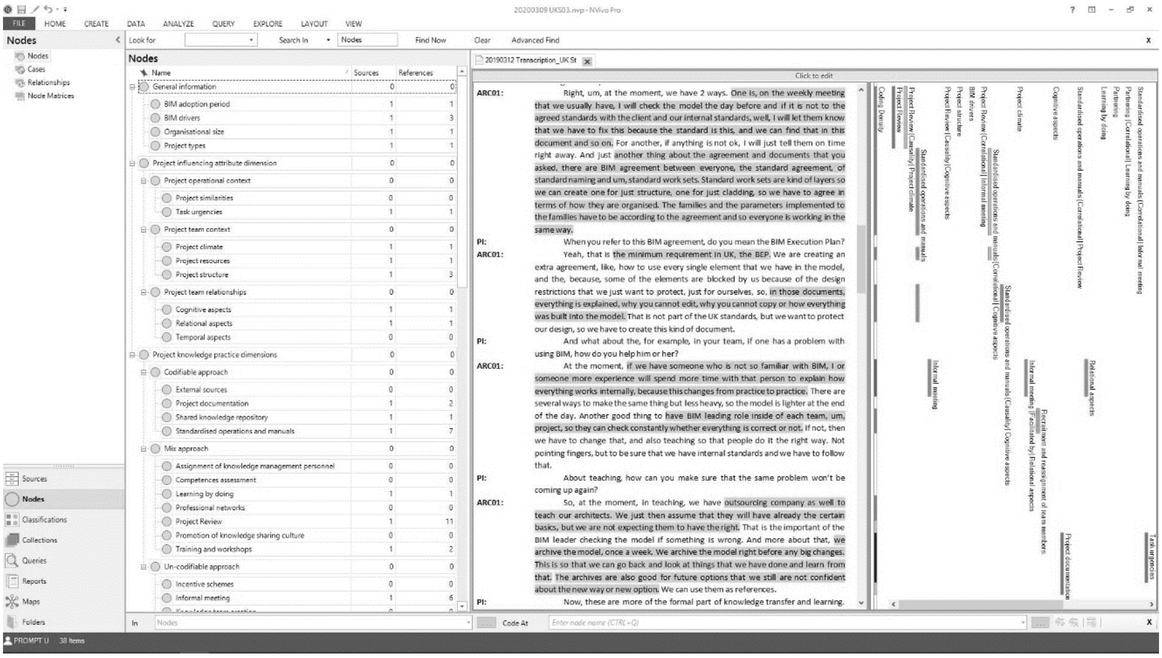
ทางผู้ทำการวิจัยขอกราบขอบคุณในความสนใจที่จะเข้าร่วมในการวิจัยนี้

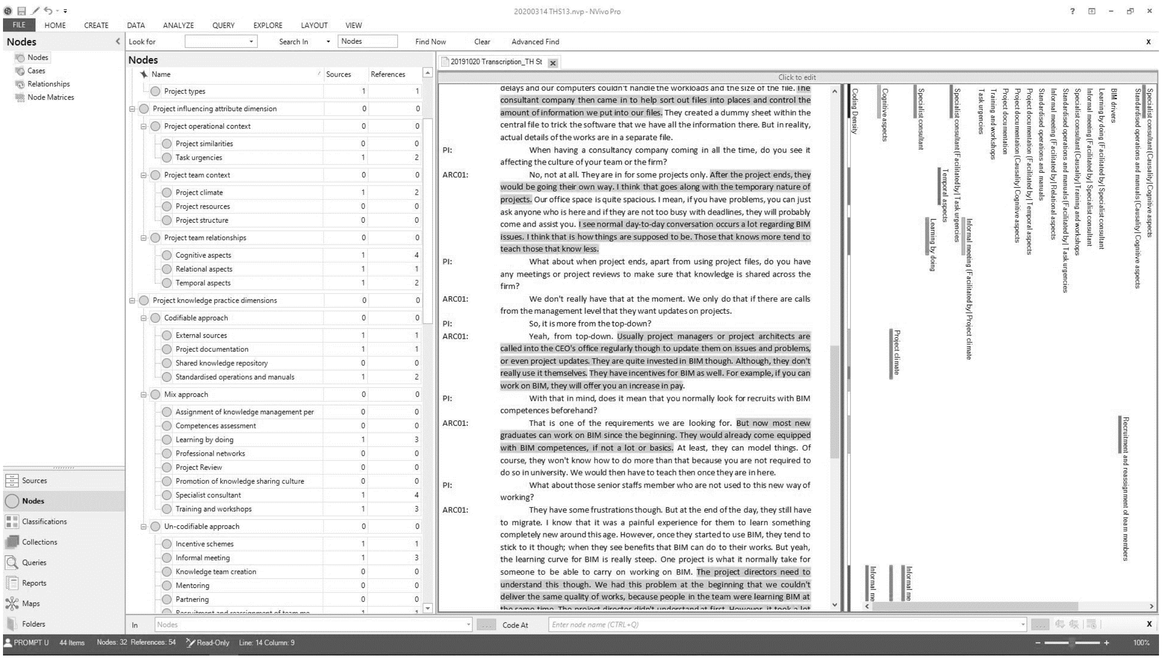
Appendix 9 – The coding scheme as created in NVivo qualitative analysis software.



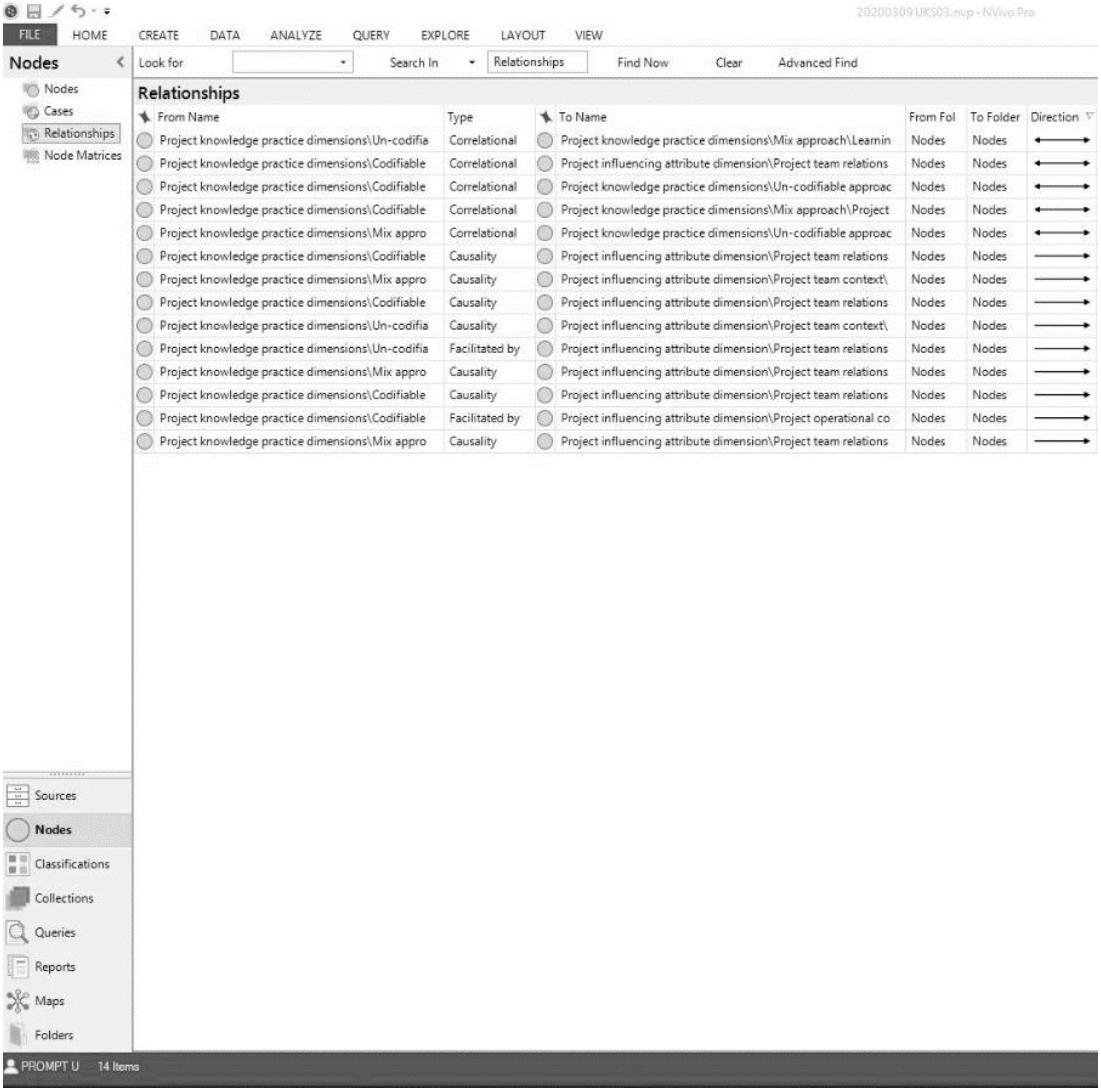


Appendix 10 – An example of how texts, keywords, and passages of the data are coded in NVivo qualitative analysis software.



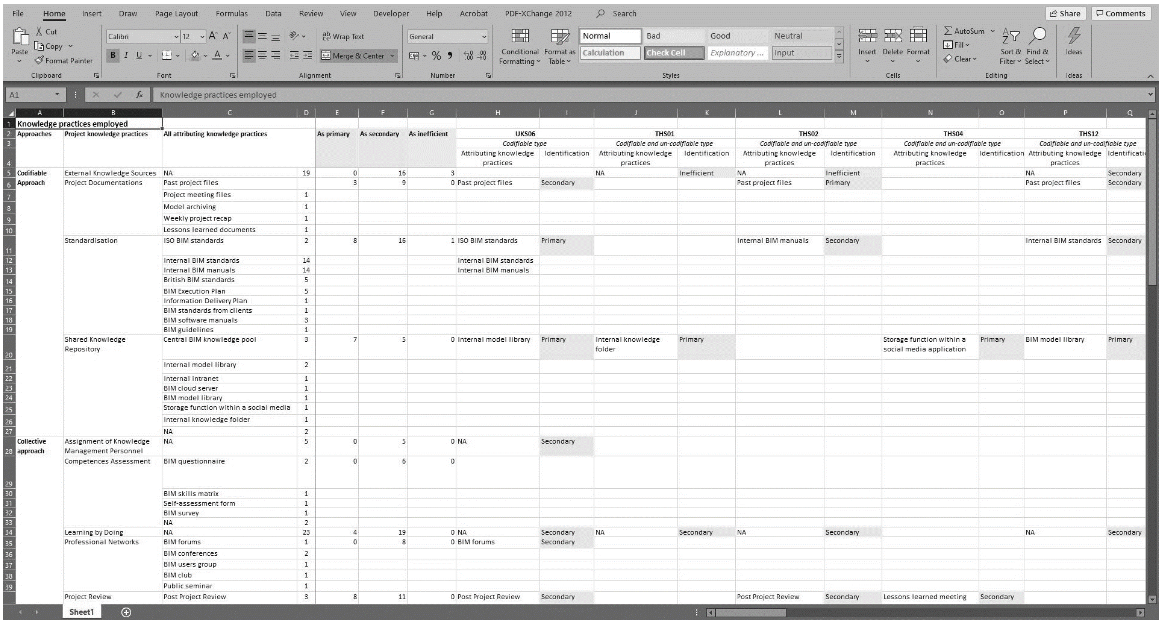


Appendix 11 – An example of the coding of relationships between the coding nodes.



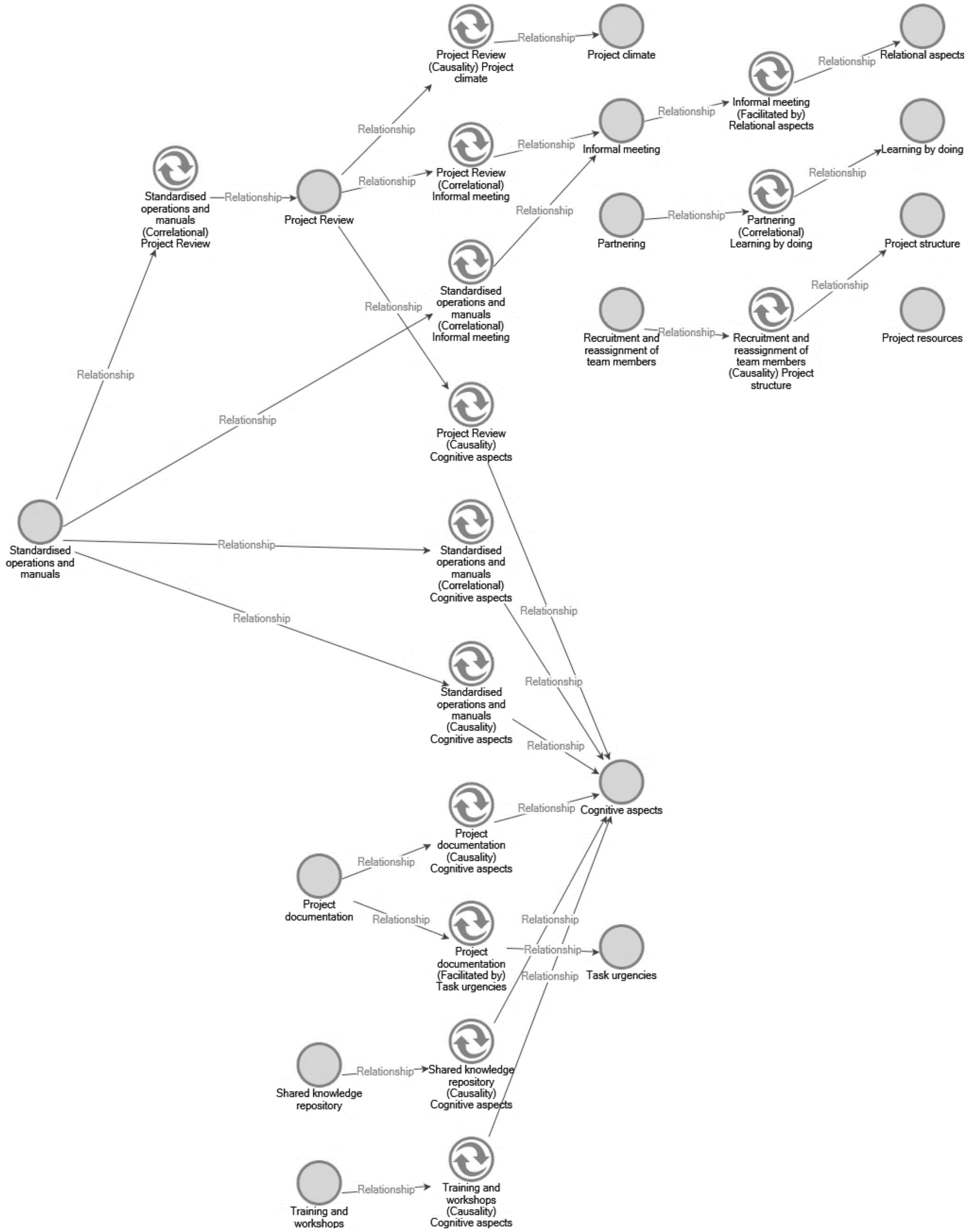
From Name	Type	To Name	From Fol	To Folder	Direction
Project knowledge practice dimensions\Un-codifia	Correlational	Project knowledge practice dimensions\Mix approach\Learnin	Nodes	Nodes	←→
Project knowledge practice dimensions\Codifiable	Correlational	Project influencing attribute dimension\Project team relations	Nodes	Nodes	←→
Project knowledge practice dimensions\Codifiable	Correlational	Project knowledge practice dimensions\Un-codifiable approac	Nodes	Nodes	←→
Project knowledge practice dimensions\Codifiable	Correlational	Project knowledge practice dimensions\Mix approach\Project	Nodes	Nodes	←→
Project knowledge practice dimensions\Mix appro	Correlational	Project knowledge practice dimensions\Un-codifiable approac	Nodes	Nodes	←→
Project knowledge practice dimensions\Codifiable	Causality	Project influencing attribute dimension\Project team relations	Nodes	Nodes	→
Project knowledge practice dimensions\Mix appro	Causality	Project influencing attribute dimension\Project team context\	Nodes	Nodes	→
Project knowledge practice dimensions\Codifiable	Causality	Project influencing attribute dimension\Project team relations	Nodes	Nodes	→
Project knowledge practice dimensions\Un-codifia	Causality	Project influencing attribute dimension\Project team context\	Nodes	Nodes	→
Project knowledge practice dimensions\Un-codifia	Facilitated by	Project influencing attribute dimension\Project team relations	Nodes	Nodes	→
Project knowledge practice dimensions\Mix appro	Causality	Project influencing attribute dimension\Project team relations	Nodes	Nodes	→
Project knowledge practice dimensions\Codifiable	Causality	Project influencing attribute dimension\Project team relations	Nodes	Nodes	→
Project knowledge practice dimensions\Codifiable	Facilitated by	Project influencing attribute dimension\Project operational co	Nodes	Nodes	→
Project knowledge practice dimensions\Mix appro	Causality	Project influencing attribute dimension\Project team relations	Nodes	Nodes	→

Appendix 12 – How the primary, secondary, and inefficient project knowledge practices were recorded in Microsoft Excel.



	A	B	C	D	E	F	G	H	I	J	K
1	**Knowledge practices employed**										
2	**Approaches**	**Project knowledge practices**	**All attributing knowledge practices**		**As primary**	**As secondary**	**As inefficient**	**UKS06**		**THS01**	
3								*Codifiable type*		*Codifiable and un-codifiable type*	
4								Attributing knowledge practices	Identification	Attributing knowledge practices	Identification
5	**Codifiable**	External Knowledge Sources	NA	19	0	16	3			NA	Inefficient
6	**Approach**	Project Documentations	Past project files		3	9	0	Past project files	Secondary		
7			Project meeting files	1							
8			Model archiving	1							
9			Weekly project recap	1							
10			Lessons learned documents	1							
11		Standardisation	ISO BIM standards	2	8	16	1	ISO BIM standards	Primary		
12			Internal BIM standards	14				Internal BIM standards			
13			Internal BIM manuals	14				Internal BIM manuals			
14			British BIM standards	5							
15			BIM Execution Plan	5							
16			Information Delivery Plan	1							
17			BIM standards from clients	1							
18			BIM software manuals	3							
19			BIM guidelines	1							
20		Shared Knowledge Repository	Central BIM knowledge pool	3	7	5	0	Internal model library	Primary	Internal knowledge folder	Primary
21			Internal model library	2							
22			Internal intranet	1							
23			BIM cloud server	1							
24			BIM model library	1							
25			Storage function within a social	1							
26			Internal knowledge folder	1							
27			NA	2							
28	**Collective approach**	Assignment of Knowledge Management Personnel	NA	5	0	5	0	NA	Secondary		
29		Competences Assessment	BIM questionnaire	2	0	6	0				
30			BIM skills matrix	1							
31			Self-assessment form	1							
32			BIM survey	1							
33			NA	2							

Appendix 13 – An example of a BIM learning scenario created in NVivo qualitative analysis software.



Appendix 14 – Project-based learning mechanisms of BIM from UK07, UK11, and TH06.

UK07 – Project-based learning mechanism of BIM from UK07 contained Standardisation, Project review, Training & Workshop, and Knowledge team creation as major. It did not included any obsolete knowledge practice. Figure A- 1 displayed the learning mechanism.

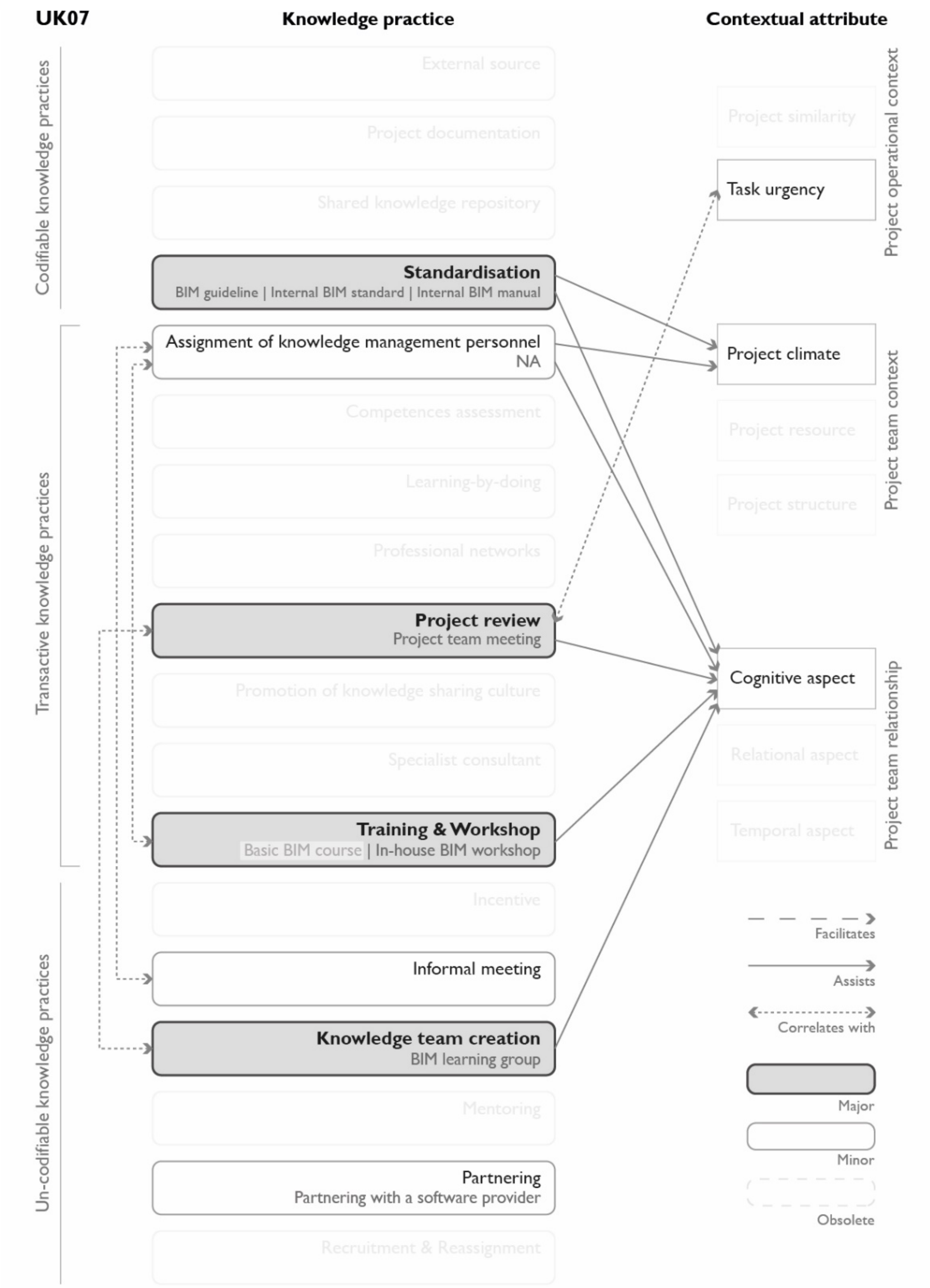


Figure A- 1: Project-based learning mechanism of BIM from UK07.

Standardisation within the project-based learning mechanism of BIM from UK07 contained instrumentalities of BIM guideline, Internal BIM standard, and Internal BIM manual. Standardisation was employed as a reference point for project actors to guarantee that works were carried out according to BIM level 2 standard. UK07 pointed, *"We have documents which summarise the way in which drawings, models, files, and layer structuring are set up. The also explain about how the structure of the model is organised and recorded … They are there to show the correct way, the correct method, and the correct information …"*. BIM guideline was utilised additionally as the roadmap for project actors to understand potential changes in BIM operation for upcoming projects. The knowledge practice assisted both Project climate and Cognitive aspect of project teams.

Project review assisted Cognitive aspect of project teams. UK07 implied that the knowledge practice was utilised to align BIM understanding between project teams. UK07 explained, *"I mean, as we start adopting it, different people would learn to do it in a different way. So, we need to get everyone back together from time to time to raise the knowledge of the team and the firm up."*. Project team meetings were regularly held in both small and large groups. UK07 added, *"With smaller group, it is more project by projects. We talk about how we organise things for each project and there might be a better way of doing things."*. Meeting sizes were influenced by project deadlines of each project actors. This presented how Project review was facilitated by Task urgency.

Training & Workshop contained two instrumentalities of Basic BIM course and In-house BIM workshop. Similar to UK04, Basic BIM course was highlighted as obsolete from the fact that knowledge learned were generic. In-house BIM workshop was a counter measure to Basic BIM course. BIM managers would be gathering problems found and would host workshops specifically on such complications. In-house BIM workshop assisted Cognitive aspect by keeping tracks on performance of project actors, as well as new updates that can improve current operation.

Knowledge team creation entailed the creation of a BIM learning group. Project actors from different project teams were brought together to formulate an internal group to help with BIM-related knowledge distribution. UK07 described, *"… we have a BIM user group, where everyone working on BIM is on that email chain. We can feed back discussions, ask queries, and also hold events and workshops where they will update and discuss things on BIM."*. The knowledge practice correlated with Project review as significant discussions or findings from this group often led to Project review. Additionally, BIM-related knowledge from Project review were being regulated within this knowledge team. Knowledge team creation also assisted Cognitive aspect of project teams.

UK11 – Project-based learning mechanism of BIM from UK11 included Standardisation, Training & Workshop, and Informal meeting as major. UK11 did not underline any obsolete knowledge practice. Figure A- 2 presented the project-based learning mechanism of BIM from UK11.

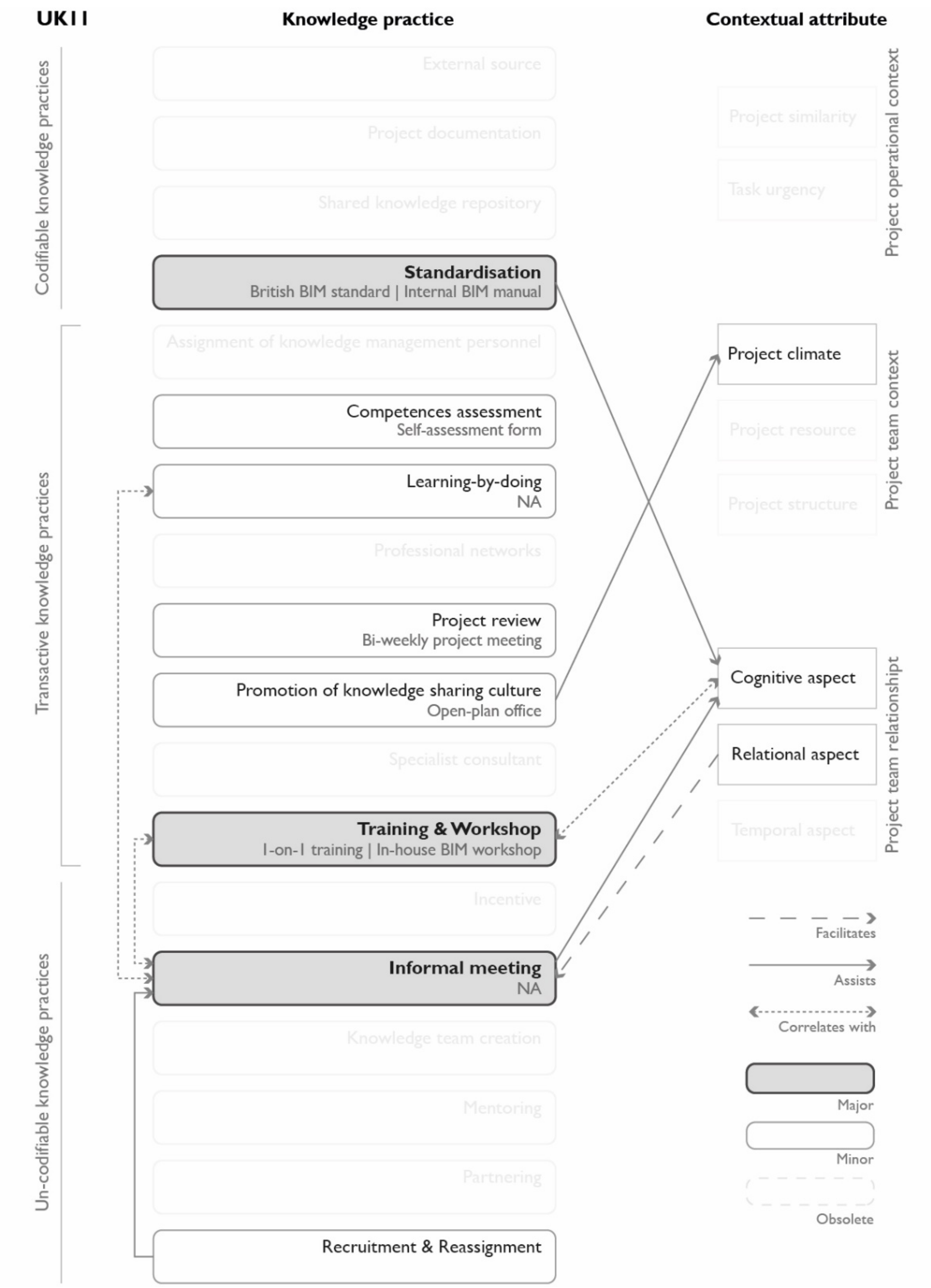


Figure A- 2: Project-based learning mechanism of BIM from UK11.

Standardisation of the project-based learning mechanism of BIM from UK11 entailed instrumentalities of British BIM standard and Internal BIM manual. While British BIM standard was utilised as a more formal BIM reference for project actors, Internal BIM manual was exercised to capture any emerged BIM knowledge. British BIM standard were used more often when BIM level 2 was required by clients. Standardisation was described to assist Cognitive aspect of project team members.

1-on-1 training and In-house BIM workshop were instrumentalities within Training & Workshop. In-house BIM workshops were employed from time to time to increase overall competence of project actors on new or useful features of BIM. 1-on-1 training was used more towards making sure that no one was left behind in BIM learning and adoption. UK11 explained, *"If I find anyone who is not good at it, it is better to spend a little bit more time and bring them up to speed, so everyone is on the same level."*. This correlated Training & Workshop to Learning-by-doing and Informal meeting. Working on real projects and informal communication were necessary for 1-on-1 training to be successful.

Informal meeting was exercised in relation to 1-on-1 training of Training & Workshop. The knowledge practice was facilitated by Relational aspect. UK11 provided, *"As referring to myself, we know the team quite well. So, it has been pretty good. Everybody knows that they can just come up to me and get advice."*.

TH06 – Project-based learning mechanism of BIM from TH06 entailed Shared knowledge repository, Training & Workshop, and Knowledge team creation as major. There was no obsolete knowledge practice. Figure A- 3 depicted the project-based learning mechanism of BIM from TH06.

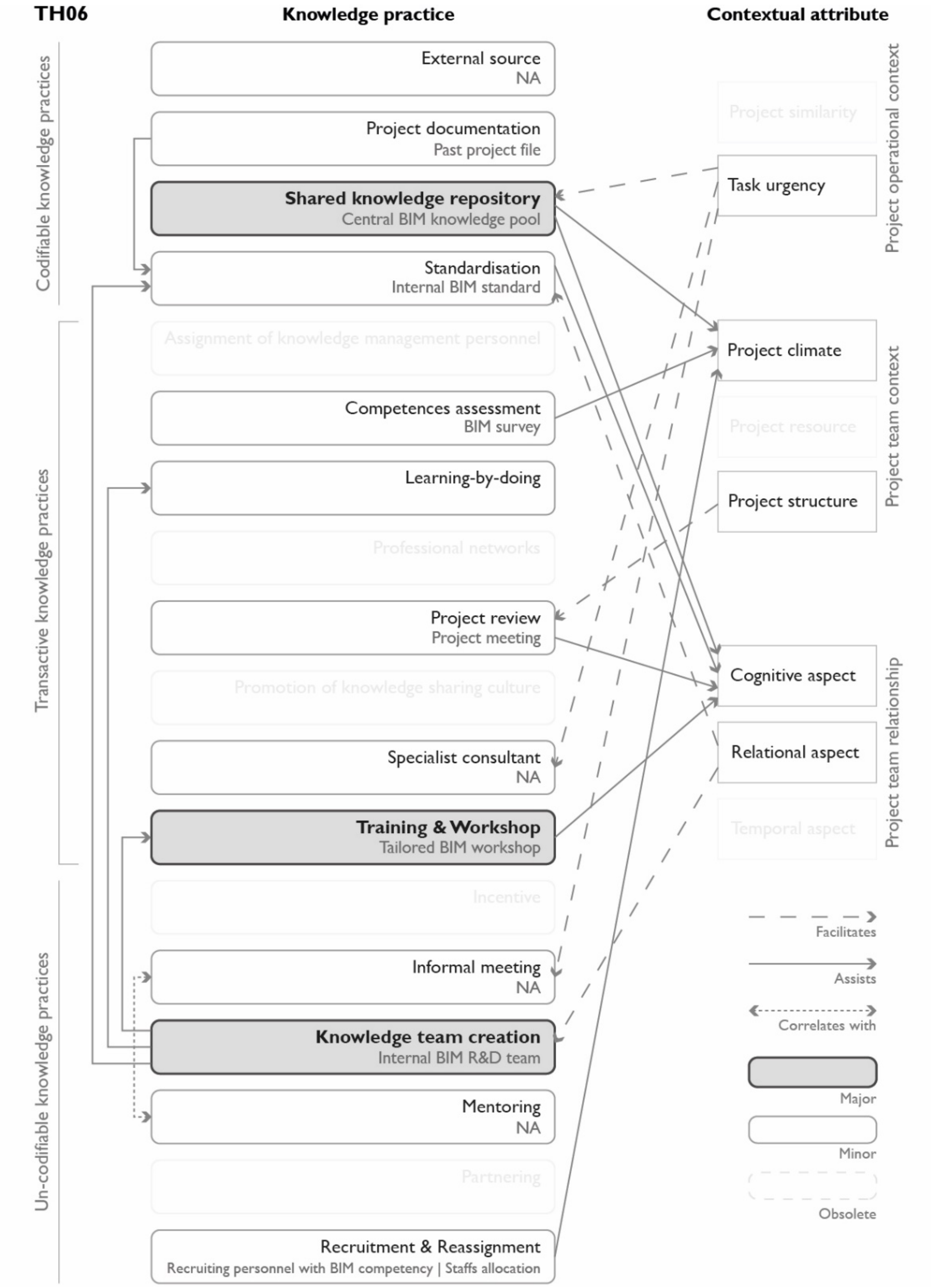


Figure A- 3: Project-based learning mechanism of BIM from TH06.

Central BIM knowledge pool was an instrumentality of Shared knowledge repository. The knowledge pool acted as the central folder for BIM-relate file and knowledge. TH06 elaborated, *"If we see something that are interesting or we see that they might be useful in the future projects, we will be throwing those in the folder so that everyone can access."*. The knowledge practice assisted both Project climate and Cognitive aspect in leveraging BIM understanding between project actors and setting up BIM learning environment. Shared knowledge repository was facilitated by Task urgency. TH06 described, *"If someone comes to us with a problem and none of us have time, we would be directing the person to this knowledge pool."*.

Training & Workshop contained an instrumentality of Tailored BIM workshop. TH06 described, *"At the start, training is number one priority of this office. This is because, not only that people will get to learn how to use BIM, but they will also learn the processes of working on BIM which I think is more important."*. The knowledge practice assisted Cognitive aspect of project teams. TH06 added, *"BIM is more of a process. They need to know and understand the process of BIM first so that they can navigate through it."*. Training & Workshop was assisted by Knowledge team creation.

Knowledge team creation included an instrumentality of Internal BIM R&D team. The organisation established its own team that is responsible for BIM learning and adoption in all projects. TH06 explained, *"Our R&D department would be helping us with what we learned and help us distribute that knowledge across."*. The team regularly hosted Tailored BIM workshop and assisted any project actors on their daily operation. This provided how Training & Workshop assisted Learning-by-doing knowledge practice.

Appendix 15 – Project-based learning mechanisms of BIM from TH01, TH02, and TH19.

TH01 – Project-based learning mechanism of BIM from TH01 (Figure A- 4) included Shared knowledge repository and Recruitment & Reassignment as major. TH01 underlined External source, Incentive, and an instrumentality of Training & Workshop as obsolete.

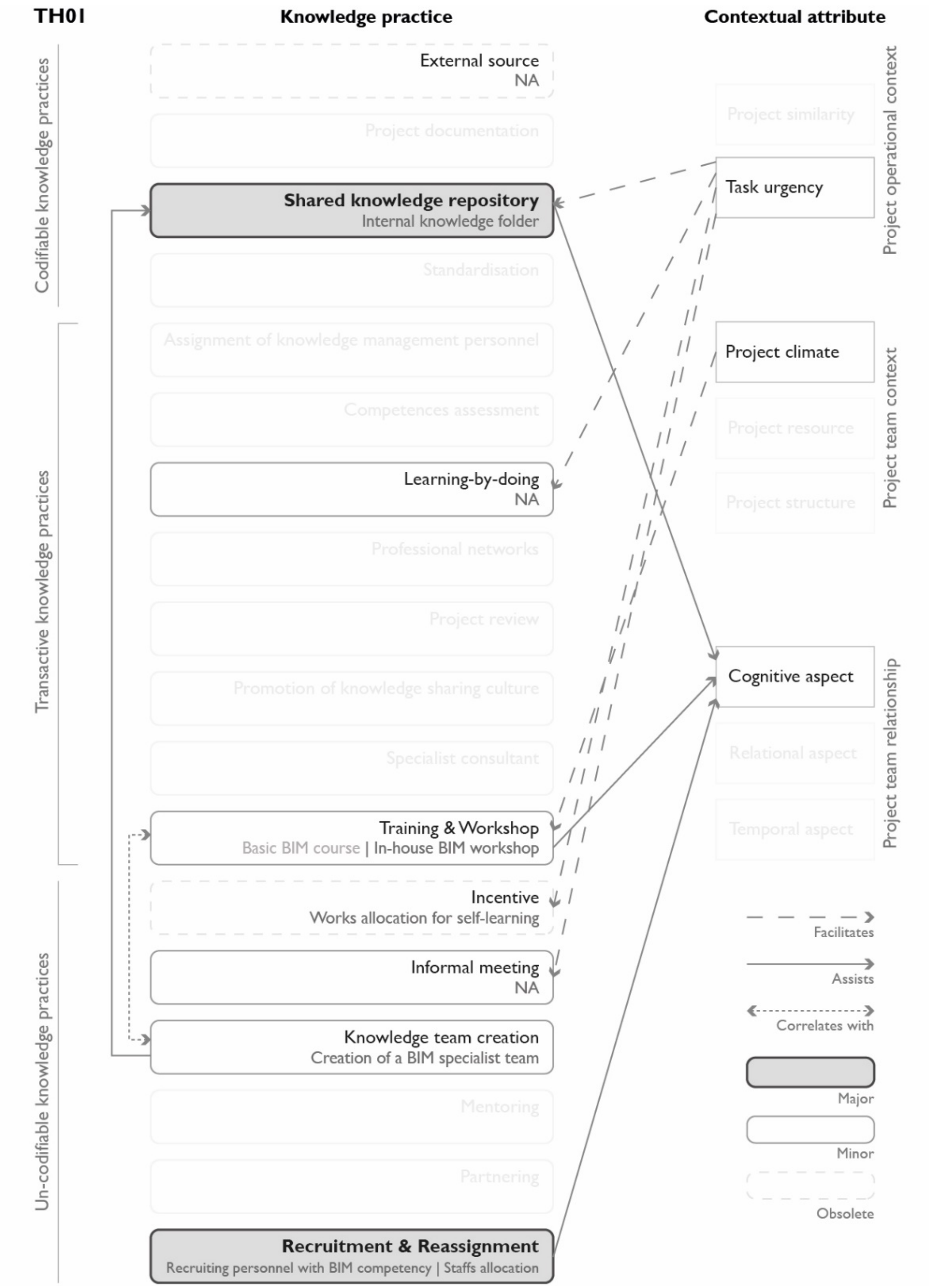


Figure A- 4: Project-based learning mechanism of BIM from TH01.

Shared knowledge repository was mentioned to include an instrumentality of Internal knowledge folder. It assisted Cognitive aspect of projects. TH01 explained, *"I think going through the firm's knowledge hub is actually the best. You make the effort to learn and that is obviously better ...".* The knowledge practice was assisted by Knowledge team creation. TH01 added, *"We used to have a BIM team, a special team that manage BIM centrally within ... this team was responsible to set up course and knowledge files within the firm so that others can access.".* Shared knowledge repository was reported to be facilitated by Task urgency. TH01 elaborated, *"If people have too much work to be done, or too many deadlines to meet, they won't have time to actually learn.".*

TH01 explained Recruitment & Reassignment to entailed instrumentalities of Recruiting personnel with BIM competence and Staffs allocation. The knowledge practice assisted Cognitive aspect. TH01 commented, *"Later, we started to source for new recruits that either can work on BIM or have potentials ... we were also looking for new recruits with an understanding that we need to change the way we work all the time … allocation of staffs is also effective, ... we allocation staffs based on the effectiveness of their works ...".*

External source was highlighted as obsolete due to the lack of English proficiency and the fact that online knowledge was not specific to works within the organisation. TH01 elaborated, *"We don't really search through an external knowledge sources anymore as the knowledge are not specific and that they are in English. Only 20% of staffs within the firm can actually understand English.".* Incentive was also labelled as obsolete. Project actors saw BIM as a mandatory part in their daily operation. Additionally, Basic BIM course, an instrumentality of Training & Workshop was mentioned as obsolete. Basic BIM course was introductory and was regarded as a significant change for project actors. It resulted in project actors leaving the organisation. TH01 concluded, *"From that, we did have a crisis moment where more than 10 staffs leave per month.".*

TH02 – Project-based learning mechanism of BIM from TH02 (Figure A- 5) entailed major knowledge practices of Project documentation, Knowledge team creation, and Mentoring. TH02 regarded External source as obsolete.

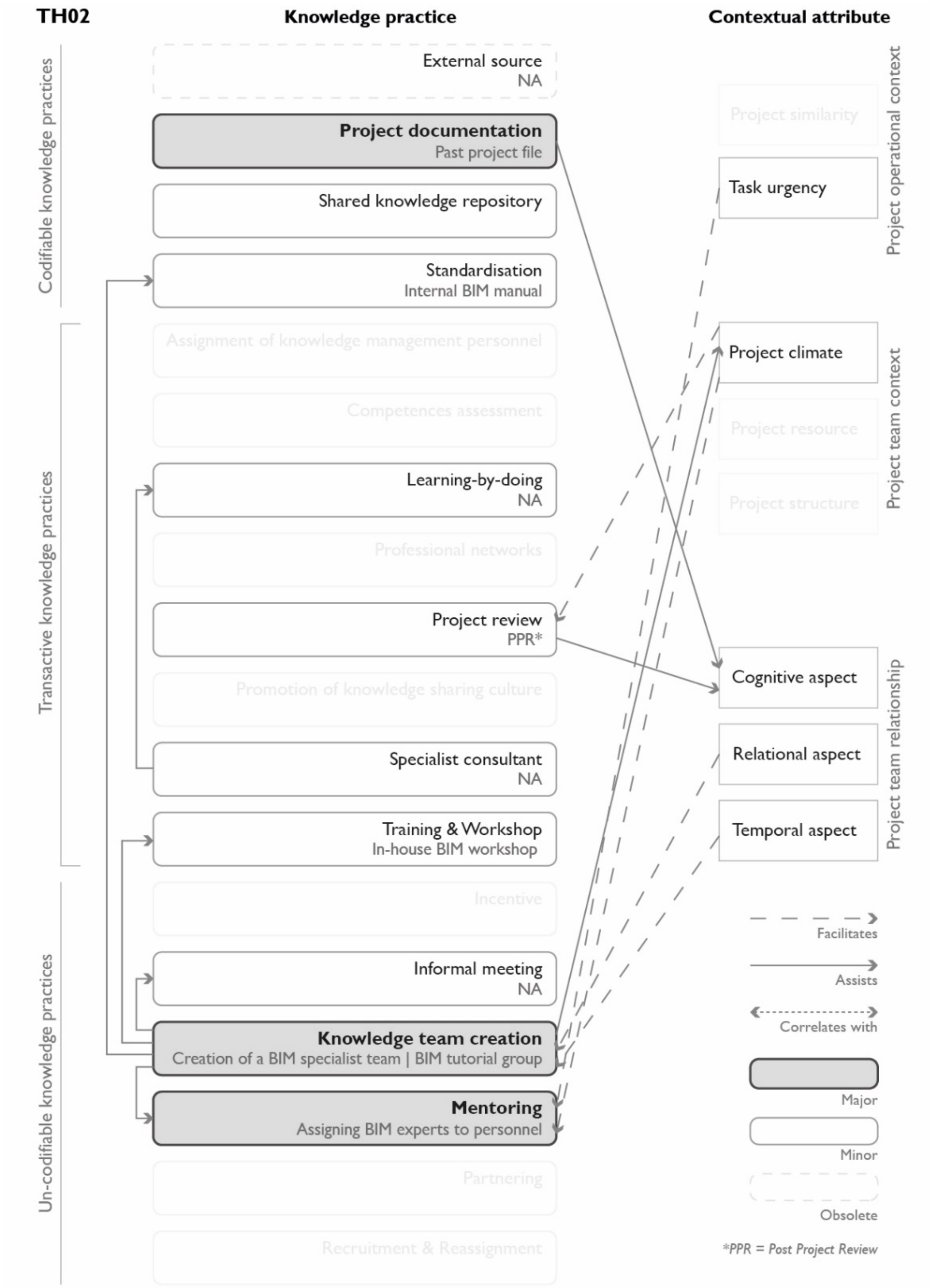


Figure A- 5: Project-based learning mechanism of BIM from TH02.

Knowledge team creation was described as the centre of attention. It was the key player that assisted Informal meeting, Training & Workshop, and Standardisation. TH02 provided, *'We have a specific team who are BIM specialists within the firm that help us ... these people will be the one managing* *the manual ... they also go around helping people on a one-to-one basis and assist with ongoing projects.".* The knowledge practice assisted Project climate and facilitated by Relational and Temporal aspects. TH02 extended, *"... the fact that we have an in-house team. I mean, this team is like a backbone of the firm …, we are now so close personally, we discuss through all problems we usually have.".*

Project documentation assisted Cognitive aspect by leveraging understanding on BIM and BIM operation between project actors. Past project file was an instrumentality of this knowledge practice. TH02 explained, *"We also have project documents from other projects or previous ones that we can look up all the time ... people would be referring a lot to previous projects.".*

Mentoring was another major project knowledge practice. TH02 elaborated, *"... we, the architects were assigned a mentor where if we have problems, he or she would be our go-to person ... we either come up to him in the office or the person would just come to us.".* It was facilitated by Task urgency and Project climate. Going to their mentors was the most convenient solution for project actors under deadline pressures. TH02 pointed, *"Especially if I have problem and there is a deadline as well. Going to my mentor is way faster than searching for it online or going through internal documents.".*

Similar to TH01, External source was referred to as obsolete. This was mainly due to the lack of English proficiency in project actors. TH02 explained, *"I think for people whose English is not so good is a bit too hard. When you go to these forums, they are all in English. That means you need a certain level of English proficiency ...".*

TH19 – Project-based learning mechanism of BIM from TH19 placed Shared knowledge repository, Standardisation, and Mentoring as major. There was no obsolete knowledge practice. Figure A- 6 illustrated the project-based learning mechanism of BIM from TH19.

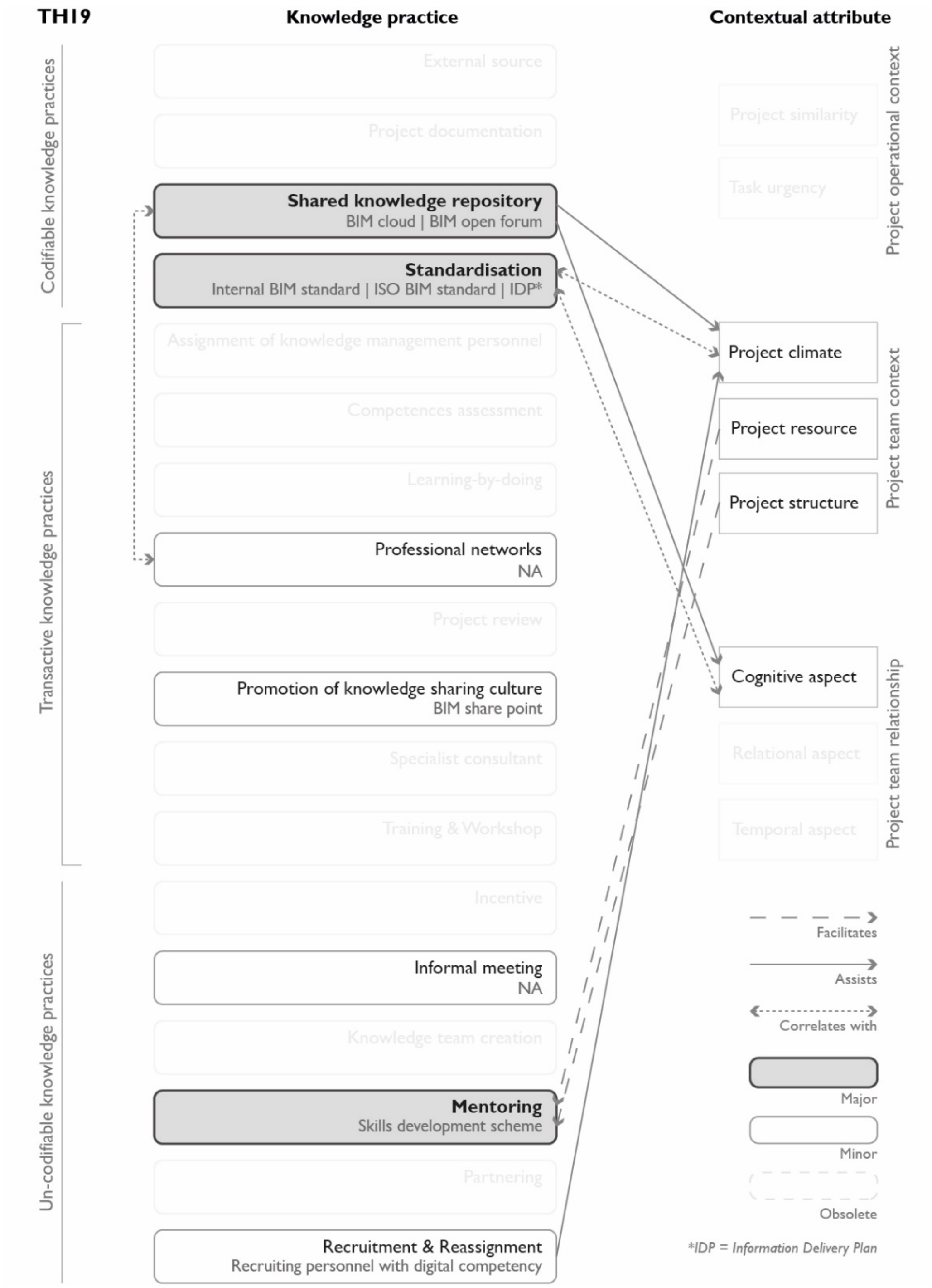


Figure A- 6: Project-based learning mechanism of BIM from TH19.

Shared knowledge repository was exercised to assist Project climate and Cognitive aspect. BIM cloud and BIM open forum were instrumentalities employed to formulate BIM learning environment for project actors, as well as to leverage BIM understanding. For the prior mode, TH19 explained, *"The BIM models, issues, problems, revisions, problems, and everything can be found on our server ... it is a cloud digital space that everyone can look up things and participate in discussion."*. For the latter, TH19 described, *"We are now establishing an open forum that contains video tutorials for certain part of the works ... Anyone in the office can enter that ... we would be tracking the process as well. Every year, we have an evaluation to see what people have looked into. This practice sets a learning environment of the whole firm."*. Shared knowledge repository correlated with Professional networks. BIM specialists from outside the organisation were regularly invited to join and share BIM-related knowledge through BIM cloud and BIM open forum.

Standardisation was utilised as the organisation often took on international projects. TH19 explained, *"We have a very strong standard derived from the Australian BIM standards. Again, it was because we work on so many Australian projects ... it is a bar that everyone has to work up to."*. This became the Internal BIM standard and later resulted in the employment of ISO BIM standard. IDP was also used in explaining project actors of how to operate within standards. This knowledge practice was highlighted to correlated with Project climate and Cognitive aspect. It provided a framework of understanding and operating on BIM for project actors.

Mentoring was necessary for new recruits. TH19 described, *"This is for new recruits though. When someone new join the firm, we would assign someone to be with that person to supervise and teach that person of how things are done, to how to work on BIM."*. It was facilitated by Project structure and Project resource. Senior project actors would be supervisors, while the organisation would invest in updating resources such as BIM software to allow teaching to be more convenient.

Appendix 16 – Project-based learning mechanisms of BIM from UK02, UK12, and TH10.

UK02 – Project-based learning mechanism of BIM from UK02 included Standardisation and Project review as major knowledge practices. Figure A- 7 displayed the project-based learning mechanism of BIM from UK02.

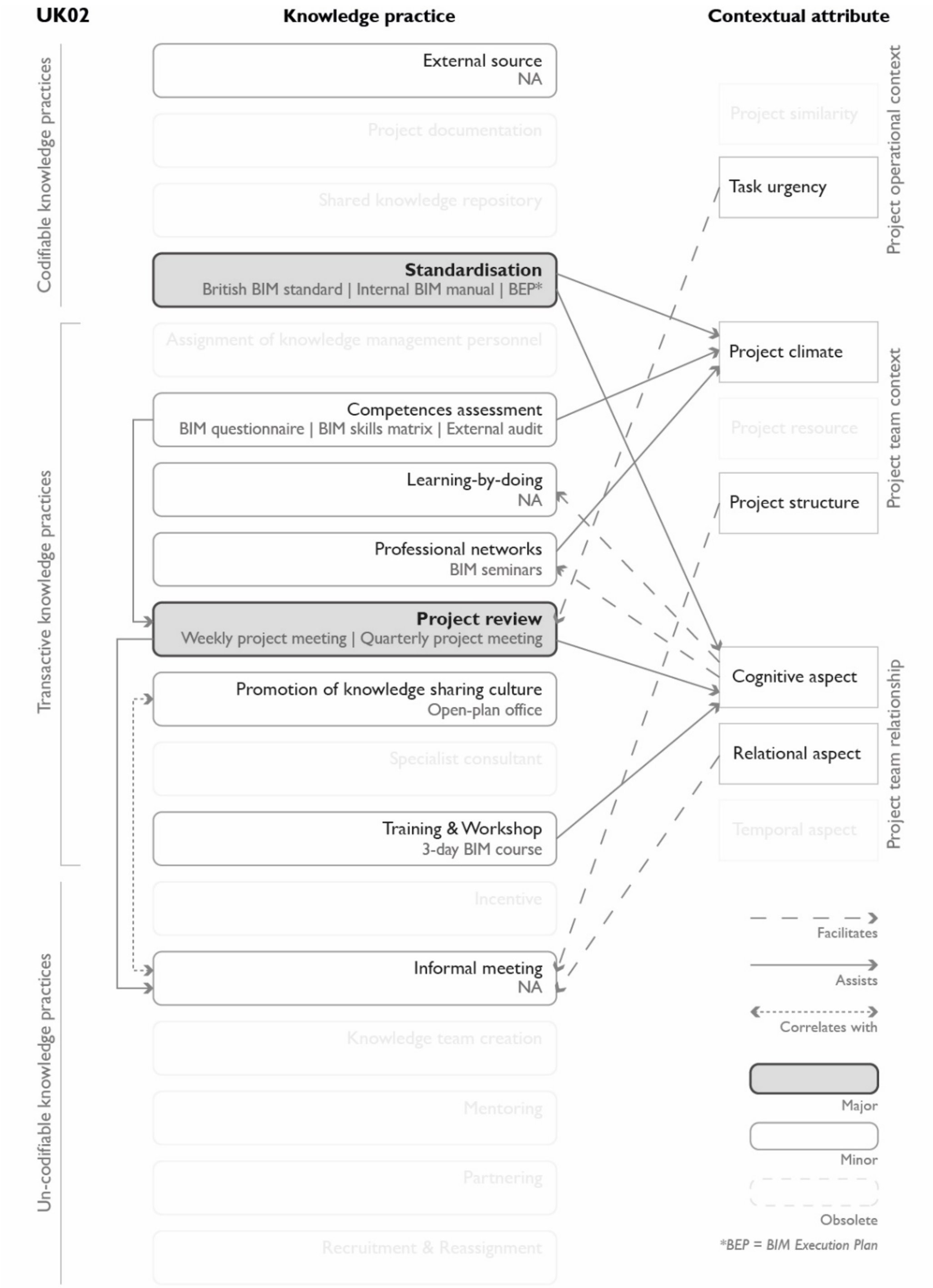


Figure A- 7: Project-based learning mechanism of BIM from UK02.

Standardisation was regarded as the most important knowledge practice. This was due to the fact that the organisation had received BIM level 2 accreditation. British BIM standard, Internal BIM manual, and BIM Execution Plan (BEP) were instrumentalities of Standardisation. They assisted directly to both Project climate and Cognitive aspect by formulating a BIM-based environment and leveraging BIM understanding amongst project actors. With British BIM standard, UK02 explained, *"…, there are actually 9 different sets of documentation to comply with to technically be a level 2 project … it is a standardised information, structured, classified, and everything."*. Internal BIM manual and BEP performed as best practice documents that explain and clarify BIM operation within projects and an organisation. This included from file naming, setting up templates, version of BIM software, to how project actors should communicate with others. UK02 commented, *"The aim here was to, if for example, you didn't know how to use BIM and you try to set up a project and there was no one else around. Technically, this gives context."*.

Project review included instrumentalities of Weekly project meeting and Quarterly project meeting. Weekly project meeting was referred to by the interviewee as the 'Brown bag session'. UK02 described that it was *"… the American phrase meaning for lunch time sort of session … someone might be researching or done something interesting, and we encourage them to just sort of, … present the findings."*. It was a mean to ensure that essential knowledge is regularly shared informally between project actors. Quarterly project meeting was described as a more formal mode, where knowledge shared is systematically presented and documented. Project review assisted Cognitive aspect of projects and was facilitated by Task urgency. While it set up a BIM learning environment for project actors, it was often pressured from project deadlines. UK02 extended, *"…, the difficult thing to balance is that, there are so much stuffs happening, … often me and people just don't have enough time to prepare."*.

UK12 – Project-based learning mechanism of BIM from UK12 possessed Project documentation, Project review, and Specialist consultant as major. UK12 regarded Training & Workshop as obsolete. Figure A- 8 illustrated the project-based learning mechanism of BIM from UK12.

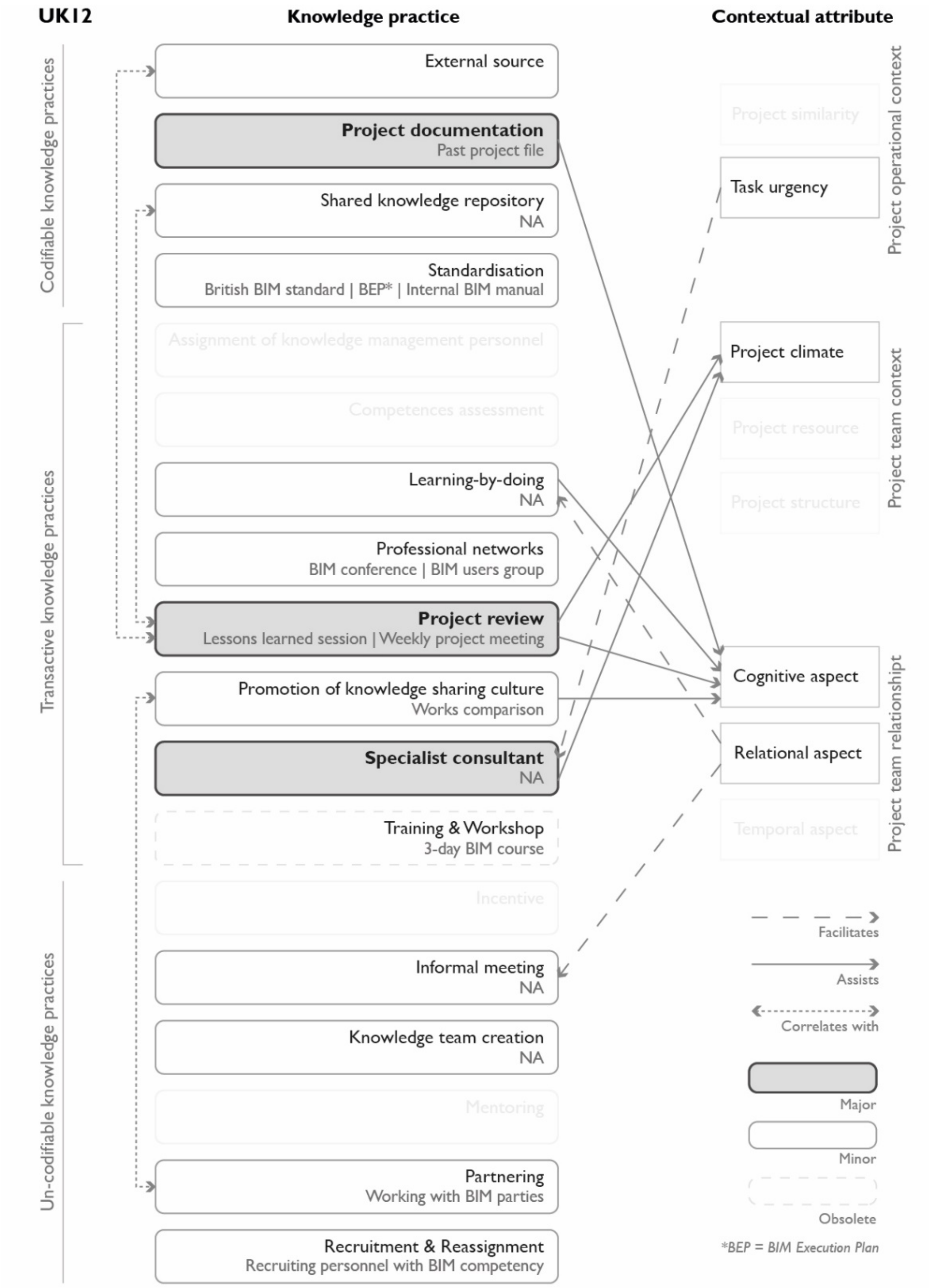


Figure A- 8: Project-based learning mechanism of BIM from UK12.

Differently from other BIM level 2 accredited organisations such as the organisations of UK02 and UK04, the organisation of UK12 utilised Project documentation as the major knowledge practice instead of Standardisation from the Codifiable knowledge practice landscape. UK12 provided that it was because the project team started their BIM journey in the middle of a project lifecycle. Therefore, they were learning BIM through Past project file provided by other organisations. UK12 added, *"It was quite useful to see how they set up how they set up things and how they detail things … it taught us loads of things, even little things such as setting up templates or creating a family and share things."*.

Project review was mandatory in setting up BIM atmosphere and managing BIM understanding amongst project actors. Lessons learned session and Weekly project meeting were mentioned as instrumentalities of Project review. With Weekly project meeting, UK12 elaborated, *"If there are new regulations, now with the ISO, we send an email around, do presentation, and get the documents out on the coffee table so that people can gather around and have a look at it."*. Referring to the sharing of BIM understanding amongst project actors through Lessons learned session, UK12 added, *"…, some people are focusing on some certain areas. They would go through courses and look up things online. They later share that around the office. These sessions are for people to take ownership of BIM."* The knowledge practice correlated with Shared knowledge repository. Shared knowledge repository was exercised to store all BIM-related knowledge discussed from Project review. UK12 extended, *"…, all this knowledge is also kept within the office so anyone can come back to that information."*.

Specialist consultant was employed to review on-going BIM project files and answer any concerns in working on BIM. It was facilitated by Task urgency as the project team was entering a BIM project in the middle of its lifecycle. UK12 explained, *"In the beginning we have the external consultancy coming in to look at our model and how we are doing it … we had an agreement with the external consultant and so we could pick up the phone and ask them."*. Having a BIM specialist on stand-by eased any frustration and resistant to change for project actors. This presented how the utilisation of Specialist consultant assisted Project climate.

Training & Workshop was identified as obsolete. With 3-day BIM course, it was inefficient as project actors were not able to apply most knowledge learned immediately on a practical setting. UK12 commented, *"So, everyone in the office went to a 3-day course runs by an external consultant …, but it was useless if you don't use them right away."* Another BIM specialist was appointed instead for consultation, rather than providing a BIM course.

TH10 – Project-based learning mechanism of BIM from TH10 incorporated Standardisation as the only major knowledge practice. Figure A-9 presented the project-based learning mechanism of BIM from TH10.

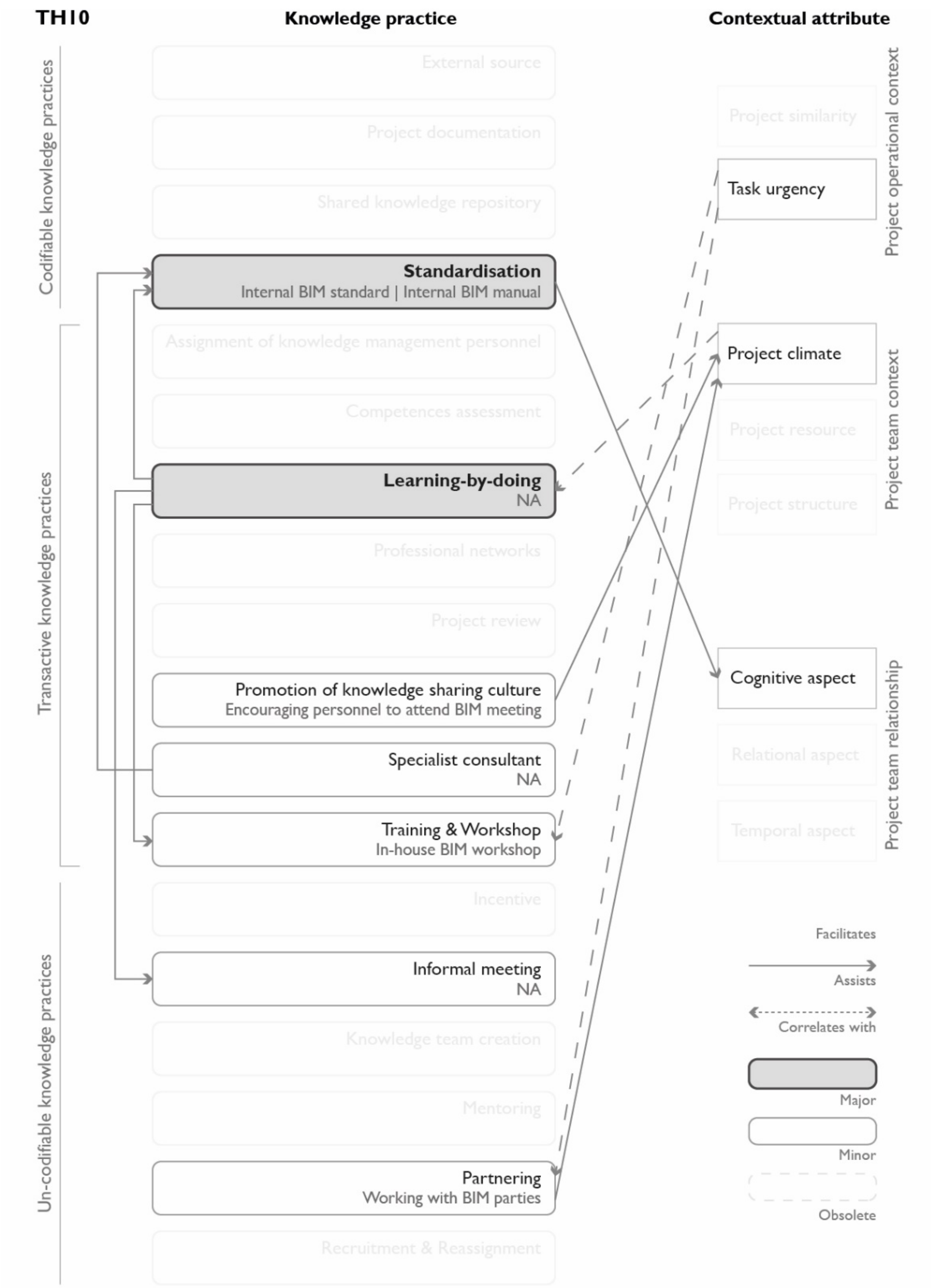


Figure A- 9: Project-based learning mechanism of BIM from TH10.

Standardisation included instrumentalities of Internal BIM standard and Internal BIM manual. Both instrumentalities internally developed within the organisation. This was due to how most publicly available BIM knowledge was in English and was too complicated for project actors to comprehend. TH10 stated, *"I ended up making my own videos and manuals teaching my team how to go through specific tasks and problems."*. Standardisation was crucial in assisting Cognitive aspect of project teams as it was described as the main reference point for BIM operation. It was also constantly updated. The interviewee added, *"The manuals are being updated all the time after each project ended. This is to make sure that the knowledge is captured, and that people can learn from what they and the others have done."*.

Learning-by-doing was evaluated as the most significant project knowledge practice within this learning mechanism. However, similar to UK04, it would not be substantial if not utilised together with Standardisation. The interviewee added that Learning-by-doing was also assisted by Training & Workshop and Informal meeting. Immediately, BIM managers would be assisting project actors through problems by sitting together and going through such complications together. BIM managers would also gathered problems found and articulated solutions to all project actors through Training & Workshop. TH10 added, *"I usually set up a day within a week, saying that hey, today is for internal learning and workshop of BIM and tomorrow is for working on actual projects."*

Appendix 17 – Project-based learning mechanism of BIM from UK01 and TH03

UK01 – Project-based learning mechanism of BIM from UK01 included Learning-by-doing and Project review as major knowledge practices. External source and Training & Workshop were obsolete. Figure 4.5 presented the project-based learning mechanism of BIM from UK01.

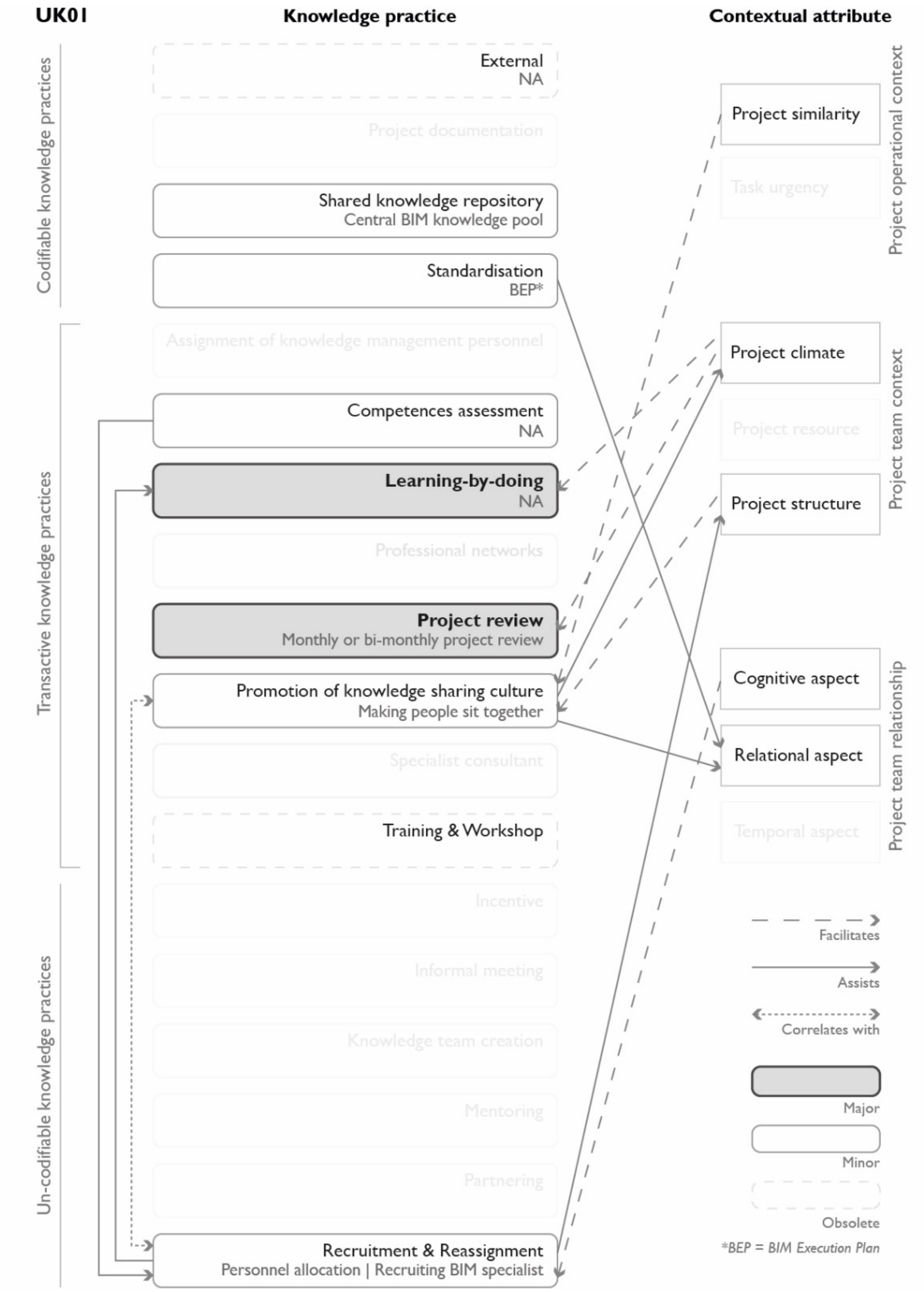


Figure 4.1: Project-based learning mechanism of BIM from UK01.

Learning-by-doing was perceived as the most significant knowledge practice within the project-based learning mechanism of BIM from UK01. UK01 explained, *"However, coming back to that of how BIM knowledge is learned, I believe that 70% of that happens on the job."*. Learning-by-doing was assisted by Recruitment & Reassignment as project actors must be allocated to ensure that everyone is learning different aspects of BIM. The knowledge practice was facilitated by Project climate. The interviewee added that because the organisation contained a no blame culture, it was easier for project actors to learn BIM on actual projects. They were allowed to make mistakes. Project climate also facilitated Project review, another major knowledge practice.

Project review contained an instrumentality of knowledge practice of Monthly or bi-monthly project review. Project review was important for project actors in gaining BIM-related knowledge from other projects within the organisation. UK01 elaborated, *"I think it is a good exercise as well to help you refine what you learned and let other knows what you have learned as well."*.

External sources was regarded as obsolete as it relied too much on interests of project actors to pursue BIM on their own accords. With Training & Workshop, UK01 highlighted that the knowledge learned were not practical to be used on actual projects. UK01 added, *"Classrooms have that particular function where you get a whole classroom of people together, and you get them really excited. They will learn very little and what they learn they will forget tomorrow."*.

TH03 – Project-based learning mechanism of BIM from TH03 contained Specialist consultant as the only major knowledge practice. TH03 identified Training & Workshop as obsolete. Figure A- 10 illustrated the project-based learning mechanism of BIM from TH03.

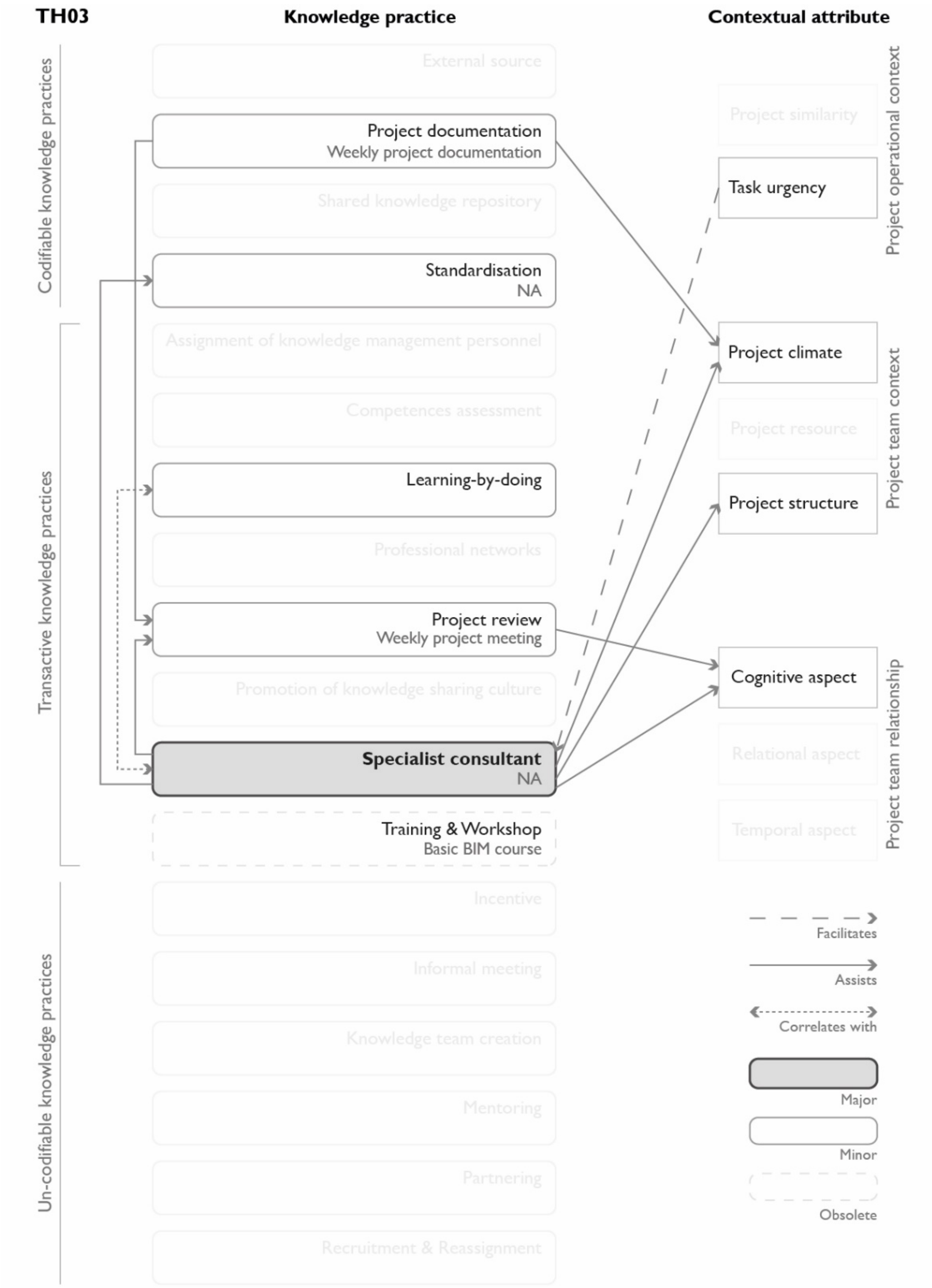


Figure A- 10: Project-based learning mechanism of BIM from TH03.

Specialist consultant assisted Project climate, Project structure, and Cognitive aspect. BIM specialist team was appointed to assist in every step of BIM adoption. TH03 explained, *'We learned mainly from the external BIM consultant. Since it was really bizarre then. We appointed them to help* *us with modelling, managing the system for BIM, sitting with us to work, and teach us on-the-go. So, they would be sitting right next to us and if we have problems, they would be teaching us immediately.".* TH03 described Specialist consultant as correlated with Learning-by-doing and assisted Standardisation and Project review. It was facilitated by Task urgency. The degree of interaction between project team members and the consultant organisation depended on the project deadlines. Additionally, TH03 added that the project knowledge practice was only significant in the short run. TH03 furthered, *"However, this spoiled us a bit. We, in the end, overlooked the documents in which we have to follow. We relied so much on the external consultant … to be honest, we still don't know what to do once we are not working with this consultant anymore.".*

Training & Workshop in the project-based learning mechanism of BIM from TH03 contain an instrumentality of Basic BIM course. It was described as obsolete by TH03 mainly due to the fact that BIM-related knowledge being taught within the course was too generic to be applied in a practical setting. Specialist consultant was perceived as being more effective.

Appendix 18 – Project-based learning mechanism of BIM from UK03, UK05, UK09, UK10, TH07, TH09, TH13, TH14, and TH16.

UK03 – Project-based learning mechanism of BIM from UK03 regarded Project review and Informal meeting as major. UK03 did not identify any obsolete knowledge practice. Figure A-11 illustrated the project-based learning mechanism of BIM from UK03.

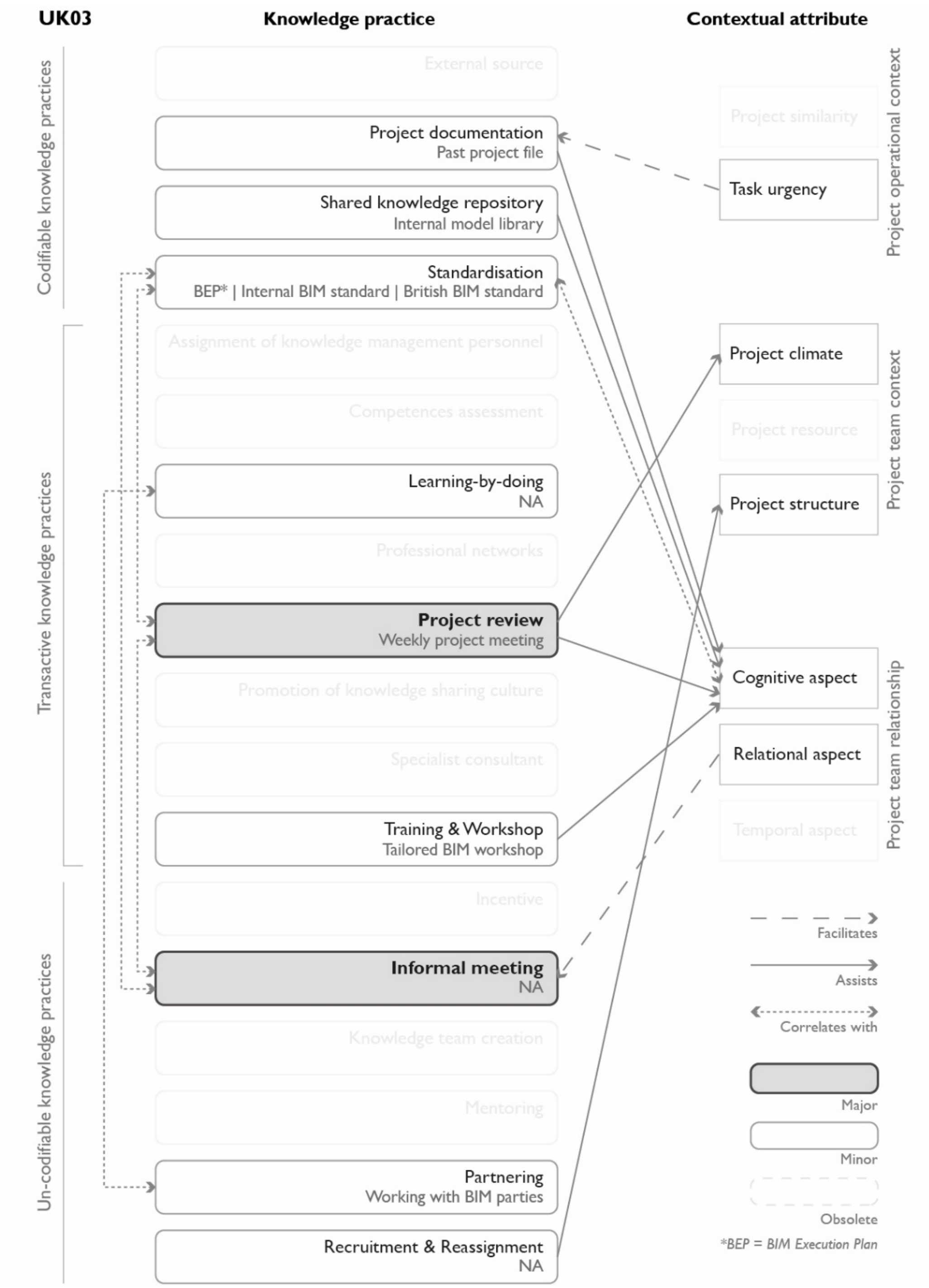


Figure A- 11: UK03 project-based learning mechanism of BIM.

Project review was described to contain an instrumentality of Weekly project meeting. UK03 referred to this as *Happy Friday*. Project team members would be coming together every Friday to review projects together. UK03 added, *"Because we have so many options that at some point, someone forgot to do something. It is always good to review that and create a list and go back to the team and say, so these are items that are not current because of this and that. It is for everyone to learn."*. This knowledge practice assisted both Project climate and Cognitive aspect as it helped in forming a BIM learning environment and leveraging BIM understanding amongst project actors.

Informal meeting correlated with Project review. BIM managers were relying on this knowledge practice to make sure that discussions from Project review were implemented in projects. BIM managers would be coming over and talk to project actors after each Project review to make sure that implementation is at ease for inexperience project actors. UK03 commented, *"…, if we have someone who is not so familiar with BIM, I or someone more experienced will spend more time explaining … from one person to another, we learn more if we discuss more, so we can decide the new way of working."* Informal meeting was facilitated by Relational aspect as informal communication could not be done without good relationship between project team members. Informal meeting and Project review were described to be correlated with Standardisation. As the organisation was aiming for BIM level 2 accreditation, UK03 was hoping that knowledge emerged from these knowledge practices could be applied to perfect standard of the organisation.

UK05 – Project-based learning mechanism of BIM from UK05 entailed Project review and Informal meeting as major. The learning mechanism did not contain obsolete knowledge practice. Figure A- 12 displayed the project-based learning mechanism of BIM from UK05.

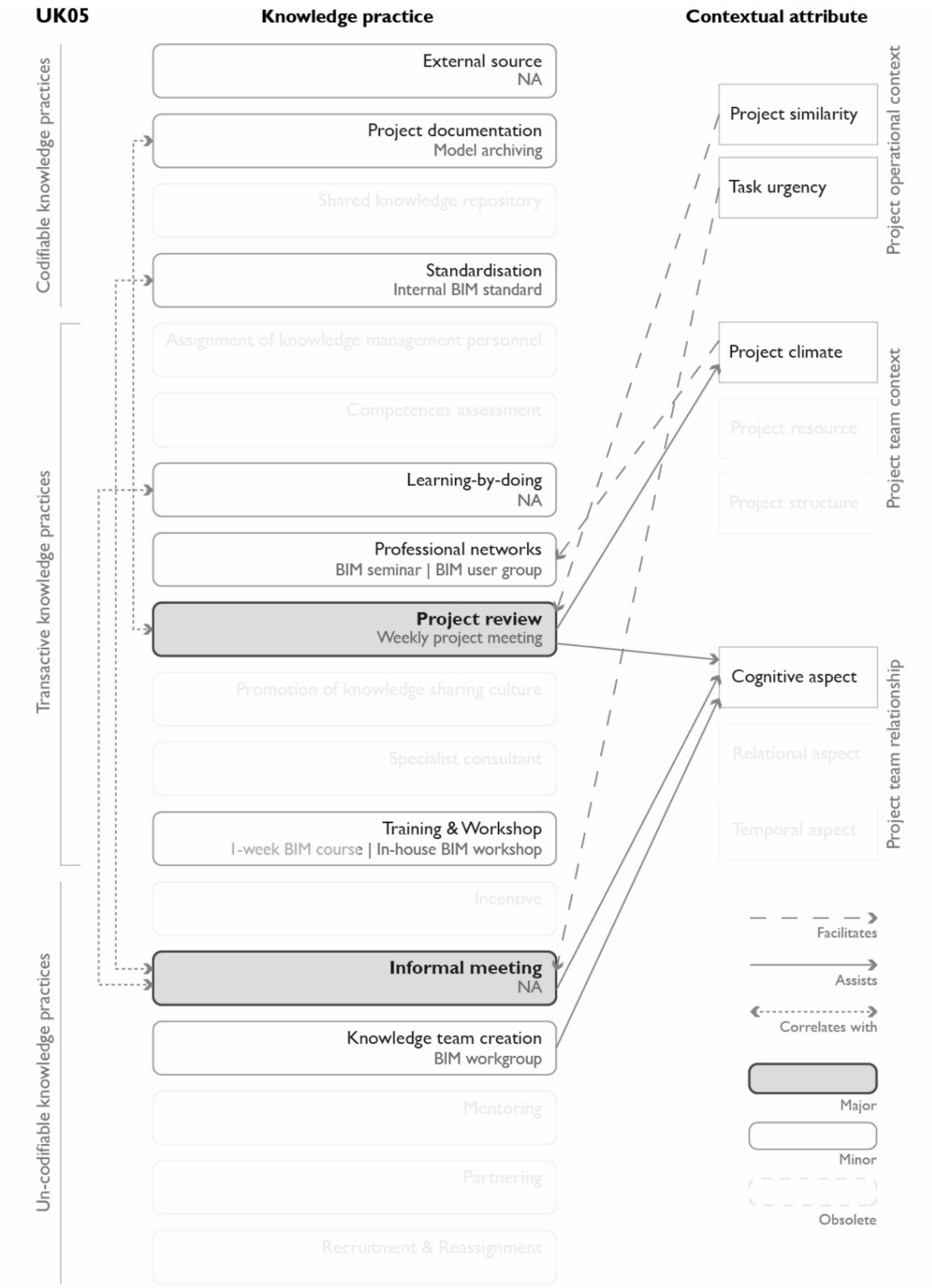


Figure A- 12: Project-based learning mechanism of BIM from UK05.

Project review was mentioned to assisted both Project climate and Cognitive aspect. Similar to UK03, Project review contained an instrumentality of Weekly project meeting. This was scheduled for every Monday, where project actors would be going through what had been done together. UK05 explained, *"… we update the whole team on progresses of every project … if someone sees something on my screen and wonder how to do that, or if I found something interesting, I will show them of how I deal with this problem."*. It helped guided project actors in working towards the same direction and with an equal level of understanding. The knowledge practice was facilitated by Project similarity. UK05 added, *"Often, we find ourselves, especially in small residential projects that we keep coming up with the same problem again and again. Having this discussion help us talk about it and realise that maybe someone else dealt with that issue last week."*. It correlated with Project documentation as every meeting was recorded and stored for future reference.

Informal meeting correlated with Standardisation and Learning-by-doing. With the organisation being small, BIM managers would be coming over and going through problems emerged together. The knowledge practice was described to be facilitated by Task urgency. UK05 commented, *"I think it is because, I believe, we allow enough time in our programme to have the time to discuss and interrogate the design … Usually, if we have a deadline on Friday, works will be done by Wednesday …"*.

In addition, an instrumentality of knowledge practice of 1-week BIM course within Training & Workshop was underlined as obsolete. It was perceived to only cover basic knowledge of BIM, while BIM operation required a more specific BIM competence.

UK09 – Project-based learning mechanism of BIM from UK09 included Project review and Partnering as major knowledge practices. There was no obsolete knowledge practice. Figure A- 13 visualised the project-based learning mechanism of BIM from UK09.

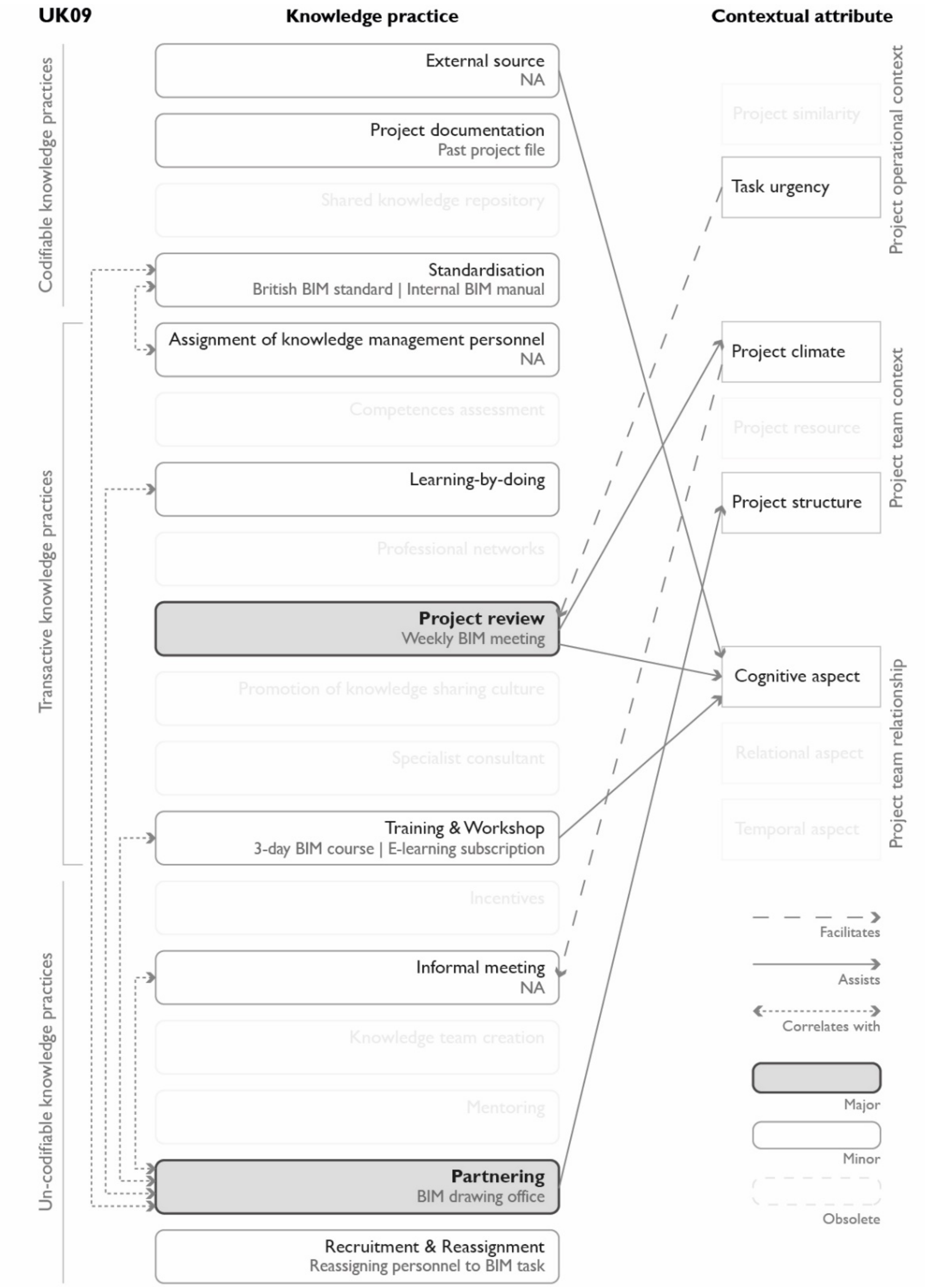


Figure A- 13: Project-based learning mechanism of BIM from UK09.

Project review was utilised so that project actors could go through several BIM problems all together at once. UK09 elaborated, *"There were sessions where one of our associates, who is really good with BIM, he demonstrate new things that has been found out on BIM, answer questions, or problems that* *anyone is having on anything. It was also kind of a forum for everyone to ask questions. To get everyone engaged with it.".* Project review contained an instrumentality of Weekly project meeting. It assisted to both Project climate and Cognitive aspect. It was facilitated by Task urgency. UK09 added that it was from deadline pressures. The interviewee extended, *"If people have issues, I mean, with projects running, it is really hard to have everyone coming in together at once.".*

Partnering was highlighted as the more significant of the two major knowledge practices within this learning mechanism. The organisation partnered with a BIM drawing office in Vietnam. The organisation would be sharing project works with the partnering organisation. The Partnering organisation would then assist with every step of BIM adoption, as well as sending project actors over to work in projects. Project actors from the Vietnamese organisation would be assisting the organisation in setting up BIM standards, arranging workshop, as well as going through BIM complications from projects. UK09 elaborated, *"With the Vietnamese partner, we got one of the staffs from the Vietnam office here and have her for a few months to help me get the project running as BIM projects … having her was brilliant. To have this kind of constant resource that can show us what to do if we are struggling with anything.".* The interviewee pointed further, *"I mean, our best person at BIM was obviously the best because he learned it from the job and from the Vietnamese girl as well.".* This showed how Partnering correlated with Standardisation, Learning-by-doing, Training & Workshop, and Informal meeting.

UK10 – Project-based learning mechanism of BIM from UK10 encompassed Project review, Specialist consultant, and Informal meeting as major knowledge practices. With no obsolete knowledge practice mentioned, the project-based learning mechanism of BIM from UK10 was visualised in Figure A- 14.

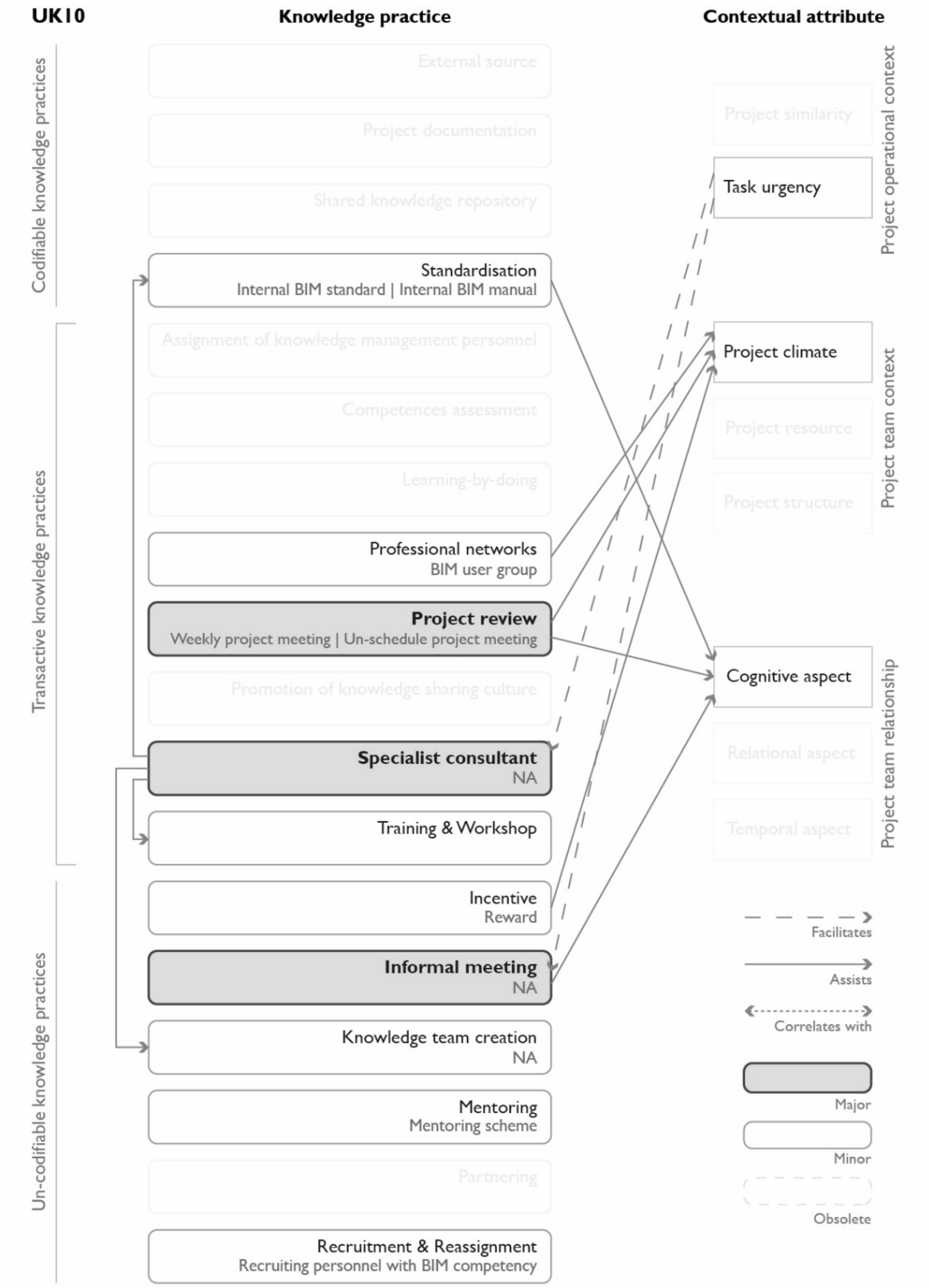


Figure A- 14: Project-based learning mechanism of BIM from UK10.

Project review entailed instrumentalities of Weekly project meeting and Un-scheduled project meeting. They were exercised to ensure that project actors were working with the same understanding and direction. UK10 explained, *"… we get some people around for couple of hours to go through of how something is done … this is not just a demonstration, but more of a collaboration of what are the best way to do this. People giving ideas and there we are trying to solve problems as we go."* The project knowledge practice assisted both Project climate and Cognitive aspect.

For Specialist consultant, a BIM specialist organisation was employed to help formulating BIM standard and manual, as well as fostering BIM development program for project team members. UK10 elaborated, *"…, we are employing an external consultant, but not someone just to come and do trainings, but a company who is going to come in and help us, basically pull together a set of templates, manuals, and resources from what we already have."* This showed how the knowledge practice assisted Standardisation, Training & Workshop, and Knowledge team creation.

Informal meeting assisted Cognitive aspect and was facilitated by Task urgency. UK10 described the importance of Informal meeting that, *"Sitting around demonstrating is more efficient of course since everyone is seeing it at the same time."* In relation to Task urgency, UK10 interviewee elaborated, *"…, but that means people will have to stop working for an hour and that is difficult to do because people have deadlines."*.

TH07 – Project-based learning mechanism of BIM from TH07 entailed Specialist consultant and Knowledge team creation as major. It did not contain any obsolete knowledge practice. Figure A- 15 illustrated the project-based learning mechanism of BIM from TH07.

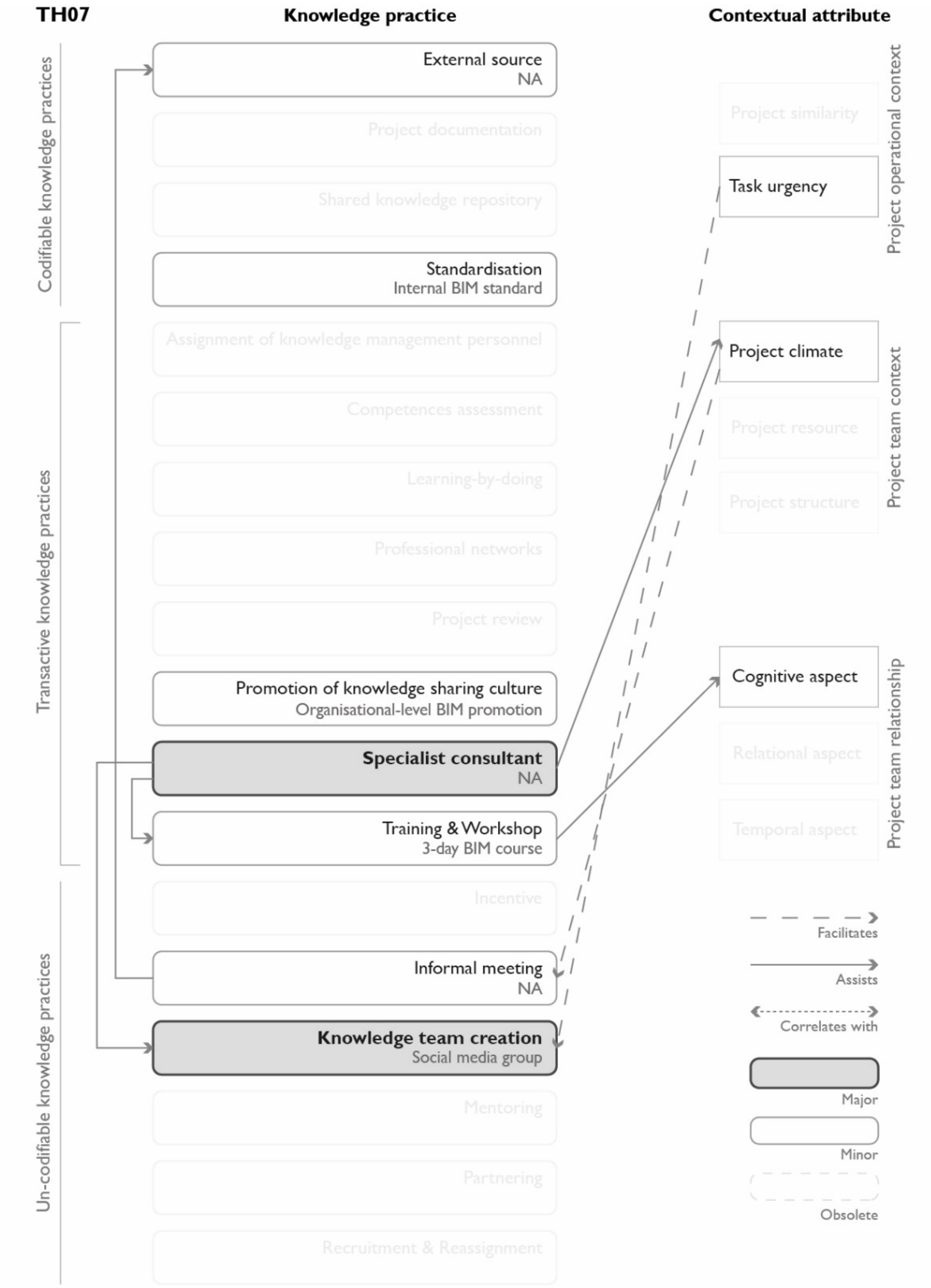


Figure A- 15: Project-based learning mechanism of BIM from TH07.

Specialist consultant was utilised to assist project actors on projects and to deal with any emerged BIM-related complications. This was similar to UK10, where BIM specialists would be sitting together with project actors in the project team. TH07 elaborated, *'I mean, having a* *person who is an expert here with us in every step is really effective … The instructor was working alongside everyone in the team on the same project. Everyone is then able to see and learn from how the instructors work on BIM and ask questions if had any."*. The knowledge practice directly assisted Project climate. TH07 added, *"This creates quite an atmosphere of learning that everyone is in it together and it doesn't matter if you have problems, others will be just right next to you and we can all work on it together."*. Additionally, it assisted Training & Workshop and Knowledge team creation. BIM specialists from Specialist consultant were hosting workshop for project actors, as well as managing the BIM-specific social media group.

With Knowledge team creation, a BIM-specific social media group was formulated and managed by BIM specialists. This group was tailored towards BIM discussions, where BIM-related problems would be answered immediately. TH07 commented, *"This allows us to go through every problem in real time … sometimes, we have problems we need answers around ten pm. The instructors still answer."*. This also implied how the knowledge practice was facilitated by Task urgency, specifically of project deadlines.

TH09 – Project-based learning mechanism of BIM from TH09 provided Training & Workshop, Informal meeting, and Knowledge team creation as major knowledge practices. TH09 did not locate any obsolete knowledge practices. Figure A- 16 presented the project-based learning mechanism of BIM from TH09.

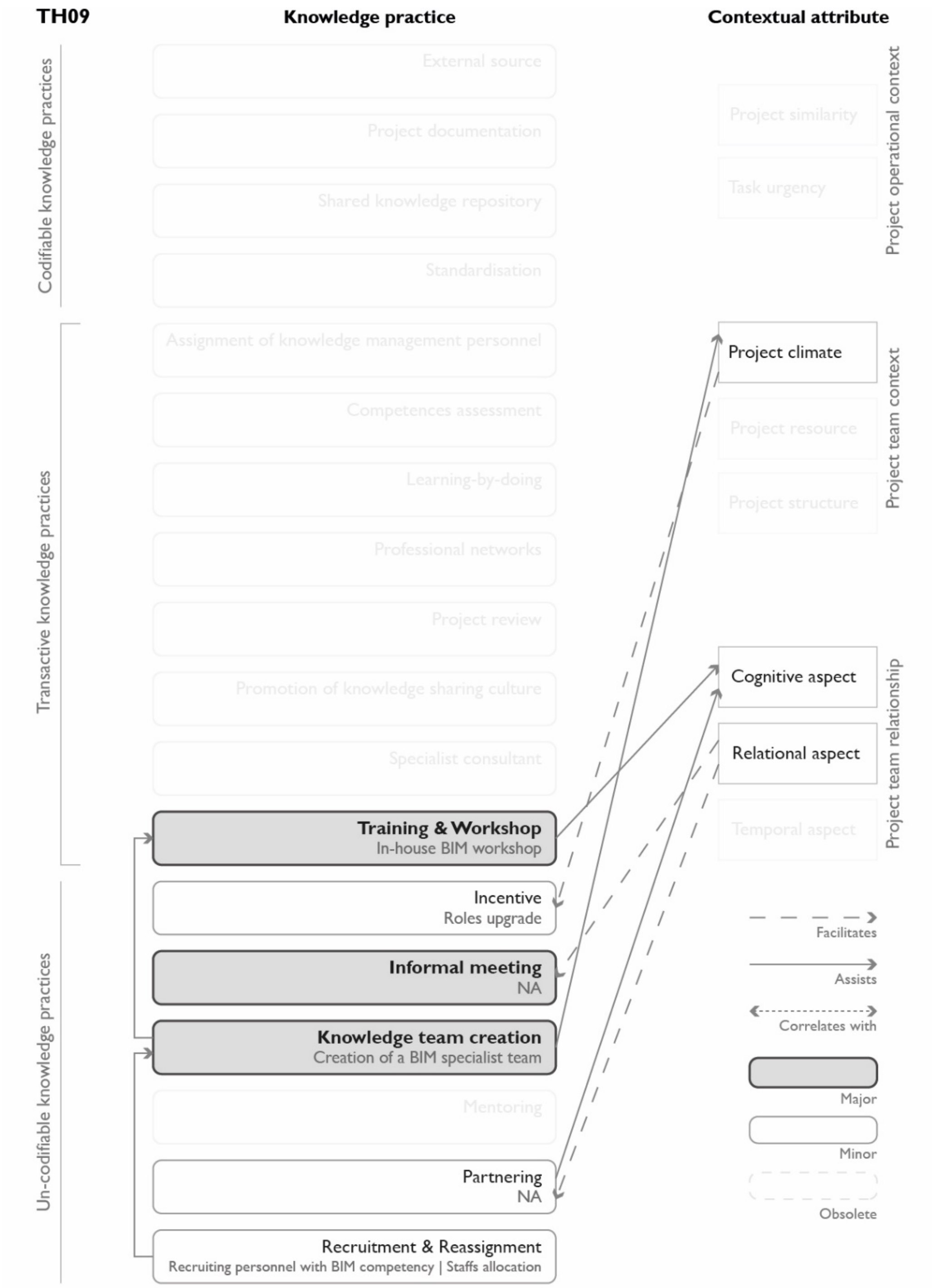


Figure A- 16: Project-based learning mechanism of BIM from TH09.

Training & Workshop contained an instrumentality of In-house BIM workshop. It was compulsory for project actors to go through two to three months of BIM training rotation hosted by the in-house BIM specialist team and the BIM manager. TH09 described, *"We set up the teaching ourselves. We divided trainings into different levels. We started with the director courses, followed by project engineer and project architect trainings. Now we are doing the operational level staffs."*. The knowledge practice was exercised to assist Cognitive aspect and was assisted by Knowledge team creation.

Informal meeting was considered as one of the major knowledge practices as a lot of BIM learning were done through informal conversation between project actors and the BIM manager. TH09 explained, *"…, we do teach everyone on the go. For example, if you have any questions or parts that you don't know how to do, you can just come to us and we will help you though."*. The knowledge practice was facilitated by Relational aspect. TH09 added, *"I mean, it is more comfortable to teach someone I am familiar with, rather than those that I don't really know or uncomfortable with."*.

For Knowledge team creation, a BIM specialist team was formed to handle BIM learning and implementation. The knowledge practice was assisted by Recruitment & Reassignment as the organisation recruited project actors with BIM competence to create this specialist team. With the BIM specialist team, TH09 commented, *"We set up the teaching ourselves. We divided trainings into different levels. We started with the director courses, followed by project engineer and project architect trainings. Now we are doing the operational level staffs."*. This presented how Knowledge team creation assisted Training & Workshop. It also assisted Project climate as the specialist team helped generate BIM learning environment in projects and the organisation.

TH13 – Project-based learning mechanism of BIM from TH13 entailed major knowledge practices of Specialist consultant and Informal meeting. It did not contain any obsolete knowledge practice. Figure A- 17 displayed the project-based learning mechanism of BIM from TH13.

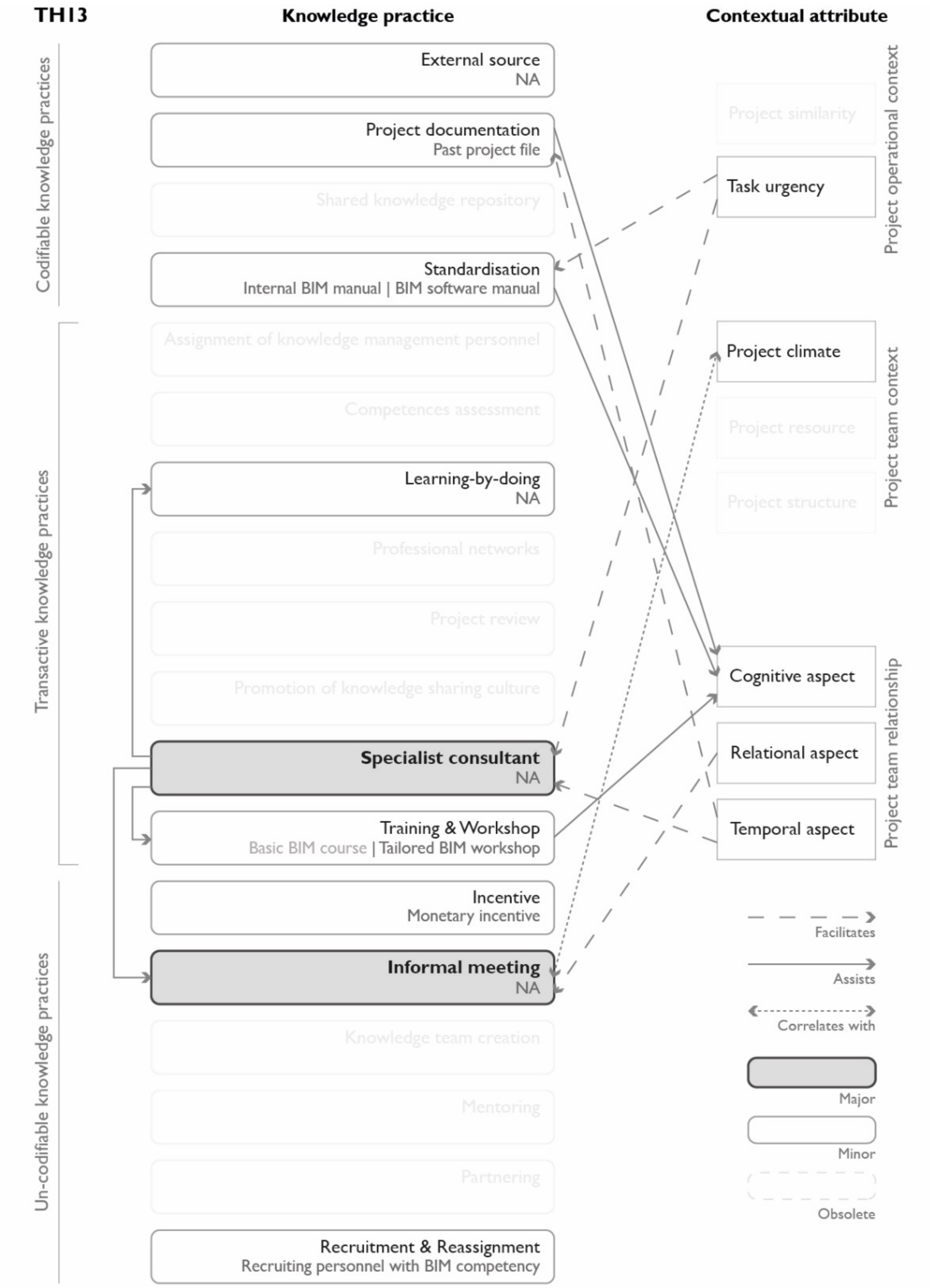


Figure A- 17: Project-based learning mechanism of BIM from TH13.

Similar to TH07, a BIM specialist organisation was hired to set up Training & Workshop, as well as to closely monitor BIM learning and adoption within projects. TH13 explained, "*So, we* *outsourced consultant company to help with modelling and making the BIM model ready to be delivered to clients. They also set up trainings for us as well.".* Specialist consultant was described to assist Informal meeting. TH13 commented, *"We would then send out staffs to sit right next to these people to work and learn directly from them.".* The knowledge practice was facilitated by Task urgency and Temporal aspect of project teams. It was due to project deadlines that the organisation decided to exercise Specialist consultant. Regarding the Temporal aspect, BIM specialists could only assist in some projects as each project contains different requirement and standard.

Informal meeting was necessary in comprehending immediate problems. When asked about how regular BIM problems were sorted, TH13 answered, *"Usually, by asking others within the team. We are at the point now where there is going to be someone here who knows how a specific problem can be solved.".* Informal meeting was facilitated by Relational aspect. TH13 extended, *"I think it was mainly from relationships between team members. The members in the team were very close to one another … Without proper supports from friends and colleagues, it is impossible to go through problems.".*

Basic BIM course within Training & Workshop was perceived as obsolete. This was due to the fact that it only provided generic BIM knowledge that was too complicated to be applied immediately on a practical setting. TH13 commented, *"I mean, going to training courses will give you basics. Those are just general skills. You can't really implement those on real projects.".*

TH14 – Project-based learning mechanism of BIM from TH14 included Informal meeting and Knowledge team creation as major knowledge practices. It did not entail any obsolete knowledge practice. Figure A- 18 provided the project-based learning mechanism of BIM from TH14.

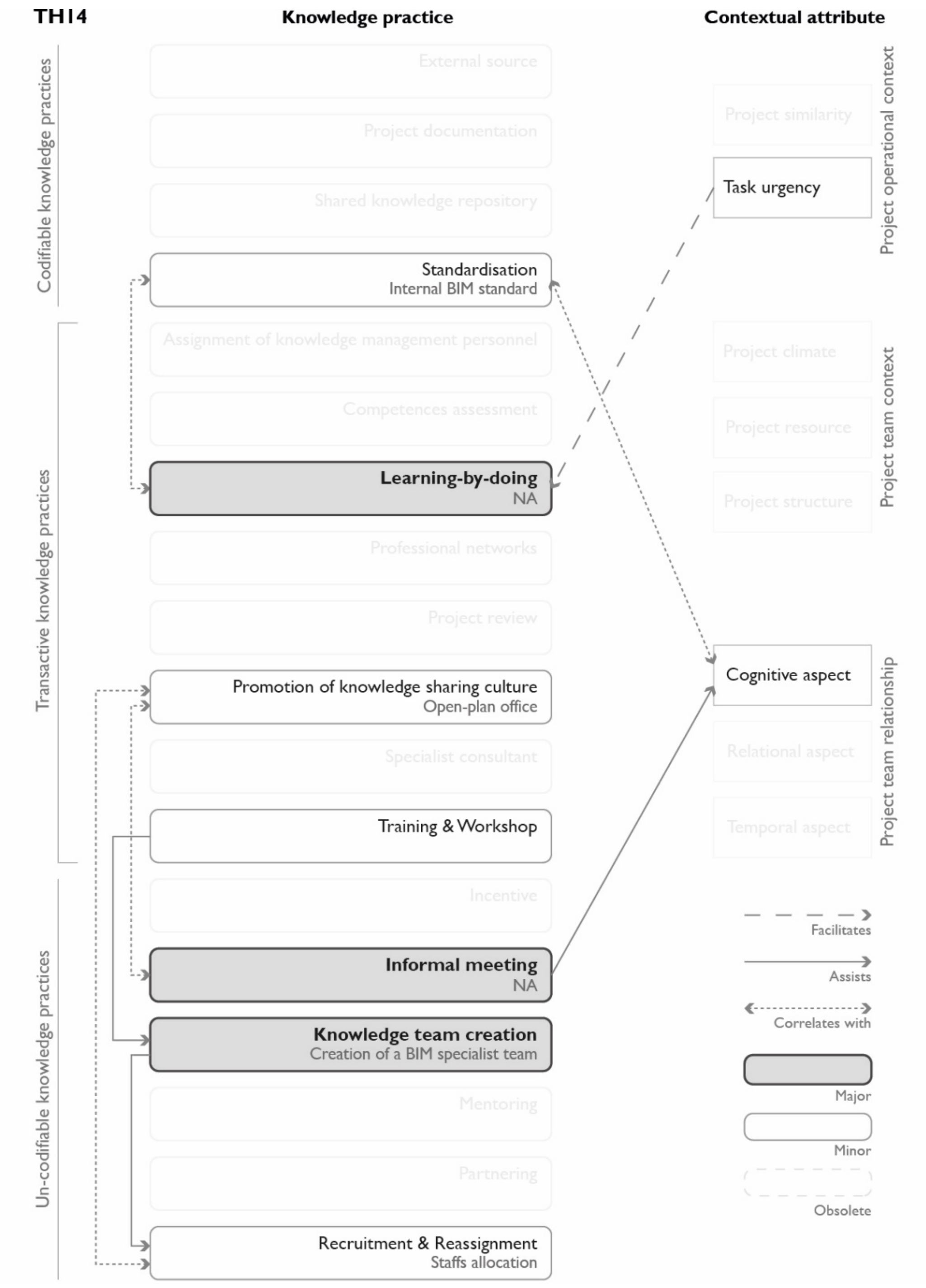


Figure A- 18: Project-based learning mechanism of BIM from TH14.

Learning-by-doing was classified as major from how working on real projects was described by project actors as necessary in BIM learning. TH14 explained, *"…, people are more interested in* *working on actual projects. When I mention that you can just use old projects to work on to learn BIM, staffs would not have as much drive as they usually have.".* The knowledge practice was facilitated by Task urgency. Project deadlines restricted learning of BIM for project actors. TH14 extended, *"If BIM is not required and the schedule is tight, you then have to decide which part you are going to be working on BIM …, you might decide to do the conceptual bits on BIM and the rest in 2D CAD if you don't have time.".* The dream project for BIM would be the one without any time constraint. Learning-by-doing correlated with Standardisation as Internal BIM standard was developed in conjunction with Learning-by-doing. TH14 elaborated, *"I would have then have them work on some pilot projects, and at the same time, setting up standards. This is so that they don't forget skills that they have learned from projects.".*

Informal meeting was regarded as major due to the fact that switching from the traditional CAD to BIM required a lot of persuasion for both operational and managerial members. TH14 added, *"the understanding of what to be delivered within will be the main discussion of those in the management position … the workflow will be more for the team. Different positions will have different focuses.".* This resulted Informal meeting to assist Cognitive aspect of project teams and the organisation.

Knowledge team creation contained an instrumentality of Creation of a BIM specialist team within the organisation. A formulation of this in-house BIM specialist team was necessary to foster efficient BIM learning in project actors. TH14 described, *"I would be seeing someone that has potential in leading BIM further and then put them together to form a BIM specialist team."* The creation of this BIM specialist team also allowed each project team to have designated project actors to be in charged. TH14 elaborated, *"I think you need more than 1 BIM manager. It doesn't have to be a know-it-all person who knows everything. It can be a group of people with different BIM competences that can complete the eco-system of the firm. Setting this team up is really important.".* The knowledge practice was facilitated by Project climate. The specialist team required encouragement and support from the directorial organisational members.

TH16 – Project-based learning mechanism of BIM from TH16 contained Promotion of knowledge sharing culture and Informal meeting as major knowledge practices. TH16 highlighted Training & Workshop as obsolete. Figure A- 19 presented the project-based learning mechanism of BIM from TH16.

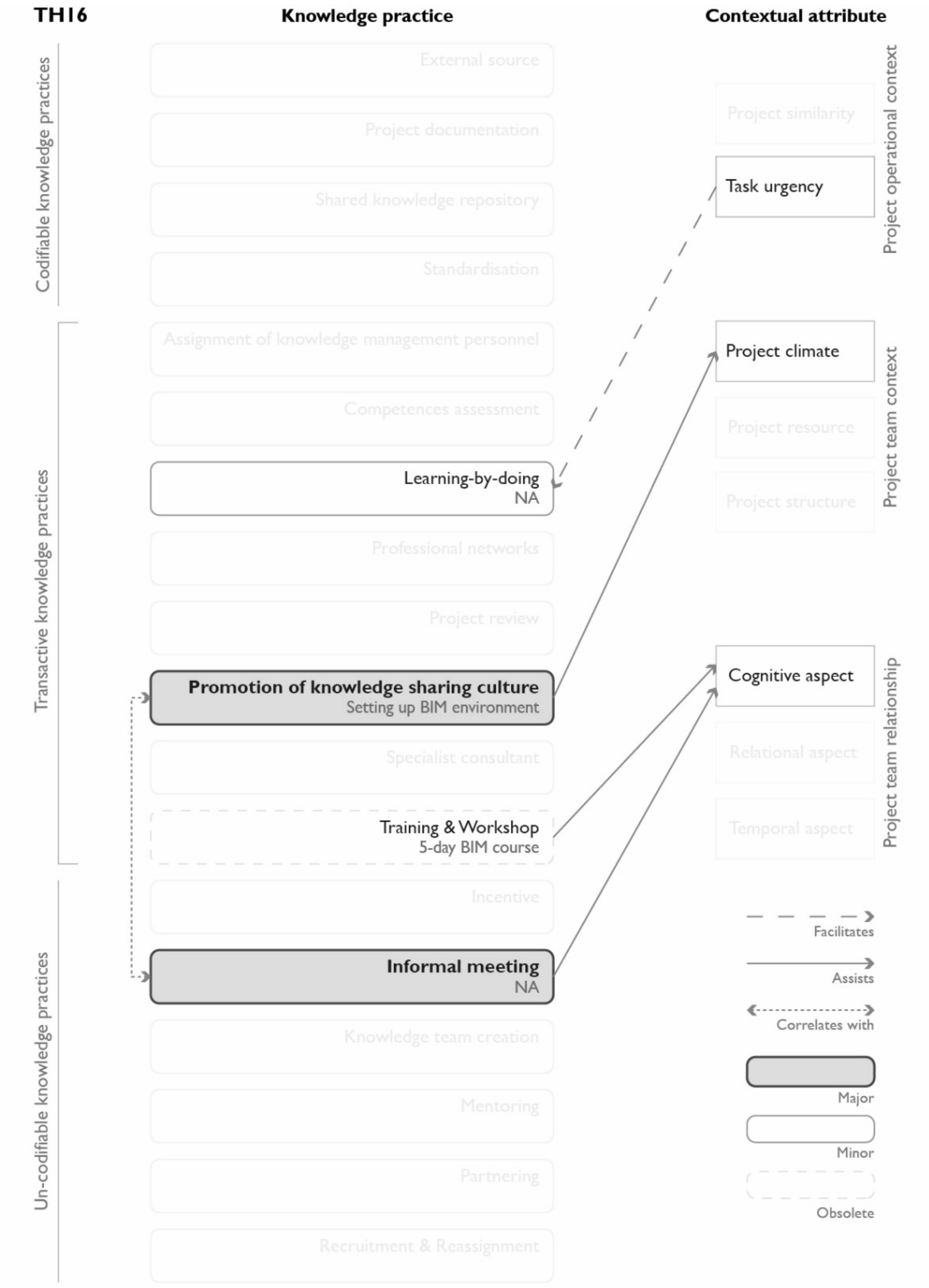


Figure A- 19: Project-based learning mechanism of BIM from TH16.

Promotion of knowledge sharing culture was utilised to assist Project climate of BIM learning. The organisation decided to base all of its formal communication and most of the informal communication to be within a BIM-based platform as a way to promote the use of BIM within an organisation. TH16 elaborated, "*Working directly on BIM platform also motivates people that we can work on the new system. They could see how easier it is to work on this platform.".* The knowledge practice correlated with Informal meeting.

Informal meeting was highlighted as another major knowledge practice. The knowledge practice covered other informal BIM-related knowledge sharing between project actors that was not included within the BIM-based communication platform. TH16 explained, *"With this, when problems are found, I often ask people to come around and I go through issues on the platform.".*

Training & Workshop was identified as obsolete. TH16 commented, *"The whole company went through a 5 days training program. To be honest, we only understand the first day. This was because the rests were about modelling and it was too soon to fully understand what is going on.".* Similar to Basic BIM course stated by other interviewees, 5-day BIM course was perceived as generic. Working on actual projects required more specific competence of BIM.