A BIM MATURITY-KPI ASSESSMENT FRAMEWORK FOR A UK PUBLIC SECTOR LOCAL AUTHORITY CLIENT

AHMED ADEL ABOUMOEMEN

Ph.D. Thesis 2022

A BIM Maturity-KPI assessment framework for a UK public sector local authority client

Ahmed Adel AbouMoemen

School of Science, Engineering, and Environment
University of Salford,
UK

Submitted in partial fulfilment of the requirements of Doctor of Philosophy, May 2022

Table of Contents

List of Figures

List of Tables

ACKNOWLEDGEMENTS

This thesis might have not been completed as suggested, without full recognition and support of my supervisor, along with additional support from Ph.d Candidates and my family.

I would like to take this massive opportunity and show appreciation and gratitude to my supervisor Professor Jason Underwood for his full support and guidance throughout the whole development of this thesis. I would like to specifically be grateful to him for selecting me to be involved in this study, in which I might have not been selected to work with the NWCH, and therefore not deliver prospects that were required.

In addition to this, I would like to show my appreciation and extremely thank the Digital Construction SIG focus group members of the North West Construction Hub Platform for their full assistance and guidance upon achievement of the current framework presented in this study. It was a great pleasure to work with everyone during this journey, and for your hospitality in hosting me in your platform to conduct the necessary workshops means a lot to me and without this I could have failed to complete my dissertation.

Special thanks to Lewis Sharman for his contribution at the very beginning of this journey. You have provided me with special guidance and support in developing my research and to connect me with BIM experts and professionals in the UK industry. Your participation throughout this journey means a lot to me and I would have not been able to reach a handful of contacts without your support. Thank you and good luck with your masters.

I would like to deeply thank the 4 members of the focus group workshops, 15 interviewees, 40 BIM questionnaire participants, and 5 external validation members for their valuable inputs to this research. Your participation has assisted in developing an enhanced understanding on BIM adoption in the UK. Without your participation, I would have not been able to collect the information that would support my research, and therefore I would like to show my gratitude to every single one of you.

I would like to congratulate my fellow Ph.d candidates who have successfully completed their research during the same time as me and for their continuous guidance and discussions through the research journey. We have held productive discussions that helped contribute widely on this research. I would also like to wish the best of luck with future Ph.d candidates who would be expected to complete their research around this same time and best of luck with your future prospects.

DEDICATION

I would like to dedicate this thesis to my parents and entire family, who have continuously supported me throughout this journey, and would like to dedicate it to my future wife and kids.

DECLARATION

This thesis is submitted to the University of Salford rules and regulations for the award of a PhD degree. Some research findings were published in Conference and Journal paper(s) prior to this submission (refer to Appendix I).

The researcher declares that contents of this thesis has not been submitted for another degree, or any other university or institution of learning.

AHMED ABOUMOEMEN

LIST OF ABBREVIATIONS

2-6D- Two – Six Dimension
AEC- Architecture, Engineering and Construction
AIA- American Institute of Architects
AIM- Asset Information Model
AIR- Asset Information Requirements
AGC- Association of General Contractors
AM- Assessment Methods
Aw- Awareness
ANOVA- ANalysis Of VAriance
BDS- Building Descriptive Systems
BEIIC- Built Environment Innovation and Industry Council
BIM- Building Information Modelling
BIMMI- Building Information Modelling Maturity Index
BEP- BIM Execution Plan
BIS- Business, Innovation and Skills
BS-British Standards
BSA- Building Smart Alliance
BSI- British Standard Institution
CADD- Computer-aided drafting and design
CAPEX- CAPital EXpenditure
CDE- Common Data Environment
CDBB- Centre Digital Built Britain
CE- Constructing Excellence
CMM- Capability Maturity Model
Co- Consistency
CO- Change Orders
COBie- Construction Operations Building Information Exchange
CP- Construction Programme
CPA- Construction Products Associations
CSF- Critical Success Factors
DETR- Department of Environment, Transport, and Regions
ECI- Early Contractor Involvement
EFQM- European Foundation Quality Management
EU- European Union
ESI- Early Supplier Involvement
EIR- Employers Information Requirements, Exchange Information Requirements
FM- Facilities Management
GSA- General Services Administration of the US
GSL- Government Soft Landings
HM- Her Majesty Government
HS2- High Speed Two
IAI- International Alliance for Interoperability
IDEFO- Integrated Definition for Functional Modelling
IFC- Industry Foundation Class
IFM- Institute for Manufacturing
IPA- Infrastructure and Projects Authority
ISO- International Organization for Standardization
KRIs- Key result indicators
KPI- Key Performance Indicators
LOD- Level of Details, Level of Definition
LOI- Level of Information

MCC- Manchester City Council
MIDP- Master Information Delivery Plan
MPDT- Model Product Delivery Table
MOJ- Ministry Of Justice
NACF- The National Association of Construction Frameworks
NAO- National Audit Office
NBS- National Building Specification
NBIMS National BIM Standard
NEDC- National Economic Development Council
NEDO- National Economic Development Office
NFB- National Federation of Builders
NIBS- National Institute of Building sciences
NIC- National Infrastructure Comission
NIST- National Institute of Standards and Technology
Nvivo- Navigating Viewpoints, Images and Value Observed
NWCH- North West Construction Hub
NACF- National Association of Construction Frameworks
NOMIS- National Office Labour Market Statistics
OA- Occasional Application
OAM- Organisation Assessment Models
OGC- Office of Government Commerce
OIR- Organisation Information Requirements
OM- Operational Management
ONS- Office of National Statistics
OPEX- OPerational Expenditure
PAM- Project Assessment Models
PAS- Publicly Available Specifications
PDM- Process Definition and Management
Penn- Pennsylvania
PIM- Project Information Model
PIP- Project Implementation Plan
PIR- Project Information Requirements
PLQ- Plain Language Questions
PM- Performance Measurements
POE- Post Occupancy Evaluation
QA- Quality Assurance
RICS- Royal Institution of Chartered Surveyors
RII- relative Importance Index
ROI- Request for Information
RM- Responsibility Matrix
3-6D- 3 to 6 Dimension
SIG- Special Interest Group
SEI- Software Engineering Institute
SMART- Specific, Measurable, Attainable, Relevant and Timely.
SPSS- Statistical Package for the Social Sciences
TIDP- Task Team Information Delivery Plan
TM-Task Manager
UK- United Kingdom
UK IPR- UK Industry Performance Reports

Abstract

The UK construction industry outlined construction problems related to delivering values to clients and construction performance. UK industry reports aimed to address various problems and provide milestones on how to tackle such problems, through setting a set of improvement targets to the industry, known as Key Performance Indicators (KPIs). A set of targets were addressed to achieve by 2025 that includes Building Information Modelling (BIM). The UK government mandated the usage of Level 2 BIM across the construction industry in 2016, which was superseded by the BS EN ISO19650 standards in 2019. This research aimed to develop a BIM Maturity-KPI assessment framework for the UK public sector local authority client to assess BIM adoption in line with the UK construction strategy.

The research was conducted with a case study through workshops to develop a BIM maturity assessment. This was followed by conducting interviews to investigate levels of BIM maturity and KPI metrics adoptions in the UK client sector, to fill out the BIM maturity assessment, to establish potential relationships with KPI metrics, and propose any further KPI metrics to be considered. This was further examined through a questionnaire survey to statistically examine the relationships of BIM maturity and KPI metrics.

A 3-level BIM maturity assessment (Awareness, Occasional Application, Consistency) for 3 organisational levels (Strategic, Implementation, Operational) was proposed. 10 standardised KPI metrics (Cost, Time, Quality, Satisfaction, Health and Safety, Performance, Profitability, Productivity, Sustainability, and Collaborative Culture) were delivered. The KPI metrics relationship with BIM maturity were assessed through a 4-level relationship (No relationship, Weak, Medium, Strong). The findings indicated that there was a relationship that existed between the BIM maturity and KPI metrics.

The research proposed a final BIM Maturity-KPI assessment framework to the UK client sector. Finally, the research provided the UK client sector with an overview on the existing BIM maturity and KPI metrics, and how they can both be linked together.

Chapter 1: Introduction

1.1 Introduction

This chapter aims to provide a brief background to the research topic and elicit the key topic areas that shall be explored in this research. Problems associated to this research, such as lack of client demand, absence of understanding to BIM and how it is being implemented across the UK will be highlighted and justification to the need of proposing a BIM maturity and KPI assessment framework to tackle such existing problems and enhance overall performance of the UK construction industry will be discussed in brief detail. The aim and objectives in addressing the research problems and justifications will be provided, and questions that the research will address related to understanding BIM maturity and KPI metrics, how they will both be linked, and the benefits that they could offer to the client sector will be presented. The scope of the research related to public sector local authority client, UK construction KPIs, Level 2 BIM and the new UK specific BS EN ISO19650 standards will be outlined, the methodological approach of this research will be highlighted to outline the adopted methods for this research, and the overall structure of the thesis and the research process will be given at the end of the chapter that represents a starting point to this research.

1.2 Research background

The UK economy is strongly influenced by the construction industry, which was evident from the first growth review by the government published in 2011 (Greaves, 2008). According to the latest statistics, in 2019, the construction sector contributed £117 billion to the UK economy, equating to 6% of the total economic output (Office for National Statistics, 2019). Previous reports have noted that addressing existing problems within the UK construction industry would enable the delivery of value to clients. The set of reports covers the context of the UK construction industry and are all demanding change; indeed, some were reviewed during the time period 1934-2021 (Design buildings wiki, 2019; Gruneberg, 2018; Murray and Langford, 2003). These reports have addressed key issues related to fragmentation, lowest cost mentality, and the need for a high drive to change. They offered ways to overcome problems related to performance, profitability, productivity and predictability to name a few areas. Nevertheless, additional problems have emerged in recent years (Mckinsey, 2017; 2018) that relate to low productivity.

Building on previous reports, there has been a greater emphasis on Building Information Modelling (BIM) and digital transformation, and more focus on issues related to collaboration, modernisation, health and safety, apprenticeships, digitisation, and whole life cycle performance, thus the need to adopt BIM in order to tackle issues that existed in the UK construction industry (Farmer, 2016; HM government. 2017, 2018, 2020a, 2020b, Mckinsey, 2020), and the need to adopt the UK BIM framework across one of the government 14 policies (Further embedded digital technologies) to use the UK BIM Framework to support the adoption of the Information Management Framework (HM government. 2020c). The concept of BIM emerged as a subset of computer-aided design (CAD) software; this replaced manually generated 2D drawings (AbuEbeid and Nielsen, 2020; Akdag and Maqsood, 2019). From this, Architecture Engineering and Construction (AEC) progressed from using sketch boards to illustrate architectural drawings, to instead present drawings via technological software through computer-aided drafting and design (CADD) systems. The reduction to public sector costs was a key approach following these reports through a set of construction strategy actions for implementation by 2025 (HM government. 2013). This involved attaining growth opportunities for the construction market of up to 70% (Leadership), whilst 50% derive from the following actions: improvement in exports (growth), lower emissions (sustainable), and faster deliver (smart), and 33% lower costs (people). These were the major actions set by the government strategy for the UK to achieve by 2025 (HM Government. 2013).

The UK Construction Strategy considered that the main development challenge for BIM was the implementation process, which the government subsequently mandated on all public sector construction projects from April 2016 onwards (Greaves, 2008). The mandate was established to recognise how could BIM change the project process by transforming the whole industry (Haron, 2013). Therefore, the UK government imposed a mandate to implementing Level 2 BIM on their UK projects by 2016 (HM Government. 2012). Level 2 BIM has been defined as: “A series of domain and collaborative federated models, and the models consists of both 3D geometrical and non-graphical data, and are prepared by different parties during the project life-cycle” (BIM level 2. 2016; BIM Task Group, 2013; NBS, 2016). The BS EN ISO19650 is an international set of standards, which defines the collaborative processes for effective information management throughout the asset delivery and operational phase in the use of BIM. There has been a transition from Level 2 BIM to the new BS EN ISO19650 standards (UK BIM framework, 2019a, b). Although BIM has grown rapidly within the UK, other studies have identified complications associated with such growth. It has been stated that, as it was understood in different ways, this resulted in lack of a recognition and appreciation for BIM throughout the UK construction industry (Underwood, 2010). To overcome such challenges, a measurement process to help resolve some of these existing challenges in the UK was introduced, called “BIM maturity”, which conceptualised a set of advancements in terms of capability and performance in relation to its application. These advancements were based on degrees of accomplishment, and characterised by "*the extent to which a specific process is explicitly defined, managed, measured, controlled, and effective*" (Paulk, Curtis, Chrissis, & Weber, 1993, p. 9). Moreover, BIM maturity models have emerged from numerous research studies. A fundamental reason for, and the significance of, BIM maturity relies on the capability to measure the effectiveness of BIM capabilities. This would enable reflection on the impact of the government mandate and prompt an examination of the level of BIM project success across the UK. The UK Government outlined a set of targets that directed the focus on the introduction to digital transformation and BIM, and Key Performance Indicator (KPI) measures (Egan, 1998; Latham, 1994; HM. Government. 2011; 2016; Wolstenholme, 2009).

Targeted enhancements were projected, which lead to the appearance of KPIs that intended to deliver overall improvements in the UK construction industry (Wolstenholme, 2009). Although the overall measures and success of project performance related to cost, time, and quality, other assessments have also been considered that differ from one place to another, such as safety and performance. BIM maturity focuses on maturity assessments, and construction performance measurements; however, in order to demonstrate the value and benefit of KPIs and establish potential enhancements, it is vital to link BIM maturity with KPIs (Ashworth and Tucker, 2018; Badrinath et al., 2019; Khanzadi et al., 2019; Shin et al., 2015; Wong et al., 2016).

Methods have been presented to enable the combination of BIM maturity and KPI metrics by signifying how they can function together in the construction industry. Although there are potential strengths from combining these, very few publications have mentioned the linkages that may occur (Ashworth and Tucker, 2018; Badrinath et al., 2019; Coates et al., 2010; Hassan, 2012; Manzione et al., 2011). Although the aforementioned publications address the potential links of BIM maturity and KPI metrics, none have addressed the linkage of BIM maturity and KPIs for the client sector and according to the new BS EN ISO19650 standards.

Although there have been previous attempts to link BM maturity and KPI metrics, however, there has been a lack of understanding on what BIM maturity and KPI metrics are, which has led to an absence of a standardised linkage between BIM maturity and KPI metrics to recognise the benefits that could influence the overall performance of the UK construction industry. Therefore, this suggests no attempt of a standardised linkage between BIM maturity and KPI metrics, and since there has been an absence of a standardised linkage between BIM maturity and KPI metrics, this suggests a current knowledge gap; therefore this research will explore the potential ways to link BIM maturity and KPI metrics together and how both could operate together; such as the strength of relationships and if they move in the same direction (BIM maturity increase/decrease vs KPI increase/decrease) or different direction.

1.3 Problem Statement/Research Gap

A number of publications exist on how to support the implementation of BIM within stakeholder construction organisations. However, a lack of client demand and a lack of training represent some existing problems in implementing BIM in the UK construction industry (Arayici, Egbu, & Coates, 2012; Azhar et al., 2008; Khosrowshahi & Arayici, 2012; Smith & Tardiff, 2009; Yan & Damian, 2008). The NBS reports (2019, 2020, 2021) indicated that there is no client demand for BIM, unlike other disciplines (such as consultants and contractors), and thus BIM implementation is still far from the client's priority. They face obstacles in deciding whether to implement BIM, which are mostly influenced by their limited understanding as to the expected benefits for them (NBS. 2020). Furthermore, there is no clear view on where BIM could deliver benefits to the client during its project lifecycle, which is the result of this lack of understanding; thus the client is not clear what some of the challenges could be, and what values BIM could offer the client (AbuEbeid and Nielsen; 2020; Blay et al., 2019; Cousins and Knutt, 2017). Clients across the construction industry have widely recognised the barriers to BIM implementation and acceptance. This is due to the lack of clarity as to the benefits of BIM to clients, which contrasts with the understanding amongst other construction industry stakeholders (AbuEbeid and Nielsen; 2020).

Although the governmental mandate imposed the implementation of Level 2 BIM on governmental projects by 2016 (HM Government. 2012) and the increase to levels of BIM adoption over time (NBS. 2021), results have shown that there is no standardised definition to Level 2 BIM leading to a confusion on how to adopt Level 2 BIM (Winfield, 2018), and results have also shown that there are still issued related to people's understanding and industry's issues revolving around Information Management using BIM (Kemp, 2020, Winfield, 2020; UK BIM Alliance. 2020). Limited awareness and low adoption results from the slow uptake and low adaptation of BIM to different UK disciplines. Thus, although BIM maturity exists, it is not currently at Level 2 BIM, and few benefits are realised and demonstrated to clients. Therefore, the relationship between BIM maturity and benefits is still unclear and requires more attention Kassem & Li, 2020). The recent approach of BIM under the new BS EN ISO19650 standards has led to some confusion on the differences between this and Level 2 BIM and how this transition would occur; this may impact the UK's vision in terms of adopting BIM in recent years and the clients understanding to the new standards (NBS, 2021; UK BIM framework. 2019b).

KPIs have previously existed but presented in various ways to organisations; this has meant that there is no standard list of KPIs available for the UK construction industry (Parmenter, 2019,

2020) and difficulties to measure them (Cox et al., 2003). Moreover, misconceptions exist concerning the definition of BIM maturity and KPI metrics, and the ways they function within the UK industry. This has resulted in unsuccessful approaches to combine them in order to extract benefits that positively influence overall performance of the UK industry (Aboumoemen, 2016; Aboumoemen and Underwood, 2017, 2019).

Although there have been previous attempts to link BIM maturity and KPI metrics together through an assessment (Ashworth and Tucker, 2018; Badrinath et al., 2019; Coates et al., 2010; Manzione et al., 2011; MoJ. 2016; Mom and Hsieh, 2012; Ozorhon and Karahan, 2016; Park et al., 2013; Sarkar et al., 2015; Sebastian and Berlo, 2010; Smits et al., 2016; Wong et al., 2016), there has been a lack of understanding to what BIM maturity and KPI metrics are, which has resulted in an absence of a standardised linkage between BIM maturity and KPI metrics to recognise the benefits that could influence the overall performance of the construction industry. As a result, there has been no attempt to deliver a generalised usage of BIM maturity and KPI metrics for use within assessments.

Therefore, the essential aim of this research is to separately identify the levels of BIM adoption and KPIs, in order to deliver a generalised list of KPI metrics for use by clients within the UK construction industry, and to propose a BIM maturity and KPI linkage through an assessment framework that will be validated and examined by the UK construction industry clients.

1.4 Justification/Rationale and significance of research

Reasons for the barriers to BIM implementation by clients exist across the industry, and are attributed to the lack of definition regarding the benefits; this contrasts with other stakeholders within the construction industry who have far greater clarity (Azhar, 2011; Barlish and Sullivan, 2012; Bryde et al., 2013; Yan and Damian, 2008). Thus, it is vital to address the BIM requirements that could positively impact on construction industry clients. BIM has been presented differently, which has resulted in limited awareness and its slow uptake amongst UK disciplines; hence, the concept of BIM maturity was developed to assess organisational capabilities and measure its adoption to allow people to assess their position. This would help to outline the benefits identified from the BIM maturity concept across organisations (Dakhil, 2017; Kassem & Li, 2020; Mahamadu, 2017; Marsh, 2017; Smits et al., 2016; Wong et al., 2015). The adoption of a maturity model would present BIM benefits to users, which can be simplified and tailored to achieve such positive outcomes (Azzouz et al., 2016b; Dakhil, 2017; Giel and Issa, 2013c; Kassem & Li, 2020; Nepal et al., 2014; Succar, 2010a); therefore, it is essential to address BIM maturity. The usage of the new BS EN ISO 19650 standards reflects back on the UK strategy highlighted in the

Construction Playbook (HM government. 2020c) across one of their policies (Further embedded digital technologies), which indicates the need from local authorities to use the UK BIM Framework to standardise the approach to generate and classify data, data security and data exchange, and to support the adoption of the Information Management Framework. The adoption of the UK BIM framework will improve the performance, sustainability and value for money of projects and programmes. Hence, it is essential that this research would address the key aspects of the UK BIM framework and ensure that the proposed assessment would adopt the information addressed across the UK BIM framework, and this further justifies the need to develop the proposed BIM maturity/KPI assessment that follows the new standards based on the UK government strategy.

Moreover, KPIs have been presented differently across diverse projects and organisations with varying levels of achievement, as a measure of a process that is critical to the success of an organisation (Parmenter, 2020; Peterson, 2006). By linking BIM maturity and KPI metrics together, this would help to demonstrate the benefits that could be expected by clients in enhancing the overall performance of projects within the UK construction industry and upskilling the users from one level to another. Furthermore, the usage of KPIs would help to realise potential impacts on the overall performance of projects and organisations. A limited number of publications exist that report the possible links between implementing BIM maturity across the most used KPI metrics on construction projects (Aboumoemen and Underwood, 2017,2019; Ashworth and Tucker, 2018; Badrinath et al., 2019; Coates et al., 2010; Khanzadi et al., 2019; MoJ. 2016; Ozorhon and Karahan, 2016). Although BIM maturity and KPI metrics were previously linked, no clearly defined relationship yet exists between BIM maturity and KPI metrics for the UK client sector. Hence this research reviews various BIM maturity metrics to support the delivery of a standardised set of such metrics. It will also review previously developed KPI metrics to support the provision of a standardised set, in which both BIM maturity and KPI metrics will be used to examine their potential relationship and assess how this would reflect on the performance of construction projects. Together, this will develop a BIM Maturity-KPI assessment framework to determine the level of BIM maturity and adoption in accordance with the UK strategy, how linking BIM maturity and KPI metrics would enhance the performance of construction projects across the sector, and examine its applicability amongst the UK construction industry clients.

1.5 Research Aim and Objectives

This research aims "*to develop a BIM Maturity-KPI assessment framework for the UK public sector local authority client to assess BIM adoption in line with the UK construction strategy.*"

The following objectives will help to achieve this aim:

1) To determine the Building Information Modelling (BIM) approach, its relevance to the client sector, and its level of adoption across the construction industry, both globally and within the UK specifically.
2) To establish key principles of BIM maturity and evaluate existing BIM assessment frameworks, models, and tools to understand the principles of existing industry key performance metrics and indicators.
3) To evaluate existing combined BIM-KPI assessment methods, models and tools, and establish the main drivers, barriers and challenges of BIM maturity and KPIs for the UK construction strategy.
4) To develop a BIM maturity-KPI assessment framework for a UK public sector local authority construction industry client.
5) To examine the relationships between the proposed BIM maturity and the KPIs.
6) To evaluate and propose a final BIM maturity-KPI assessment framework for the UK public sector local authority construction industry client.

1.6 Research Questions

The research will answer the following questions being associated with the aim and objectives:

1. What does BIM maturity mean and what does it measure? How could BIM maturity support / facilitate BIM implementation?
2. How are the Key Performance Indicators approached by the construction industry? What do they measure and which criteria do they follow?
3. Is there a link between BIM maturity and KPIs as a measure of the benefits of adopting BIM? If so, how can linking BIM maturity and KPIs provide a measure of BIM adoption and support BIM implementation?
4. Can the proposed BIM maturity-KPI linkage benefit the UK public sector local authority client? If so, to what extent could the linkage reflect on the UK construction industry client?

1.7 Scope of this research

A client's role with the BIM implementation process, namely to develop the requirements and validate information across the UK industry, is identified within the research. The UK public sector local authority client, UK construction KPIs, Level 2 BIM and the new UK specific BS EN ISO19650 standards are the main scope of this research. These will help to identify the potential linkage of BIM maturity and KPI metrics through a proposed framework, which will be presented to the UK public sector local authority client. This framework will measure BIM maturity by realising the benefits and determining the impact on the overall performance of UK construction industry clients by delivering a proposed list of standardised KPI metrics that are linked with a proposed list of standardised BIM maturity metrics. This research will only be conducted with UK clients concerning BIM; moreover, it will only focus on Level 2 BIM and BS EN ISO19650 standards. However, a set of BIM standards are becoming adopted globally, which presents a potential spread of BIM adoption across the globe.

1.8 Research Methodology- adopted research methods

The adopted research methodological model for this research is the **Research Onion**, developed by Saunders, Lewis, and Thornhill (2019) which represents six layers of a research methodology. The adopted research studies that links back to the research onion layers are a combination of **Exploratory and Explanatory** studies. The ontological position for this research is a mix of **Objective and Subjective** stance. The adopted epistemological position is **Pragmatism** that links back to the mix of both the objective and subjective stances in demonstrating a potential relationship between BIM maturity and KPI metrics. The adopted axiological position that links back to the ontological mix of Objective and Subjective stance and the epistemological Pragmatic philosophical stance is a **Value-driven** position. The adopted research approach will be **Abductive**. The adopted research methodological choice position shall be **Sequential Mixed Method**. The adopted research strategy position will be **Single Embedded Case Study**. The adopted time horizon will be **Cross-sectional**. The adopted data collection techniques and the data analysis for each technique are as follows: 1) **Focus group workshops**, where the data will be analysed through filling out the proposed BIM maturity assessment across three organisational levels (Strategic, Implementation, Operational) and through three maturity levels (Awareness, Occasional Application, Consistency). 2) **Semi structured interviews**, where the data will be analysed by the usage of, a) **Thematic analysis**, and b) **Content analysis**. 3) **Online questionnaire**, where the data will be analysed by the usage of **a) Descriptive statistics**, which will deliver results **(Frequencies and Mean)** of the BIM maturity levels and the strength of relationships between BIM maturity and KPI metrics, and **b) Inferential statistics**, which will deliver results [i) **Chi Square** test of relationship, ii) **Kruskal Wallis** test of independence, iii) **Spearman Correlation**, and iv) **Linear Regression**)] of the relationship between BIM maturity and KPI metrics. The next section will present the overall structure of the report.

1.9 Structure of the thesis

The thesis is structured within ten chapters, which are as follows:

Chapter 1: provides an introduction to this research, including the research gap and significance of the study. The research aim and objectives have been outlined, an overview of the research scope has been given and a brief summary of the thesis structure.

Chapter 2: defines the government's involvement within UK construction, and the historical reports that were used to identify the nature of the industry, drive for digital transformation, lack of/slow adoption/realisation of the benefits, to help develop the essence of BIM maturity and KPI metrics. This provides a critical literature review that is relevant to this research in terms of BIM and KPI adoptions. This includes in depth discussions on the UK construction industry, clients' roles, the approach to BIM generally and Level 2 BIM specifically, the benefits and challenges of BIM, the transition from Level 2 BIM to BS EN ISO19650, BIM for client organisations, and BIM adoption across the globe. The chapter also offers a number of definitions to BIM in UK construction, identifies how it is being adopted globally, explores the different principles in use, and notes the essential approaches towards BIM adoption in the UK.

Chapter 3: This chapter evaluates existing BIM maturity assessments across the globe, how they are used to measure and solve problems, and the strategies that could be adopted to enable future improvements. It explains and identifies the key principles of KPIs, the different types of KPIs used, and how they are used in various projects to solve different problems and deliver successful solutions. It presents a number of existing combined BIM maturity and KPI assessments and establishes the main drivers, barriers and challenges of BIM maturity and KPIs for the UK construction strategy.

Chapter 4: The chapter presents the management 'dimensions' 'representations' and 'approaches' for a research, for which a conceptual framework has developed based on it. The definition of a framework from previous related studies is discussed in depth, and a conceptual framework is presented. The framework consists of 3 stage elements "The What", "The How", and "The Evidence and The Why". Its formulation is discussed in detail, and experts' views of the framework are collected to help determine key ideas and opinions and gather feedback.

Chapter 5: A review of different research methodologies is presented and analysed. The "Research Onion" proposed by Saunders et al. (2016) is selected and its layers are discussed in detail. Justifications for selecting the particular methodological choices are presented, while the data collection procedures, their related data analysis, data sampling and selection criteria techniques are debated and justified.

Chapter 6: This chapter presents the findings of the BIM maturity assessment proposed for this research. This is achieved through the analysis of qualitative data, which are gathered from a number of focus group workshops. These were conducted to develop a proposed 3-level BIM maturity assessment (Awareness, Occasional Application, Consistency) across three organisational levels (Strategic, Implementation, Operational) and an initial agreement to construction KPI metrics would be achieved.

Chapter 7: Having developed the BIM maturity assessment, this chapter explores the potential ways that BIM maturity and KPI metrics could work together in organisations. This is achieved by conducting the proposed BIM maturity assessment from the focus group workshops, which is followed by linking the proposed KPI metrics back to BIM maturity metrics. From this process, a final standardised list of ten KPI metrics (Cost, Time, Quality, Satisfaction, Health and Safety, Performance, Profitability, Productivity, Sustainability, and Collaborative Culture) was generated and a number of recommendations are presented on how the linkages should work. This information is collected through qualitative data through semi-structured interviews open ended questions with a number of BIM practitioners who deliver in-depth and rich information on this.

Chapter 8: Having linked BIM maturity and KPI metrics together, this chapter examines the relationships between both, through the quantitative data via a questionnaire survey. The questionnaire was designed to gather views of participants who could offer useful views on such relationships. Having presented a list of questions to explore how BIM maturity and KPI metrics would work together, a relationship assessment is conducted to assess BIM maturity through the 3-level BIM maturity assessment and how it would then be linked with the KPI metrics through a 4-level KPI strength of relationship (No relationship, Weak, Medium, Strong). This will also explore the levels of association to determine if BIM maturity and KPI metrics would share the same association (Awareness and Weak), and the degree to which both impact each other.

Chapter 9: Having completed the data collection stage, this chapter discusses the development of the conceptual framework and its evaluation through presenting the data collection findings that are subsequently related to the literature, which is then linked back to each of the framework's 3 stage elements towards proposing an initial framework development. The analysis and discussions will outline the key findings including the similarities and differences that exist, which represent the internal validation stage that compares this information, and provides steps on how the framework has evolved from the conceptual framework being presented as a result of the critical review of the literature to the initial framework development being presented as a result of the data collection findings. Having discussed the findings and linked them to the literature, the chapter then undergoes an external validation stage, which presents the data findings of the initial framework development and collects the level of agreement to the framework from a number of UK BIM experts. This will be achieved through focus group validation workshops with the experts to gather feedback on the initial framework development towards delivering the final framework for this research. As a result, this chapter presents the final BIM maturity-KPI assessment framework, which thereby meets the aim for this research, and presents the mechanism on how the framework shall operate within the UK client sector.

Chapter 10: After the completion of the data collection and the validation stages, this chapter outlines a number of outcomes from this research. This is achieved by reviewing the aim and discussing the achievement of each objective. The chapter identifies a number of contributions by this research in terms of knowledge and practice, and notes the limitations and challenges encountered within this research, The chapter offers a list of recommendations that to address these challenges and in relation to the industry adopting such a framework, following which a number of actions for future research are noted and the final conclusions delivered.

1.10 Research Process

The research process delivers the proposed research phases that aligns to the aim and objectives set for this research, reviews the existing literature related to the research field, develops a new concept based on the research area, collects data and examines the data and presents the overall findings that presents a contribution to knowledge and targets the existing gap of knowledge (Sarantakos, 2012). Figure 1.1 illustrates this research's process, which included the alignment of the chapters across the research objectives and questions (Input), six main phases and the alignment of the proposed ten chapters across the phases (Process), and the proposal of a final framework to be generated from this research (Output). These are represented as follows:

Phase one (Preliminary study): This includes the research background, gap, justification, scope of study, and literature review to do with what are the BIM maturity and KPI metrics and how can both be linked together. This phase is aligned with Chapters 1-3, and with Objectives 1-3, where Chapter 1 is aligned with Objective 1, Chapter 2 aligned to Objectives 1 and 2, and Chapter 3 aligned with Objectives 2 and 3.

Phase two (Conceptual framework process): This includes the proposition of a conceptual framework from 4 stages based on the literature review on: Stage 1) The BIM maturity and KPI metrics (The What), Stage 2) Both be linked together (The How), Stage 3) The benefits that could emerge from linking both together (The Evidence), and Stage 4) Future actions to link both (The Why). This phase is aligned with Chapter 4, which is aligned to Objective 4.

Phase three (Research Methodology): This includes the research methodological approach adopted for this research based on the literature review findings and the proposition of a conceptual framework. This phase is aligned with Chapter 5, which is aligned to Objective 4.

Phase four (Data collection): This includes the primary data collection based on the literature review findings, proposition of a conceptual framework, and the identified data collection methods from the research methodological adopted approach. The data will be analysed based on the collected results and an update to the framework will be conducted based on the findings. This phase is aligned with Chapters 6-9, and with Objectives 4-5, where Chapter 6 is aligned to Objectives 4, Chapters 7 and 8 aligned with Objectives 4-5, and Chapter 9 aligned to all objectives.

Phase five (Initial framework development process): This includes discussions on the initial framework development based on the data that has been collected and steps that were taken to move from the conceptual framework to the initial framework development. This phase is aligned with Chapters 6-9, and with Objectives 4-5, where Chapter 6 is aligned to Objectives 4, Chapters 7 and 8 aligned with Objectives 4-5, and Chapter 9 aligned to all objectives.

Phase six (Framework Validation, and Research Recommendations): This includes the final framework based on the initial framework and external validation being held with experts to finalise the final framework, and offers a number of contributions and recommendations to future research. This phase is aligned with Chapters 9-10, and with Objectives 5-6, where Chapter 9 is aligned to all objectives, and Chapter 10 is aligned to Objective 6.

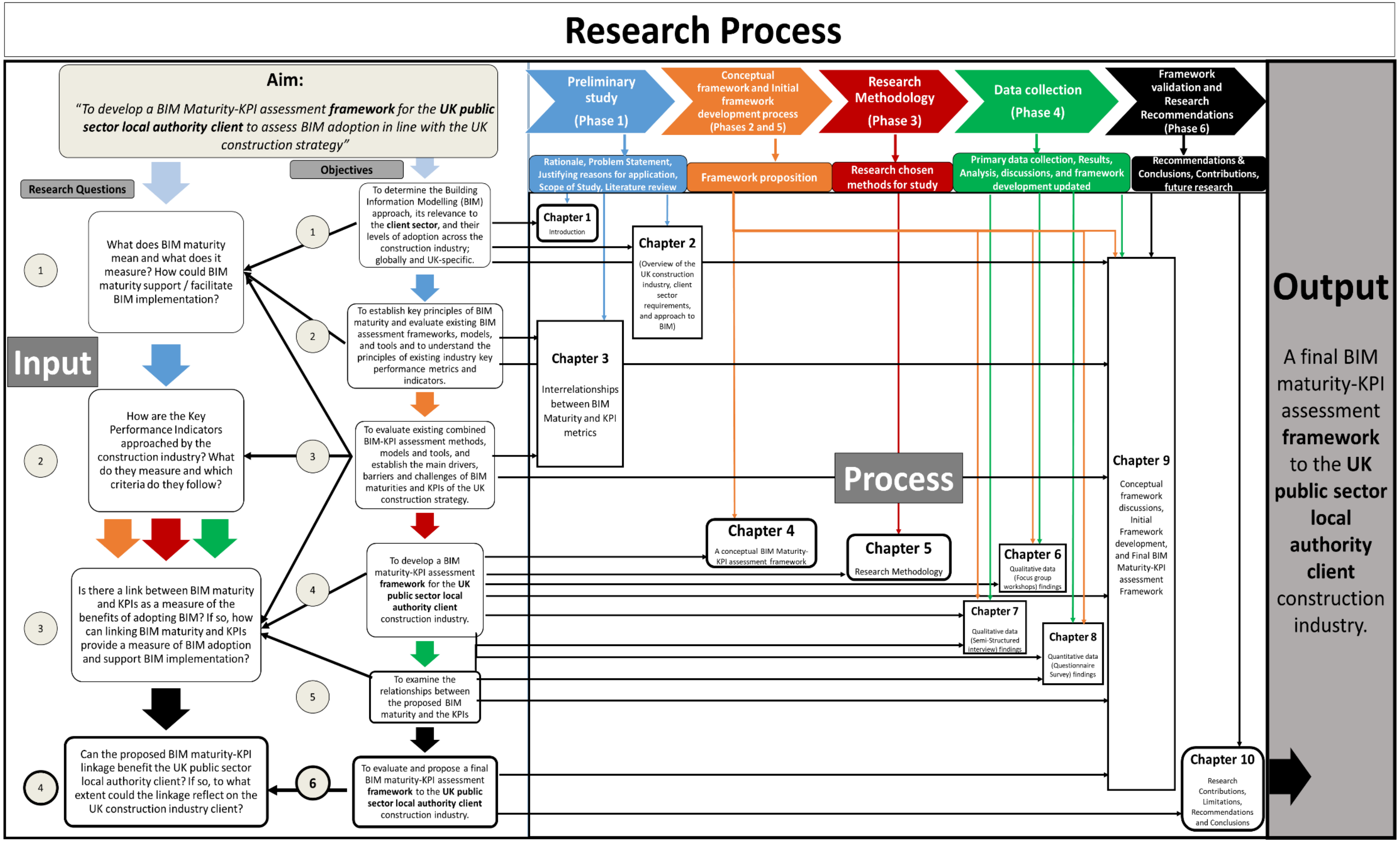


Figure 1.1 Research Process

1.11 Summary

A brief background to the research has been provided that highlights the absence of a standardised linkage between BIM maturity and KPI metrics to recognise the benefits that could influence the overall performance of the UK construction industry. The justification on the need to develop a BIM Maturity-KPI assessment framework to determine the level of BIM maturity and adoption in accordance with the UK strategy and how linking BIM maturity and KPI metrics would enhance the performance of construction projects across the sector was established. The aim and objectives of the research that addresses the research problems and justifies the significance of the research was presented, which was followed by a number of questions that the research will aim to provide answers to related back to the research aim and objectives. The scope of the research linked to the UK public sector local authority client, UK construction KPIs, Level 2 BIM and the new UK specific BS EN ISO19650 standards was presented, the adopted research methodology methods have been highlighted and the structure of the thesis and the overall research process was demonstrated. The next chapter will provide a critical review of the literature that highlights existing problems within the UK construction industry, presents information on the UK clients sector and their levels of understanding to BIM, highlights the benefits and barriers to the adoption of BIM across the globe, and explores the levels of BIM adoption in the UK and links to the transition from Level 2 BIM to the new BS EN ISO 19650 standards.

Chapter 2: Overview of the UK construction industry, client sector requirements, and approach to BIM

2.1 Introduction

This chapter aims to investigate the key literature relating to the UK construction industry, clients, and BIM implementation in the UK and across the globe. It will start by presenting some general information about the UK construction industry in which an overview of UK government and industrial reports will be outlined to demonstrate existing problems, such as fragmentation, and ways to tackle them, such as the need and drive for change. A clear definition to the type of clients and their requirements will be made to avoid perpetuating any existing misinterpretations. This will be followed a description of current problems and challenges that clients face. The client's approach to BIM and their lack of understanding will be discussed in order to help meet the objectives set. Client-related BIM benefits will be outlined to explore how they can endorse the client sector. Finally, the adoption of BIM across the globe will be explored, which will relate to an understanding of the levels of BIM adoption in the UK. This will specifically link to the transition from Level 2 BIM to the new BS EN ISO 19650 standards.

2.2 Overview on the UK construction industry

The UK construction industry has a vital role and is a main contributor to the UK's economic growth (Construction Industry Training Board. 2019). According to the latest statistics, in 2019, the construction sector contributed £117 billion to the UK economy, equating to 6% of the total economic output (Office for National Statistics. 2019) and it represents 2.4 million jobs, which comprises 7% of the UK total (Rhodes, 2019). Furthermore, according to the latest statistics from the UK Government, the number of people employed in the UK construction industry exceeds 3 million and the number of organisations in the construction sector total 314,590 (NOMIS. 2018, ONS. 2019; Statista. 2019). Despite its relative importance to the UK economy, this is an industry that faces several deep-rooted problems, which derive from its origins as a craft-based industry. For example, the key stakeholders in any construction project are 'forced' to form short-term relationships and collaborate in order to successfully deliver projects (Kumar, 2015). The Construction Products Association's (CPA) Summer Forecast report provided a full analysis of the construction drivers across thirty industry sectors; it identified infrastructure as a main driver of growth and vital to the fortunes of the construction industry in the next few years (CPA. 2019). Therefore, the industry needs to have appropriate infrastructure strategies, such as effective information exchange for effective partnerships. Key ingredients of this infrastructure, which are critical to the facilitation of smooth information flow is use of standards and protocols for effective information creation, storage, exchange and management (Kumar, 2015).

2.2.1 The need for improvement and drive for change

Over several decades, a series of industry and government reports have been published to demonstrate key construction problems that exist and to provide recommendations that are considered to address many of these problems. The set of reports covers the context of the UK construction industry and are all demanding change; indeed, some were reviewed during the time period 1934-2018 (Design buildings wiki. 2019; Gruneberg, 2018; Murray and Langford, 2003). These reports have addressed key issues related to fragmentation, lowest cost mentality, and the need for a high drive to change. They offered ways to overcome problems related to performance, profitability, productivity and predictability to name but a few areas. Nevertheless, additional problems have emerged in recent years (Mckinsey. 2017, 2018) that relate to low productivity. The key focus and conclusions from the reports were the drive for change and prompted the need to focus on construction performance in order to modify how it operates for future improvement. These reports focused on promoting improvements to key areas, such as performance, profitability, productivity and predictability (Marsh, 2017); these are also known as the Key Performance Indicators (KPIs). A summary of key construction industry reports is provided in Table 2.1.

Table 2.1 UK industry reports key focus and issues (Gruneberg, 2018; Murray and Langford, 2003)

General problems of the UK construction industry identified within key UK construction industry reports		
Chronological focus	**Issues**	**Report name and Reference**
Procurement Culture Urbanisation	**Contractual, Fragmentation, Productivity, Performance, Relationships, Late delivery, Inadequate quality, Poor budget control, Predictability, Profitability, wasteful, adversarial, low efficiency**	**Building to the Skies** (Bossom, 1934)
		Placing and Management of Building Contracts (Simon, 1944)
		The Working Party Report to the Minister of Works (Philips, 1950)
		Survey of Problems Before the Construction Industries (Emmerson, 1962)
		The Placing and Management of Contracts for Building and Civil Engineering Work (Banwell, 1964)
		Interdependence and Uncertainty: A study of the building industry, (Tavistock, 1966)
		Large Industrial Sites (National Economic Development Council (NEDC), 1970)
		The Public Client and the Construction Industries. (Wood, 1975)
		Faster Building for Industry (National Economic Development Office (NEDO), 1983)
		Faster Building for Commerce (NEDO. 1988)
Procurement Client Focus, Key Performance Indicators (KPIs), Introduction to Modern technology Leadership and governance, Improvement agenda Supply chain	**Fragmentation, Productivity, Performance, Relationships, lowest cost mentality, need for a high drive of change, Late delivery, Inadequate quality, Poor budget control, Predictability, Profitability, Sustainability**	**Constructing the Team** (Latham, 1994)
		Progress through Partnership, Report from the steering group of the Technology Foresight Programme (Stewart, 1995)
		Rethinking Construction (Egan, 1998)
		Achieving Excellence (Office of Government Commerce (OGC), 1999)
		Modernising construction (National Audit Office (NAO), 2001)
		Accelerating change: A report by the Strategic Forum for Construction (Egan, 2002)
		Improving Public Services through Better Construction (NAO. 2005)
		Be Valuable (Constructing Excellence (CE), 2005)
		Callcutt Review of Housebuilding Delivery (Callcutt, 2007)
		The Strategy for Sustainable Construction (Strategic Forum, 2008)
		Construction Matters (Business and Enterprise Select Committee (BESC), 2008)
		Never waste a good crisis. (Wolstenholme, 2009)
BIM and Digital transformation, Supply Chain Modern methods of construction	**Productivity, Performance, Predictability, Profitability, Sustainability, Digital transformation, Modernisation, collaboration, low profit margin, health and safety, apprenticeships and training, digitisation and off-site production and whole life asset performance**	**Government Construction Strategy** (Cabinet Office, 2011)
		Lessons from PFI and other projects (NAO. 2011)
		Construction 2025 (HM government, 2013)
		Government Construction Strategy: 2016-2020 (Infrastructure and Projects Authority (IPA), 2016)
		The Farmer review of the UK construction Labour Model: Modernise or die (Farmer, 2016)
		REINVENTING CONSTRUCTION: A ROUTE TO HIGHER PRODUCTIVITY (McKinsey Global Institute, 2017)
		Industrial Strategy: building a Britain fit for the future (HM government, 2017)
		Transforming Infrastructure Performance (IPA. 2017)
		Data for the Public good (Adonis, 2017)
		SOLVING THE PRODUCTIVITY PUZZLE (McKinsey Global Institute, 2018)
		Construction sector deal: Industrial Strategy (HM government, 2018)
		Building a safer future (Hackitt, 2018)
		Government transformation strategy (HM government. 2020a)
		National Infrastructure Strategy (HM government. 2020b)
		The Next Normal in Construction (Mckinsey, 2020)
		Construction Playbook (HM government. 2020c)
		National Infrastructure and Construction Pipeline (HM government. 2021a)
		Golden Thread Report (HM government. 2021b)

From a chronological perspective, the series of reports goes back as far as 1934; they trace the development of criticisms against the standard performance of the construction industry and highlight problems associated with the UK industry (Bossom, 1934). Similar problems have been addressed in further reports, with a chronological focus on procurement, culture, and urbanisation, and mainly related to contractual problems, fragmentation, and productivity, performance and relationship issues (Banwell, 1964; Emmerson, 1962; NEDC. 1970; NEDO. 1983, 1988; Philips, 1950; Simon, 1944; Tavistock, 1966; Wood, 1975). The issues presented in Table 2.1 identify the main problems that the UK construction industry have faced over time, during which they have been criticised for being wasteful and adversarial. Moreover, problems mainly relate to late delivery, poor budget control, inadequate quality, and more persistently poor performance (Design buildings wiki. 2019; Gruneberg, 2018). A few years later after further emphasis on existing problems a set of targets were developed to tackle those problems.

These aimed to reflect changes to the industry, and recommendations were provided on how the industry could improve. Therefore, the reports published between 1994 and 2009 were critical in providing steps on how to tackle existing problems, and acknowledged a change in the way the industry worked, for example in its culture (BESC. 2008; Calcutt, 2007; Constructing Excellence, 2005; Egan, 1998, 2002; Latham, 1994; NAO. 2001, 2005; OGC, 1999; Stewart, 1995; Strategic forum, 2008; Wolstenholme, 2009). Similarly, the chronological focus of these reports builds on previous publications, and they focus more on client involvement, the introduction of measures known as Key Performance Indicators (KPIs), the impact of new modern technological methods, and a greater focus on supply chain management. Similar issues continue to be mentioned within these reports, and sustainability was also introduced as an additional concern. In particular, the Latham (1994), Egan (1998), and Wolstenholme (2009) reports proposed that the industry adopts improvements and suggested key issues to help support the UK sector's competitiveness in driving and demanding more efficiency. This included enhancing client endorsements and partnering, and announcing supply chain management methods to construction projects and programmes (Dakhil, 2017; ECLLP. 2013). The recommendations and key issues suggested across these reports are known as the improvement agenda, and present a set of tasks to improve the UK industry as a whole.

Between 2011 and 2021, a cultural shift occurred including minor changes to the UK industry's vision which saw the focus placed on enabling economic growth through enhanced construction, but with reduced overall public sector cost (Adonis, 2017; Cabinet Office. 2011; Farmer, 2016; Hackitt, 2018; HM government. 2013, 2017, 2018, 2020a, 2020b, 2020c, 2021a, 2021b; IPA. 2016;

IPA. 2017; Mckinsey. 2017, 2020; NAO. 2011). Likewise, building on previous reports, they placed greater emphasis on BIM and digital transformation, and more focus on issues related to collaboration, modernisation, health and safety, apprenticeships, digitisation, and whole life cycle performance. The reduction to public sector costs was a key approach following these reports and mainly outlined in the Government Construction 2011-2015 Strategy report (Cabinet Office, 2011). It focused on the government as a key player in securing better value for money through construction industry improved performance by controlling the cost expenditure, thus, the construction industry would be responsible for 40% of the total cost.

Building on the key themes of the Government Construction 2011-2015 Strategy, the Construction 2025 report (HM Government. 2013) released a set of construction strategy actions for implementation by 2025. This involves attaining growth opportunities for the construction market of up to 70% (Leadership), whilst 50% derive from the following actions: improvement in exports (growth), lower emissions (sustainable), and faster deliver (smart), and 33% lower costs (people). these were the major actions set by the government strategy for the UK to achieve by 2025 (HM Government. 2013). Further to the Construction Strategy 2011-2015 (Cabinet Office, 2011) and the Construction 2025 Strategy (HM government. 2013), the Construction Strategy 2016-2020 released a strategy plan to improve delivery, efficiency and performance (IPA. 2016). The report sets out targets and strategies, which build on the aforementioned reports by focusing on smarter procurement, improved digital skills, and increased client capability. This aims to drive collaboration and deliver enhanced efficiencies.

Furthermore, a review of the UK construction industry was published, called “The Farmer Review” (Farmer, 2016). The report suggested that the UK’s construction industry faced ‘inexorable decline’ unless longstanding problems were addressed. It also called for the government to drive change and to promote modernisation. For this, a set of recommendations were offered that focused on reforming the Construction Industry Training Board (CITB), while the industry, clients and the government were called to collaborate to increase investment in R&D and innovation, and to shift production towards prefabrication, and governmental intervention in order to maintain appropriate skills and promoting the use of pre-manufactured solutions. Following this, the Government published actions to deal with productivity, known as the Industrial Strategy (HM Government. 2017), which focused on a long-term plan to boost productivity and the earning power of people throughout the UK. The Industrial Strategy (2017) aimed to deliberately strengthen the five foundations of productivity: Firstly, ideas - the world’s most innovative economy; secondly, people - good jobs and greater earning power for all; thirdly, infrastructure - a major upgrade to the UK's infrastructure; fourthly, business environment - the best place to start and grow a business, and finally, places - prosperous communities across the UK. This set a challenge to put the United Kingdom at the forefront of industries of the future, considering: clean growth, health ageing, and the future of mobility underpinned by AI and a data economy. Three strategic outcomes of the Transforming Construction Sector Deal were: Firstly, digital - delivering better, more certain outcomes using digital technologies; secondly, manufacturing - improving productivity, quality and safety by increasing the use of manufacturing, and performance – optimisation through life performance via the development of smart assets, as delivered by three key enablers (procure for better value, industry-led innovation, and skills for the future).

Moreover, the Construction Sector Deal (HM Government. 2018) was published, which built on the set of construction industry reports previously mentioned and aimed to transform the productivity of the sector by working collaboratively on: procuring for value, industry-led innovation, and skills for the future. It recommended the provision of funds over three years to target the UK's infrastructure in order to transform the sector through: the better adoption of digital and manufacturing technologies, the delivery of quality infrastructure and boosts to the skills of construction workers and training.

Finally, The Construction Playbook (HM government. 2020b) outlines 14 key policies and guidance for how public works projects and programs are assessed, procured, and delivered. Those are: 1) Commercial pipelines, 2) Market health and capability assessments, 3) Portfolio and longer term contracting. 4) Harmonise, digitise and rationalise demand, 5) Further embedded digital technologies, 6) Early Supply Chain Involvement (ESI), 7) Outcome-based approach, 8) Benchmarking and Should Cost Models, 9) Delivery Model Assessments (DMA), 10) Effective contracting, 11) Risk allocation, 12) Payment mechanism and pricing approach, 13) Assessing the economic and financial standing of suppliers, and 14) Resolution planning. The policies are addressed throughout the project and programme lifecycle. The playbook states that the government will use public sector procurement to achieve the transformational change envisaged for the construction industry. The Playbook through using the power of public sector procurement seek to demand for the use of BIM and other digital technologies, platforms and standardised components and the creation of digital twins for built assets (Oti-Sarpong, 2021).

In summary, the aforementioned set of reports published throughout the years has shown that problems continue to exist within the UK construction sector related to overall performance and poor productivity. In addition, the UK industry was criticised for being wasteful, adversarial, fragmented, reluctant to innovate, and poor at disseminating knowledge (Design buildings wiki. 2019). The economics of the construction industry should inform the direction of change by the construction industry to resolve the many issues it faces, including skills shortages, an adversarial culture, disputes, productivity in the industry, and many more challenges (Gruneberg, 2018). Following a discussion on the problems associated with nature of the UK construction industry and the need for change, the next section will expand further on construction industry related problems that have emerged in recent years and the UK Government's plans to address them.

2.2.2 Common problems in the UK construction industry and the UK Government's response

As previously mentioned, one of the key problems faced by the UK construction is fragmentation. Examples of these issues relate to the short-term relationships between 'collaborating' firms in a typical project, which results in insufficient long-term engagement, and investments to increase productivity via effective collaboration (Kumar, 2015). According to Crotty (2013, p.26), *"Unpredictability and low profitability are both caused by the same underlying phenomenon in large part – the devastatingly low quality of most of the information used on modern construction projects".* The lack of a holistic approach throughout the entire project asset lifecycle by the team has led to unacceptable outcomes, and this has become a significant characteristic of the industry (Kumar, 2015). It is a cause of fragmentation and the lack of coordination between team members; it has resulted in deliverables that do not meet team members' project requirements. This ensures the importance of collaboration between team members and indicates that such constructability issues could be avoided or tackled at an early phase of the project lifecycle. The efficiency of a projects' delivery cycle is illustrated by the Macleamy curve that delivers the concept of "shifting the effort" (Figure 2.1) (MacLeamy, 2004).

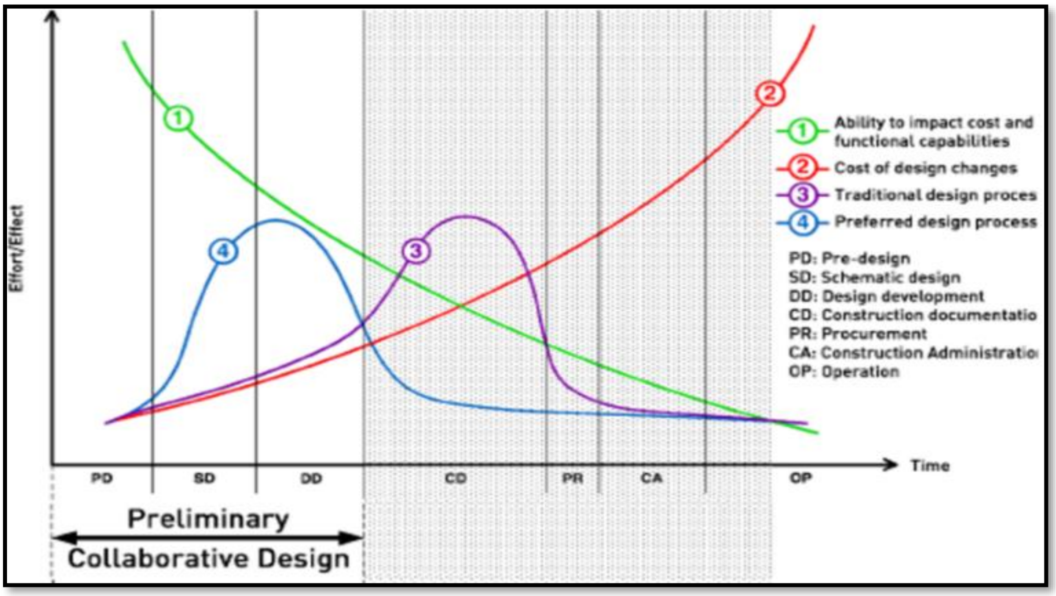


Figure 2.1 Macleamy Curve (Macleamy, 2004)

The MacLeamy Curve highlights that the further you are through the design process, the higher the cost of design change. This also has a direct correlation with potential project delays, wastage, and increased delivery costs. MacLeamy explained that the optimal project plan calls for high initial effort in the preliminary design phase for a more effective, cost-efficient project. The “MacLeamy Curve” shows that design decisions made earlier in the project are more cost effective since the opportunity to influence positive outcomes is greatest at this stage and the cost of change is minimal (AIA. 2007). Hence, it supports the delivery of construction projects through early involvement from different project parties, including clients, and thus it delivers in a way that focuses on client requirements, project KPIs, and initiatives that operate under a BIM-enabled environment. As mentioned in the previous section, the UK Government outlined a set of targets that directed the focus on clients, KPI measures, and the introduction to digital transformation and BIM (Egan, 1998; HM Government. 2011, 2016; Latham, 1994; Wolstenholme, 2009). This justifies the need to focus on clients and their requirements, along with how different project teams could collaborate. For this, the UK Government’s response to meeting clients’ needs dates back to Latham’s report (1994), which focused more on clients’ attitudes. Thus, industry requirements would significantly reflect clients’ needs, which vary from one to another. The recommendations of this report tended to focus on clients’ needs through attaining improved value for money by enhancing the overall performance of the industry. This was revisited in Egan’s report (1998) who introduced five main drivers for improvements to the UK construction industry: 1. Committed Leadership, 2. A focus on the customer, 3. Integrated processes and teams, 4. A quality-driven agenda, and 5. Commitment to people. By focusing on clients, some ways have been offered to resolve the aforementioned challenges and deliver solutions to tackle them. The next section will discuss how the focus on clients helps to tackle such problems and emphasise the client type targeted for this research.

2.2.3 Clients

Client requirements constitute the primary source of information for a construction project, and their adequate understanding by members of the project team play a vital role in the successful outcome of the project and in satisfying the client perspective (Kamara et al., 2000; Sanvido et al., 1992). In understanding the client, the project team can become fully aware of, and understand, their needs (Masterman, 2003). However, the relationships between clients and the industry is fraught because of its complexity and adversarial nature (Boyd & Chinyio, 2008). However, in terms of the construction stage, clients are typically identified as a group of people, organisations or equivalents, rather than individuals. Hence, data is explained to clients on how they can act better with the industry for their own benefit (Boyd & Chinyio, 2008). While this ensures that clients would meet different objectives, key industry reports (Egan, 1998; Latham, 1994; Wolstenholme, 2009) indicated that client similarities would exist as represented by their project requirements. This would be achieved through: *Obtaining value for money; ensuring the project is delivered on time; incurring reasonable running costs; and being free from defects on completion*" (Latham, 1994). Although clients may not have the relevant expertise, it is important that they are involved in the construction project process in order to deliver their project requirements by working with industry professionals. Different client categorisations will be explored to understand their nature and needs. Masterman (2003) stated that client organisations would typically be classified into private, public and mixed sector, and each has their own characteristics that reflect the organisation's source of funding ownership. The different types of clients within the UK industry are thereby based on their funded sources and presented in Figure 2.2 and defined in Table 2.2 (Boyd and Chinyio, 2008; Dakhil, 2017; Kometa et al., 1994; Vennström, 2008).

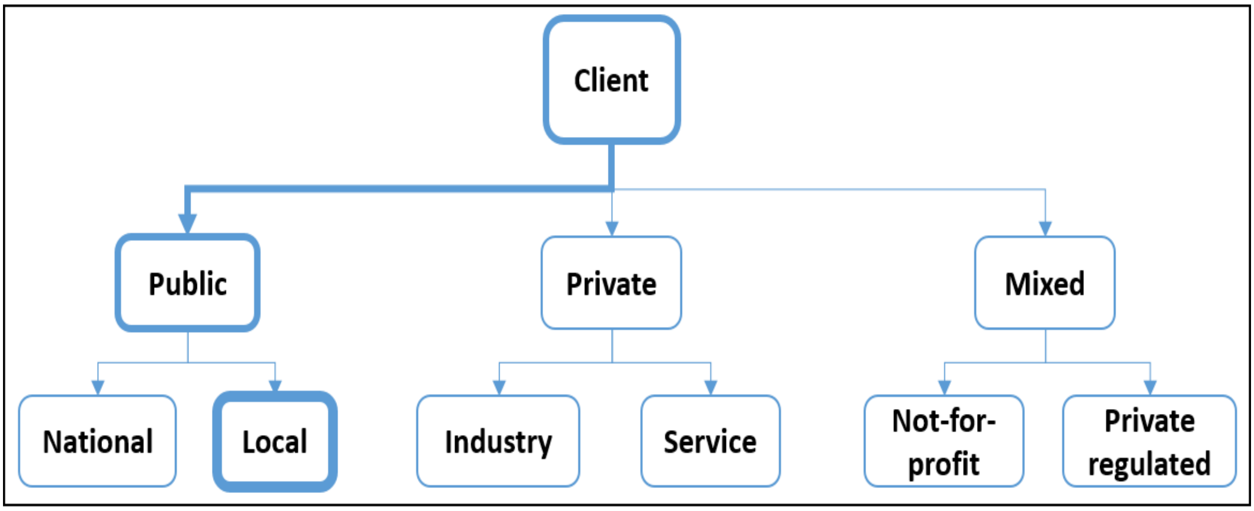


Figure 2.2 Client main types in UK construction industry (Boyd and Chinyio, 2008; Dakhil, 2017)

Table 2.2 Client definitions (Dakhil, 2017; Kometa et al., 1994; Vennström, 2008)

According to Wiggins (2014), construction (design and management) regulation (CDM) defines a client as an individual or organisation who, in the course or furtherance of a business, has a construction project carried out by another or by himself.
According to Cabe (2003), a construction client has been defined as the person or group that 'owns' the building. The client initiates the project, employs the design and construction teams, and finds the resources to make it a reality. The client is sometimes referred to as the 'employer', 'champion' or 'manager'. The executive client is the name sometimes given to the most senior person in the client organisation. The lead client is the name of the senior person on the client project team.
Kometa et al. (1994) simply define the client as the one who pays the bills. The client can be an individual or an organisation but is responsible for financing the project.
The construction client represents both owners and end-users who are responsible for ensuring that all the requirements of owners, customers, and wider society are met by a construction project, from its initial conception to the final implementation (Vennström, 2008).

Clients are important to the construction processes as they are normally the creators and funders of projects and as such the drivers for their developments. The ultimate goals of projects should be geared around the clients' requirements in terms of their aspirations, ambitions, visions, aims and objectives (Challender and Whitaker, 2019). Hence, the Clients' involvement at the early stages of projects is as such a paramount importance. According to Boyd and Chinyio (2008), in order to understand client businesses and their operational requirements, it is necessary to know the corporate environments that they work within. This involves examination of the purpose or service of their respective organisations, together with their company structures and the defining processes of their businesses. As such, this research aims to develop a BIM maturity and KPI assessment for the UK public sector local authority client and for this, it is of vital importance and based on the noteworthy governmental reports, the involvement of the clients in the early stages of the research to capture their current understanding with BIM maturity and KPI metrics, and how can both be linked together. This would indicate the need to educate clients with BIM maturity and KPI to understand what they are, and how can they both be linked together to enhance the overall performance of projects and team members within the UK industry. As a result, this research would target the public sector clients in delivering an assessment that would examine their levels of understanding with BIM maturity and KPIs and how they both link together, and how can this reflect back across the overall UK construction industry. This ensures that this research will be relevant in delivering an assessment that meets the clients' vision on how BIM maturity and KPI metrics could be linked, how it can enhance the clients' understanding with BIM, and will aim to improve the overall performance levels within UK organisations.

After delivering a review of different types of clients, it is essential to explore ways that the lifecycle of construction projects is monitored and measured through KPIs, since this will help to address key areas related to poor productivity and performance, and low profitability and productivity. Likewise, it is vital to understand BIM, the digital transformation and modernisation in order to better understand how to overcome the previously mentioned problems and identify how this support could resolve other problems across the UK construction industry. The next section will deliver more detail on BIM and its approach to solving the UK construction industry's problems. This will begin by delivering a review on the BIM evolvement.

2.3 The evolvement of BIM

An international timeline for BIM development is shown in Figure 2.3 (Nisbet & Dinesen, 2010). This timeline depicts how BIM developed over time to reach to its current state.

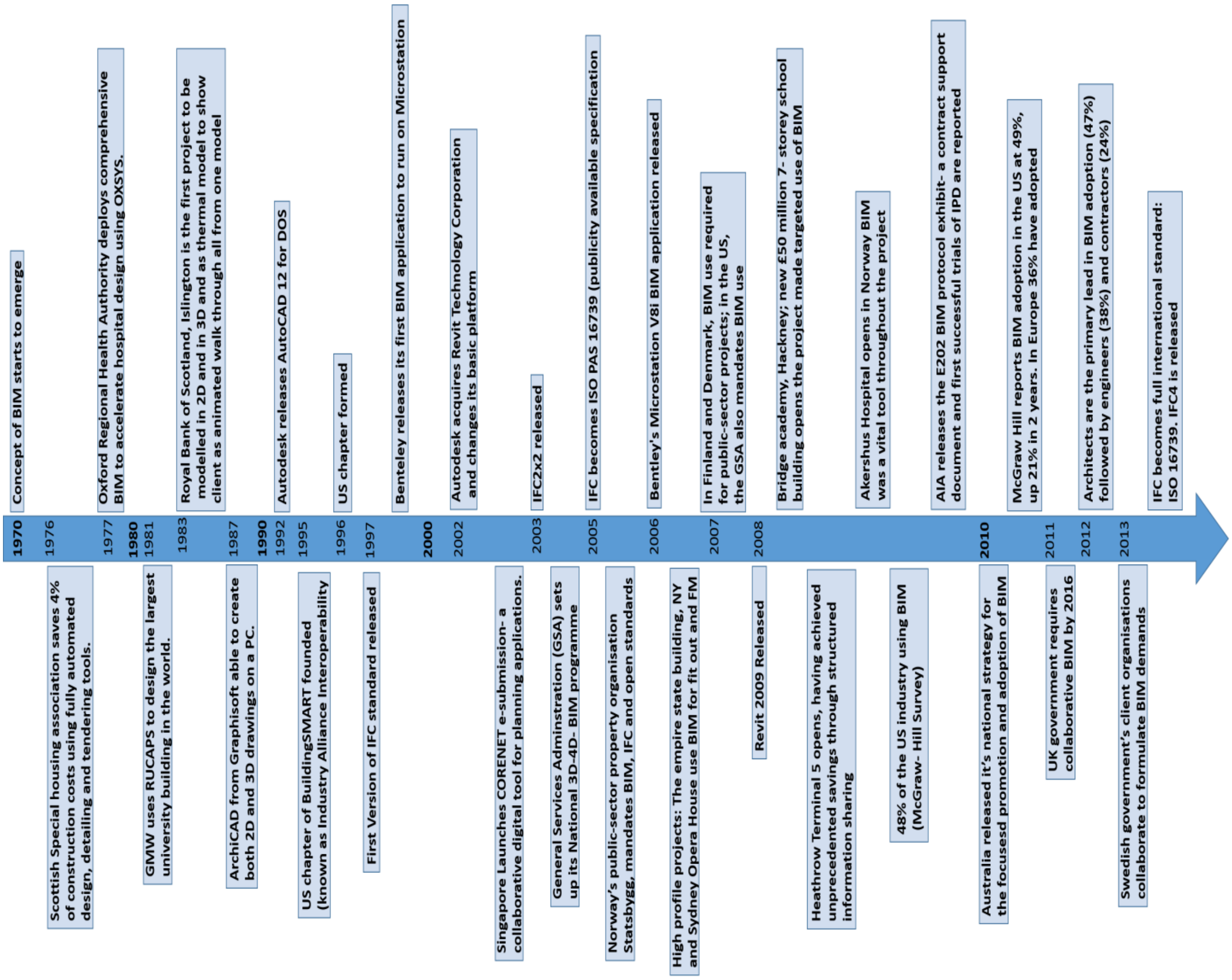


Figure 2.3 BIM international Timeline (Nisbet & Dinesen, 2010)

Around the late 1960s, the concept of BIM emerged as a subset of computer-aided design (CAD) software; this replaced manually generated 2D drawings (AbuEbeid and Nielsen, 2020; Akdag and Maqsood, 2019). As such, the Building Descriptive Systems (BDS) that was developed by Charles Eastman is widely acknowledged as the start of BIM in the 1970s. In the late 1970s and early 1980s building information modelling was based on 3D solid modelling and replaced 2D CAD for design development. Furthermore, in the 1980s, Gobar Bojar developed a BIM enabled modern building tool, namely ArchiCAD software (Gobar Adviseurs, 2010; Staub-French et al., 2011). Moreover, a collaboration of data exchange and open standards sharing was delivered in 1983 as a clear strategy to enable a process that combined success by improving engineering information communications (Bew and Underwood, 2010). The early 1990's saw the need within the AEC industry for a data-sharing solution between organisations. Many within the industry wanted to develop a solution that used the Internet for project management, data storage, and collaboration (AbuEbeid and Nielsen, 2020; Akdag and Maqsood, 2019; Varghese, 2020; Vidalakis et al., 2020). Following this, deficiency issues related to technological information flow were recognised between 1990 and 2000s, which required action to tackle such problems. BIM authorising and model checking tools were released to support its evolution (Bew and Underwood, 2010) as software, and data transferred between these tools would be accessible through open data standards, known by IFC (Gobar Adviseurs, 2010). Over the years, BIM has seen further enhancements to include models (3D), a time/schedule model (4D), cost model (5D) operation model (6D), and sustainability model (7D) among others depending on the available information (AbuEbeid and Nielsen, 2020; Akdag and Maqsood, 2019; Gobar Adviseurs, 2010; Staub-French et al., 2011; Varghese, 2020; Vidalakis et al., 2020). The next section will consider the various definitions of BIM across the literature.

2.4 What is Building Information Modelling (BIM)?

Several definitions of BIM have been derived, which have mainly emerged from academia or government bodies; however, there is no single definition of BIM (Suermann & Issa, 2009). From an academic point of view, the BIM Handbook defined it as, *"a new approach to design, construction, and facility management…BIM is not a thing or a type of software but a human activity that ultimately involves broad process changes in construction"* (Eastman et al., 2018, p.366). From a government perspective, the US Associated General Contractors Guide (AGC) defines BIM as *"……the development and use of a computer software model to simulate the construction and operation of a facility……..from which views and data appropriate to various users' needs can be extracted and analysed to generate information that can be used to make decisions"* (AGC. 2006, p.3). However, the National Institute of Building Sciences (Abbasnejad & Moud, 2013, p.289; NIBS. 2007) states that,

> *A Building Information Model, or BIM, utilizes cutting edge digital technology to establish a computable representation of all the physical and functional characteristics of a facility and its related project/lifecycle information, and is intended to be a repository of information for the facility owner/operator to use and maintain throughout the life-cycle of a facility*.

The "M" in both definitions' has been defined as a model that helps to serve existing project lifecycle information rather than a modelling process. An interesting note on this definition is the absence of 3D modelling description, which is replaced by a computable representation of all physical entities, and shows that the description of BIM is not only related to 3D but would relate to other dimensions such as 4D- 6D. Additional definitions of BIM are provided by Van Nederveen (2009) in (Abbasnejad & Moud, 2013, p.289),

> *A model of information about a building that comprises complete and sufficient information to support all lifecycle processes and which can be interpreted directly by computer applications. It comprises information about the building itself as well as its components, and comprises information about properties such as function, shape, material and processes for the building life cycle.*

McGraw Hill (2008) defines BIM as: "*The process of creating and using digital models for design, construction and/or operations of projects".* Azhar's (2011, p.241) definition is as *"one of the most promising recent developments in the architecture, engineering, and construction (AEC) industry………… This model, known as a building information model, can be used for planning, design, construction, and operation of the facility".* In comparison, Kiviniemi et al. (2008, p.8) defines BIM as "*an object-oriented model — a digital representation of a building to facilitate exchange and interoperability of information in digital format".* Moreover, the UK Government (HM Government. 2012, p.3) defines BIM as *"a collaborative way of working, underpinned by the digital technologies which unlock more efficient methods of designing, creating and maintaining our assets.".* Finally, Hooper (2015) outlined three "M" definitions of BIM:

1) An object-oriented representation of a 3D physical attributes identified as a Model,
2) The engagement of a creative processes within Modelling, and
3) A management platform introduced as Management.

Across most governmental bodies approaches, these definitions expressed BIM as either a model or management while most academic publications expressed it as Modelling. This shows the variations in approach when defining the "M" in BIM and confirms the absence of a universal approach across academia and the government. This suggests ongoing confusion when defining BIM between the academia and industry, which has resulted in a missing link within various BIM applications. These definitions are believed to be more relevant to BIM and clearly define its different concepts. As a result, this research aims to overcome issues in defining BIM at an early stage, which demands the identification of BIM requirements and the need to undertake actions to ensure its successful application. Having demonstrated a range of BIM definitions, the next section will explore how clients understand BIM.

2.4.1 BIM for clients

Previous challenges relate to clients' understandings of construction projects and in meeting their needs (Boyd & Chinyio, 2008). In addition, BIM has been defined in different ways and a lack of understanding exists amongst clients on what BIM means to them, and how it could be applied across construction projects (NBS. 2020). Hence, it is essential for clients to be led into the BIM implementation phase, by educating them on BIM and providing a better understanding of BIM requirements on construction projects; this would require significant change. However, the lack of client demand continues to represent a key barrier that prevents the gain of value from its adoption and arrests the widespread implementation of BIM within the industry (NBS. 2020). The absence of a push (or support) from clients prevents the full realisation of its benefits (Lindblad & Vass, 2015). Key ways to tackle these issues involves the inclusion of sound knowledge and an experienced client representative; these are key BIM role requirements and represent an important BIM adoption process. A higher quality delivery process and whole life cycle asset performance are some benefits that the BIM process - or tool - may offer clients (Eastman et al., 2011). Design and construction methods are changed through BIM (Yan & Damian, 2008), and the reductions to cost and time result from this change (Love et al., 2013). Furthermore, performance through the various stages of the project lifecycle would significantly improve if the stakeholders ensured collaboration, which would help to expand the client's organisational boundaries in understanding BIM. As a result, project stakeholders would get together at an early stage of a project to exchange project information and help deliver a better understanding of BIM to the clients, thus, creating a BIM collaborative environment (Arayici et al., 2011; Dado, 2011; Eastman et al., 2011; Laine & Karola, 2007). The usage of reliable project data and BIM processes are issues that client could make advantage of (Wilkinson, 2013). The next section will discuss the benefits and opportunities being linked to BIM, which would then reflect on how this who relate to clients.

2.5 BIM Benefits and Opportunities

Following a review of the links between BIM and the client, this section focuses on the benefits related to BIM. In particular, the benefit is "*an outcome of change which is perceived as a positive by stakeholders*" (Bradley, 2010). Haron (2013) claimed that realising the advantages of BIM would promote a comprehensive understanding by helping companies navigate a BIM implementation action plan to meet their needs. A range of benefits are widely recognised in association with the successful adoption and implementation of BIM, and the following positive outcomes for individuals, projects, and organisations. The benefits relate to BIM skills amongst user, namely: Early collaboration, reduced rework, improved quality through quality assurance, clarity in communication, increased profits, improved sustainability and creativity, more and faster decision making, and higher quality delivery (Azhar, 2011; Barlish and Sullivan, 2012; Becerik-Gerber and Kensek, 2009; BSI. 2010, Blay, Tulli, Mensah, 2019; Bryde et al., 2013; Farnsworth et al., 2015; Ghaffarianhoseini et al., 2017; Hardin and McCool, 2015; Kassem and li, 2020; Marsh, 2017; McGraw Hill construction. 2013; Underwood, 2010; Yan and Damian, 2008).

Benefits that relate to project outcomes include: Reducing requests for information and changed orders, improving awareness of progress and current status, reduced overall project duration, improved visualisation, reducing time, reducing errors and omissions, overall better construction projects outcomes, fewer claims and litigation, and reduced workflows cycle times (Eastman et al., 2011; Kassem and li, 2020; McGraw hill construction reports. 2009, 2010, 2013; Nisbet and Dinesen, 2010).

Most of their aforementioned benefits are associated with projects that have well-produced model developments. These would be primarily enhanced through these benefits and focus on improved building quality and performances alongside the combination and maximisation of design and construction. In addition, some of the aforementioned benefits focus on the overall enhanced value brought to projects, and the continuously improved internal benefits. Finally, NBS surveys (2019, 2020) revealed that, across projects and organisations, BIM would bring: cost efficiencies amongst 60% of the participants, increased coordination of construction documents amongst 81% of the participants, and changes in the workflow, practices or procedures amongst 91% of the participants. The aforementioned are some examples of benefits that would exist elsewhere. This helps to develop an initial list of benefits that could be realised to thus enable greater efficacies, performance and cost effectiveness across the overall UK construction industry.

A summary of the benefits are provided in Table 2.3, which list the most frequently cited BIM benefits across the literature. It shows that six frequently cited benefits: Early collaboration, reduced time, improved quality, clarity in communication and better coordination, reduced rework, and reduced overall project duration. However, all of the benefits addressed are relevant to projects and organisations, and help to form an initial standardised list of BIM benefits. The next section will discuss how BIM relates to clients and the benefits that would be most relevant fore this sector.

Table 2.3 Summary of BIM benefits and opportunities

BIM general benefits

Benefits
a) Early Collaboration
b) Reduced time
c) Improved quality through quality assurance
d) Clarity in Communication and better coordination
e) More and faster decision making
f) Higher Quality Delivery
g) Improved visualisation
h) Cost efficiencies
i) Require changes in our workflow, practices or procedures
j) Increase coordination of construction documents
k) Reducing Requests For Information (RFI) and change orders.
l) Reducing rework
m) Reducing Errors and Omissions
n) Increased profits
o) Overall better construction projects outcomes
p) Reduced overall project duration and scheduling
q) Improved Sustainability and creativity
r) Reducing Workflows cycle times
s) Fewer Claims/Litigation
t) Improving awareness of progress and current status.

References	Benefits																			
	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t
(Azhar, 2011)	x	x	x	x	x		x	x			x	x		x	x	x				x
(Barlish and Sullivan, 2012)	x	x	x	x						x	x	x	x	x		x		x	x	
(Becerik-Gerber and Kensek, 2009)	x	x	x	x		x	x	x		x	x	x		x		x			x	
(Blay, Tulli, Mensah, 2019)	x	x	x	x								x		x						
(Bryde et al., 2013)	x	x	x	x						x	x	x		x	x	x				
(BSI. 2010)	x	x	x	x		x	x		x		x	x	x	x		x				
(Eastman et al., 2011)	x	x	x	x	x		x			x	x			x		x	x	x		
(Farnsworth et al., 2015)	x	x	x	x		x	x	x				x	x	x		x	x	x		
(Ghaffarianhoseini et al., 2017)	x	x	x	x		x	x	x		x		x	x	x	x	x			x	
(Hardin and McCool, 2015)	x	x	x	x		x		x		x	x	x		x		x		x		
(Kassem and li, 2020)	x	x		x	x	x				x	x		x			x	x		x	x
(Marsh, 2017)	x	x	x	x	x	x						x		x						
(McGraw Hill Construction, 2009, 2010, 2013)	x	x		x		x		x	x		x		x		x			x	x	
(NBS. 2020)	x	x		x				x	x	x						x		x		x
(Nisbet & Dinesen, 2010)	x	x		x							x					x				x
(Underwood, 2010)	x	x	x	x		x	x	x			x	x		x		x	x	x		
(Yan and Damian, 2008)	x	x		x													x			

2.5.1 BIM relationship to clients and its benefits

Considering the relationship of BIM to clients helps to determine the potential benefits from this linkage. A total of 16 benefits have been linked to clients (Dakhil, 2017); having reviewed the benefits, some are linked to those presented in Table 2.3. Hence, Table 2.4 presents additional benefits along with their description, which are directly relevant to clients.

Table 2.4 BIM benefits for the clients

Benefits
a) Enhanced integration of processes
BIM implementation can provide solutions to acquire, manage and make use of information and processes from various project and enterprise level systems and integrate them with asset models.
b) Lower number of CO (Change orders)
Digital technology can speed up and streamline the change order process by providing a secure, fast, and simple way to share and send these orders.
c) Improved relationship with project stakeholders
BIM serves as a collaborative platform for all stakeholders to share their knowledge resource and information, and sufficient information increases communication effectiveness.
d) Improved data availability / accessibility
BIM can offer data availability and accessibility for all project stakeholders throughout the project life cycle.
e) Enhanced accuracy and validity of information
Information quality, in terms of accuracy and validity, plays a critical role in the construction industry.
f) Less service works required
BIM can help create and maintain facilities that are more efficient, have lower carbon emissions, cost less to run, and are better, more effective, and safer places to work.

References	Benefits					
	a	b	c	d	e	f
(Ahamed et al., 2010)	x		x	x	x	x
(Arayici et al., 2012)	x		x	x	x	x
(Azhar, 2011; Azhar et al., 2012)	x		x	x	x	
(Barlish and Sullivan, 2012)	x	x	x			x
(Becerik-Gerber and Kensek, 2009)	x		x	x	x	x
(Bryde et al., 2013)	x		x	x	x	
(Dado, 2011)	x	x		x	x	
(Eastman et al., 2011)	x	x	x	x	x	x
(Giel, 2009)	x		x	x	x	x
(Gilkinson, 2010)	x		x	x	x	x
(Hardin, 2011)	x	x	x	x	x	x
(Hergunsel, 2011)	x	x	x		x	x
(HM Government. 2012)	x		x	x		x
(Lorime, 2011)	x		x	x		x
(McGraw Hill Construction, 2009)	x		x	x	x	
(Migilinskas et al., 2013)	x			x	x	x
(Morrison, 2010)	x		x		x	x
(National BIM Standard, 2011)	x		x		x	x
(Rodriguez, 2011)	x	x	x	x	x	x
(Succar, 2010b)	x		x	x	x	x
(Suermann, 2009)	x	x	x	x	x	x
(Sullivan, 2007)	x			x	x	
(Underwood, 2009)	x		x	x	x	x
(Yan and Damian, 2008)	x			x	x	x

The benefits emerge as a direct result of clients' use of BIM in various areas across the project lifecycle (Bryde et al., 2013; Dakhil, 2017; Eadie et al., 2013). Its application across both design and construction phases along with significant operating savings could sell BIM's benefits (Eadie et al., 2015; Lindblad and Vass, 2015). For stakeholders to provide high-quality, relevant information, BIM requirements need to be clearly defined. As such, its usage across different project lifecycle stages would require clients to meet certain BIM project requirements, in order to enable them to achieve the required benefits. This would be possible through the adoption of a BIM investment plan that is accompanied by reviews to ensure alignment with strategic business interests and project specific focal points. BIM implementation through clients would play a vital role in the construction industry since it would help to enhance the levels of BIM understanding and thus provide a successful path to its implementation across projects (Lindblad and Vass, 2015; Underwood et al., 2016). Thus, 3D modelling to deliver digitally-enabled key decision makers and promote greater visual clarity on projects are the key benefits expressed by clients that would impact on the local context should the general public understand the finished asset. Furthermore, most agreed that the construction design delivery phases have become more effective and efficient through BIM's improved collaboration and data sharing steps (Cousins and Knutt, 2017). According to the NBS report (2019), 61% of clients stated they would insist on using BIM due to the benefits it offers their practice. This indicates documented demands to tacking existing industry's challenges for improvement. Those benefits are presented in Figure 2.4.

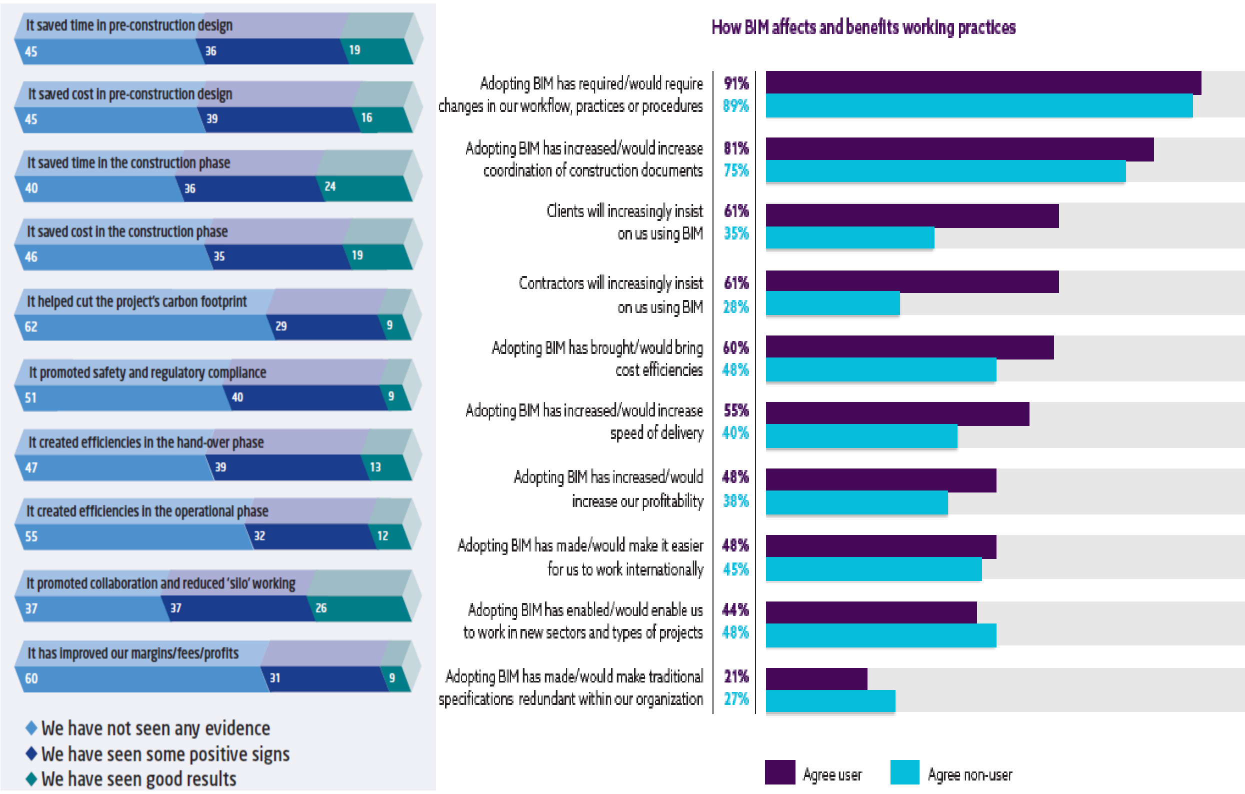


Figure 2.4 BIM benefits for the Clients (Cousins and Knutt, 2017; NBS. 2019)

It is necessary to identify how benefits could be measured in order to understand their impact on the client's understanding of BIM, and how projects could be delivered through its use. Hence, it is vital to explore tools and methods that exist and to provide steps to quantify and measure the benefits (Kassem & Li, 2020). The next section will discuss the potential ways that BIM could be quantified and measured against client and project requirements.

2.5.2 Quantifying and Measuring the Benefits of BIM

Although general and client specific BIM benefits have been identified, there is currently no method to identify how these benefits could be measured or quantified. Hence, it is necessary to quantify and measure BIM benefits to understand how it would reflect on clients and the construction industry. As a result, existing tools and methods to assess BIM benefits have increased in number over recent years due to their promised value in guiding BIM implementation (e.g. identifying implementation challenges, informing BIM improvement strategies) and improving the outcomes for organisations and projects (Kassem & Li, 2020). Having reviewed a number of existing BIM benefits tools and methods, six have been identified: three are BIM benefit measurement tools and three are BIM benefit methods (Kassem & Li, 2020). The three BIM benefits tools are: BIM Return on Investment tool (Scottish Future Trust. 2017), BIM Value (NATSPEC. 2015), and BIM benefits (Kassem & Li, 2020). These are online questionnaire tools that measure the benefits across projects and organisations. The Three BIM benefits methods are: Transport for London (TfL) BIM Benefits Methodology Strategy in 2017 (Kassem & Li, 2020), BIM Level 2 Benefits measurement methodology (PwC. 2018), and ROI BIM analysis (Giel & Issa, 2013). All tools and methods can be used to measure the project benefits from adopting BIM. The distinction between tools and methods is simply that a tool has a platform, such as an online survey or an Excel workbook, to conduct the assessment. Methods, on the other hand, provide details of the methodology behind the maturity measure, but do not have a platform for measurement that is available for review.

Some of the strengths of the BIM benefits tools were:

1) All tools address benefits that are inherently associated with enablers/activities available through BIM and the supporting project/standards ecosystem under which BIM is adopted;
2) The tools address benefits across the whole asset life cycle, from the early strategy through to design and construction, and operation and service delivery, and
3) All tools provide useful information on the general benefits of adopting BIM.

Some of the weaknesses of the BIM benefits tools were:

1) The accuracy of the BIM benefits evaluation by the tool is questionable;
2) The outputs from the evaluation, including the quantitative evaluation provided by the tools, are generally not informative, and
3) The complex nature of projects means that several factors influence the outcomes at different stages of the life cycle.

As this research will identify and extract key benefits that emerge from combining BIM maturity and KPI metrics, the benefits within the methods and tools will be reviewed, and a random list will be populated. This list will identify the key benefits that arise from combining BIM maturity and KPI metrics, and will be correlated with the set of benefits extracted from the literature, as noted in the previous sections. Following a review on the expected benefits from implementing BIM, the next section will review the existing key barriers and challenges associated with BIM and its negative impact on clients.

2.6 BIM Challenges and Barriers

Although BIM benefits and opportunities are widely acknowledged, several key challenges also exist. A key challenge lies in clients' lack of acknowledgment of the latest processes. They would be entitled to be transferred to new emerging BIM possibilities, hence, to ensure clients can access BIM outcomes, they first need to understand what BIM is and how it can benefit them. The latest NBS survey (2020) on clients' views on BIM barriers across the UK industry shows that, although the same barriers exist from the previous year's survey (NBS, 2019), there has been a drop in percentage for the BIM barriers identified from the client's point of view. The results revealed that 48% of clients involved in the survey indicated the lack of BIM training was a barrier, which was previously 59%. Moreover, 28% indicated a lack of collaboration (which was 33% in 2019), and 27% suggested the lack of standardized tools and protocols (33% in 2019). This indicates that, although year after year more clients in the UK industry are more aware of BIM, its meaning and the tasks involved, barriers still exist.

Challenges related to information sharing issues concerning the operations and model were identified by Eastman et al. (2011), including: challenges with teaming, technical barriers, and legal and liability issues, changes in practice, legal changes to documentation ownership, and production and interoperability issues. Users may face challenges in finding suitable methods for sharing model information, which is particularly important for architects and contractors. Potential delays can be avoided should these methods be used and tailored to different project teams. It would be necessary to implement a controlled means to produce models and determine its progress; this means it would be necessary to go through operational and maintenance data and address any associated legal issues (McGraw Hill. 2009, 2010, 2013). The required hardware upgrades are too expensive, while users lack sufficient time to evaluate them; moreover, functionality does not apply well enough to what we do, while costs issues and adaptation to the new process represent some key challenges that have been visualised in these reports.

Reports raise concerns over the possibility that new technology will generate challenges related to over-costing and time consumption, and the focus needs to be on the project, rather than on converting to BIM. Furthermore, insufficient time to evaluate the presented data similarly impacts clients' decisions on whether to adopt BIM. Additional challenges exist concerning BIM skills amongst users, which were: the lack of BIM skills across team members, issues with access to information, deficiencies with COBie, and excessive demands on time, a lack of clear responsibility allocation, organisational and cultural differences, Inconsistency in file naming, and the absence of information (Alwan et al., 2017; Anderson et al., 2012; Arayici et al., 2011; Azhar, 2011; Azhar et al., 2015; Bataw et al., 2014; Blay et al., 2019; BSI. 2010, Dakhil, 2017; Eadie et al., 2013; Eastman et al., 2011; Gledson et al., 2016; Gu and London, 2010; Gyarteng, 2014; Hardin and McCool, 2015; Khosrowshahi and Arayici, 2012; Mahamadu, 2017; Navendren et al., 2014; Succar, 2009). Such challenges may affect the progress of BIM, and thus, it is vital to consider alternative strategies to overcome such challenges. A summary of the general challenges associated with BIM is presented in Table 2.5. The next section will present challenges faced by clients.

Table 2.5 Summary of BIM general Challenges

Challenges
a) Lack of BIM skills
b) Challenges with teaming
c) Legal changes to documentation ownership and production
d) Changes in Practice
e) Legal and liability issues
f) Lack of sufficient time to evaluate it
g) Required hardware upgrades too expensive
h) Functionality doesn't apply well enough to what we do
i) Dealing with costs issues, and adaptation to the new process
j) Technical barriers
k) Interoperability
l) Access restriction to all information
m) Absence of information
n) Lack of training
o) Lack of standardized tools and protocols
p) Lack of collaboration
q) Lack of clear responsibility allocation
r) More time spent in explaining COBie
s) Inconsistency in file naming
t) Organisational cultural differences

References	Benefits																			
	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t
(Alwan et al., 2017)	x											x	x				x	x	x	x
(Anderson et al., 2012)	x											x	x				x	x	x	x
(Arayici et al., 2011)	x											x	x				x	x	x	x
(Azhar, 2011)	x											x	x				x	x	x	x
(Azhar et al., 2015)	x											x	x				x	x	x	x
(Bataw et al., 2014)	x											x	x				x	x	x	x
(Blay et al., 2019)	x											x	x				x	x	x	x
(BSI. 2010)	x											x	x				x	x	x	x
(Dakhil, 2017)	x											x	x				x	x	x	x
(Eadie et al., 2013)	x											x	x				x	x	x	x
(Eastman et al., 2011)	x	x	x	x	x					x	x	x	x				x	x	x	x
(Gledson et al., 2016)	x											x	x				x	x	x	x
(Gu and London, 2010)	x											x	x				x	x	x	x
(Gyarteng, 2014)	x											x	x				x	x	x	x
(Hardin and McCool, 2015)	x											x	x				x	x	x	x
(Khosrowshahi and Arayici, 2012)	x											x	x				x	x	x	x
(Mahamadu, 2017)	x											x	x				x	x	x	x
(McGraw Hill Construction, 2009, 2010, 2013)						x	x	x	x											
(Navendren et al., 2014)	x											x	x				x	x	x	x
(NBS. 2019, 2020)														x	x	x				
(Succar, 2009)	x											x	x				x	x	x	x

2.6.1 BIM Challenges for Clients

Having presented key challenges associated with BIM implementation, this section will focus on those faced by clients. The report, *What Clients Really Think: BIM Whitepaper* (Cousins and Knutt, 2017) was based on a survey of industry professionals within the Scottish client sector, which explored clients' reflections on the Level 2 Mandate in Scotland. This study revealed that overall levels of confidence to implement BIM were relatively low, as 27% of respondents ranked themselves as "very unsure" about operating at Level 2 BIM; only 14% rated themselves as having "some confidence" and only 5% claimed to be "fully confident." The reports indicated that level 2 experience was still dispersed unevenly across the industry. Overall, 49% said they had not worked on a Level 2 BIM project, while 28% had only worked on one to three projects. A question on "BIM's eight pillars" suggested its standards were weakly embedded.

The latest NBS reports (2020, 2021) outlines a set of challenges that clients face to adopting BIM. The greatest challenge noted was no client demand for BIM as indicated by 64% pf the total respondents. Other examples included a lack of in-house expertise (56%), too costly (46%), and an inability to see the benefits (15%). Since collaboration is a key driver within the construction industry, these results indicate that users still see the problems. This shows that a key route to meet client demand, and enable collaborative are yet to be achieved within the industry. Figure 2.5 presents the challenges and barriers to the UK industry concerning BIM adoption by clients (Cousins and Knutt, 2017; NBS. 2020).

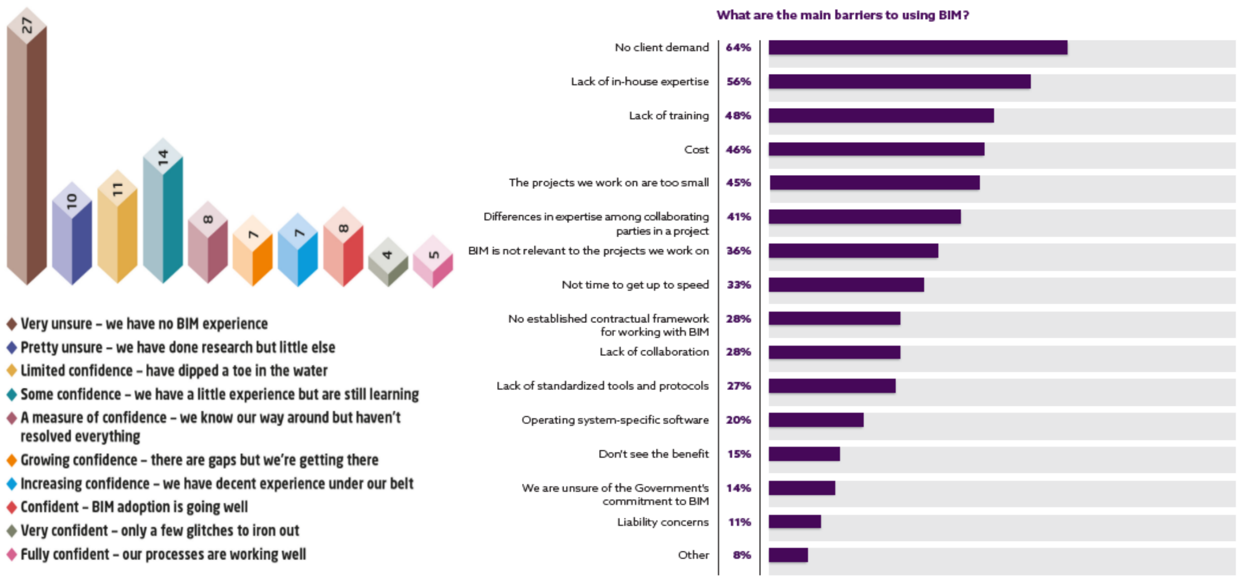


Figure 2.5 Companies experience on Level 2 BIM (Cousins and Knutt, 2017) vs Main barriers of using BIM (NBS. 2020)

Having identified the general benefits and barriers associated with BIM and how they relate to clients, the next section will discuss how was BIM adopted across the globe, and focus its adoption in the UK.

2.7 BIM Adoption Across the Globe

Building Information Modelling is approached differently in various countries across the globe, while the adoption of BIM across the globe has increased over recent years. According to surveys conducted by Jung and Lee (2015), BIM has been adopted in 41 countries across six continents, including the UK, showing its rapid growth across the globe. According to Badrinath, Chang, and Hsieh (2016, p.839) *"The BIM research associated literature review illuminates us that there are more than 1,500 BIM publications that have been published in the past 25 years by global BIM researchers from 65 countries".* There is an increase in the adoption of BIM across the international construction community and in countries with (or planning) a regulatory requirement for BIM (McAuley et al., 2017). This correlates with previous studies, which reveal that BIM is growing widely in various countries. The adoption of BIM is mandatory for increased productivity and efficiency through the digitalisation of work processes (Varghese, 2020).

The adoption of BIM as an on-going process requires continuous monitoring, planning and execution (Acampa, et al., 2020; Akdag and Maqsood, 2019; Babatunde et al., 2020; Lindblad and Guerrero, 2020; Ma et al., 2020; Olawumi and Chan, 2019; Vidalakis et al., 2019). This suggests that the adoption of BIM continues to increase and there is global demand for its implementation across various construction sectors. Research direction and model uses (known as custom models) focus on its adoption in various sectors and construction organisations, and existing maturities have been presented across the globe. The BIM research compass consists of twelve directions, which are: Conceptual boundaries, adoption, maturity, standardisation, lean and green, process simulation and monitoring, Building Information Services (BIS), building and geo-information integration, emergency response, industry-wide adoption, education and training, and real-life cases. It was recognised that related research directions were mainly evident in the US, Australia, and UK, which indicates that BIM is covered widely in these countries (Badrinath, Chang, and Hsieh, 2016). The compass is shown in Figure 2.6 on the left (Isikdag and Underwood, 2010). The elements of the compass related to this research are highlighted in Figure 2.6 on the right. Thus, the highlighted areas represent 34% of the total distribution of studies related to this research. This indicates that the study is essential to explore how maturity is developed amongst clients within the UK construction industry.

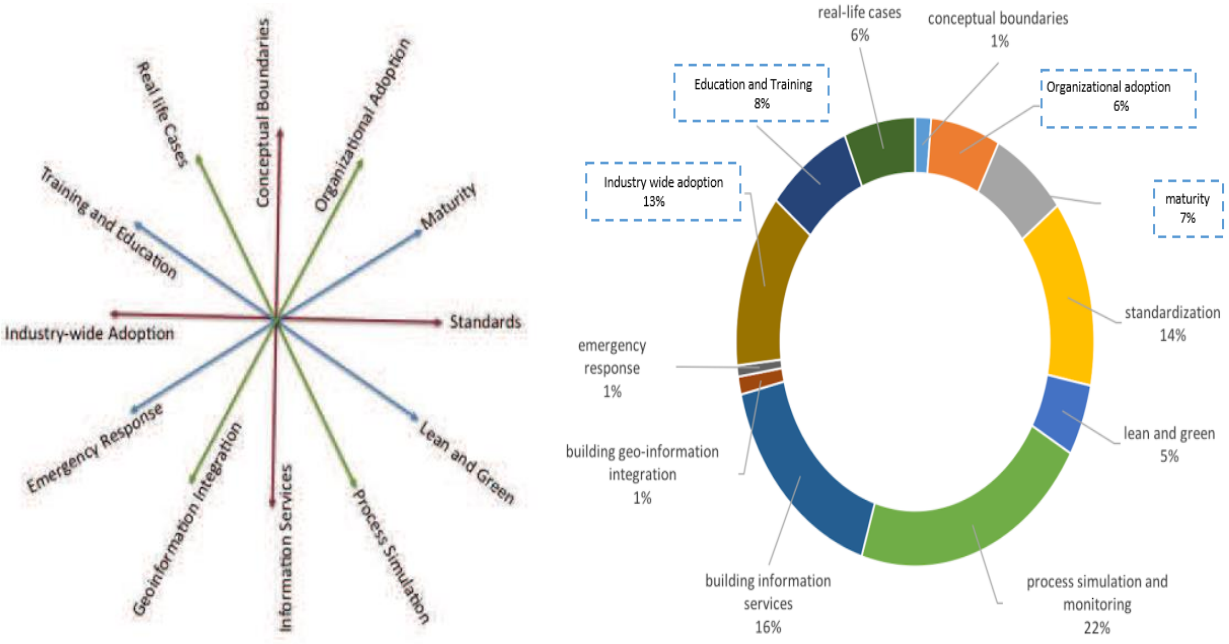


Figure 2.6 BIM research compass (left) and Research direction distribution related to research (right) (Badrinath et al., 2016; Isikdag and Underwood, 2010)

The main reasons for the relatedness of the highlighted areas are as follows:

1) Organisational adoption: Studies in this area relate to the BIM approach within the UK client sector, and the readiness to adopt BIM within organisations.
2) Maturity: The development of BIM maturity to facilitate the UK client sector and identify key success factors associated with its implementation. Studies under this category will be useful, as they will help to understand how BIM maturity will be applied within the UK industry.
3) Industry wide adoption: Better understanding of BIM adoption across the UK construction industry to achieve a governmental mandate to BIM. Studies under this category support a better understanding of how previous BIM applications have influenced its industry wide adoption based on the current and future statuses.
4) Education and training: Understanding issues that may arise from the adoption of BIM maturity amongst the client sector. Studies in this category will help to see what current issues may exist from adopting the suggested BIM maturity to the UK client sector.

The four research compass areas mainly cover the aspects addressed in this research and meet the ultimate research aim. Table 2.6 provides a definition and additional reasons for the compass area selections.

Table 2.6 Research compass areas definition and selection reasons (Isikdag and Underwood, 2010)

Research compass area	Description	Reason for selection
Organisational adoption	BIM adoption most likely occurs in phases but serious effort should be taken to move from one phase into another. As indicated by the authors, in the evolutionary approach to implementing BIM, organisations must be realistic as to their current capability and progress through the evolution.	Studies that fall under this category are believed to be related to how will BIM be approached within the UK client sector, its current progress to the capability, and readiness to adopt Level 2 BIM within the organisation.
Maturity	A key area in BIM is organisational readiness which plays a significant role in the absorption within enterprises. If BIM is considered as a set of new technology and methodologies supporting information management in the AEC industry, then maturity in terms of implementing and using BIM (technology and methodologies) is critical to the success of a BIM implementation. Frameworks for measuring BIM maturity can greatly facilitate organisations in positioning themselves against their competitors in terms of technological, methodological, and process maturity.	Studies under this category will be useful, as they will help to understand how BIM maturity will be applied within the UK industry. The various BIM maturities produced will be assessed to identify key factors that help provide success to BIM implementation within the organisations, and this shall help to develop a Level 2 BIM maturity for this research to facilitate the UK client sector within the construction industry and see how it will be used within the sector.
Industry wide adoption	In terms of the focus of studies on industry-wide adoption then this is very much towards the positioning of BIM adoption across disciplines in relation to their current status and future expectations and based on such factors as the tools, people and processes. The efforts on measuring the extent to which BIM has been implemented nationwide provides an indication of the industrial uptake of BIM, which can be used to position the BIM maturity of organisations in the context of their national BIM adoption level.	Studies under this category support a better understanding on how previous BIM applications have influenced the industry wide-adoption based on the current and future status. This shall help to see how the developed framework for this research shall influence the client sector within an organisation, and how can this reflect on the UK wider industry adoption to the tool towards their uptake to the governmental level 2 BIM mandate.
Education and Training	Education and Training is *sine qua non* for the successful BIM implementation and adoption in addressing such issues/barriers as culture, etc.	Studies in this category will help to see what current issues that may exist from adopting the suggested Level 2 BIM maturity to the UK client sector.

In order to request the right information at the right time, it is vital that the BIM implementation process is fully understood by the client; thus, some studies discuss the importance of client involvement within the BIM implementation process and throughout the project lifecycle (Badrinath et al., 2016; Dakhil, 2017). However, a lack of client demand and minimal client understanding of BIM exists, which are essential for its successful implementation throughout the life cycle of the project. This represents a research gap that this research intends to address concerning the UK approach to BIM. This could be embedded within Key Performance Indicators (KPIs) to determine how BIM maturity and KPI metrics could be integrated in order to serve the client and extract benefits to impact the overall performance of the construction industry for the UK client sector. Having reviewed the adoption of BIM across the globe, the next section will demonstrate how BIM has been adopted across the globe; this will be achieved by presenting a sample of standards that form part of the adoption of BIM globally.

2.7.1 International BIM standards

The previous section demonstrated where BIM is adopted and what methods were used in its adoption across the globe. A set of international standards have been published which explains how each country has met their governmental drive to adopt BIM. Figure 2.7 presents an overview of the BIM guides across the globe (McAuley et al., 2017).

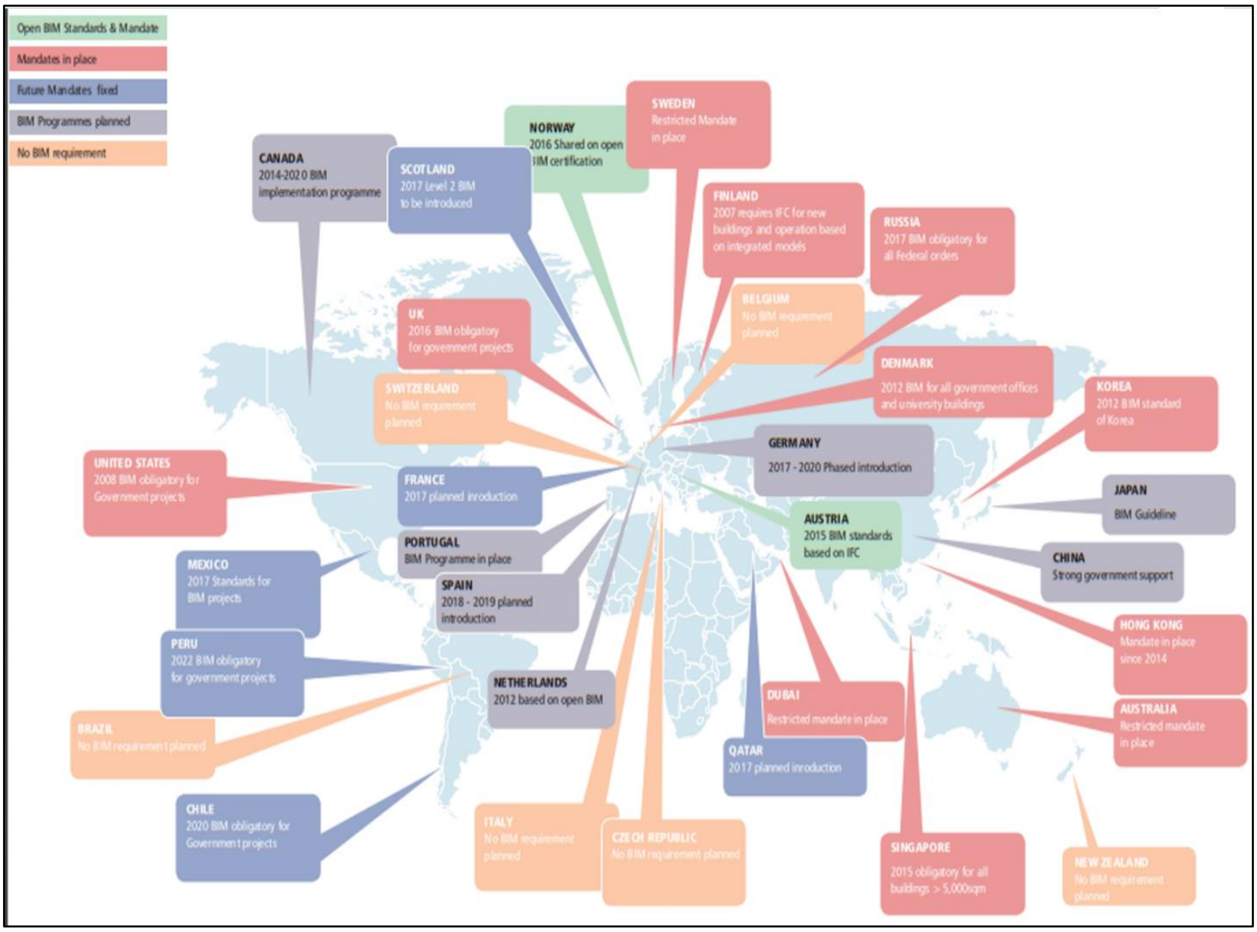


Figure 2.7 Global BIM Regulation Evolution adoption of standards across the globe (McAuley et al., 2017)

This shows that the countries covered in the figure require certain criteria and standards in order to effectively adopt BIM. Eleven countries (US, UK, Sweden, Finland, Russia, Denmark, Korea, Hong Kong, Australia, Dubai, and Singapore) have mandated the implementation of BIM across their industries, two countries (Norway and Austria) have IFC, Open BIM standards, and a mandate in place, six countries (Scotland, France, Mexico, Peru, Chile, and Qatar) will have future mandates fixed and adjusted across their industries, seven countries (Canada, Portugal, Spain, Netherlands, Germany, Japan, and China) have BIM programmes planned, and finally six countries (Brazil, Switzerland, Italy, Belgium, Czech Republic, and New Zealand) are setting out plans to prompt BIM adoption. This indicates the fast pace at which the globe is adopting BIM, whereby countries are either currently adopting or mandating it, or have various future plans to adopt and enforce BIM across their industries. Hence, as a result of government mandates on BIM, organisations and projects could be more ready to implement BIM, since it will help to recognise the benefits on construction projects, such as reduced overall cost and time, and increased efficiencies. Having reviewed how BIM was mandated across the globe, the next section examines the UK's approach to BIM, known as the Level 2 BIM mandate and the new BS EN ISO19650 standards.

2.8 UK Approach to BIM

To introduce the UK BIM approach, maturity was used to define its implementation phases (Succar, 2009). The universal adoption road map expects that Level 2 BIM maturity is implemented across all public projects by 2016 (BIM Level 2. 2016). Thus, 73% of more than 1000 professionals and organisations surveyed reported using BIM within the UK. Moreover, the majority (at 37%) identified that the BIM use is a standardised process that either follows the BS and PAS 1192 series, previously known as BIM Level 2; In addition, 26% of the sample indicated the use of the latest BS EN ISO19650 standards (NBS. 2020). Figure 2.8 distributes the four levels of BIM demonstrated by Bew and Richards (2008), which was then transferred to the new BS EN ISO19650 standards (BS EN ISO 19650-1:2018, 2019).

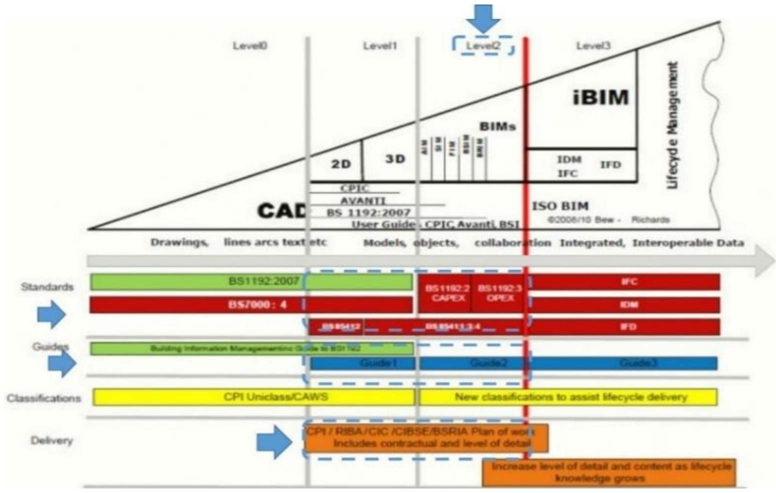


Figure 2.8 UK BIM task group maturity levels (Bew and Richards, 2008; BIM task group, 2013)

A BIM maturity/evolution was developed by the BIM task group, which consists of four levels (0-3). These levels provide an overview of project development, and enables and supports the collaborative delivery of a project. Table 2.7 provides the definition of BIM levels by the British Standards Institution (Bew and Richards, 2008; BSI. 2008).

Table 2.7 BIM maturity levels definition (Bew and Richards, 2008; BSI. 2008)

UK BIM maturity levels	Definition
Level 0	Unmanaged CAD, in 2D, with paper (or electronic paper) data exchange.
Level 1	Managed CAD in 2D or 3D format with a collaborative tool providing a common data environment with a standardised approach to data structure and format. Commercial data will be accomplished by standalone finance and cost management packages without integration.
Level 2	A managed 3D environment detained in separate discipline 'BIM' tools with data attached. Commercial data will be managed by initiative resource planning software and integrated by proprietary interfaces or bespoke middleware. This level of BIM may utilise 4D construction sequencing and/or 5D cost information.
Level 3	BIM Level 3 is defined as a fully integrated and collaborative process enabled by 'web services' and compliant with emerging Industry Foundation Class (IFC) standards. This level of BIM will utilise 4D construction sequencing, 5D cost information and 6D project lifecycle management information in a fully collaborative environment.

Level 0 indicates that collaboration does not exist. This is what the industry worked on as a whole following the computer revolution of the 1990's. CAD platforms were used to create drawings and Excel spreadsheets used to calculate costs on an organisational level (HM Government.

2012). Thus, data exchange was limited to different paper formats. Level 1 refers to a combination of 3D CAD models with 2D drawings. This information is shared on a common platform at the contractor level and not shared with other disciplines. Overall, the industry has been operating at Level 1 for the past decade. Level 2 BIM focuses on the collaborative sharing of this 3D information. Whilst each party can use its own 3D CAD model, the sharing of information is made possible through a common file format. This in turn allows for any organisation to combine data from different models to form a federated BIM model. A federated model is a combination of data from various models that allows for the different analysis of the design's integrated aspects (i.e. clash detection). Level 3 takes a step further than the federated model approach, or collaborative BIM. It requires the use of a single BIM model, and demands that all participants use this model for data input. According to Bew and Richards (2008) and the UK BIM task group (2013), the classification of BIM into levels aimed to provide collaborative employment to better address various processes and evaluate the tools and techniques available. Overall project success rates and performance improvements are expected to occur from the application of Level 2 BIM.

According to the government’s targeted aim, this includes 33% cost reduction, improved carbon performances and project delivery efficiencies (BIS. 2011, 2013a). It is hoped that, as a result of its many claimed benefits, BIM would promote these changes. BIM’s economic development is guided by local and international economies, according to HM Government (2013). By meeting the ambitious 15-20% savings goal for capital projects by 2025, the expected savings for UK infrastructure and its clients through the widespread adoption of BIM are expected to total £2bn. Nonetheless, as BIM is seen differently across various stakeholders, its various definitions have resulted in a lack of awareness and knowledge across the UK industry (Bew and Underwood, 2010). Bew and Underwood propose that BIM can improve a facility's construction and operational efficiency by bridging the knowledge loss gap that occurs within the project’s handling stages from the design to construction teams and to prospective stakeholders. As a result, this would allow for a review of the BIM template information needs (Bew and Underwood, 2010). The next section will explore how BIM was adopted across the UK in general.

2.8.1 BIM Adoption in the UK

The introduction of BIM is progressive and is often characterised as a journey. The government set out a specific direction of travel for the industry by defining various levels of BIM and mandating Level 2 BIM, as presented in Figure 2.11. The NBS report (2018) shows that only 30% confirmed reaching Levels 0, 1 and 3, whereas 70% confirmed reaching Level 2 BIM in their organisations. This indicates successful approach to Level 2 BIM as set out by the UK government and confirms the industry is moving forward with its implementation. However, BIM in the UK has moved from Level 2 BIM to the BS EN ISO19650 standards, and its levels of adoption are presented in the NBS report (2018). Figure 2.9 presents the levels of BIM adoption in the UK.

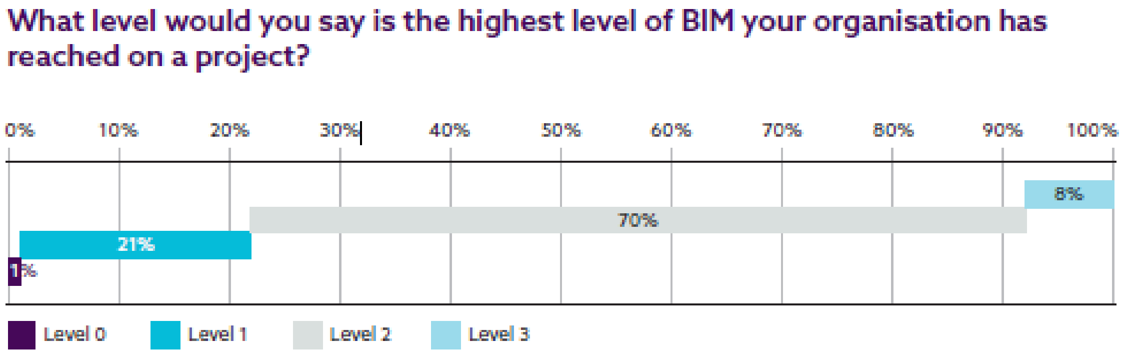


Figure 2.9 Levels of BIM adoption in the UK (NBS. 2018)

As a result of the HM Government mandate of Level 2 BIM in the UK and the NBS reports (2019, 2020), the adoption of BIM has increased in the UK over recent years. It is worth mentioning that, since the UK mandate on Level 2 BIM in 2016, the statistics have subsequently shown an increased level of BIM adoption. This was based on a survey conducted with the UK construction industry on the knowledge of BIM users. The findings are shown in Figure 2.10 (NBS. 2021).

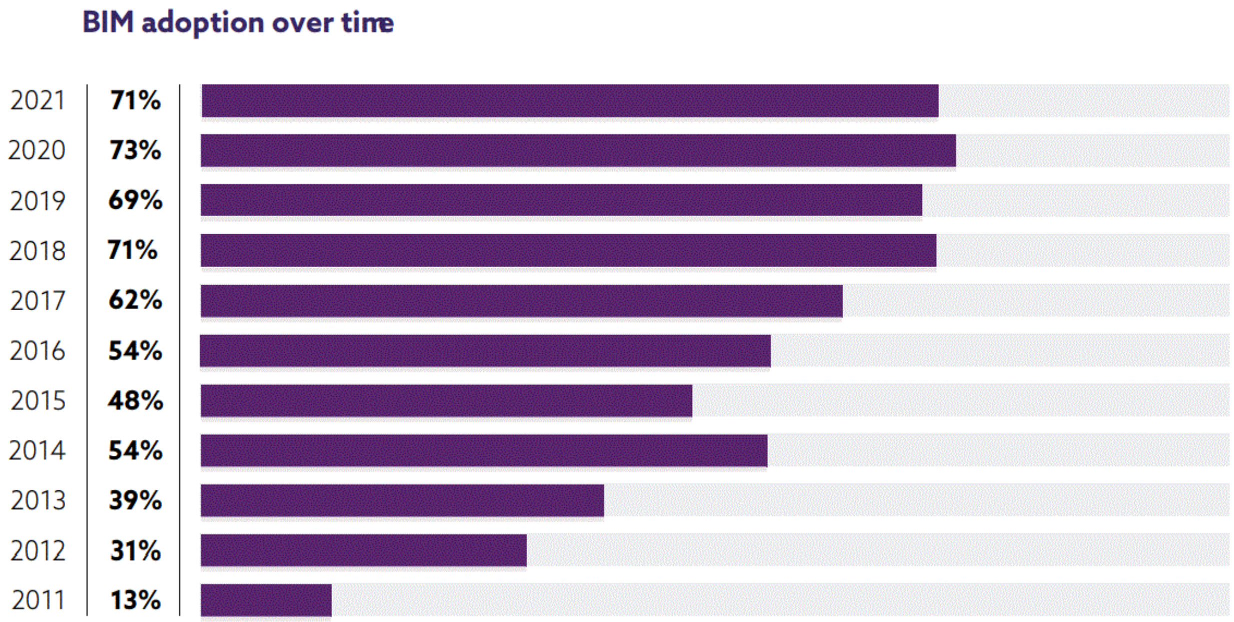


Figure 2.10 Levels of BIM adoption in the UK (NBS. 2021)

This indicates that, since Farmer's report (2016), the HM Government mandate on the implementation of Level 2 BIM (2012), and the NBS earlier reports (2019, 2020) have helped to raise industry awareness and understanding of BIM, as 54% stating this, while 71% confirmed this to DATE in 2021 (NBS. 2021). However, earlier in 2019, BS EN ISO19650 standards (Parts 1 and 2) were launched, which supersede Level 2 BIM and refer to information requirements across projects (NBS. 2020, 2021). This indicates the transformation from reference to a vague BIM concept, to better, specific information management on projects. This occurs by superseding Level 2 BIM standards, such as PAS1192:2 and BS1192:2007, to BS EN ISO19650 standards such as the PD19650 transition guidance, BS EN ISO19650 Parts 1 and 2. These are defined as collaborative processes for effective information management and would be recognised globally as the UK approach to BIM (UK BIM framework, 2019a; b). According to Shillcock (2019), the need for an international standard became apparent from the PAS1192 series benefits, which were recognised internationally by clients. Hence, an international set of standards; BS EN ISO19650 standards were suggested to recognise the level 2 BIM standards at an international level. Having reviewed BIM adoption in the UK, the next section discusses the Level 2 BIM approach, followed by the transition from Level 2 BIM series to the BS EN ISO19650 standards.

2.8.2 BIM in the UK (Level 2 BIM)

The UK government imposed a mandate on Level 2 BIM on all central publicly procured UK projects by 2016 (NBS. 2016). The government mandate discusses a number of criteria on the main components that formulate Level 2 BIM. Thus, it is vital to clearly define Level 2 BIM and to clearly outline its expected benefits, which could be reflected amongst the UK industry towards their rapid adoption of BIM. Level 2 BIM has been defined as: *"A series of domain and collaborative federated models, and the models consists of both 3D geometrical and non-graphical data and are prepared by different parties during the project life-cycle"* (BIM level 2. 2016; NBS. 2016). It also states that, *"BIM Level 2 requires all project and asset information, documentation and data to be electronic, which supports efficient delivery at the design and construction phases of the project."* (BIM Level 2. 2016).

In 2012, the UK Government launched the Industrial Strategy to reduce the cost of public sector capital by up to 20 percent by 2016 (HM Government. 2012). This was implemented to accelerate the adoption of BIM processes across both the public and private sector in order to promote benefits such as: reduced risk, increased carbon efficiency, and consistent planning (BIM Level 2. 2016). The strategy highlighted its challenge to existing business models and practises and encouraged greater collaboration, efficiency, innovation and value across all market elements. Table 2.8 presents a number of the Level 2 BIM standards and processes.

Table 2.8 Level 2 BIM Standards and Processes (BIM level 2. 2016; BSI. 2013, Kumar, 2015)

Level 2 BIM standards and processes	**Description**
BIM Execution plan **(BEP)**	The BIM Protocol is a supplementary legal agreement that is incorporated into professional services appointments and construction contracts by means of a simple amendment. The Protocol creates additional obligations and rights for the employer and the contracted party.
Common Data Environment **(CDE)**	The CDE is a means of providing a collaborative environment for sharing work and can be implemented in a number of ways. In addition to this, being a single source of information for any given project, used to collect, manage and disseminate all relevant approved project documents for multi-disciplinary teams.
Collaborative working	All parties use their own 3D CAD models, but not necessarily working on a single, shared model. The collaboration comes in the form of how the information is exchanged between different parties – and is the crucial aspect of BIM level 2.
Employers Information Requirements **(EIR)**	Provides an effective platform to communicate these requirements as part of an appointment process. Information Requirements need to be defined as part of the Employer's Requirements. 3 stages: Technical, management, commercial. Complex technical document.
Asset Information Requirements **(AIR)**	These define the information that is required for an asset information model. An example of an AIR is a planned preventative maintenance schedule.
Education and Training **(Learning and outcomes framework)**	The remit of the Training / Education team is to (1) support the up-skilling of employees in the government department in the near-term for early adopter projects, (2) up-skill employees across departments for the long-term rollout of BIM across the public works and (3) to provide near- and long-term support to the industry to ensure the Level 2 BIM target for Government are met for 2016.
Master Information Delivery Plan **(MIDP)**	This document is used to manage the delivery of information during a project. The MIDP is an example of an Information Delivery Plan which is part of the BEP.
Organizational Information Requirements **(OIR)**	These describe what information is required by an organization for asset management systems and other organizational functions. An example of an OIR may be a requirement for occupation data from a portfolio of buildings.
Plain Language Questions **(PLQs)**	Defines a broad information requirement against which a supplier will respond with data taken from models and other sources.
Digital Plan of Work	A UK Government BIM Task Group draft document on concepts and detail of the management of built asset data derived from BIM.
Publicly Available Specifications **(PAS)**	Specification for information management for the capital /delivery phase of construction projects using Building Information Modelling. The purpose of the PAS is to support the objective to achieve BIM maturity Level 2 by specifying requirements for this level, setting set out the framework for collaborative working on BIM enabled projects and providing specific guidance for the information management requirements associated with projects delivered using BIM.
BS 1192:2007 + A2:2016	Collaborative production of architectural, engineering and construction information. Code of practice
BS 1192-4:2014	Collaborative production of information. Fulfilling employer's information exchange requirements using COBie. Code of practice
PAS 1192-2: 2013	Specification for information management for the capital/delivery phase of construction projects using building information modelling
PAS 1192-3:2014	Specification for information management for the operational phase of assets using building information modelling (BIM)
PAS 1192-5: 2015	Specification for security-minded building information modelling, digital built environments and smart asset management
BS 8536-1:2015	Briefing for design and construction. Code of practice for facilities management (Buildings infrastructure)
BS 8536-2:2016	Briefing for design and construction. Code of practice for asset management (Linear and geographical infrastructure)
CIC BIM Protocol.	A supplementary legal agreement incorporated into professional services appointments and construction contracts by means of a simple amendment. The protocol creates additional obligations and rights for the employer and the contracted party and is based on the direct contractual relationship between the employer and the supplier.
Government Soft Landings **(GSL)**	To champion better outcomes for our built assets during the design & construction stages through Government Soft Landings (GSL) powered by a Building Information Model (BIM) to ensure value is achieved in the operational lifecycle of an asset.

The sample of standards shown in Table 2.8 demonstrates the required standards and processes when implementing Level 2 BIM. The BIM task group published the Level 2 BIM standards across a set of reports and publications. Level 2 BIM requirements were identified through a set of standards and processes for application. The UK Level 2 processes for the Level 2 BIM approach in Asset Capital Delivery and Operational phases are available in Figure 2.11 (Kumar, 2015; NBS. 2016). They demonstrate the processes for implementing the information set out in the PAS1192 standards parts 2 and 3.

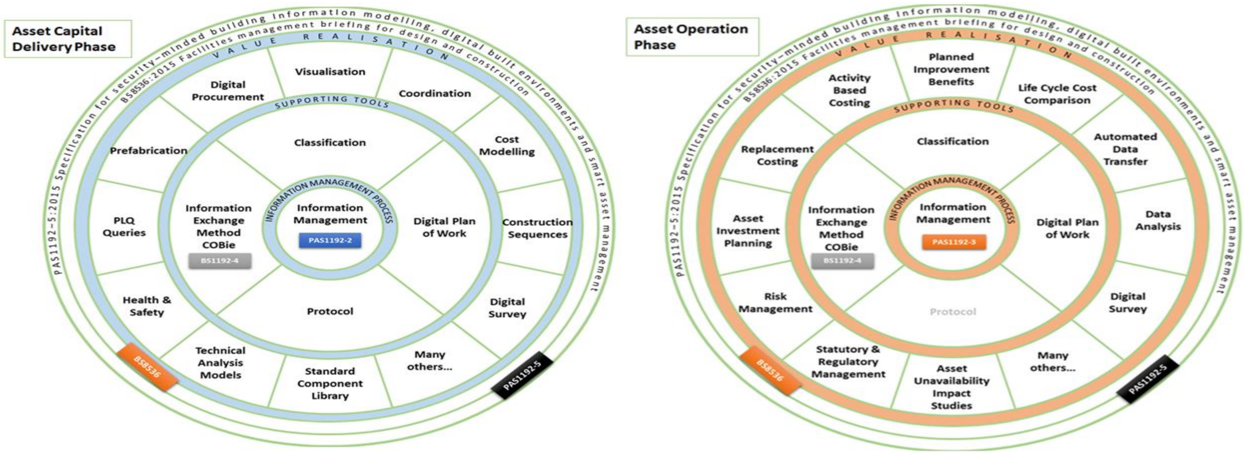


Figure 2.11 Level 2 BIM Processes across the asset capital delivery and operational phases (NBS. 2016)

Projects teams when adopting and implementing Level 2 BIM on projects follow these documents. Nevertheless, all documents are considered in many instances, but are not generally accepted, so the plan is often defined as operating "in the spirit" of Level 2 BIM, since there is a fear that the lack of understanding by clients that would prevent the adoption of the set of standards, as set out in the NBS survey (NBS. 2020). Having reviewed and presented the essence of Level 2 BIM, the next section will discuss the transition to the new BS EN ISO19650 standards, which superseded Level 2 BIM in early 2019.

2.8.3 BIM in the UK (Transition to the new BS EN ISO19650 standards)

The BS EN ISO19650 is based on a set of international standards that are recognisable from the PAS1192 standards. Thus, building upon the PAS 1192 standards, the BS EN ISO19650 standards enables teams from around the world to minimize wasteful activities and increase predictability around cost and time, through a common approach to the management of information (Shillcock, 2019). International organizations from different countries demanded that the International Organization for Standardization (ISO) elevated the PAS 1192 standards to an international level (Dadmehr and Coates, 2019). According to Shillcock (2019) *“the adoption of the UK 1192 series in the UK was hampered due to the lack of clear guidance. As a result, we ended up with a scattergun approach to guidance that was based upon different interpretations of the standards, which invariably included misinterpretations, contradictions or mistakes.”* This clearly suggests that the PAS1192 standards lacked clear guidance, which resulted from the lack of understanding of level 2 BIM standards amongst clients (NBS. 2020). Although the results from the NBS reports (2020, 2021) indicated the relatively successful adoption of BIM (and specifically Level 2 BIM), in early 2019, this took a step forward when the new BS EN ISO19650 standards replaced Level 2 BIM to promote better information management on projects through BS EN ISO19650 standards (NBS. 2020, 2021; Shillcock, 2019).

BS EN ISO 19650 is an international set of standards, which defines the collaborative processes for effective information management throughout the asset delivery and operational phase in the use of information modelling (BIM). The BS EN ISO19650 standards can be adopted by international organisations from various countries. For the UK, BS 1192 and PAS 1192-2 are superseded by BS EN ISO19650-1 and BS EN ISO19650-2; moreover, the publication of BS EN ISO19650-1 and BS EN ISO19650-2 represents a significant step forward in standardising information management requirements on projects through BIM as part of an internationally agreed set of concepts and principles. In addition, the transition guidance, known as the PD19650-0 has been prepared specifically to support existing adopters of BS 1192 and PAS 1192-2. This helps to understand the changes made between the UK's existing standards, and the superseding ISO documents (UK BIM framework. 2019a, b). The usage of the new BS EN ISO 19650 standards reflects back on the UK strategy highlighted in the Construction Playbook (HM government. 2020c) across one of their policies (Further embedded digital technologies), which indicates the need from local authorities to use the UK BIM Framework to standardise the approach to generate and classify data, data security and data exchange, and to support the adoption of the Information Management Framework. The adoption of the UK BIM framework will improve the performance, sustainability and value for money of projects and programmes. This further justifies the need to develop the proposed BIM maturity/KPI assessment that follows the new standards based on the UK government strategy. Figure 2.12 demonstrates the timeline from Level 2 BIM standards to the new BS EN ISO19650 standards, while Table 2.9, on the next page, presents the transferred terms from PAS 1192 to BS EN ISO19650, which ensures that the essence of both remain the same and only the terminology used to describe the terms have been changed. This ensures that the usage of BIM in this research remains relevant to the UK approach to BIM as a result of the transition from Level 2 BIM to BS EN ISO19650.

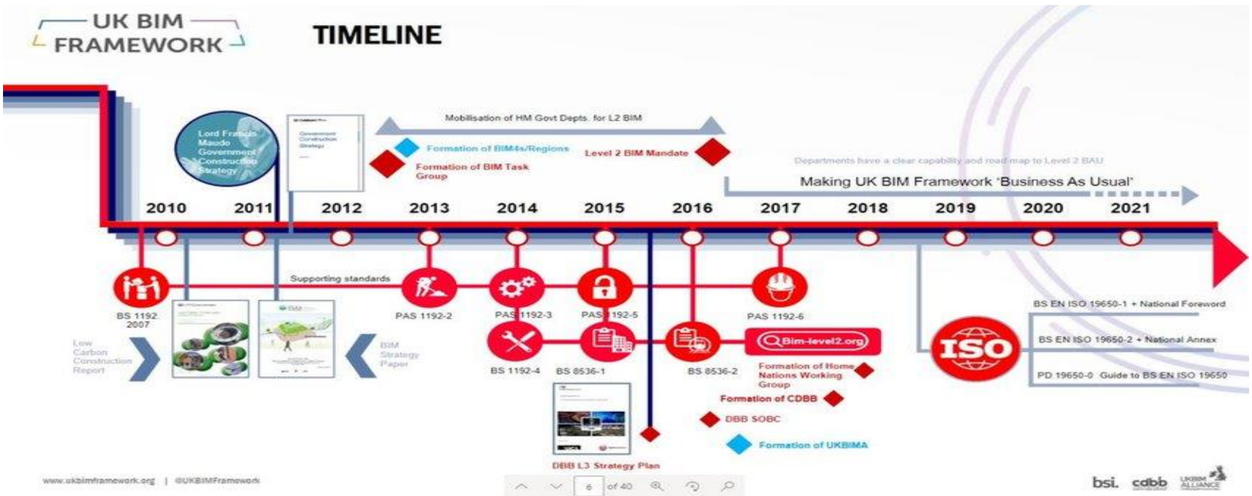


Figure 2.12 Transition from Level 2 BIM to BS EN ISO19650 (UK BIM frameworks. 2019a, b)

Figure 2.12 and Table 2.9 illustrate the transition from Level 2 BIM to BS EN ISO19650 as part of the UK approach to BIM from 2016 to the present time. In addition, the new BS EN ISO19650 standards provide an updated transition for the levels from Level 2 BIM to BS EN ISO19650 parts 1 and 2 (Figure 2.12). The figure demonstrates the transition of the BIM levels, and shows how the benefits are transferred into models across four layers and three different stages, in which the BS EN ISO19650 Parts 1 and 2 are met. This helps to better understand the purpose of the new standards.

Table 2.9 Translated BIM metrics from PAS1192 to BS EN ISO19650 (PD 19650-0:2019, 2019)

1192 term	19650 term	Comments
[New]	Risk register	The reference to the risk register is now explicit in BS EN ISO 19650-1
BIM execution plan	Information delivery plan (in BS EN ISO 19650-1) BIM execution plan (in BS EN ISO 19650-2)	BS EN ISO 19650-1 uses information delivery plan as the generic term for any plan in support of information delivery.
Capital/delivery phase	Delivery phase	Delivery phase is a simplification of capital/delivery phase without making any assumption about how the project funding is being treated in financial accounting
<CDE> area/section	<CDE> state	Area and section imply moving information from one place to another. This is not necessary in a CDE. It is the state of the information container that is important, not where it is stored.
CDE gate	Transition	Transition is used to denote change (in the state of the information container)
Container / file / document	Information container	ISO 19650 standardizes on the term Information container
Contract	Appointment	The more generic term appointment has been used in ISO 19650 instead of contract. This means one term can be used for both external contracts and internal work instructions
Employer	Appointing party / lead appointed party / appointed party	ISO 19650 term depends on where in the hierarchy the employer is located. Lead appointed party is not the same as design lead or construction lead in PAS 1192-2.
Employer's information requirements (EIR)	Exchange information requirements (EIR)	These are synonymous.
Graphical / non-graphical	Geometrical / non-geometrical	Geometrical is more appropriate to describe spatial positioning and relationships
Level of model definition / level of detail (LOD) / level of information (LOI)	Level of information need (no acronym)	Level of information need is a more generic term than any of the existing "Level of ..." terms used in 1192. It is not supposed to be shortened to an acronym.
Model / information model	Information model	ISO 19650 focuses specifically on the concept of the information model containing multiple types of information (geometrical and/or non-geometrical). This concept was in PAS 1192-2 but was not spelt out as consistently as it could have been.
Plain language questions (PLQ)	Project information requirements (PIR)	PLQ and PIR are both expressions of the high-level information needed by the client and/or their stakeholders to make key decisions concerning the project. The PIR, like the PLQ, are used to develop the detailed and contractual EIR. However, PIR can also include non-technical requirements and therefore can be broader than PLQ.
Project delivery team	Delivery team	In ISO 19650, delivery teams are the first-level breakdown of a project team and are led by a lead appointed party. Within a delivery team (both 1192 and 19650) there are one or more task teams who have their own appointments. In 19650 these are from the lead appointed party
Responsibility matrix	Responsibility matrix / Assignment matrix	In ISO 19650 there is a principle to develop responsibility matrices to cover information management activities and information delivery. The former is illustrated as the assignment matrix in BS EN ISO 19650-2:2019, Annex A.
Roles	Function	Information management roles are not included within BS EN ISO 19650-2. Instead, all activities within the information management process are to be undertaken by a single "information management function". BS EN ISO 19650-2:2019, Annex A provides a template for an information management function assignment matrix, which can be used by the appointing party to assign each activity (requirement) to themselves, to an appointed party or a third-party. Once an activity has been assigned, it is for the relevant party to identify the role that is responsible for the activity.
Standard method and procedure (SMP)	Combination of information standard and information production method and procedure	The 1192 term has been broken down into an information standard and an information production method and procedure. The content of the SMP is covered by these two separate elements
Suitability	Status	The terms are equivalent, as both define the permitted uses of information. BS 1192 also uses the term "status" to mean the combination of suitability and revision. There is no ISO 19650 equivalent for this BS 1192 use of "status"
Supplier	Lead appointed party (tier 1) / appointed party (tier 2 and below)	ISO 19650 term depends on where in the hierarchy the supplier is located.
Task team	Task team	There is no change in meaning, but compare with Project delivery team
Volume strategy	Federation strategy	The concept of volumes for sub-division of an information model is now described in terms of the reasons for which separate information models might need to be federated. This was an easier concept for non- UK countries to understand.

Figure 2.13 shows that maturity has been translated from Levels 0-3 to stages 1-3, and the maturity for which BS EN ISO19650-1 and BS EN ISO19650-2 have been designed apply predominantly across ISO maturity stage 2, but with some applicability in both stages 1 and 3 (UK BIM framework. 2019a, b).

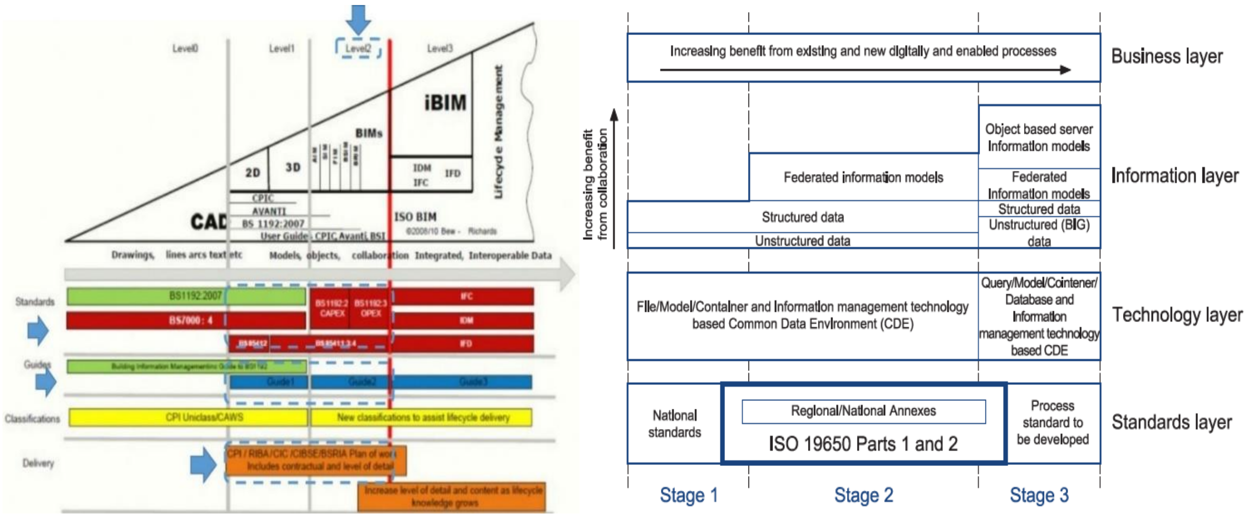


Figure 2.13 Transition from UK Level 2 BIM maturity levels to ISO19650 levels (BS EN ISO 19650-1:2018, 2019)

The BS EN ISO19650 diagram covers what has been referred to in the UK as BIM Level 2, plus some aspects of what has been referred to as BIM Level 1 and BIM Level 3. This is diagram is significant as it highlights that the ISO 19650 suite remains relevant as BIM implementation continues to develop. According to the PD 19650-0:2019 Standard (2019), the similarities between both diagram are in the:

1) increasing complexity and sophistication of information moving from left to right;
2) recognition of differences in standards at different stages or levels of maturity; and
3) increasing levels of collaboration with increasing maturity. However, the differences are as follows: 1) four clear layers to the ISO 19650-1 diagram, including a business layer which is not explicit in the UK maturity model; 2) no equivalent to UK BIM Level 0 in the ISO 19650-1 diagram; and 3) clearer subdivision of the information layer in the ISO 19650-1 diagram than is shown in the UK maturity model.

As a result, this shows the importance of the BS EN ISO19650 and how it has helped to deliver a better understanding of BIM in the UK. It also ensures that the proposed assessment as the main aim set for this research will need to reflect and embed the new standards to align with the UK government adoption strategies with new technologies (HM government. 2020c), which will return overall benefits to the UK public sector clients, and thus, this emphasises the importance of this research in achieving the aim of delivering an assessment (according to the new standards) that will be adopted across the client sector. Having reviewed the UK approach to BIM in relation to Level 2 BIM and the transition to BS EN ISO19650, the next section will summarise this chapter.

2.9 Summary

This chapter presented a review of the literature on the current UK construction industry. Historical reports were presented and highlighted the significance of BIM to the UK industry. Problems that have continued to exist within the UK were discussed in order to explore the barriers and challenges that the UK construction sector currently faces. An exploration of construction clients and their different uses were emphasised. In addition to this, the chapter highlighted the vital role of clients in leading the implementation of innovation in the UK construction industry. The history of BIM, including what it is and the BIM approach for clients, was outlined; moreover, the BIM approach was explained in detail and some of the benefits and challenges derived for clients were extracted. A clear definition of the UK approach to BIM was presented, which examined the approach to Level 2 BIM in the first instance. This was followed by the transition to the new BS EN ISO19650 standards and the need to adopt the UK BIM framework as part of the government initiative on the usage of Further embedded digital technologies. The next chapter will review BIM maturity assessments, KPIs, and their relationship. The next chapter will also discuss BIM and KPIs separately, including how they relate, and what they can offer clients.

Chapter 3: Interrelationships between BIM Maturity and KPI metrics

3.1 Introduction

Having reviewed the UK construction industry and the UK approach to BIM and digital transformation, this chapter explores existing BIM maturity assessments, KPI metrics, and their relationship. It also examines how this aligns with the adoption of Level 2 BIM/BS EN ISO19650 standards amongst UK construction clients. Hence, this chapter aims to explore maturity assessments, and highlight those mostly closely related to BIM maturity, as it is important to explore how maturity assessments began, and how BIM maturity is adopted across maturity assessments. Furthermore, a critical review of BIM maturity assessments in the literature will be presented to demonstrate their usage and various applications in the UK and across the globe. In addition, KPIs will be explored to identify the key elements that are used to measure the overall performance of the construction industry within the UK and across the globe. Moreover, a review will be conducted into how BIM maturity and KPI metrics have been linked to recognise the gaps that exist, which will help to deliver solutions to link the two, which is the aim of this research.

3.2 What are Capability, Maturity, and Competency?

Industry practitioners have offered Various definitions of capability, maturity and competencies. For example, capability is generally defined by the quality or state of being capable of or ability to perform a particular outcome. However, according to Winter (2000, p.983) *"An organizational capability is a high-level routine (or collection of routines) that, together with its implementing input flows, confers upon an organization's management a set of decision options for producing significant outputs of a particular type"*. This indicates that capability refers to the ability to perform and produce outputs that are significant to an organisation.

In terms of maturity, Andersen and Jessen (2003) define maturity as the quality or state of being mature, whilst Appleby et al. (2007) state that maturity is, *"a comparative level of advancement an organisation has achieved with regard to any given process or set of activities. Organisations with more fully defined and actively used policies, standards, and practices are considered more mature."* However, the general definition of maturity is the state of being fully developed, or of development having reached its optimum.

Finally, competencies have been defined as *"the skills, knowledge, abilities and other characteristics that someone needs to perform a job effectively"* (Schuler and Jackson, 2003). Selby et al. (2000) described competency as an ability expressed in terms of behaviour. This indicates that competency is defined as applied skills and knowledge, which enable people to successfully perform their work, while learning objectives are specific to a course of instruction. Having defined each concept, existing assessments are performed for each concept. In terms of capability assessments, these relate to how capable an entity is to perform activities under assessment. Maturity assessments test the performance of activities as a set of progressions from one level to another. Competence assessments determine the skills needed to perform under an assessment, which relies on the individual's knowledge, experience, and behaviour. These three concepts denote the concept of ability; however "minimum ability" refers to the context of capability; "the extent of that ability" applies to maturity, and "a set of abilities" to competencies (Mahamadu, 2017). Having identified the differences between each concept, the next section will relate each concept to BIM.

3.2.1 Differences between BIM Capability, Maturity, and Competency

Individuals and organisations are unable to measure their success or failure without the presence of BIM metrics (Mahamadu, 2017; Succar, 2010). BIM metrics allows users to benchmark their performance and measure their methods (capabilities/maturity/competencies) across competitors (Succar *et al.,* 2012; Kam et al., 2014). They also help to identify areas for better performance and improvements (Kam *et al.,* 2013b). A series of frameworks conceptualising BIM capability, maturity, and competency have been developed (Azzouz et al., 2016; Badrinath et al., 2019; Dakhil, 2017; Giel and Issa, 2013b; Mahamadu, 2017; Succar, 2009; Succar *et al*., 2013). In addition, such BIM assessment frameworks and toolsets have been developed for different capability assessments including at an individual, team, organisation, project and even country-level (Succar, 2010; Dakhil, 2017). According to Succar *et al.* (2012), the presence of a BIM capability metrics measure would enhance capabilities to deliver better BIM services.

Nevertheless, there are different definitions for each concept. The terms capability, qualification, performance, maturity, competence and readiness have been used inter-changeably to describe the ability to measure BIM progression (Dakhil, 2017). BIM capability has been defined as: "*BIM capability is the basic ability to perform a task or deliver a BIM service*" (Succar, 2009). Maturity has thus been defined: *"BIM maturity is the quality, repeatability and degree of excellence within a BIM capability* (Succar, 2009). According to Paulk et al. (1994) maturity is defined as, "*the extent to which a specific process is explicitly defined, managed, measured, controlled, and effective."* Competency was described as *"a combination of skills, abilities and knowledge needed to perform a specific task and an essential indicator and generic set of abilities suitable for implementing BIM"* (Jones, & Voorhees, 2002).

In the context of this research, "the extent of that ability" will be acknowledged when developing a BIM assessment, since not only it will be important to assess "the minimum ability and a set of abilities" when implementing BIM across individuals and organisation, but it will also be vital to recognise the extent of that ability and how they could assess the implementation of BIM across an assessment. Maturity in this research is used to cover all relevant BIM concepts, namely assessments, models, capability, competencies, and maturities. As a result, the BIM concept that would best fit this research is BIM maturity, as it is represented by a list of BIM activities and processes which measure its progression from one point to another. Maturity is involved in simply delivering the required measure and a set of descriptions from one level to another. Furthermore, maturity assessments best fit with this research, since this type assesses the level of activity achievement from one level to another, which reflects the aim and objectives for this research. The next section will give a more detailed description of maturity assessments, review the most popular, and justify the assessment type for this research.

3.2.2 Maturity Assessments

In terms of management disciplines, the global market has developed an interest in maturity models, which similarly reflects an increasing concern to develop a BIM maturity model that enables growth in maturity and allows for the transformation within organisations by offering a model to guide the route (Almarabeh and AbuAli, 2010; Khoshgoftar and Osman, 2009). Maturity models have been used in many domains including construction, for example Standardised Process Improvement for Construction Enterprise (SPICE) (Sarshar *et al.,* 2000). Other models have been developed for IT related capability including Benchmarking and Readiness Assessment for Concurrent Engineering in Construction (BEACON) (Khalfan *et al*., 2001).

Maturity models are used to guide improvement efforts (Jugdev and Thomas, 2002) and the models help an organisation to benchmark their strengths and weaknesses through the information they obtain. All models were driven by the Quality Management Maturity grid developed by Crosby (1979) and related to the quality management requirements at each maturity level. Furthermore, maturity models differ from one another in the concepts they embody and the suggestions they make as to what the path to maturity looks like.

Since there is an existing focus on the maturity assessments and models, a critical review of different types of maturity models is presented. Having reviewed the existing models that followed the same components of Crosby's model, nine popular models are believed to correlate with a maturity model. Those are as follows: Process Maturity (Rummler-Brache Group. 1995), Project Management (PM2) (Kwak and Ibbs, 2002), NASCIO Enterprise Architecture maturity (NASCIO. 2013), Project Management Maturity (Cooke-Davies, T. 2004), Business Process Maturity (Fisher, 2004), Supply Chain Maturity (Lockamy III and McCormack, 2004), Portfolio, Programme and Project Management Maturity (P3M3®) (Sowden, Hinley, & Clarke, 2008), Capability Maturity Model Integration (CMMI) (Chrissis et al., 2003), and European Foundation for Quality Management (EFQM) Excellence (EFQM. 2012). The models, along with their descriptions, are available in Appendix B. In the context of this research, maturity is used as a set of levels to assess the progression of BIM as a software, management, and technological approach from one level to another.

Having reviewed the existing maturity models, the most relevant model for the nature of BIM is the five-level Capability Maturity Model Integration (CMMI) since most of the BIM related maturity models have adopted the **CMMI** approach (Chrissis et al., 2003; Paulk et al., 1994). BIM has been defined as a software process and has been used as software; thus, CMMI is used to assess maturity. The model has frequently been used by organisations as the basis of a maturity model. Having presented the maturity model that is most relevant to the nature of BIM, the next section reviews the existing types of BIM Maturity Assessments to be linked back to the CMMI.

3.2.3 BIM Maturity Assessments

BIM maturity assessments have emerged from various studies by different authors across the globe, and a number of BIM assessments have been conducted. The main purpose of BIM maturity is to measure the effectiveness of BIM maturity abilities across construction industries, which may reflect the UK mandate and enable an examination of BIM project success across the UK (Aboumoemen and Underwood, 2017, 2019). BIM maturity assessments formally measure the level of ability, based on specific criteria, in order to help to derive benefit and value by developing their organisational maturity in relation to the implementation of BIM. To achieve the desired BIM benefits, the required maturity levels within models should be simplified in order to deliver valued benefit to BIM users and client organisations (Giel and Issa, 2013b; Nepal et al., 2014; Succar, 2010a). According to Azzouz et al. (2016), BIM assessment methods (AMs) have been developed in different countries, such as the US (7 AMs), UK (3 AMs) and Australia (3 AMs); thus, BIM maturity models mainly focus on these countries. Models can be categorised into two main maturity classifications based on their evaluation process (Giel and Issa, 2013b), which are project and organisational. This agrees with the findings of Dakhil (2017) who categorised models into three classifications, namely individual, project and organisational.

There has been an increase to the number of BIM maturity assessment methods in recent years (BRE. 2016; Badrinath et al., 2019; Chen et al., 2012; Giel and Issa, 2013a; Kassem & Li, 2020; Mom and Hsieh, 2012; Nepal et al., 2014; Succar, 2010a). Assessments were available in various countries across the globe, which ensures that BIM is spread widely across several countries. BIM maturity assessments in the literature measure BIM maturity at a project or organisational level.

Therefore, a review of these assessments shows that various BIM assessments exist, which measure the level of BIM maturity across different organisations. Furthermore, the number of existing assessments range from six (Aboumoemen, 2016; Giel and Issa, 2013), nine (Bougroum, 2016; Wu et al., 2017), eleven (Dakhil et al., 2015; 2016; Månsson and Lindahl, 2016) 16 (Azzouz et al., 2016a; 2016b; Kassem & Li, 2020), 32 (Badrinath et al., 2019), 45 (Aboumoemen and Underwood, 2019) to 64. These are classified into three maturity types (project, organisational, and individual) and based on seven sub categories (Aboumoemen and Underwood, 2017).

The maturity of a project is based on different maturity uses and categorised under project assessment models (PAM). The implementation of BIM across organisations' maturity measurement processes is categorised under organisation assessment models (OAM). The classification of BIM assessments into project and organisational would follow the five-level assessment used by the Software Engineering Institute (SEI-CMM) (Humphrey, 1988; SEI. 1993), which in return follows the **CMMI** approach (Chrissis et al., 2003; Paulk et al., 1994). This is therefore relevant to an existing five-level assessment for assessing software levels that is relevant to the measurement of BIM maturity. Figure 3.1 illustrates the five-level SEI-CMM, and offers a description of each level (Paulk et al., 1994; SEI. 1993).

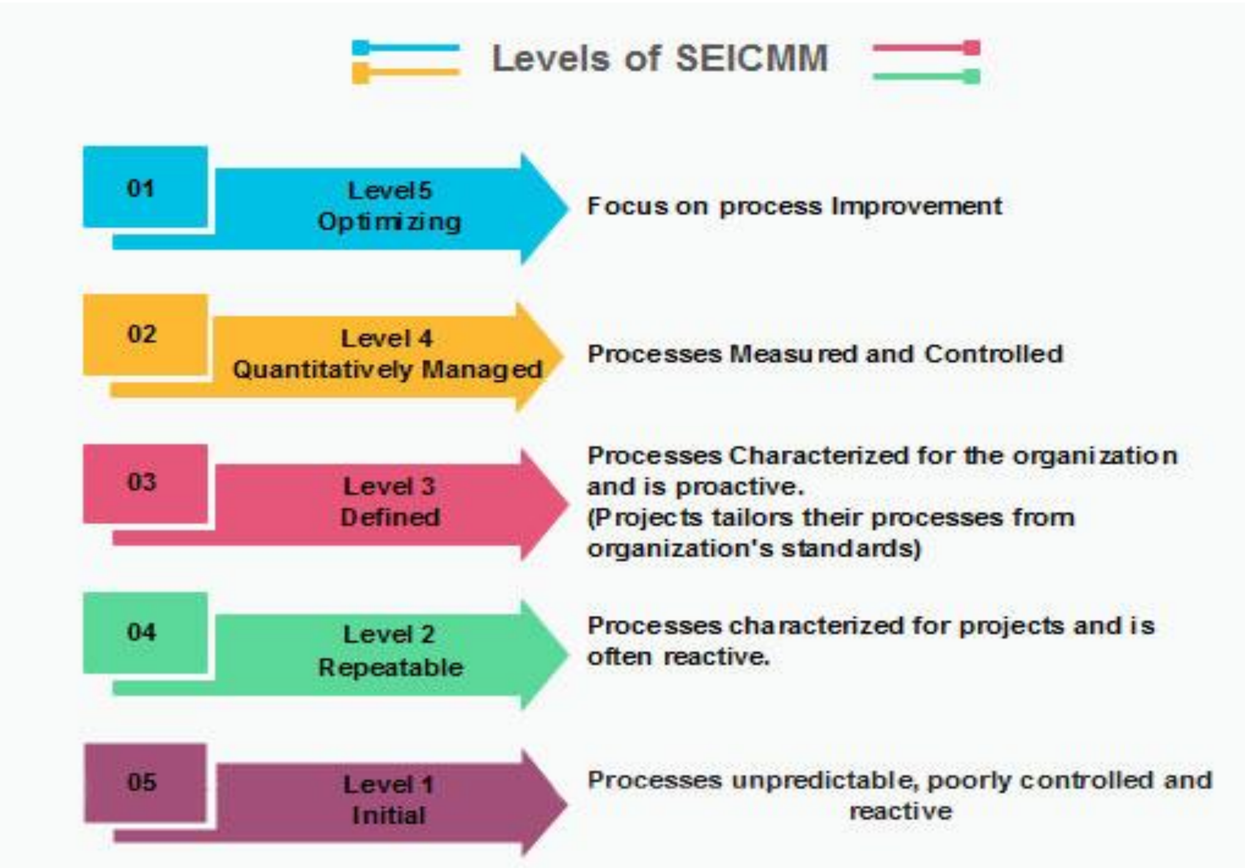


Figure 3.1 Software Engineering Institute-Capability Maturity Model levels explanation (Paulk et al., 1994; SEI. 1993)

According to Figure 3.1, there are five maturity levels. The levels that define the BIM of implementation are defined as follows (Paulk et al., 1994; SEI. 1993):

1) **Initial (Ad-hoc)**: At this maturity level, a process produces results in which specific goals are satisfied; however, processes are unpredictable, poorly controlled and reactive, are usually ad-hoc and chaotic, and organisations do not usually provide a stable environment.
2) **Repeatable (Managed):** A process is planned and characterised for projects, is often reactive, and executed in accordance with policy; it employs skilled people with adequate resources to produce controlled outputs. Software development successes are repeatable. The processes may not be repeatable for all projects in an organisation.
3) **Defined:** A process is tailored to the organisation's standard processes according to the organisation's guidelines and is proactive. The organisation's set of standard processes is established and improved over time. These standard processes are used to establish consistency across the organisation.
4) **Quantitatively Managed (Integrated):** A process is managed and integrated using statistical and other quantitative techniques to build an understanding of the performance, or predicted performance of processes, where the processes are measured and controlled. Using precise measurements, management can effectively control the software development efforts. At this level, an organisation sets a quantitative quality goal for both software process and software maintenance.
5) **Optimising:** A process is continually improved through incremental and innovative steps and technological improvements are based on a quantitative understanding of its business objectives.

This shows that the essence of a BIM maturity assessment should follow the CMMI approach to maturity assessments in general and the SEI level assessment with BIM in specific. Having presented the five levels of maturity that are most relevant to the nature of BIM and having introduced existing BIM maturity assessments from key sources, and classified them into project and organisational assessments, the next section will demonstrate the method of analysis for BIM maturity assessments, which will be followed by an in-depth exploration of KPIs and their various assessments. The potential relationship between BIM and KPIs will then be determined, and the analysis will be repeated across all three areas (BIM maturity, KPIs, and the combination).

3.3 Literature Review on Interrelationships between BIM Maturity and KPI metrics

As the maturity assessment has been outlined and maturity, related to this research, has been selected, the next section aims to demonstrate how BIM assessments are relate to maturity assessments. Furthermore, it will provide a description of KPI metrics and how they have been used. Finally, it is vital to establish the previous efforts to combine BIM maturity and KPI metrics, including how they have been used in the construction industry across the globe. This will help to achieve the aim and objectives set within the literature. It is essential to provide a literature review on BIM maturity, KPIs, and their combination, including how they were previously used.

KPI metrics provide the essence to identify a set of indicators that measure a project's success. Furthermore, key KPIs act as good measures to meet the vision of UK clients. In comparison, KPI assessments deliver a number of assessments that help to deliver predefined KPIs, and measure and monitor the progress of construction projects within organisations through various types of assessments. Hence, BIM maturity assessments assess the level of ability related to BIM through progression from one level to another; in contrast, KPI assessments measure and monitor the performance of construction projects. BIM maturity and KPI metrics can be linked through the delivery of a list of metrics that could be used to assess one another and how they could be linked. Therefore, to achieve the main aim for this research, the concept will be used to measure project success and then linked to BIM to monitor project performance through KPIs. As a result, this section aims to demonstrate how BIM maturity and KPIs could be linked to measure project performances for UK clients.

A comparative analysis will be conducted to provide the necessary information on what has existed previously. This will be achieved through the following procedures:

1) A qualitative analysis will be provided, which will discuss the main reasons for the classifications and the main types relating to the assessments for comparison. This will include the classification of assessments into categories based on the methods used and the types of assessments applied. This entails outlining the strengths and weaknesses in order to reflect on the strengths and consider how to avoid/address the weaknesses. This type of analysis helps to answer questions related to who, what, why, and how.
2) A quantitative analysis will be provided on the existing assessments to demonstrate their similarities and differences. This will include a statistical summary of the findings in the form of numerical representation. This type of analysis helps to answer questions related to how many, and where.

3) Finally, a critical evaluation from which key findings will be outlined and include an overview of the assessments including how they compare to those emerging from the literature.

These procedures help to deliver a balanced of qualitative and quantitative analysis by extracting the findings for each type to determine the existing gaps in the literature. This also helps to summarise and compare the outcomes. The next section presents the BIM maturity assessments that emerged from both the project and organisational levels. The BIM maturity assessments will be demonstrated to show how assessments were used, the type of methods and categories in existence, and a summary of the main features within each assessment, along with their strengths and weaknesses.

3.4 An Evaluation of BIM Maturity Assessments

Industry practitioners and academics have developed a set of assessments was to evaluate BIM within the Architecture, Engineering, and Construction (AEC) industry (Giel & Issa, 2014). Following an extensive review of BIM maturity assessments from the literature, it was concluded that there are currently **92** in existence. Based on an analysis conducted on BIM, seven categories were established. These include the following:

1. **BIM competencies and capability assessment (self) (23 assessments)**: these assess individuals' competencies and capability within organisations through a self-assessment tool (Amuda-Yusuf 2018; BIM-Profiler. 2020; BIMIcon. 2021; BIMTASKFORCE. 2013; BRE. 2016; CDBB. 2021a; Chan et al., 2019; CPI. 2011; Dakhil, Underwood, & Alshawi, 2019; DBE Careers. 2021c; DFT. 2016; Giel & Issa, 2014; HS2 BIM. 2016, IfM. 2018; Lee and Yi, 2011; Liu et al., 2021; Mahamadu et al., 2019; NBS. 2016; NFB. 2016; Scottish future trust. 2017; Supply Chain Sustainability School, 2017; Wates, 2019; Yilmaz, Akcamete, & Demirors, 2019).
2. **Assessment framework (22)**: outline requirements of BIM maturity through the provision of an assessment framework (Abbasianjahromi et al., 2018; Aboumoemen, 2016; Bew & Richards, 2008; CDBB. 2021b; Chen, 2015; Dakhil, 2017; DBE Careers. 2021b; Gao, 2011; Haron, 2013, Jayasena and Weddikkara, 2013; Jones, 2020; Jung and Joo, 2011; Kumar and Hayne, 2016; Mansoon, Hampson, and Lindahl, 2017; Manzione et al., 2011; Mom, & Hsieh, 2012; Marsh, 2017; Nepal, Jupp, and Aibinu, 2014; Olawumi and Chan, 2018; Shin, Jungsik, & Kim, 2015; Walters, 2021; Wu et al., 2017).
3. **Assessment method (other) (14)**: Other methods that were used to assess BIM (ACE. 2008; Cerovsek, 2011; Edirisinghe et al., 2021; Khosrowshahi and Arayici, 2012; Olawumi and

Chan, 2019; Olugboyega and Windapo, 2019; Park et al., 2013; PlanBIM. 2019; Shin and Choi, 2016 and 2017; Sun et al., 2021; Taylor and Bernestein, 2009; Tian et al., 2019; Won & Lee, 2014; Yun et al., 2018).

4. **BIM Functional model (tool) (11)**: assesses BIM progression on models through a functional model (Ahankoob et al., 2018; Chen, Dib, & Cox, 2014; Chen et al., 2016; DBE Careers. 2021a; Enegbuma, Aliagha, & Ali, 2014; Lee, Yu, & Jeong, 2015; Liu et al., 2020; Olugboyega et al., 2020; Rojas et al., 2019; Sebastian & Berlo, 2010; Siebelink et al., 2018).
5. **Maturity model for levels 1-5 (nine)**: maturity models are based on five levels: a) Initial, b) Defined, c) Managed, d) Integrated, and e) Optimised. These are driven by the Capability Maturity Model and assess BIM maturity (ARUP. 2014; Badrinath, ASCE, & Hsieh, 2019; Hore et al., 2017; Messner and Kreider, 2013; Mott Macdonald, 2017; Munir et al., 2019; Pontes, 2016; Succar, 2009; Succar & Kassem, 2015).
6. **Scoring criteria percentages for projects (nine)**: identify where projects are regarding the adoption of BIM through project scoring criteria (BIMexcellence. 2016; bimSCORE. 2013; Böes et al., 2021; Jenaban, Dawood, Graggs, and Kassem, 2016; Joblot et al., 2019; Kam et al., 2013; Liang et al., 2016; MoJ. 2016; Vico. 2011).
7. **Scoring criteria percentage on a model with possible certification (four)**: scoring criteria with certification can help to identify where models are in relation to BIM adoption (Alaghbandrad et al., 2015; Du, Liu, & Issa, 2014; Indiana University. 2009b; NIBS. 2007).

For the purpose of this study, nine of the BIM maturity assessments within these categories included KPI metrics, as identified by the authors of those studies, and are included in the following category:

8. **Combined BIM/KPI (driven from other categories) (11):** Various lists of KPIs and methods are included within the BIM assessments (Aboumoemen, 2016; Manzione et al., 2011; MoJ. 2016; Mom and Hsieh, 2012; Olugboyega et al., 2020; Park et al., 2013; Sebastian & Berlo, 2010; Shin and Choi, 2016 and 2017; Shin, Jungsik, & Kim, 2015; Won & Lee, 2016; Yun et al., 2018).

The complete set of studies on BIM maturity is available in Table 3.1.

Table 3.1 Existing BIM maturity assessments across the literature

Existing BIM maturity assessments in the literature

Legend [(number of studies) (total = 92)]
BIM competencies and capability assessment – self (23)
Assessment framework (22)
Assessment method – other (14)
BIM Functional model (tool) (11)
Maturity model on levels 1-5 (9)
Scoring criteria percentages for projects (9)
Scoring criteria percentage on a model with possible certification (4)
Combined BIM / KPI [driven from other categories (11)]

Existing most popular BIM maturity models / assessment / tools / frameworks

Model Name- Country	Year (new update)	Maturity type
NBIMS Capability Maturity Measure - (NIBS. 2007; NIBS. 2012) US	2007	Organisational (Model) Maturity
Maturity index (level 2)- (Bew and Richards, 2008) Information management maturity stages (ISO19650)- (BS EN ISO 19650-1:2018, 2019) UK	2008 and (2019)	Project Maturity
Succar BIM Maturity Matrix- (Succar, 2009; Succar, 2010a; Succar et al. 2012) Australia	2009 (2016)	Organisational Maturity
IU's BIM Proficiency matrix- (Indiana University, 2009a; Indiana University, 2009b) US	2009	Project (Model) Maturity
BIM Quickscan TNO- (Berlo, Dijkmans, Hendriks, Spekkink, & Pel, 2012; Sebastian & Berlo, 2010). Netherlands	2010	Organisational Maturity
BIM Characterisation framework- (Gao, 2011) US	2011	Project Maturity
VICO BIM score- (Vico. 2011, 2016). US	2011	Project and Organisational (model) Maturity
CPIx BIM assessment- (CPI. 2011). UK	2011	Organisational Maturity
CIFE VDC Scorecard (kam, Senaratna, Xiao, and McKinney 2013a; Kam, Song, and Senaratna, 2016) US	2012	Project Maturity
BIM Capability Maturity Model Toward performance assessment of BIM technology implementation - (Mom and Hsieh, 2011 and 2012) Taiwan	2012	Organisational Maturity
Penn State CIC organisational BIM assessment profile- (Messner and kreider, 2013) US	2013	Organisational Maturity
BIM excellence individual assessment Change agents AEC (Change Agents AEC, 2013; BIMexcellence, 2016). Australia	2013 (2016)	Project and Organisational Maturity
BIMscore- (bimSCORE, 2013; Kam, 2014) US	2013	Project Maturity
Owner's BIMCAT- (Giel & Issa, 2014) US	2014	Organisational Maturity
Goal-Driven Method for Sustainable Evaluation of BIM Project Success (SLAM BIM) Level- (Won & Lee, 2014; Won & Lee, 2016) Korea	2014	Project Maturity
Measurement model for BIM Maturity (Chen, Dib , & Cox, 2014) US	2014	Organisational Maturity
ARUP BIM Maturity Measure- (ARUP, 2014; Duncan and Aldwinckle, 2014) UK	2014	Project Maturity
BIM cloud score (Du, Liu, and Issa, 2014) US	2014	Project (Model) Maturity

Existing additional BIM maturity models / assessment / tools / frameworks

Model Name- Country	Year (new update)	Model type
BIM deliverable matrix, ACE Building Information Modelling: An Introduction and Best Methods Approach. (Alliance for Construction Excellence, 2008) US	2008	Organisational Maturity
Paradigm trajectories of building information modelling practice in project networks.- (Taylor and Bernestein, 2009) US	2009	Project Maturity
A multi-standpoint framework for technological development- The 'BIM Schema. (Cerovsek, 2011) Slovenia	2011	Project (Model) Maturity
A study on BIM capability evaluation for design organization- (Lee and Yi, 2011) Korea	2011	Organisation Maturity
Building information modelling (BIM) framework for practical implementation - BIM Practical Implementation Model- (Jung and Joo, 2011) Korea	2011	Project Maturity
A BIM Integrated Management Model. Design process maturity level. 4 interfaces (Manzione, Wyse, Sacks, Van Berlo, & Melhado, 2011; Manzione, 2013; Manzione and Melhado, 2015). Brazil	2011 (2013 and 2015)	Project (model) Maturity
Roadmap for implementation of BIM in the UK construction Industry- (Khosrowshahi and Arayici, 2012) UK	2012	Project Maturity
BIM Capability Compass and Upskilling toolkit BIMTASKFORCE BIM Knowledgesmart.net- (BIMTASKFROCE, 2013) UK	2013	Organisational Maturity
Key Performance Indicator on Benefits of BSC-based BIM and Validation Methods- (Park et al., 2013) Korea	2013	Organisational Maturity
Assessing the BIM Maturity in a BIM Infant Industry- (Jayasena and Weddikkara, 2013)- Sri Lanka	2013	Organisational Maturity
BIM ORGANISATIONAL READINESS FRAMEWORK (Haron, 2013) Malaysia	2013	Organisation Maturity
Evaluations of BIM: Frameworks and Perspectives (TOPC) – (Nepal, Jupp, and Aibinu, 2014) Australia	2014	Project Maturity
Preliminary building information modelling adoption model in Malaysia: A strategic information technology perspective- (Enegbuma, Aliagha, & Ali, 2014) Malaysia	2014	Project Maturity
iBIM- BIM capability self assessment tool- (Badrinath, ASCE, & Hsieh, 2019) UK-2014	2014	Project Maturity
AHP Based Weighting System for BIM Implementation & Assessment Framework and A Strategic Decision Making framework for Organisational BIM implementation - (Chen, 2015; Chen and Li, 2015) China	2015	Project and Organisational Maturity
BIM Macro Maturity components model- (Succar and Kassem, 2015). Australia	2015	Project and Organisational Maturity
BIM Platform Maturity Model- BIM MATURITY ASSESSMENT AND CERTIFICATION IN CONSTRUCTION PROJECT TEAM SELECTION- (Alaghbandrad, April, Forgues, and Leonard, 2015). Canada	2015	Project Maturity
A Study on BIM Performance Assessment Framework for Architecture Firm (Shin, Jungsik, & Kim, 2015)- Korea	2015	Organisational Maturity
BIM Acceptance Model- (Lee, Yu, & Jeong, 2015). Korea	2015	Organisational Maturity
Development of a Multifunctional BIM Maturity Model- (Liang, Lu, Rowlinson, and Zhang, 2016) Hong Kong	2016	Project and Organisational Maturity
BRE BIM Certification Scheme- (BRE, 2016) UK	2016	Project Maturity
BIM Level 2 Maturity / KPI assessment framework- (Aboumoemen, 2016) UK	2016	Project Maturity
Structural Equation Model of Building Information Modelling Maturity (Chen, Dib, Cox, Shaurette, and Vorvoreanu, 2016) US	2016	Project Maturity
Tool for assessing BIM level 2 projects (Jenaban, Dawood, Graggs, and Kassem, 2016) UK	2016	Project Maturity
MoJ BIM maturity assessment tool/KPI system (Used by DSTL and public sector group BMAT) (MoJ. 2016) UK	2016	Project Maturity
HS2 Atkins BIM capability Compass and Upskilling toolkit Model- (HS2 BIM, 2016) UK	2016	Organisational Maturity
NBS BIM toolkit. (NBS. 2016) UK	2016	Project Maturity
NFB BIM online maturity assessment. (NFB. 2016) UK	2016	Organisational Maturity
Guidance for Infrastructure bodies maturity assessment tool (Department for Transport). (DFT. 2016) UK	2016	Organisational Maturity
Development of KPIs of BIM performance measurement (Shin and Choi, 2016 and 2017) Korea	2016	Project Maturity
A Framework for Developing a BIM Strategy (Kumar and Hayne, 2016) UK	2016	Project and Organisational Maturity
BIM Maturity Model for the Nacional Industry (Pontes, 2016) Portugal	2016	Project Maturity
Supply Chain School BIM maturity self assessment. (Supply Chain Sustainability School, 2017) UK	2017	Project and Organisational Maturity
Scottish future trust BIM Grading tool and Return on investment tool- (Scottish future trust, 2017) UK	2017	Project and Organisational Maturity
Building Information Modelling (BIM) and the UK Quantity Surveying Organisation: A Framework for Value Creation. (Marsh, 2017) UK	2017	Organisational Maturity
Building Information Modelling (BIM) maturity-benefits assessment relationship framework for UK construction clients (Dakhil, 2017) UK	2017	Project Maturity
Ireland's BIM Macro Model (Hore et al., 2017) Ireland	2017	Project Maturity
Project 13 Industry Readiness Level - (Mott Macdonald, 2017) UK	2017	Organisational (Industry) Maturity
BIM maturity measurement framework. (Wu et al., 2017) Hong Kong	2017	Project and Organisational Maturity
BIM performance through self-assessed benchmarking. (Mansoon, Hampson, Lindahl, 2017) Australia	2017	Project Maturity
IFM BIM Maturity Assessment. (IfM. 2018) UK	2018	Project Maturity
Critical Success Factors for Building Information Modelling Implementation. (Amuda-Yusuf 2018) Nigeria	2018	Organisational (Industry) Maturity
A three-stage BIM maturity Model. (Ahankoob et al., 2018) Australia	2018	Project Maturity
Developing and testing a tool to evaluate BIM maturity: Sectoral analysis in the Dutch construction industry (Siebelink et al., 2018) Netherlands	2018	Project and Organisational Maturity
A maturity assessment framework for applying BIM in consultant companies (Abbasianjahromi et al., 2018) Iran	2018	Organisational Maturity
BIM Service Level Assessment in Construction Phase (Yun et al., 2018) Korea	2018	Project Maturity
Building information modelling and project information management framework for construction projects (Olawumi and Chan, 2018) Hong Kong	2018	Project Maturity
A reference model for BIM capability assessments. (Yilmaz, Akcamete, & Demirors, 2019) Turkey	2019	Project and Organisational Maturity
BIM capability assessment. (Mahamadu et al., 2019) UK	2019	Project and Organisational Maturity
Critical success competencies for the BIM implementation process. (Dakhil, Underwood, & Alshawi, 2019) UK	2019	Organisational Maturity
Supply Chain BIM capability assessment (Wates). (Wates. 2019) UK	2019	Organisational Maturity
BIM Execution Plan Maturity Matrix. (Joblot et al., 2019) France	2019	Project and Organisational Maturity
Development of a BIMAsset maturity model (Munir et al., 2019) UK	2019	Organisational Maturity
Development of a benchmarking model for BIM implementation in developing countries (Olawumi and Chan, 2019) Hong Kong	2019	Organisational Maturity
Mibim Organisational BIM Maturity Assessment (PlanBIM. 2019) Chile	2019	Project and Organisational Maturity
A COMPREHENSIVE BIM IMPLEMENTATION MODEL FOR DEVELOPING COUNTRIES: COMPREHENSIVE BIM IMPLEMENTATION MODEL (Olugboyega and Windapo, 2019) South Africa	2019	Project and Organisational Maturity
Global Building Information Modelling Maturity (Tian et al., 2019) US	2019	Project Maturity
Critical success factors for BIM adoption during construction phase: a Singapore case study (Chan et al., 2019) Singapore	2019	Organisational Maturity
BIM use assessment (BUA) tool for characterizing the application levels of BIM uses for the planning and design of construction projects (Rojas et al., 2019) Chile	2019	Project Maturity
BIM connect competency assessment (BIM-Profiler. 2020) Germany	2020	Organisational Maturity
Development of a tool for measuring building information modeling (BIM) user satisfaction–method selection (Liu et al., 2020) China	2020	Project (User) Maturity
A study of Building Information Modeling (BIM) uptake and proposed evaluation framework (Jones, 2020) UK	2020	Organisational Maturity
Development of a conceptual model for evaluating the success of BIM-based construction projects (Olugboyega et al., 2020) South Africa	2020	Project Maturity
CDBB BIM toolkit (CDBB. 2021b) UK	2021	Project and Organisational Maturity
CDBB National digital twin Skills and Competency Framework (Walters, 2021) UK	2021	Project and Organisational Maturity
An Actor–Network Approach to Developing a Life Cycle BIM Maturity Model (LCBMM) (Edirisinghe et al., 2021) US	2021	Project Maturity
Building Information Modeling Application Maturity Model (BIM-AMM) from the Viewpoint of Construction Project (Sun et al, 2021) China	2021	Project Maturity
BIM maturity model for higher education institutions (Bões et al., 2021) Brazil	2021	Project (institution) Maturity
Critical success factors for building information modelling (BIM) implementation in Hong Kong (Liu, 2021) Hong kong	2021	Organisational Maturity
BIM Icon Practical BIM Level Assessment (BIMIcon. 2021) UK	2021	Organisational Maturity
DBE careers BIM COMPETENCY assessment tool (DBE Careers. 2021a) UK	2021	Organisational Maturity
DBE careers BIM competence framework (DBE Careers. 2021b) UK	2021	Project and Organisational Maturity
DBE careers BIM competence self assessment (DBE Careers. 2021c) UK	2021	Project Maturity
CDBB BIM self assessment (CDBB. 2021a) UK	2021	Project Maturity

This section presents the qualitative findings of the BIM maturity assessments available. Based on the evaluation of available BIM assessments, eight outcomes are required to evaluate existing BIM maturity assessments in the literature. They are:

1. **BIM parameters (minimum of ten which will cover the basic outcomes of BIM in the construction industry)**: this helps to set assessment criteria for the levels of BIM maturity.
2. **BIM should be considered as a modelling process that uses a set of documentation and not as a piece of software or 3D model**: this is the universal definition of BIM, and the UK and other governmental bodies have acknowledged BIM as a modelling process.
3. **BIM should follow the 1-5maturity levels concept:** most of the BIM maturity studies have adopted the concept of the BIM maturity levels 1-5.
4. **BIM capability self-assessments should reflect not only individuals, but also projects and organisations:** it expects that benefits from a self-assessments should not only target the individual but also to be recognised within the organisation and amongst projects.
5. **A number of conclusions exist that some are considered strengths in the limited BIM maturity assessments within the literature**: the conclusions will help recognise effects of the final outcomes in the studies and how these could be reflected in this research.
6. **A set of limitations exist which may be considered weaknesses in the limited BIM maturity assessment within the literature:** these limitations will help to recognise the negative effects of the outcomes in the studies presented, and thus what actions could be required to overcome them, as directly reflected in the findings of this research.
7. **Existing most popular BIM maturity models/assessment/tools/frameworks**: this helps to determine the common assessments that exist in the literature and their different types.
8. **Existing additional BIM maturity models/assessment/tools/frameworks**: this helps to determine additional assessments that are not covered across studies and their different types.

These outcomes help to visualise how BIM assessments are presented, what is required to develop a BIM maturity assessment, and what is the basis for developing an assessment that focuses on BIM maturity. These outcomes help to identify key focus areas for BIM maturity and the Level 2 BIM/BS EN ISO19650 standards. Thus, they represent a starting point to develop an assessment that expects to assess BIM maturity in relation to the BS EN ISO19650 standards. This would be the first assessment to exist since it was not available for existing literature; this represents the main aim for this research. A complete list of the evaluations for a selective number of studies is available (Appendix B).

Having presented a detailed analysis of each study, the next section will present a summary of the assessments (Table 3.1) in order to extract key findings across the studies for each category. Having identified eight categories across the 92 available BIM maturity assessments, Table 3.2 presents a definition of each category, its purpose of usage, and a summary of the overall strengths and weaknesses that occurred across the studies under each category, a number of categories are outlined that align with the aim of this research.

Table 3.2 BIM maturity assessments category selection purposes, and strengths and weaknesses associated with studies in each category

BIM maturity assessments categories selection purposes, and strengths and weaknesses associated with studies in each category				
Nature of the category (number of studies)	**Definitions for each category**	**Category selection and consideration for this research**	**Summary of strengths across the studies**	**Summary of weaknesses across the studies**
BIM competencies and capability assessment – self (23)	An assessment that aims to assess individuals competencies and capability within organisations.	Some studies considered assessments to assess individuals competencies and capabilities within organisations which expects to answer a set of questions to recognise where each individual stands.	A self assessment strategy through the BIM competencies and capabilities that shall be completed by various disciplines to visualise where they stand.	Individuals are being assessed on a limited set of BIM elements, and thus no consideration of a BIM maturity approach.
Assessment framework (22)	An assessment framework that was presented in a BIM maturity study (i.e. BIM performance assessment framework	Various assessment frameworks have been presented in a set of studies that has achieved the aims set within them and succeeded in delivering new ideas to be used in different BIM studies.	Various types of frameworks was delivered, which reflected positively on them and delivered a set of BIM guidelines and standards to consider.	Some frameworks are considered as conceptual, and might not operate well amongst various projects and organisations.
Assessment method – other (14)	Different assessment methods that were presented in other BIM maturity studies	A few studies have presented other assessment methods within their studies which helped them according to the requirements of each study	A consideration of alternative assessment methods existed which could be reviewed for assessing BIM implementation across projects and organisations.	No approach have been considered to deliver assessment methods related to BIM maturity, and depends on Individual perspectives.
BIM Functional model (tool) (11)	Studies which included a BIM function model or tool (i.e a measurement model)	A BIM functional model or tool was presented in a few studies which delivered models on BIM progression, however these functional models are somehow not compatible with the BIM maturities expected in this research	Previous maturity related models were reviewed which lead to development of a functional model (tool) to examine BIM operations within organisations.	The proposed BIM functional models are not validated widely, and thus various BIM requirements are considered with different users.
Maturity model on levels 1-5 (9)	Maturity models that are based on 5 levels known as: a) Initial, b) defined, c) Managed, d) Integrated, and e) Optimised. Driven from the Capabililty Maturity Model	The Maturity models based on the 5 measures driven from the Capability Maturity Model is an essential method that was used in a set of publications to measure their BIM approach.	A comprehensive model through the 5 levels of maturity was delivered within organisations and across various projects.	A delivery of a BIM maturity that varied from one industry to another, causing an absence of standardisation for BIM maturity.
Scoring criteria percentages for projects (9)	A scoring criteria was presented on projects that used BIM, which delivered percentage of achievements within projects	A scoring criteria percentage for projects could be helpful to identify where projects and organisations are in relation to BIM implementation.	Scoring criteria percentages were focused on projects used in organisations that examined BIM deliverables across a set of models used in the industry.	A delivery of a scoring criteria that doesn't include a BIM maturity criteria in it, which resulted in not being validated in the industry.
Scoring criteria percentage on a model with possible certification (4)	A scoring criteria was presented on a BIM model that resulted in a certificate achievement in relation to BIM	A scoring criteria percentage for models with certification could be helpful to identify where models are in relation to BIM implementation and the certification could help visualise the achievements of these models.	A positive impact of the delivered scoring criteria percentages with certificate on the projects and organisations operating BIM that are being assessed against.	Scoring criteria focused on assessing BIM as a software, resulting in assessing a BIM model that doesn't follow a BIM maturity criteria.
Combined BIM / KPI [driven from other categories (11)]	BIM maturity assessments that considered an inclusion of KPIs in their studies	It was recognised that 9 of the presented BIM maturity publications contained KPIs within them, and they focused mainly on assessment framework, on assessment methods, and functional model accordingly.	A successful approach towards introducing a new idea of enhancing the BIM operations through including KPIs parameters within them.	The usage of BIM has been limited to a low set of elements that did not cover the overall view of BIM across industries and some studies did not deliver the necessary KPIs that could strengthen the BIM approach.

The categories of BIM assessment in this research are mainly taken from a set of studies. Some of these studies support the delivery of BIM maturity assessment through a five-level maturity matrix. The BIM maturity assessments presented demonstrate:

1. A self-assessment strategy through BIM competencies and capabilities would be completed by various disciplines to visualise where they stand.
2. Various types of frameworks are delivered, which is positive, and incorporate a set of BIM guidelines and standards to consider.
3. The consideration of alternative assessment methods could be reviewed to assess BIM implementation across projects and organisations.

4. Previous maturity related models were reviewed which led to the development of a functional model (tool) to examine BIM operations within organisations.
5. A comprehensive model was delivered incorporating five levels of maturity within organisations and across various projects.
6. Scoring criteria percentages focused on projects used in organisations that examined BIM deliverables across a set of models used in the industry.
7. A positive impact from the scoring criteria percentages with certificates for projects and organisations operating BIM.

However, a set of distinctions exist, such as:

1. Individuals are assessed on a limited list of BIM metrics, and thus, there is no consideration of an applicable BIM maturity approach (i.e. a standardised maturity level criteria).
2. Some frameworks are considered conceptual, as they may not operate well amongst various projects and organisations.
3. There is no approach that delivers a standardised assessment method related to BIM maturity; most depend on individual perspectives.
4. The proposed BIM functional models are not widely validated; thus, different users consider various BIM requirements.
5. The delivery of a BIM maturity assessment that varies from one industry to another results in the lack of standardised delivery for BIM maturity assessment.
6. The delivery of scoring criteria that does not follow a standardised BIM maturity, which results in its lack of validation by various industries.
7. BIM is assessed as software through particular scoring criterion; this results in the assessment of a BIM model that does not follow a standardised BIM maturity criterion.

These limitations will be reviewed in order to develop a BIM maturity assessment that will tackle existing obstacles across the studies. It was noted that some approaches were highlighted due to their significant impacts; which resulted in these studies, and the approaches were highlighted since they have a direct influence on the development of BIM assessment. Thus, it represents a starting point for a set of steps to be used as a basis to develop an approach to BIM assessment. Having qualitatively analysed the BIM maturity assessments, the next section will present the quantitative analysis of these assessments, including statistical data on the existing assessments to outline where and how many exist in the UK and globally.

From the **92** identified BIM maturity assessments, **18** were presented as the most common, representing 20% of the total sample. Moreover **74** were available as additional existing assessments, representing 80% of the sample. Furthermore, a total of eight categories emerged from the BIM maturity assessment types, of which one was acknowledged as a BIM maturity and KPI metrics approach. As previously mentioned, the assessments were classified into project and organisational. Moreover, 43 BIM maturity assessments were classified as Project Maturity, which accounts for 47% of the total; on the other, 31 BIM maturity assessment were classified as Organisational Maturity, representing 33% of the total. In comparison, only 18 BIM assessments were acknowledged as project and organisational maturity combined (20%). Furthermore, in relation to the most popular assessments, seven project maturity (39%), nine organisational maturity (50%) and two project and organisational maturity assessments exist (11%). With regards to the additional assessments, 34 exist for project maturity (46%) 24 for organisational (32%), and 16 for project and organisational combined (22%).

Finally, based on the literature review on maturity assessments, BIM maturity assessments exist in 23 countries across the globe. Moreover, both the US and UK had 48 studies, representing 52% of the total sample, and 44 studies were presented from other countries, representing 48% of the total sample. This confirms with studies that recognised a wide range of assessments covered across both the UK and the US and ensured that assessments were mainly used within both countries (Aboumoemen and Underwood, 2017; Azzouz et al., 2016a, 2016b; Badrinath et al., 2019; Kassem & Li, 2020). A summary of the BIM maturity findings is available in Table 3.3.

Table 3.3 BIM maturity findings

BIM maturity findings				
Number and Percentage of Existing most popular BIM maturity models / assessment / tools / frameworks		**92 total** (up to date)	**18**	**20 %**
Number and Percentage of Existing additional BIM maturity models / assessment / tools / frameworks			**74**	**80 %**
Number of categories for all BIM assessments ***(1 driven from other categories and considered as BIM/KPI)***				**7**
Number and percentage of **(Project)** Maturity types in BIM assessments= **43 total**	**47%**	Most Popular assessments= **7 Project** (39% of most popular) **9 Organisational** (50%) **and 2 Project and Organisational** (11%)	Additional assessments= **34 Project** (46% of additional) **24 Organisational** (32%) **and 16 Project and Organisational** (22%)	
Number and percentage of **(Organisational)** Maturity types in BIM assessments= **31 total**	**33 %**			
Number of countries where BIM maturity assessments existed				**23**
Number and percentage of studies in the 23 countries	**UK= 33 (36%)**	**US= 15 (16%)**	**Both UK and US = 48 (52%)**	**Other countries= 44 (48%)**

As previously mentioned, a total of eight categories emerged from the BIM maturity assessments, of which one was acknowledged as a BIM/KPI approach relevant to this research. Figure 3.2 distributes the percentage of the BIM maturity assessments according to these categories, which would help to identify the most familiar category used with BIM assessments. Therefore, the BIM competencies and capabilities assessment (self) had the highest number of classifications with 23 assessments in total, representing 25% of the total sample. After this, Assessment framework had 22 in total, representing 24% of the total sample. Furthermore, the Assessment method (other) had 14 in total, representing 15% of the total sample. Moreover, BIM Functional model (tool) had 11 BIM assessments, representing 12% of the total sample. Scoring criteria percentages for projects had eight assessments, representing 13% of the total sample. After that, both Maturity model levels 1-5 and Scoring criteria percentages for projects had a combination of 18 assessments (nine each), representing 20% of the total sample or 10% each. In addition, the Scoring criteria percentage model with possible certification had four BIM assessments, representing 4% of the total sample. Finally, the Combined BIM/KPI (driven from other categories) had 11 assessments, representing 12% of the total sample. These statistics are highlighted below (Figure 3.2).

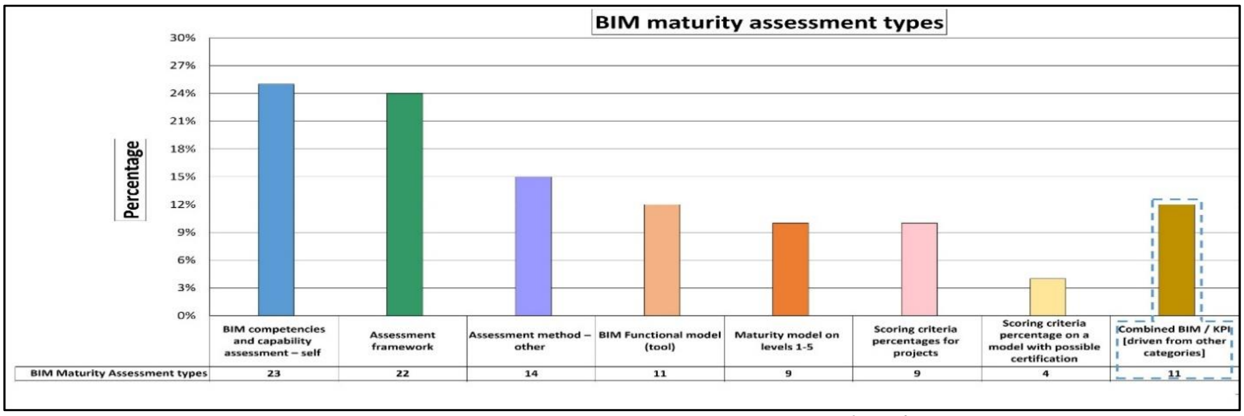


Figure 3.2 BIM maturity assessment percentage distribution

BIM maturity assessments exist in 23 countries across the globe. The UK has the most assessments at 33, representing 36% of the sample, whereas the US had the second greatest number of assessments at 15, representing 16% of the sample. Multiple assessments exist in countries, such as Korea (eight studies), and Australia (six studies), Hong Kong (five studies), China (three studies), and Malaysia, Chile, South Africa, Brazil, and Netherlands (each had two studies). A single study existed in the following 12 countries: Taiwan, Canada, Sri Lanka, Iran, Portugal, Singapore, Slovenia, Ireland, Nigeria, Turkey, France, and Germany. The distribution of the BIM maturity across the globe is presented in Figure 3.3.

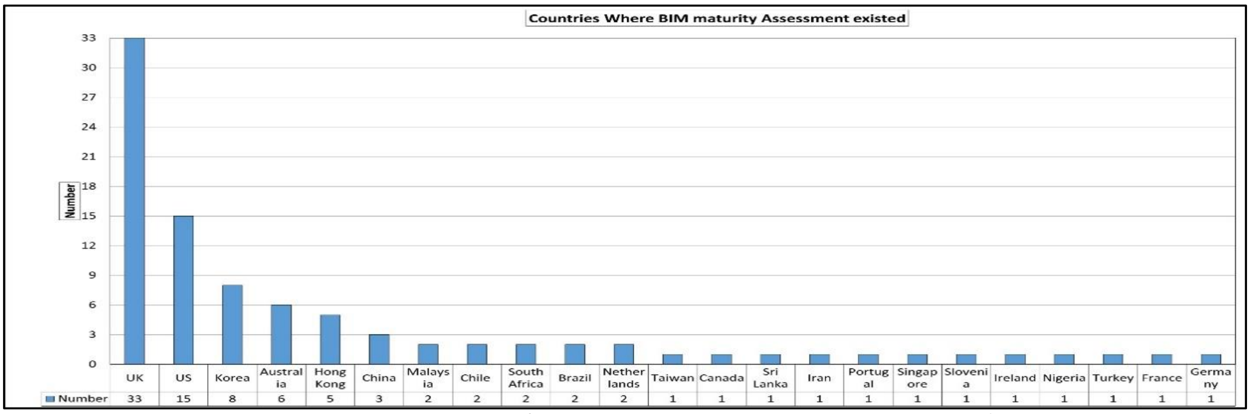


Figure 3.3 Countries Where BIM maturity assessments existed

Having critically evaluated the findings of the BIM maturity assessments from key literature, the next section will provide a summary of the BIM maturity assessment findings and discuss the outcomes relevant to the aim of this research.

3.4.1 A Summary of the Findings from BIM maturity Assessments

There has been a comprehensive review of BIM assessments across the literature. A number of studies have presented a list of BIM maturity assessments across the globe that ranged between six and forty five (Aboumoemen, 2016; Aboumoemen and Underwood, 2017; Azzouz et al., 2016a; 2016b; Badrinath et al., 2019; Bougroum, 2016; Dakhil et al., 2015; 2016; Giel and Issa, 2013; Kassem & Li, 2020; Månsson and Lindahl, 2016; Wu et al., 2017). With a focus on previous BIM maturity assessments in the UK, 33 assessments were identified based on the findings of this research, and a few points are noted on the outcomes of these assessments. According to Kassem & Li (2020), the BIM assessments addressed in their study cover nine key areas: strategy, the mobilisation and management of human resources, the mobilisation and management of technology, procurement, handover, the generation and delivery of information, assurance, organisational processes and management, and BIM processes. These areas have been addressed as part of the main categories and elements of BIM assessments, and hence correlate with those of Kassem & Li (2020), Azzouz et al. (2016a), and Badrinath et al. (2019). The key strengths of the assessments addressed by Kassem & Li (2020) were that they cover a range that varied from areas of readiness, capability, and maturity and competency. This correlates with Azzouz et al. (2016a), Badrinath et al. (2019) and this research by presenting the differences between capability, maturity and competency and assessments that covered the same areas. Most of the studies are available to access and are free to use, which is a key strength that allows for the sharing of information and data amongst others and was addressed by Kassem & Li (2020), Azzouz et al. (2016a), Badrinath et al. (2019), and this research.

However, some weaknesses were found amongst the assessments. Kassem & Li (2020) highlighted that most assessments were conducted at a low depth and with limited understanding of the performance of BIM across organisations and projects. This is confirmed by Azzouz et al. (2016a), Badrinath et al. (2019), and this research, as some of the assessments were not easy to understand and the level of assessments provided were low. Some of the assessments reviewed experienced issues with the quality of the assessments, and with the consistency and accuracy of the overall results. Moreover, some of the offered metrics are unreliable, whilst others were not properly defined and had insufficient descriptors. These points have been addressed across studies (Aboumoemen and Underwood, 2017; Azzouz et al., 2016a; Badrinath et al., 2019; Bougroum, 2016; Dakhil et al., 2015; 2016; Giel and Issa, 2013; Kassem & Li, 2020; Månsson and Lindahl, 2016; Wu et al., 2017) and were applicable to this research.

According to Kassem & Li (2020), the presented assessments did not deliver actions on how BIM maturity could be improved. This is a key focus for the assessments developed in the UK, which would assess compliance to standards, specifically to Level 2 BIM standards. There is currently no assessment aligned and relevant to the BS EN ISO19650 standards. Thus, most of the UK assessments focus on Level 2 BIM adoption, and do not align with the BS EN ISO 19650. However, it is worth mentioning that most assessments align with the guidance, since it would be necessary to convert and transfer the terms used in BS 1192 and PAS 1192-2 to those in the BS EN ISO 19650-1 and BS EN ISO 19650-2 standards. This is presented in Table 2.10 (PD 19650-0:2019, 2019; UK BIM framework, 2019a). As a result, a number of recommendations have been offered by Kassem & Li (2020) that cover existing gaps in BIM maturity assessments and provide guidance on what actions need to be taken (Table 3.4).

Table 3.4 Recommendations for maturity assessment tools and approaches (Kassem & Li, 2020)

Recommendations
The gaps in BIM maturity assessment tools and practices for both organisations and projects need to be addressed in order to fulfil the industry requirements and expectations.
For organisation BIM maturity assessment, a multi-level framework should be developed to provide a common approach to BIM maturity assessment at industry level. The framework should identify a comprehensive range of BIM competencies required and propose metrics for their assessment.
For project BIM maturity assessment, a BIM assessment method should be developed, based on the UK BIM Framework (including the ISO 19650 Series) and the additional topics and items identified during analysis of the existing tools in this report. The assessment method should ensure flexibility and adaptability to suit different actor and project types.
Improve awareness and provide learning and professional development opportunities about the importance of BIM maturity assessment as an internal function for business and project improvement.

These recommendations provide a set of stepping-stones to consider for the assessment in this research. As such, the assessments should meet industry requirements, be able to extract benefits from a multi-level framework, provide learning opportunities from the assessments, and align with the BS EN ISO19650 standards. Most of these recommendations will be considered in this research; however, in terms of the BS EN ISO19650 standards, the assessment would be developed on the basis of Level 2 BIM and would supersede terms from Level 2 BIM to BS EN ISO19650 standards. Having critically discussed and reviewed existing BIM maturity assessments, the next section will discuss KPIs that exist across the literature along with their assessments. It will aim to demonstrate how KPIs have been used, existing types of method and category, and how this could provide a means of assessment for this research. Like the procedure conducted for BIM assessments, the same process will be repeated in this section to recognise existing key features, including similarities and differences between them. Finally, a relationship between KPIs and project performances will be outlined to provide an understanding of project performance measurement within UK industry. This will also establish how this can be beneficial for the client sector, and how KPI metrics can be linked with BIM maturity assessments.

3.5 Differences between Critical Success Factors (CSF), Key result indicators (KRIs), Performance Measurements (PM), and Key Performance Indicators (KPIs)

Similar to the adoption and implementation of BIM, there is significant interest in measuring project success; however, individuals and organisations could not measure success or failure without the presence of Performance Metrics (Parmenter, 2015). Over the past few decades, a vast amount of publications and assessments has discussed concepts and topics related to performance metrics and the importance of criteria to measure performance success (Yang et al., 2010). As a result, a series of publications have been published that cover performance measurement, project success, performance indicators. A set of definitions has been delivered to define project success in construction (Chan, 2004). Joblot et al. (2019) states that *"factors that affect the success of a project are called the critical success factor (CSF), key success factors (KSF), or at the startup, factors of technology acceptance; these must be studied and will be useful"*. Performance measurement is used by organisations to ensure they are going in right direction, achieving targets in terms of organisational goals and objectives. Project success is an abstract concept, and to determines whether a project is a success, or failure is far more complex. The subject of performance is vast and numerous authors continuously add to this body of literature. Too many, too few or inappropriate performance measures can easily create deterioration in overall performance (Parmenter, 2015).

A CSF is described as a manageable critical factor that is responsible for the attainment of a desirable performance (Tsai et al., 2014). Key Result Indicators (KRIs) have been defined as an overall summary of how the organisation performs. KPIs inform management how one organisation could perform in terms of project success, which could allow an increase in overall performance (Parameter, 2015). Performance measurements are used to evaluate and control their overall business operations. Different concepts measure a project's performance and success, which would be relevant to this research and to BIM maturity specifically in delivering the necessary linkage to measure the performance of UK construction organisations. The next section provides a detailed description of KPIs and emphasise their measures.

3.6 Key Performance Indicators (KPIs)

Having identified KPIs as the main measure for use, it is necessary to deliver a number of definitions on what KPIs are, the different types of KPIs that exist, and the different types of KPI assessments across the literature. It is necessary to determine what KPIs are in order to demonstrate improvement within them. A KPI is the measure of a process that is critical to the success of an organisation. According to the Constructing Excellence report, several performance measures define the success of a project or organisation (Swan and Kyng, 2004). Lim argues that KPIs depend on a criterion for project success, which is split into macros and micros. Project success should be viewed from different perspectives that include the individual owner, developer, contractor, user, general public, and so on (Lim and Mohamed, 1999). Many researchers have applied the concept of KPIs to conduct benchmarking studies in construction management (Chan and Chan 2004).

Key performance Indicators are numbers designed to succinctly convey as much information as possible. Good key performance indicators are well defined, well presented, create expectations and drive actions (Peterson, 2006). KPIs have been split into two categories: Firstly, quantitative is the most commonly accepted performance indicator, whilst qualitative is not commonly accepted as a reliable performance and productivity evaluation tool due to its perceived difficulty to measure them (Cox, Issa, and Athrens, 2003). Initially, Karim and Marosszeky (1999) introduced KPIs as performance measurement. After this, to review construction industries' overall organisational performances and project measurements, KPIs included eight main factors, namely: Time, cost, quality, client satisfaction, client changes, business performance, health and safety, and environmental.

In its latest report, the UK construction industry outlined the KPIs used in their study, which are: Economic indicators, client satisfaction, contractor satisfaction, profitability, predictability, respect for people, environmental indicators, housing, non-housing, consultants (UK industry performance report. 2017). Furthermore, for organisations to achieve best practice, KPIs could have benchmarking purposes that will act as key components (Enshassi, Mohamed, and Abushaban, 2009). Samson and Lema (2002) state that the importance of KPIs lie in the receipt of values by stakeholders; therefore, the right capabilities and processes should be identified by companies. This allows KPIs to illustrate improvements and maintenances, along with competitive and distinctive capabilities and processes. Ugwu and Haupt (2007) classified site-specific and project-specific KPIs.

According to Long, Ogunlana, Quang, & Lam (2004), time, budget, quality, specifications and stakeholder satisfaction are indicators related to project performance measurement. Meng (2012, p.188) found that construction projects often suffer from poor performance in terms of time delays, cost overruns and quality defects, and concluded that *"time, cost and quality are the three most important indicators to measure construction project performance".* From a survey of 400 construction practitioners in the UK, at a response rate of 30%, his research found that 35.6% of the projects studied were delayed, 25.2% were overspent, and 17.7% had significant defects. Brown and Adams (2000) undertook 15 case studies derived from UK data, and found that project management within the UK failed to perform as expected in three predominant performance evaluation criteria - time, cost and quality. In fact, they showed that project management had little effect on time performance, no effect on cost performance, and a strong negative effect on quality performance. Finally, to achieve current and future projects, significant improvements in KPI performance measurements could be summarised by a performance measurement process that includes factors, such as time, cost, quality, client satisfaction, productivity and safety. Having defined what KPIs are, the next section will explore an example of how KPIs are being used across the globe.

3.6.1 KPIs Assessments - Global perspective

KPI outcomes have been presented differently in various multi-functional industries across the globe. Key Performance Indicators (KPIs) are compilations of data measures and used to assess the performance of a construction operation. They are the management methods used to evaluate employee performances on a particular task. These evaluations typically compare the actual and estimated performances in terms of the effectiveness, efficiency, and quality of both workmanship and product. KPIs have been split into two categories: first is quantitative, which is the most commonly accepted performance indicator and can be physically measured by dollars, units, or man-hours. This consists of: units/MH, $/unit, cost, on-time completion, resource management, quality control/rework, percent complete, earned man-hours, lost time accounting, punch list. The second category is the qualitative, which is not commonly accepted as a reliable performance and productivity evaluation tool due to the perceived difficulty and/or inability to be measured. This consists of: safety, turnover, absenteeism, motivation (Cox, Issa, and Athrens, 2004). According to Chan and Chan (2004), thirty measures have been provided, and some were outlined as completed measures - known as KPO - and in-progress - known as KPIs - that derived from different sources. They are all outlined as: Defects, client satisfaction, predictability, time, cost, profitability, productivity, environment, employee satisfaction, risk, reuse of design, understanding client needs, design process, mobilisation, final account, extension of time, safety, sickness, training, qualifications, communication, staff turnover, pay, and working hours. Furthermore, the respective values are calculated from mathematical formulae used by the first group. Finally, the level of satisfaction amongst various stakeholders, and the building of functionality and qualities are included by the group (Chan and Chan, 2004). Having presented a global perspective of KPIs, the next section will discuss the UK vision of KPIs.

3.6.2 KPI Assessments- UK perspective

Since BIM has delivered various benefits to, and its importance has been examined across, the UK, KPIs shall be presented to outline the benefits. The essential outcomes of KPIs have been presented differently in various industries across the UK. A number of definitions have been provided to define KPIs, which were based on the development of the Latham (1994), Egan (1998), and Wolstenholme (2009) reports.

According to the Construction Excellence report (Swan and Kyng, 2004), the success of projects and organisations are defined over a number of performance measures and, as a result, are the most common benchmarking experiences encountered by clients and companies. Furthermore, benchmarking standard data for an industry versus an organisation is possible through construction industry KPIs. Moreover, better performances and positive change in projects and organisations are led by a process of improvement and cultural change, and attained from KPIs. In addition, a commitment to continuous improvement is derived from companies that public sector clients seek to work with. Finally, three key elements are identified through a 5-6-10 model that includes the following:

1) **Drivers:** the aspects that must be in place to drive improvement; including; a) Committed leadership, b) Focus on the customer, c) Product team integration, d) Quality driven agenda, and e) Commitment to people.
2) **Processes:** the areas of process improvement, which includes; a) Product development, b) Project implementation, c) Sustainability, d) Partnering the supply Chain, e) Products of components, and f) Respect for people.
3) **Performance Targets:** Key Performance Indicators, which consists of; a) Construction Cost, b) Construction Time, c) Predictability Cost, d) Predictability Time, e) Client satisfaction- Product, f) Client satisfaction- service, g) Defects, h) Profitability, i) Productivity, and j) Safety (Swan and Kyng, 2004).

Table 3.5 outlines the ten KPI headlines description, that emerged from the targets of improvement in the 5-6-10 model.

Table 3.5 Improvement targets KPIs headlines (Swan and Kyng, 2004)

Name	Description	Type – What Measured?
Construction Cost	Improvement of capital cost year on year.	Project
Construction Time	Improvement of time year on year.	Project
Predictability Cost	Actual cost against the cost predicted at tender.	Project
Predictability Time	Actual time against the time predicted at tender.	Project
Client Satisfaction Product	Client satisfaction with the delivered product	Project
Client Satisfaction Service	Client satisfaction with the service provided by the Project Team	Project
Defects	Impact of the defects of the final product	Project
Productivity	Value added per person working on the project	Project
Profitability	Profitability of the Construction	Organisational
Safety	Company Accident Incident Rate for the Company	Organisational

Having presented the UK and global perspectives on KPIs, the next section presents the KPIs and their assessments that emerged across the literature. The KPIs will demonstrate how they and their assessments were used, the type of methods and categories that exist, a summary of the main features within each KPI and its assessment, along with the strengths and weaknesses.

3.7 An Evaluation of KPI assessments

According to Aboumoemen (2016), construction performance measurements are conducted through Key Performance Indicators (KPIs). Therefore, to outline their potential benefits, it is necessary to demonstrate KPI progression. KPIs are measures of a process that are critical to the success of an organisation. Furthermore, a number of performance measures define the success of a project or organisation (Swan and Kyng, 2004). After an extensive review of existing KPI assessments across the globe, it was revealed that a significant number of publications exist.

For the purpose of this research, the researcher narrowed down the selection of KPI assessments to the most relevant publications. As a result, 20 publications have been chosen to provide the essence of KPI assessments; these were KPIs in the literature that could be linked with BIM maturity. Having conducted analysis on existing KPIs assessments, they have been classified into the following nine categories:

1) **Questionnaires or surveys with the use of Likert scales**: Likert scales were used in questionnaires to collect data on KPIs. This uses a rating scale of three and above for responses to questions that participants answer by selecting the appropriate rating (Alkilani, et al., 2015; Cox, Issa, & Ahrens, 2003; Ramırez, Alarcon, & Knights, 2004; Sibiya, Aigbavboa, & Thwala, 2015; Vukomanović, Radujković, & Nahod, M. 2010).

2) **Listed set of KPIs**: Studies include a list of KPIs to support projects and organisations (BRE. 2016; Chan, & Chan, 2004; Swan & Kyng, 2004).
3) **European Foundation for Quality Management (EFQM) excellence model:** The model used as a continuous improvement strategy that consists of cause and effect relationships between what their organisation does on two criteria:
   i. Enablers with its five areas of: Leadership; strategy; people; partnerships, and processes and products, and
   ii. Results with its four areas of: People, customer, society, business it achieves (Bassioni, Price, & Hassan, 2004; Beatham et al., 2004).
4) **Balanced Scorecard**: Balanced Scorecard is presented and used to measure goals. The scorecard includes four perspectives, known as: Financial, customer, internal business, and innovation and learning (Luu et al., 2008).
5) **Other**: includes methods to outline KPIs other than those already presented (Bassioni, Price, & Hassan, 2005; NWCH. 2014; Scottish Government. 2012).
6) **Relative Important Index (RII)**; Relative Importance Index is a method that indicates the importance of parameters. This is a mathematical formula that aims to identify the importance of KPIs through a numerical ranking procedure that is correlated with others (Yeung et al., 2013).
7) **Rating criteria**; Rating Criteria ranks the most used metrics in projects. It uses criteria to rate KPIs used in a study to outline their importance (Ali, Al-Sulaihi, & Al-Gahtani, 2013).
8) **Framework attempt**: A framework approach exists to outline the distribution of KPIs (Takim & Akintoye, 2002; Toor, & Ogunlana, 2010).
9) **All (except Other and Likert Scale)**: This includes a set of methods that are used to outline the KPIs (Cha and Kim, 2011).

The performance measures and KPIs of project performance and success were generalised on cost, time, and quality; however, other aspects of assessment have been introduced differently, such as Safety and Performance, which varied from one place to another. The KPIs aim to deliver overall improvements within the UK construction industry (Wolstenholme, 2009). Table 3.6 presents a number of the most popular studies on KPI assessment in the literature. A number of KPIs will be extracted from these assessments to deliver a standardised set of KPIs for use.

Table 3.6 Selected most popular available KPI assessments across the literature

Selected most popular KPI assessments for construction projects across the literature

Legend (number of studies)
Questionnaires or surveys with the use of Likert scale (5)
Listed set of KPIs (3)
EFQM excellence model or Balanced Scorecard (3)
Other (3)
Relative important Index or rating criteria (3)
Framework attempt (2)
All of the above (1)

KPIs and their assessments used in construction projects in the UK

Publications on Key Performance Indicators (KPIs)- UK	Year	Assessment used in study
PERFORMANCE INDICATORS FOR SUCCESSFUL CONSTRUCTION PROJECT PERFORMANCE (Takim and Akintoye, 2002)	2002	Framework development
Introduction to Key Performance Indicators (Swan, & Kyng, 2004)	2004	Listed set of KPIs
KPIs: a critical appraisal of their use in construction. (Beatham, Anumba, Thorpe, & Hedges, 2004)	2004	EFQM excellence model
Performance Measurement in Construction. (Bassioni, Price, & Hassan, 2004)	2004	EFQM excellence model And Balanced Scorecard
Building a conceptual framework for measuring business performance in construction: an empirical Evaluation (Bassioni, Price, & Hassan, 2005)	2005	block diagram, through process modelling technique (IDEF0)
Development of Key Performance Indicators to support the building standards verification system (Scottish Government, 2012)	2012	Follow SMART criteria: 1. Specific purpose 2. Measurable 3. Achievable 4. Relevant 5. Time-based
North West Construction Hub and NACF KPIs (NACF and NWCH 2014)	2014	Percentage Measures across contractors
Key performance indicators (KPI's) for the construction industry (BRE group, 2016)	2016	The KPI Engine provides comprehensive support for collecting, reporting and analysing data.

KPIs and their assessments used in construction projects across the Globe

Publications on Key Performance Indicators (KPIs)	Country	Year	Assessment used in study
Management perception for KPI in construction report (Cox, Issa, & Ahrens, 2003)	US	2003	Survey of a 7 likert system to determine the perceived levels of KPIs being used
Key performance indicators for measuring construction success (Chan & Chan, 2004)	Australia and Hong Kong	2004	Listed set of KPIs related to project success
Benchmarking system for evaluating management practices in the construction industry (Ramrez, Alarcón, & Knights, 2004)	Chile	2004	Questionnaire with Professionals in the Chilean industry
Initial metrics and pilot program results for measuring the performance of the Canadian construction industry (Rankin, Fayek, Meade, Haas, & Manseau, 2008)	Canada	2008	Rating criteria for 37 projects as a pilot study
Performance measurement of construction firms in developing countries (Luu, Kim, Cao, & Park, 2008)	Vietnam	2008	Balanced Scorecard and SWOT analysis
Beyond the 'iron triangle': Stakeholder perception of key performance indicators (KPIs) for large-scale public sector development projects (Toor & Ogunlana, 2010)	Thailand	2010	Iron triangle framework
Leading, lagging and perceptive performance measures in the construction industry Organization (Vukomanović, Radujković, & Nahod, 2010)	Croatia	2010	Surveys and interviews with construction companies professionals
Project Performance Measurement on Building Construction in South Korea (Cha and Kim, 2011)	Korea	2011	Preliminary list of KPIs, In-depth survey and interviews, Weighting the KPIs, Relative Importance Index and Performance Score Index
Indicators for measuring performance of building construction companies in Kingdom of Saudi Arabia (Ali, Al-Sulaihi, & Al-Gahtani, 2013)	Saudi Arabia	2013	Relative Importance Index (RII) and 24 surveys
Developing a Benchmarking Model for Construction Projects in Hong Kong (Yeung, Chan, Chan, Chiang, & Yang, 2013)	Hong Kong	2013	Reliability Interval method and Relative Importance Index (RII), Questionnaire Survey on 3 case studies
Construction Projects' Key Performance Indicators: A Case of the South African Construction Industry (Sibiya, Aigbavboa, & Thwala, 2015)	South Africa	2015	Questionnaire survey, Statistical ranking through Mean and Standard Deviations
KEY PERFORMANCE INDICATORS FOR CONSTRUCTION CONTRACTORS IN DEVELOPING COUNTRIES: A CASE STUDY OF JORDAN (Alkilani, Jupp, Kamardeen and Sawhney, 2015)	Jordan	2015	Questionnaire survey was distributed to a sample of 550 construction stakeholders thorugh delphi methods and Relative Importance Index analysis

Following a comprehensive review of such assessments and having extracted different KPI assessments, this section presents the qualitative findings of the available KPIs and their assessments. A number of outcomes are presented in the evaluation of the KPIs and their assessments. ten outcomes are required to evaluate existing KPIs and their assessments in the literature, which are:

1) **KPI elements [at least 7 (cost, time, quality, customer satisfaction, safety, productivity and performance)]**: It is believed that KPIs should be within this range to cover the essence of KPIs in the construction industry. They should not be treated as a set of questions to deliver BIM.
2) **A data collection procedure along with an assessment method should be available for the selection of KPIs:** Some studies have included a data collection technique to assess their presented list of KPIs, which has helped those studies signify their KPIs.
3) **A set of conclusions exist that some consider as strengths in KPI studies**: Most studies are expected to deliver an outcome that is practical and effective, and thus the conclusions will help to recognise the effects of the final KPI outcomes in their presented studies.

4) **A set of limitations exist which may be considered weaknesses in KPI studies**: The limitations help to recognise the negative effects of these outcomes and the set of actions needed to overcome them.
5) **Absence of one level (i.e. studies that contain project level and not organisational level and vice versa)**: Using one level may reflect negatively on the study's outcomes. Hence, using both levels may help signify positive impacts to result from using both levels together.
6) **UK studies that have reflected on KPIs from other UK studies**: These are required to recognise how UK studies reflect each other based on previous related studies.
7) **Delivering a set of studies for the UK and globally**: This helps to compare between a global and UK perspective, extract similarities and differences between them. It also helps to identify where global studies have introduced new methods and strategies to address the use of KPIs, their impacts across their industry and applicability within the UK context.
8) **Selected KPI assessments in literature**: An extensive set of KPI studies exist with various assessments, so it would be essential to focus on the most popular studies that cover the essence of KPI assessments, and helps to select the most applicable assessment.
9) **KPIs approach in study**: Each study expects to approach KPIs in a different way (i.e. project success), and hence it is necessary to see how a KPI is approached in these studies through the delivery of its particular approach.
10) **Selection of KPIs**: Each study used different KPIs, and thus it is important to distribute the KPIs used, determine which were identified, and, may present KPI benchmarking criteria for this research.

It is believed that the presented outcomes need to be available for KPI evaluations since they will help to visualise how KPIs previously existed, the requirements to develop a KPI assessment, and this shapes the requirements for a KPI assessment in this study. The presented outcomes cover KPI areas, and thus represent a starting point to develop an assessment for KPIs in this study. A complete list of evaluations for each study is available in Appendix B.

Having presented a detailed analysis for each study, the next section will present a summary of the presented assessments (Table 3.6) in order to extract key findings across the available studies for each category. After identifying nine categories across the selected most popular twenty KPI assessments, Table 3.7 presents a definition of each category, its purpose of usage, a summary of the overall strengths and weaknesses across the studies for each category, and a number of categories that are believed to align well with the aim of this research.

Table 3.7 Selected KPI assessments in Literature category selection purposes, and strengths and weaknesses associated with studies in each category

Nature of the category (number of studies)	Definitions for each category	Category selection and consideration for this research	Summary of strengths across the studies	Summary of weaknesses across the studies
Questionnaires or surveys with the use of Likert scale (5)	Studies that included the Likert scale uses a rating scale of 3 and above	It shall support the data collection procedure that will occur within all its stages (BIM, KPI, and both together).	KPIs being assessed on importance, frequencies and usage amongst organisational levels through delivery of questions.	Questions provided for the KPIs were answered by individuals based on their personal views, which could vary from one place to another
Listed set of KPIs (3)	Studies which included a listed set of KPIs defined as KPIs used within those studies	It is expected that a list of KPIs shall be presented in the KPIs of the suggested assessment.	A listed set of KPIs delivered to be examined across project or organisational levels through KPI engine.	Different lists of KPIs are used according to study's requirements, resulting in absence of standardised set of KPIs being delivered.
EFQM excellence model Or Balanced Scorecard (3)	EFQM excellence model is: Cause and effect relationships.	EFQM is complex and requires to monitor organisations which could be beyond this research scope.	EFQM excellence model used to deliver a benchmarking system for KPIs to be assessed in the project level.	KPIs are not fully understood from using this method, causing misinterpretations and lack of understanding to the presented KPIs.
	Balanced Scorecard is: A scorecard that included 4 perspectives	Balanced scorecard method shall be supportive during the formulation of the suggested assessment selection.	Balanced Scorecard integrated with other systems (EFQM model) to examine KPIs across project and organisational levels.	The method was not validated across organisations, which delivered a non comprehensive performance measurement tool.
Other (3)	Other Studies that included other methods to outline KPIs	Studies which included other methods shall not deliver the necessary information required for this study	Methods such as (SMART) used to examine the delivery of KPIs.	KPIs used extensively in studies, and requirements varied from one study to another, resulting in absence of standardisation
Relative important Index or Rating criteria (3)	A mathematical formula aimed to identify the importance of used KPIs	It could be applicable in this study since it could help indicate the importance of each BIM or KPI	Method for defining the importance of KPIs and correlating them to measure the performance of projects and organisations.	Quantitative measures are provided but are not well defined, causing discrepancies across project and organisational levels.
	A Criteria to rate the KPIs used in the study to outline their importance.	It could be applicable in this study since it will rank the most applied BIM or KPI in projects or organisations,	Simplified method to rate the KPIs used across several projects.	The basis of rating the KPIs were not defined or provided, resulting in the KPIs not reflecting on the projects necessary.
Framework attempt (2)	A framework approach has existed to outline KPIs within particular studies	Previous attempt to framework (i.e. Iron Triangle) would help and is considered in the framework formulation	New concept(s) introduced in frameworks to examine and verify performance of projects across organisations (IDEF0 diagram).	Various framework are used to examine the KPIs existence, therefore not delivering a standardised framework to be used in the project level.
All of the above (1)	A single study that used all methods addressed in this section	It could be applicable in this study since the selected study included a set of methods being used to outline the KPIs	A set of methods used (Listed KPIs, RII) to verify the importance of the KPIs being delivered	Not examined amongst the whole project lifecycle and data is not rigorous, resulting in absence of a strong relation of methods together

Having reviewed the categories, the highlighted categories are based on existing features, such as the usage of a balanced scorecard, the Relative Importance Index (RII), and Likert scales; these present the KPI requirements to consider for a KPI assessment. The rationale for the KPI classifications is based on their existence in studies, which supports the overall delivery of KPIs; however, some of the classifications may not be suitable for the KPI assessment for this research. The studies on KPIs have demonstrated the following:

1) A list of KPIs is required, which is examined across project and organisational levels.
2) Concepts, such as the IDEF0 diagram, are used in frameworks to evaluate a project's performance.
3) EFQM model and balanced scorecard as benchmarking systems and integrated to assess KPIs at the organisational level.
4) RII and rating criteria as methods to rank KPIs that define their importance and measure their performance on projects.
5) Use of a Likert scale through questionnaires to evaluate the importance and use of KPIs across projects.
6) Methods, such as Specific, Measurable, Attainable, Relevant, and Time-bound (SMART), to examine the provision of KPIs and combined methods (listed set of KPIs and RII) to verify the importance of the KPIs used.

However, a set of variances exist, such as:

1) The delivery of different sets of KPIs according to each study's requirements, resulting in the absence of a standardised set of KPIs,
2) Various frameworks used to examine KPIs, meaning the absence of a standardised framework for use in projects.
3) Not understanding the usage of KPIs through the EFQM model, resulting in the lack of understanding and misinterpretation of KPIs.
4) A non-comprehensive performance measurement tool exists as a result of the balanced scorecard, but was not validated.
5) Measures are not well defined through the RII method, causing a variance in KPI delivery across projects.
6) KPIs are ranked randomly without a rating basis, which means that KPIs do not necessarily reflect projects.
7) Multiple methods are not examined across the project lifecycle, which results in the absence of strong relationships between various methods.

The addressed limitations will be reviewed in order to develop a KPI assessment that will tackle the existing obstacles that existed amongst these studies. It was noted that some of the KPI approaches were highlighted due to their significant impact. The approaches were highlighted because they may have a direct influence on the development of a KPI assessment, and thus represent a starting point to determine a number of considerations that may need to be considered for the development of a KPI assessment. Having qualitatively analysed the KPIs and their assessments, the next section will present the quantitative analysis of the KPIs and assessments, including statistical data.

Figure 3.4 distributes the percentage of KPIs according to their classification categories. This helps to identify the most familiar category used to identify KPIs and deliver KPI assessments.

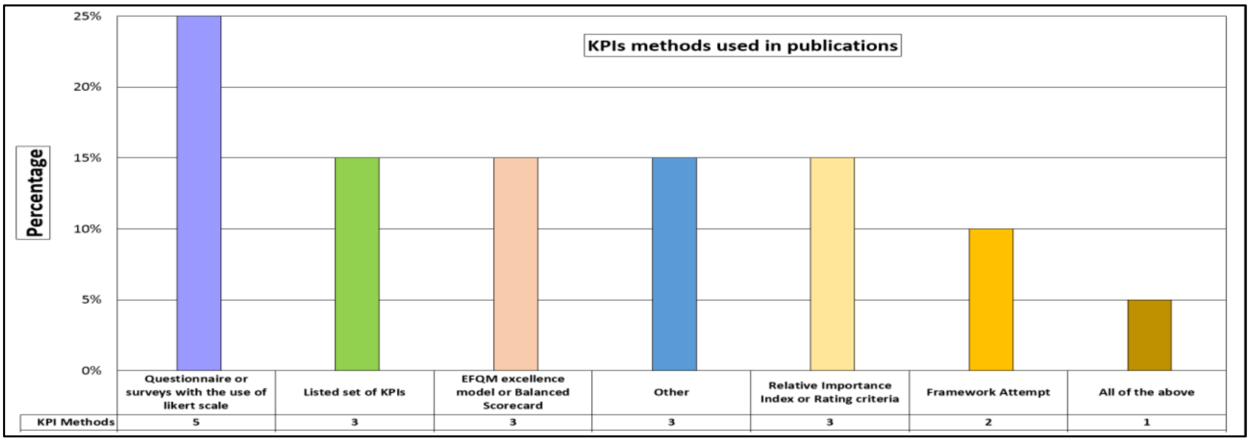


Figure 3.4 KPIs percentage distribution

The highest number of KPI assessments (five) used questionnaires (or surveys) with Likert scales, representing 25% of the total sample. Furthermore, a listed set of KPIs, the EFQM excellence model or the Balanced Scorecard, Other, and the RII and Rating criteria had a combination of twelve KPI assessment classifications, at three each, representing 60% of the total sample (or 15% each). Moreover, Framework attempt had two KPI assessment classifications, representing 10% of the sample. Finally, the category All (except Other and Likert Scale) had one assessment type for the KPIs used and represented 5% of the total sample.

Having evaluated the KPIs assessments. the next section will discuss the criteria being taken to selecting the most occurring and suitable KPI metrics for this research.

3.7.1 The selection criteria for KPI metrics and extraction of most relevant KPI metrics

This section will discuss the criteria that will be taken to extract the most relevant KPIs emerging from the literature, are believed to assess the performance of projects and organisations, and achieve the aim set for this research. According to Kerzner (2017), the criteria for defining the key characteristics of KPI metric would involve the usage of the "**S.M.A.R.T**" rule to establish meaningful objectives for projects and the identification of metrics and KPIs. This rule; in regards to the selection of the KPIs, is explained as follows: **Specific:** The KPI is clear and focused towards performance targets or a business purpose, **Measurable:** The KPI can be expressed quantitatively, **Attainable:** The targets are reasonable and achievable, **Realistic** or relevant: The KPI is directly pertinent to the work done on the project, and **Time-based**: The KPI is measurable within a given time period. Chan and Chan (2004) and Parmenter (2015) have established the criteria for identification the most relevant KPIs across projects and organisations as objective or quantitative measures, those that are measured and presented as numerical units, and subjective or qualitative measures, those that have the potential to be measured based on the behaviours of users. Finally, Cox et al., (2003), (Mincks & Johnston, 2003), and Ng et al. (2002) identified the criteria for selecting the KPIs to be **process oriented**, which deals with the management of outcomes such as resources, communication, and human resources, and **result oriented**, which deals with meeting the end goal and target for achieving a KPI and measuring it, which includes the following: Cost, Time, Quality, Safety, and Satisfaction.

Based on the identified criteria, and having reviewed the literature related to the KPI metrics, the most relevant KPI metrics that would fit within this research and meets the previous addressed criteria includes a standardised list of nine KPIs are believed to present a set that could be considered across projects and organisations (Table 3.8). On one hand, KPIs that appeared in all previous studies and industry and formed the basis of Key Performance Indicator measurement in any project or organisation are: **Cost, Time and Quality.** These are considered as the **primary KPI metrics**, since they represent the key element to assess primary and objective measures. On the other hand, after a set of KPIs has been reviewed, an additional set of KPIs emerged that varied from one study to another, and form a further set of six standardised KPIs to the existing primary three and are: **Safety, satisfaction, performance, profitability, productivity and sustainability.** These are believed to represent the **secondary KPI metrics** and relevant to assessing a project and organisation; this would form the basis for the delivery of a set of KPIs for use in this research. The KPIs that were identified from the key literature (Table 3.8) are classified, according to Parmenter (2015), as primary KPIs (Objective measures) and secondary KPIs (objective and subjective measures).

Table 3.8 A standardised set of KPIs emerging from the literature (Primary and Secondary KPIs)

Primary KPI (Objective Measures) and their description
a) Cost (Budget)
Improvement of capital cost year on year Cost is defined as the degree to which the general conditions promote the completion of a project within the estimated budget
b) Time (Schedule)
Improvement of time year on year Time is defined as the degree to which the general conditions promote the completion of a project within the allocated duration
c) Quality (Defects)
Quality is defined as the degree to which the general conditions promote meeting of the project's established requirements of materials and workmanship
Secondary KPI (Objective and Subjective Measures) and their description
d) Satisfaction (User and Organisation)
Satisfaction describes the level of ''happiness'' of people affected by a project. Satisfaction could be considered as an attribute of success.
e) Health and Safety (Safety)
Accident Incident Rate for the Company. Health and safety are defined as the degree to which the general conditions promote the completion of a project without major accidents of injuries.
f) Performance (Business or whole life)
''Meeting specifications'' is considered as one success criterion for design/build projects that is consistent with the measurement of technical performance.
g) Profitability (Finance Stability)
Profitability of the Construction Company. Nowadays, competition is increasing and firms are aware that the project must be properly managed to be profitable. Profitability measures the financial success of the project.
h) Productivity (Efficiency)
Value added per person working on the project. Productivity is universally accepted as one success criterion as it is the main key to the cost-effectiveness of projects. It refers to the amount of resource input to complete a given task and it is usually assessed on a ranked basis.
i) Sustainability (Environment)
Environmental sustainability is measured in the postconstruction Stage. One common example is the generation of construction waste, which can be measured by the difference between the amount of the total delivery of materials to the site and the amount of work completed.

References	**Primary and secondary KPIs**								
	a	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**
(CBPP. 2002)	x	x	x	x	x	x	x	x	x
(Chan, 1996)	x	x	x	x	x	x	x	x	x
(Chan and Chan, 2004)	x	x	x	x	x	x	x	x	x
(Chan, Scott, & Lam, 2002)	x	x	x	x	x	x	x	x	x
(Costa et al., 2006)	x	x	x	x	x		x	x	
(Hatzigeorgiou & Manoliadis, 2018)	x	x	x	x	x	x	x	x	x
(Hegazy, 2012)	x	x	x			x	x	x	
(Ikediashi et al., 2012)	x	x	x		x				
(Langston, 2013)	x	x	x						
(Li, 2010)	x	x	x	x			x		
(Lin and Shen, 2007)	x	x	x	x	x				x
(Marr, 2012)	x	x	x	x	x	x	x	x	x
(Maya, 2016)	x	x	x	x			x	x	
(Ofori-Kuragu, Baiden, and Badu, 2016)	x	x	x	x	x	x	x	x	x
(Parfitt and Sanvido 1993)	x	x	x	x	x	x	x	x	x
(Parmenter, 2015)	x	x	x	x	x	x	x	x	x
(Peterson, 2006)	x	x	x	x		x			x
(Robinson, Anumba, Carrillo, & Al-Ghassani, 2005)	x	x	x	x	x				
(Songer and Molenaar, 1997)	x	x	x	x			x		
(Sousa et al., 2006)	x	x	x	x		x		x	
(Swan and Kyng, 2004)	x	x	x	x	x	x	x	x	x
(UK IPR. 2018)	x	x	x	x	x	x	x	x	x
(Westerveld, 2002)	x	x	x						
(Yang et al., 2010)	x	x	x						
(Yeung et al., 2013)	x	x	x	x	x				x

Based on Table 3.8, the KPIs are defined and measured based on the S.M.A.R.T rule, result vs process oriented, objective vs subjective measures, and Primary vs Secondary KPI metrics. This is explained as follows (Chan et al., 2002; Chan and Chan, 2004; Cox et al., 2003; Kerzner, 2017; John, 2018; Mincks & Johnston, 2003; Ng et al., 2002):

1) **Cost** (Budget): The improvement of capital cost year on year cost is defined as the degree to which general conditions promote the completion of a project within the estimated budget. This KPI is classified as a Primary objective KPI that would be measured quantitatively (in currency) and is a result oriented KPI that measures cost goals as an indicator and meets target budgets as an attribute.
2) **Time** (Schedule): The improvement of time year on year time is defined as the degree to which general conditions promote the completion of a project within the allocated duration. This KPI is classified as a Primary objective KPI that would be measured quantitatively (in percentage of schedule completion) and is a result oriented KPI that measures cost goals as an indicator and meets target budgets as an attribute.
3) **Quality** (Defects): Quality is defined as the degree to which the general conditions help to meet the project's established requirements of material and workmanship. This KPI is classified as a Primary objective KPI that would be measured quantitatively (in number of man hours and material costs for repairing works) and is a result oriented KPI that measures quality goals as an indicator, and meets quality specification and addresses total number and cost of change orders as an attribute.
4) **Satisfaction** (User and Organisation): Satisfaction describes the level of ''happiness'' of people affected by a project. Satisfaction could be considered an attribute of success. This KPI is classified as a Secondary subjective KPI that would be measured quantitatively (in percentage of overall user satisfaction with end product), and is result oriented on how to improve user satisfaction and increase number of repeat users as attributes.
5) **Health and Safety** (Safety): Accident Incident Rate for the Company. Health and safety is defined as the degree to which the general conditions promote the completion of a project without major accidents of injuries. This KPI is classified as a Secondary objective KPI that would be measured quantitatively (in number of site accidents and percentage of overall safety of working environment), and is result oriented that measures safety goals as an indicator, and addresses total number of site accidents and near misses as attributes.
6) **Performance** (Business or whole life): ''Meeting specifications'' is considered one success criterion for design/build projects consistent with technical performance measurement. This KPI is classified as a Secondary subjective KPI that would be measured quantitatively (in percentage of meeting specification and overall performance of organisations and projects).

7) **Profitability** (Finance Stability): Profitability of the Construction Company. Nowadays, competition is increasing and firms are aware that the project must be properly managed to be profitable. Profitability measures the overall financial success of the project, as an indication of a Secondary objective measure being measured quantitatively (in currency of total net revenge over total net cost).
8) **Productivity** (Efficiency): Value added per person working on the project. Productivity is universally accepted as one success criterion as it is the main key to the cost-effectiveness of projects. It refers to a quantitative measure through the amount of resource input to complete a given task and it is usually assessed on a ranked basis, as an indication of a Secondary objective and subjective measure.
9) **Sustainability** (Environment): Environmental sustainability is measured in the post-construction stage. One common example is the generation of construction waste, which can be measured quantitatively by the difference between the amount of the total delivery of materials to the site and the amount of work completed, as an indication of a Secondary objective and subjective measure.

Table 3.8 reveals that the primary KPIs (cost, time, and quality) are addressed across all reviewed studies, and thus represent primary benchmarking criteria when developing a list of KPIs. Whereas secondary KPIs, (safety, satisfaction, performance, profitability, productivity and sustainability) have been addressed by some of the reviewed studies, which indicates that these secondary KPIs will form the standardised list used for KPI assessment in this research. Thus, the standardised list of KPI metrics used for a KPI assessment in this research will be the nine identified in Table 3.8, and will all be measured quantitatively according to the S.M.A.R.T rule.

Having identified the criteria for selecting KPIs, and discussed those KPIs that were selected and are relevant for this research, the next section will summarise the KPIs and the assessment findings, and discuss the outcomes relevant to the aim of this research

3.7.2 A Summary of the Available KPIs and their Assessments

An extensive review has been conducted to determine the KPIs that emerged from the literature and the assessments that were used to assess project performances and measure project success across organisations. The literature revealed an exhaustive list of KPIs and assessments, which were filtered to cover the main aspects of KPIs needed to assess project performances/success and organisations. As such, a set of standardised KPIs was presented, as follows: Cost, time, quality, safety, satisfaction, performance, profitability, productivity and sustainability (Table 3.9). These recurred across a set of studies within the body of literature reviewed (Bubashait and

Almohawis, 1994; CBPP. 2002; Chan, 1996; Chan et al., 2002; Costa et al., 2006; Hatzigeorgiou & Manoliadis, 2018; Hegazy, 2012; Ikediashi et al., 2012; Langston, 2013; Li, 2010; Lin and Shen, 2007; Liu and Walker, 1998; Marr, 2012; Maya, 2016; Ofori-Kuragu et al., 2016; Parfitt and Sanvido 1993; Parmenter, 2015; Peterson, 2006; Robinson et al., 2005; Skoyles, 1987; Songer and Molenaar, 1997; Sousa et al., 2006; Swan and Kyng, 2004; Tayler, 1992; UK Industry Performance Report (IPR). 2018; Westerveld, 2002; Yang et al., 2010; Yeung et al., 2013).

To confirm the list presented, it was essential to present a comparison of KPIs from the selective set of studies; these were believed to best align with the presented list in Table 3.10 and the aim of this research. Those KPIs were as follows: Cost, time, quality, safety, client satisfaction, business performance, productivity, sustainability, predictability, and people (Ofori-Kuragu et al., 2016), cost, time, quality, safety, satisfaction, technical performance, profitability, productivity, environment (sustainability), and educational, social and professional aspects (Chan et al., 2002), and construction cost, construction time, predictability cost, predictability time, client satisfaction product, client satisfaction service, defects, profitability, productivity, and safety (Swan and Kyng, 2004). These KPIs align with the list presented in Table 3.10 and used to examine both projects and organisations. Thus, the previously highlighted KPIs are reviewed within the data collection techniques and will be discussed later in this research.

Having critically reviewed the KPIs, the next section will discuss the combined BIM maturity/KPI assessments that exist in the literature and will demonstrate how both BIM and KPIs were used, the type of methods and categories that exist, and how these could offer a means of assessment in this research. The same process will be repeated in this section to recognise existing key features, including key similarities and differences.

3.8 Establishing a relationship between BIM maturity and KPI metrics

Having separately defined BIM maturity and KPI metrics, it is necessary to provide a link between BIM maturities and the Key Performance Indicators (KPIs). This will be further discussed in this section in order to identify the possible values and benefits of this link. BIM Maturity is about assessing abilities, and construction performance measurements are conducted through the application of Key Performance Indicators (KPIs). Therefore, to outline its potential benefits and values, it is necessary to demonstrate improvement within the KPIs, which would an understanding of the link between BIM maturity and the KPIs. According to Aboumoemen and Underwood (2017), a few publications were published that addressed the possible links of BIM implementation on the primary KPIs across construction projects.

As there have been previous efforts to link BIM and KPIs, this section will establish existing links to demonstrate the relationship. According to Ashworth and Tucker (2018), to deliver a better product, KPI operations aim to benefit the construction industry and form a key focus across the publications. Furthermore, two performance indicators are: the effective adoption of the BIM concept, and the benefits of BIM business adoption for the delivery of a company's KPIs. Although both sets are isolated, it is necessary for them to operate together in order to matching parts of the business success to the overall picture. Moreover, the business case for the adoption of BIM would be justified through the establishment of business related KPIs. It is essential to justify the return on investment, due to the costly investment of implementing BIM processes, technology and organisations. The presentation of systematic KPIs requires the adoption of BIM for business improvements that can be observed and for accurate measurements to be structured. Hence, BIM adoption methods could be: "*1) Measuring the quality of projects, 2) Standardizing information and measurement process throughout the community, 3) Setting appropriate benchmarking targets, and 4) Recording effectiveness of action*" (Coates et al., 2010).

3.9 BIM Maturity and the Assessment of KPI relationships

BIM maturity models have been widely identified across various studies by different authors. Measuring the effectiveness of BIM assessments and adoption across construction industries is the main reason for BIM maturity; it may reflect on the UK government's mandate and examine the success of BIM projects across the UK. The main KPI outcomes have been presented in diverse ways across UK industries. KPIs are measures of a process that is critical to the success of an organisation. A number of performance measures define the success of a project or an organisation (Swan and Kyng, 2004), which are based on the development of construction industry reports. There needs to be a framework to show the potential relationships between BIM maturity and KPIs and enable the measurement of construction project success (Aboumoemen, 2016; Yeung et al., 2013). Few studies identify the association between BIM and KPIs in the construction industry. According to Khanzadi, Sheikhkhoshkar, and Banihashemi (2019, p.2), "*The appropriate decision-making criteria grounded on BIM and KPIs should encapsulate a complex trade-off of different processes requiring all alternatives to be considered simultaneously*". BIM maturity emerged as a method to measure a project by assessing levels of BIM maturity across projects and organisations, and KPIs acting as a method to measure construction project and organisation success. However, an assessment is needed to combine both concepts in order to effectively assess and meet the desired end goals. As a result, a limited number of publications exist that demonstrate a link between BIM and KPIs. Therefore, the next section elicits the most recent literature on combined BIM-KPI assessments and will demonstrate the linkages between BIM and KPIs across a number of publications in order to establish some links between BIM maturity and KPIs.

3.10 An Evaluation of BIM maturity and KPI metrics combined

Few publications demonstrate the potential links between BIM maturity and KPI metrics across construction projects (Smits et al., 2016). This either implies a failure to link BIM maturity and KPIs, or that it has not been a priority to realise the benefits from such a combination. Having conducted analysis on existing combined BIM/KPI assessments across the globe, efforts were made to link BIM maturity assessment and KPIs across 22 BIM and KPI assessments. From this, 11 additional assessments were identified from the BIM assessments (Table 3.1) with KPIs, which brought the total to **33 combined BIM/KPI assessments**. Moreover, six categories comprise the essentials of a BIM and KPI combination across these assessments. These are as follows:

1) **BIM impact on construction projects (KPIs) (nine):** Demonstrate the effect of BIM on KPIs and the performance on construction projects (Chen et al., 2018; Eadie, et al., 2013; Gyarting, 2014; Hassan, 2012; John, 2018; Olawumi and Chan, 2019; Olugboyega et al., 2020; Smits et al., 2016; Suermann, & Issa, 2007).
2) **KPIs impact on BIM implementation (eight)**: The impact of KPIs on the implementation of BIM and the variations from one study to another (Awwad et al., 2020; Chan et al., 2019; Coates et al., 2010; Liu, 2021; Manzione, et al., 2011; McAuley et al., 2015; Ozorhon and Karahan, 2016; Sarkar, Raghavendra, & Ruparelia, 2015).
3) **Assessment Framework (five)**: Assessment frameworks to combine BIM and KPIs (Aboumoemen, 2016; Badrinath, ASCE, & Hsieh, 2019; Mom & Hsieh, 2012; Shin, Choi, & Kim, 2015; Wong, Salleh, & Rahim, 2016).
4) **Assessment method (five)**: The presentation of a Balanced Scorecard and its use for comparison (Khanzadi, Sheikhkhoshkar, & Banihashemi, 2019; Park et al., 2013; Shin and Choi, 2016; Won & Lee, 2016; Yun et al., 2018).
5) **BIM implementation within Organisations (four):** Outline the impact of BIM on construction industries/organisations (Ashworth and Tucker, 2018; Barlish & Sullivan, 2012; Poirier, Staub-French, & Forgues, 2015; Shin, Choi, & Kim, 2015; Sun & Zhou, 2010).
6) **Assessment tool (two)**: An assessment tool presented to demonstrate the relationships between BIM and KPIs. (MoJ. 2016; Sebastian & Berlo, 2010).

The identified studies on existing BIM/KPIs across the literature are listed in Table 3.9.

Table 3.9 Existing BIM / KPIs parameters and assessments across the literature

Existing BIM / KPIs parameters and assessments across the literature	
Legend [(number of studies) (total = 33)]	**Country [(number of studies that existed in the same country) (total = 17)]**
BIM impact on construction projects- KPIs (9)	UK (7)
KPIs impact on BIM implementation (8)	Korea (5)
Assessment framework (5)	US (4)
Assessment method (5)	Netherlands (2)
BIM implementation within Organisations (4)	Taiwan (2)
Assessment tool (2)	Hong Kong (2)
	Other countries (11) [China, Gulf countries, Canada, India, Brazil, Iran, Malaysia, Turkey, South Africa, Singapore, Ireland]

Previous literature on combined BIM / KPI parameters and assessments		Previous literature on combined BIM / KPI parameters and assessments		Previous literature on combined BIM / KPI parameters and assessments (driven from the BIM maturity table)	
Publication	**Country and Year**	**Publication**	**Country and Year**	**Publication**	**Country and Year**
US- BIM effects on construction KPIs. Doctoral thesis in University of Florida. (Issa & Suermann, 2009; Suermann, 2009; Suermann & Issa, 2007).	**US** 2007-2009	**Critical Success Factors of Building Information Modeling Implementation** (Ozorhon and Karahan, 2016)	**Turkey** 2016	**BIM Tno Quickscan tool.** (Berlo, Dijkmans, Hendriks, Spekkink, & Pel, 2012; Sebastian & Berlo, 2010)	**Netherlands** 2010-2012
China- KPIs: Analysing the impact of BIM in construction industry in china. (Sun & Zhou, 2010)	**Beijing, China** 2010	**A Relationship Framework for Building Information Modeling (BIM) Capability in Quantity Surveying Practice and Project Performance (Wong, Salleh, & Rahim, 2016)**	**Malaysia** 2016	**Key Performance Indicators To Analyze And Improve Management Of Information Flow In The BIM Design Process** (Manzione, Wyse, Sacks, Van Berlo, & Melhado, 2011).	**Brazil** 2011
The key performance indicators of the BIM implementation process. (Coates et al. 2010)	**UK** 2010	**Critical success factors for facility management employer's information requirements (EIR) for BIM** (Ashworth and Tucker, 2018)	**UK** 2018	**BIM Capability Maturity Model Toward performance assessment of BIM technology implementation** (Mom and Hsieh, 2011 and 2012)	**Taiwan** 2011 and 2012
Doctoral thesis in Arizona University and How To Measure the Benefits of BIM: A Case Study Approach (US). (Barlish, 2011; Barlish & Sullivan, 2012).	**US** (2011 and 2012)	**Building information modelling (BIM) impact on construction performance** (John, 2018)	**US** 2018	**Key performance indicator on benefits of BSC-based BIM and validation methods** (Park et al., 2013)	**Korea** 2013
GCC- Impact of BIM on KPIs in Gulf Corporate Council countries projects. Master thesis in Heriot-Watt. (Hassan, 2012).	**Gulf countries** 2012	**Qualitatively Exploring the Impact of BIM on Construction Performance** (Chen et al., 2018)	**US** 2018	**Goal-Driven Method for Sustainable Evaluation of BIM Project Success** (Won & Lee, 2014 and 2016)	**Korea** 2014 (new update in 2016)
BIM implementation throughout the UK construction project lifecycle: An analysis. (Eadie, Browne, Odeyinka, McKeown, & Sean, 2013).	**UK** 2013	**Empirical Approach to Identify Operational Critical Success Factors for BIM Projects** (Badrinath, ASCE, & Hsieh, 2019)	**Taiwan** 2019	**A Study on BIM Performance Assessment Framework for Architecture Firm** (Shin, Choi, & Kim, 2015)	**Korea** 2015
An evaluation of the impact of Building Information Modelling (BIM) on Project Performance in the UK Construction Industry (Gyarteng, 2014)	**UK** 2014	**BIM applications toward key performance indicators of construction projects in Iran** (Khanzadi, Sheikhkhoshkar, & Banihashemi, 2019)	**Iran** 2019	**BIM Level 2 Maturity / KPI assessment framework** (Aboumoemen, 2016)	**UK 2016**
Assessing the Performance of the BIM Implementation Process within a Small Specialty Contracting Enterprise (Poirier, Staub-French, & Forgues, 2015)	**Canada** 2015	**Building information modelling and project information management framework for construction projects** (Olawumi and Chan, 2019)	**Hong Kong** 2019	**MoJ BIM maturity assessment tool / KPI system** (MoJ, 2016) UK	**UK 2016**
Role of Key Performance Indicators for evaluating the usage of BIM as tool for Facility Management of Construction Projects (Sarkar, Raghavendra, & Ruparelia, 2015)	**India** 2015	**Critical success factors for building information modelling (BIM) implementation in Hong Kong** (Chan et al., 2019)	**Hong Kong** 2019	**Development of KPIs of BIM performance measurement in design phase** (Shin and Choi, 2016)	**Korea** 2016
The development of KPIs to monitor early facilities management performance through the use of BIM technologies in public sector projects (McAuley et al., 2015)	**Ireland** 2015	**Exploring the critical success factors influencing BIM level 2 implementation in the UK construction industry** (Awwad et al., 2020)	**UK** 2020	**BIM Service Level Assessment in Construction Phase** (Yun et al., 2018) **Korea**	**Korea 2018**
Yield-to-BIM: impacts of BIM maturity on project performance (Smits, van Buiten, & Hartmann, 2016)	**Netherlands 2016**	**Critical success factors for BIM adoption during construction phase: a Singapore case study** (Liu, 2021)	**Singapore** 2021	**Development of a conceptual model for evaluating the success of BIM-based construction projects** (Olugboyega et al., 2020)	**South Africa 2020**

This section presents the qualitative findings of the combined BIM and KPI assessments. A set of outcomes is presented on the evaluation of BIM and KPIs. Based on the combined BIM and KPIs assessments, 19 outcomes are required to evaluate existing studies in the literature. These are:

1) **Responses received should total at least thirty (Flick, 2011)**, since the proposed sample size allows validity and reliability across the presented studies.
2) **An assessment method should be presented in BIM maturity or combined BIM/KPI studies**, to allow for clarity on the studies' direction when presenting and delivering the data collection results.
3) **Questions prepared should total at least ten questions for each both area** to allow for easier identification and clarification on both areas along with validity and reliability.
4) **BIM and KPI parameters combined should follow the same procedures as those performed separately**, since the procedures should support the findings of those studies.
5) **Numerical data presented in the study should be meaningful and clear**; it is expected that the numerical data presented are clear in terms of meaning and representation.

6) **BIM and KPI parameters should exist in a study and not be treated as a set of questions to define them**, since it is essential that both BIM and KPIs are presented as a set of parameters instead of a set of questions that aim to arrive at BIM or KPIs.
7) **Previous literature on combined BIM/KPI**, determine the combined BIM/KPIs that exist in the literature and would represent a contribution to knowledge.
8) **Previous literature on combined BIM/KPI (driven from the BIM maturity table)** was assigned as a separate category in the evaluation of BIM maturity assessments as they contain KPIs, and signify that they have been previously acknowledged.
9) **Comparison of combined BIM/KPI according to the country**, as it is necessary to compare outcomes of each study to see how each country approached the combination of BIM/KPI.
10) **Comparison of combined BIM/KPI according to the type**, as it is necessary to compare the studies to see how the use of the same type existed in each study.
11) **BIM approach**: It is necessary to address how BIM was approached in these studies to identify the similarities or differences that exist and to compare between the studies.
12) **KPI approach**: It is necessary to address how KPIs were approached in these studies to identify the similarities or differences that exist and to compare between the studies.
13) **BIM/KPI approach in study**: It is necessary to address how both BIM and KPIs were approached in these studies to identify the similarities or differences that exist and compare between the studies.
14) **Data collection** considers how the data was collected in studies, whether similar or different data collection methods were used, and if new methods were introduced.
15) **Findings**: Considers the findings of all combined BIM/KPIs studies and reflects on the targeted sample within each study.
16) **Strengths and weaknesses based on the BIM and KPI approaches (separate)**: Consider the combination of data collection and findings, since this will determine the strengths and weaknesses in those studies.
17) **Strengths that exist in the studies**: Determines that which could be considered appropriate for the development of combined BIM and KPI assessment in this research.
18) **Weaknesses that exist in the studies**: Aims to introduce a new way to deliver BIM and KPIs together, and therefore offers a contribution to knowledge by delivering a new assessment that represents missing gaps existing in the literature.
19) **Highlighted combined BIM/KPI studies and approaches**: Those highlighted in **red** are believed to operate well within the development of the combined BIM and KPI assessment

for this research and may have a direct influence on the development of combined BIM and KPI assessment for this research, and thus represent a starting point for a set of steps that may be needed for the development of an assessment.

The outcomes will present the combined BIM maturity and KPI metrics evaluations and will help to visualise how BIM maturity and KPI metrics previously existed. They will also demonstrate the requirements to develop a BIM maturity and KPI assessment, and how this can shape the requirements for a BIM maturity and KPI assessment. The presented outcomes cover the essential areas of BIM and KPIs, and thus represent a starting point to develop an assessment that assesses BIM maturity with respect to the BS EN ISO19650 standards and KPIs. It was noted that, based on Table 3.9, 17 of these studies presented an existing relationship between various BIM metrics and the primary KPIs (cost, time, quality) (Aboumoemen, 2016; Barlish and Sullivan, 2012; Eadie et al., 2013; Gyarting, 2014; Hassan, 2012; John, 2018; Khanzadi et al., 2019; McAuley et al., 2015; Olawumi and Chan, 2019; Olugboyega et al., 2020; Poirer et al., 2015; Smits et al., 2016; Suermann and Issa, 2007; Sun and Zhou, 2010; Won and Lee, 2014; Wong et al., 2016; Yun et al., 2018). This confirms a link between BIM maturity and KPI metrics and a relationship across the primary KPIs but not the secondary KPIs. It thus shows the absence of a standardised list of secondary KPIs, and ensures the need to develop a standard list of primary KPIs. In comparison, 16 other studies demonstrated a linkage between BIM maturity and KPI metrics by presenting KPIs as either BIM components, by treating KPI metrics as Critical Success Factors or as processes that would lead to such linkages with no mention of the actual KPIs (Awwad et al., 2020; Ashworth and Tucker, 2018; Badrinath et al., 2019; Chan et al., 2019; Chen et al., 2018; Coates et al., 2010; Liu, 2021; Manzione et al., 2011; MoJ. 2016; Mom and Hsieh, 2012; Ozorhon and Karahan, 2016; Park et al., 2013; Sarkar et al., 2015; Sebastian and Berlo, 2010; Shin et al., 2015; Shin and Choi, 2016). It indicates that these studies treat KPI metrics as BIM maturity, which does not follow primary or secondary KPIs, and fails to delineate linkages between BIM maturity and KPI metrics. A complete list of evaluations for each study is available in Appendix B.

Having presented a detailed analysis for each study, the next section will present a summary of the presented assessments (Table 3.9) in order to extract the key findings across the available studies for each category. By identifying six categories across the available 33 combined BIM/KPI assessments, Table 3.10 presents a definition of each category, its purpose of use, a summary of the overall strengths and weaknesses across the studies under each category, and the categories that align well with the aim of this research.

Table 3.10 Combined BIM-KPIs categories selection purposes, and strengths and weaknesses associated with studies in each category

Combined BIM-KPIs categories selection purposes, and strengths and weaknesses associated with studies in each category				
Nature of the category (number of studies)	Definitions for each category	Category selection and consideration for this research	Summary of strengths across the studies	Summary of weaknesses across the studies
BIM impact on construction projects-KPIs (9)	Studies that considered the impact of KPIs on construction projects performance and KPIs	This approach shall help recognise how BIM and KPI could be combined which will be an essential aim of this report	KPIs as main use in projects and how will BIM be implemented within the projects	Variation of KPIs set of numbers and implementation across projects, resulting in absence of standardised set of KPIs across projects
KPIs impact on BIM implementation (8)	Studies that considered the impact of KPIs on the implementation of BIM	A few studies have considered the KPIs presented within them and their impacts on BIM where BIM was defined differently from one study to another. This shall be reviewed to see if it shall be compatible for the combined BIM / KPI stages.	BIM as a main driver and how KPIs tend to reflect on the BIM implementation within the industry	BIM being approached in various ways, resulting in absence of standardised BIM.
Assessment framework (5)	An Assessment framework (i.e. Level 2 BIM Maturity / KPI assessment framework) existed in study to be compared together	A conceptual assessment framework was presented in previous studies that aimed to combine both BIM and KPIs together. This approach shall be reviewed to see its applicability in the combined BIM / KPI stages	A framework that reflects on the combination of BIM and KPIs together	Different set of BIM and KPIs elements were used, resulting in a delivery of a framework that suits specific studies and not general
Assessment method (5)	An Assessment method (i.e. Balanced scorecard) existed in study to be compared together	A balanced scorecard has existed in a presented study which has managed to be successful within this study. It will be required to consider the assessment methods approaches	Methods such as (balanced Scorecard) that assists the integration of BIM and KPIs together	Different methods also existed, which results in diversity of methods being operated in some organisations
BIM implementation within Organisations (4)	Studies that considered the impact of BIM with construction industries / firms / organisations	This shall be supportive in seeing how was BIM being implemented within those organisations which will be an essential aim of this report	KPIs as main use in organisations and how will BIM be implemented within organisations	Variation of BIM implementation across organisations, causing an absence of standardised BIM elements across organisations
Assessment tool (2)	An Assessment tool (i.e. BIM Quickscan Tool) existed in study to be compared together	tool might be supportive somehow based on a previous online tool that delivered a combination of BIM and KPI through delivering a set of KPI questions to users on BIM elements.	A tool that combined BIM and KPIs together through delivered a set of KPI questions to reflect on the BIM elements	KPIs treated as a set of questions to meet BIM requirements of study, resulting in a different approach to KPIs for a single study

The purpose of the classification for combined BIM maturity and KPI assessments is mainly attributed to their existence in studies where they support the overall delivery of combined BIM/KPIs. BIM maturity and KPI assessments demonstrate that:

1) KPIs are mainly used in projects and how BIM maturity will be implemented within projects.
2) BIM is a main driver and how KPIs tend to reflect on the implementation of BIM maturity in the industry.
3) A framework reflects on the combination of BIM maturity and KPI metrics.
4) Methods (such as Balanced Scorecard) assist the integration of BIM maturity and KPI metrics.
5) KPIs are mainly used in organisations and how BIM will be implemented in organisations.
6) A tool that combines BIM and KPIs through the delivery of a set of KPI questions to reflect the BIM metrics.

However, a set of distinctions exist, such as:

1) KPI metrics as a set of numbers and implementations across projects, resulting in the absence of a standardised set of KPIs across projects.
2) BIM approached in various ways, resulting in absence of a standardised BIM approach.
3) BIM maturity implementation across organisations, which causes the absence of standardised BIM metrics across organisations.

4) Different methods also exist, which result in the operation of diverse methods in some organisations.
5) Different sets of BIM maturity and KPI metrics used, resulting in the delivery of a framework that suits specific studies but not applicable generally.
6) KPI metrics are treated as a set of questions to meet the BIM requirements, resulting in a different approach to KPI metrics within a single study.

The limitations will be reviewed in order to develop a combined BIM and KPI assessment that tackles existing obstacles amongst those studies. It was noted that some BIM and KPIs approaches were highlighted due to their significant impacts; this has resulted in the presented studies, and the approaches were highlighted because they have a direct influence on the development of a BIM and KPI assessment. Thus, it represents a starting point to develop a set of considerations needed for the development of a BIM and KPI assessment.

Having qualitatively analysed the combined BIM and KPI assessments, the next section will present the quantitative analysis of the assessments, including statistical data on the assessments, to outline where and how many assessments exist in the UK and globally.

According to Table 3.9, of the 33 publications on combined BIM maturity and KPI assessments, 22 presented combined BIM/KPI metrics, representing 67% of the total sample and 11 addressed combined BIM/KPI metrics being driven from BIM maturity assessments (Table 3.1), representing 33% of the total sample. Hence, a total of six categories emerged from the BIM maturity and KPI assessment types. Finally, based on the literature review findings on the available assessments across various authors; BIM maturity and KPI assessments existed in 17 countries across the globe. The UK had seven studies, 21% of the total sample, and 26 studies were present in other countries, representing 79% of the total sample. This confirms a limited range of BIM maturity and KPI assessments across the globe, but suggests that those studies only delivered a combined BIM maturity and KPI assessment based on context and relevance for each study, and that this may not be generalised (Ashworth and Tucker, 2018; Badrinath et al., 2019; Eadie et al., 2013; Ozorhon and Karahan, 2016; Smits et al., 2016; Wong et al., 2016). A summary of the combined BIM maturity and KPI assessments is available (Table 3.11).

Table 3.11 BIM maturity and KPI assessments findings

<table>
<tr><th colspan="5">BIM and KPI assessment findings</th></tr>
<tr><td colspan="2">Number and Percentage of Previous literature on combined BIM / KPI parameters</td><td rowspan="2">33 total
(up to date)</td><td>22</td><td>67 %</td></tr>
<tr><td colspan="2">Number and Percentage of Previous literature on combined BIM / KPI parameters (driven from the BIM maturity table)</td><td>11</td><td>33 %</td></tr>
<tr><td colspan="4">Number of categories for all BIM and KPIs assessments</td><td>6</td></tr>
<tr><td colspan="4">Number of countries where BIM maturity and KPIs assessments existed (Gulf countries considered as 1)</td><td>17</td></tr>
<tr><td>Number and percentage of studies in the 17 countries</td><td>UK= 7
(21%)</td><td colspan="3">Other countries= 26
(79%)</td></tr>
</table>

As previously mentioned, a total of six categories emerged from the combined BIM/KPI assessment types. Figure 3.6 illustrates the percentage distribution of the combined BIM/KPIs assessments according to their classified categories. This helps to identify the most familiar category used to link BIM and KPIs. BIM impact on construction projects -KPIs had the highest number of combined BIM/KPI classifications at nine assessments, representing 27% of the total sample. Furthermore, KPIs impact on BIM maturity implementation had eight assessments (24%). Moreover, both Assessment framework and Assessment method had ten combined BIM/KPIs assessment classifications (15% each), representing 30% of the total sample. In addition, BIM maturity implementation within organisations had four assessments (12%). Finally, the Assessment tool had two assessments acknowledged as combined BIM/KPIs and represents 7% of the total sample, as highlighted in Figure 3.5.

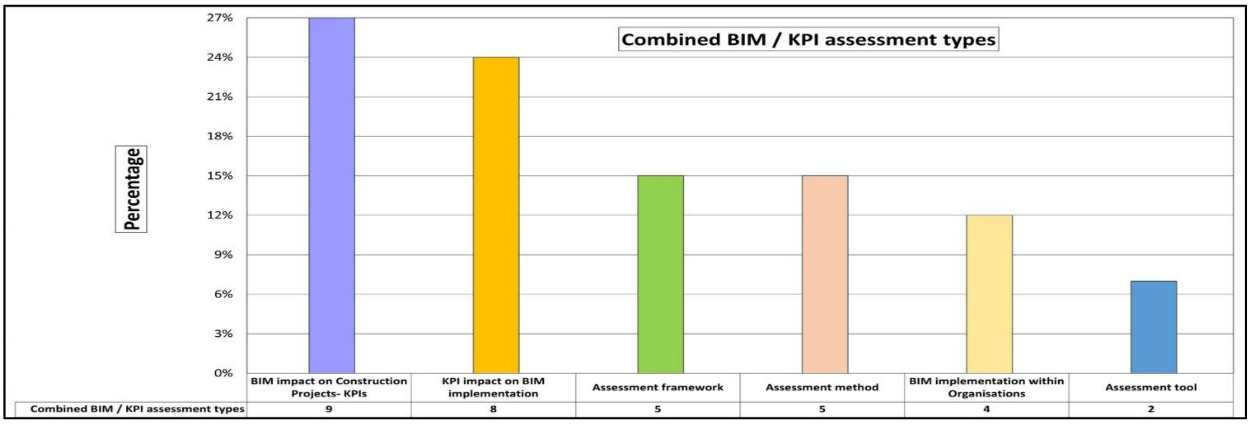


Figure 3.5 Combined BIM-KPI assessments percentage distribution

Combined BIM-KPI assessments exist in 17 countries across the globe. Accordingly, the UK has the most studies at seven, which represents 21% of the sample, Korea had five studies (15%); US had four studies (12%) Netherlands, Hong Kong and Taiwan each had two studies (6% each) representing six studies in total and 18% of the total. A single study exists in the following countries: Gulf countries, India, Canada, China, Brazil, Iran, Malaysia, Turkey, South Africa, Singapore, and Ireland, presenting 34% of the sample (Figure 3.6).

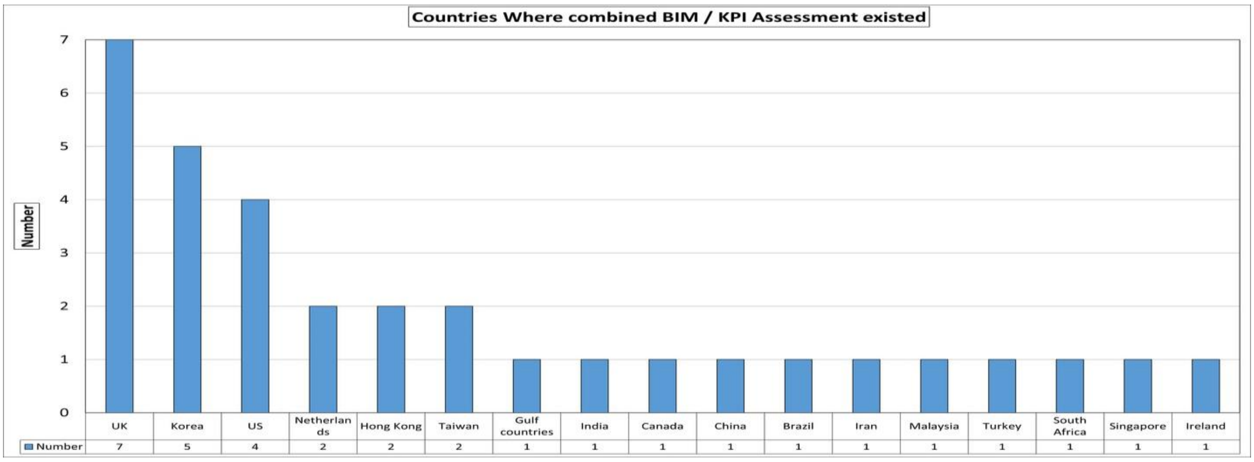


Figure 3.6 Countries where combined BIM maturity and KPI assessments existed

Having critically evaluated the findings of the combined BIM maturity and KPI assessments from the literature, the next section will provide a summary of the combined BIM maturity and KPI assessment findings and discuss the outcomes relevant to the aim of this research.

3.10.1 A summary of the available combined BIM maturity and KPI assessments findings

After the combined BIM maturity and KPI assessments were presented, a comprehensive review of BIM maturity and KPI assessments across the literature was conducted, which will be discussed in this section. Most of the previous examples identified the combined BIM and KPI assessments as a general tool or process for how it could operate within the industry. Authors have generally recognised a range of three to five assessments (Ozorhon and Karahan, 2016; Sarkar et al., 2015; Shin and Choi, 2016; Smits et al., 2016; Wong et al., 2016), six to eight assessments (Ashworth and Tucker, 2018; Khanzadi et al., 2019) and up to 16 assessments (Aboumoemen and Underwood, 2017). Although there have been several efforts to link BIM maturity and KPI metrics, all of the available studies within the UK and globally have shown that various KPIs were used, that BIM metrics were treated as KPIs, and that there was no standard assessment exists to assess combined BIM maturity and KPI metrics, which represents an existing limitation and a gap in the literature.

As a result, the studies fail to deliver a generalised usage of BIM maturity and KPI metrics for use within assessments. Furthermore, studies provided data analysis based on the information collected within each area, while some approached a relatively high sample of users within their studies. However, most of the results lacked reliability and the researcher could not rely on any of the results due to absence of a standardised list of linked BIM maturity and KPI metrics. In addition, most studies considered a number of methods on how BIM maturity could influence KPI metrics for the construction sector. In contrast, some studies considered a number of methods for how KPI metrics could influence the BIM maturity implementation process. This raises a question as to how BIM maturity and KPI metrics should be defined, whether a strong link exists between them, and if this link could occur from one parameter to another or if both could operate together to deliver this link.

Some studies delivered a tool or framework to link them; however, none of these tools could be verified and validated within these studies since some tools were not accessible, while others were conducted within a particular industry and was not being prevalent in other industries. However, the rest did not deliver potential links between BIM maturity and KPI metrics and instead collected data on a selective number of KPI metrics, or questions were posed on the impact of BIM maturity on individual KPI metrics. Therefore, this research will identify a generalised outcome concerning BIM maturity and KPI metrics along with an assessment to outline how BIM maturity and KPI metrics could be linked.

Having identified a number of strengths and weaknesses across the identified assessment, this research reflects on the strengths and tackles existing weaknesses in order to fill in the gaps that currently exist and meet the aim of this research. The similarities across the literature on BIM maturity assessments, KPI metrics, and combined BIM maturity and KPI assessments will be discussed. This will help to extract key findings across the literature.

Existing literature on BIM maturity, KPI metrics, and combined BIM/KPIs assessments have delivered the most frequently used assessments across the literature. The most common approach in the studies is the Likert scale, since it helps to explore levels of opinion on a particular query, and for this research, would help to determine potential links between BIM maturity and KPI metrics. This aligns with the "level of ability" in maturity that was discussed previously in section 3.2. Additional similarities exist across all research areas (BIM/KPI/both combined), which include the following:

1) An applicable model/framework/tool that was tested in construction industries
2) A set of conclusions that justified the goals of for the studies.
3) All presented studies were used in various countries across the globe
4) The use of questionnaires in various presented studies
5) A mixed use of quantitative and qualitative techniques for the data collection
6) A set of limitations within the presented studies, which required future work.

However, the literature review revealed that there has not been a single study to deliver an applicable assessment framework that combines BIM maturity and KPI metrics separately, and BIM maturity and KPI metrics together, nor does it offer validated results that are examined generally across the industries and in the UK specifically. This represents a key contribution to knowledge and will deliver a new combined BIM Maturity/KPI assessment for validation by the UK construction industry, the client sector specifically, and may be validated across other industries across the globe.

Based on the literature review, a set of methods and analysis that best fits with this research shall be selected to develop the assessment proposed. In total, 33 BIM assessments and five BIM/KPI assessments have been identified across the UK. Although studies have offered to link BIM maturity and KPI metrics, there has not been a single study to deliver an assessment that was validated and examined within projects and across organisations. The focus is on linking both BIM maturity and KPI metrics in the UK and on delivering an assessment to determine the relationship level between both. Therefore, the focus of this study is the development of an assessment to combine the concepts of BIM maturity and KPI metrics in order to examine the relationships between them, and to propose a final assessment for adoption and validation across the UK client sector. It is anticipated that this would align with Level 2 BIM/BS EN ISO19650 standards and their adoption in the UK construction industry. The next section will discuss the steps that will be taken to develop the proposed BIM maturity and KPI metrics assessment for the UK client sector that will be detailed in the next chapter.

3.11 Development of a BIM maturity and KPI metrics assessment for the UK client sector

Having conducted an extensive review on the available BIM maturity assessments that delivered a total of **92 assessments**, selected the most occurring list of KPI metrics which consists of **nine KPI metrics** classified as Primary and secondary, objective and subjective measures, result oriented, all being measured quantitatively and follow the S.M.A.R.T rule, and identified a total of **33 existing BIM maturity and KPI metric assessments**, the next chapter will discuss the development of the BIM maturity and KPI assessment based on the findings of this chapter. This will consist of the following steps to be taken:

1) A review of the available assessments and selecting those that are most relevant and would support the development of an assessment based on the aim set for this research.
2) The identified nine KPI metrics will be brought and assigned as part of the assessment development.
3) Reflecting back on the strengths of the identified assessments with the development of the proposed assessment for this research and tackling existing problems (i.e. weaknesses) with the identified assessments.
4) Providing a set of steps on how the assessment will be developed based on the findings of this chapter and based on the aim and objectives set for this research.

Having provided the process that will be achieved to develop the proposed assessment set for this research, the next section will provide a summary of the chapter.

3.12 Summary

This chapter discussed the differences between capability, maturity and competency along with their assessments. It described the relationship between each concept within BIM maturity, and justified reasons for selecting maturity as the main method for use for this research. Furthermore, the chapter explored maturity assessments that currently exist and highlighted the maturity assessments that were most relevant to BIM maturity. Moreover, an extensive discussion and critical review of BIM maturity assessments, KPI metrics, and both combined was provided to highlight the key findings for each assessment, how were they used, and the types of assessments between them. Due to the lack of linkages between BIM maturity and KPI metrics for the client sector, the potential relationship between BIM maturity and KPI metrics along with their assessments was outlined to examine the linkage between them and how they were broadly used.

A review of assessments concerning BIM maturity, KPI metrics, and both combined was conducted to outline the key features between them, and to offer a summary of all assessments. The main categories were highlighted, and the similarities and differences were presented, along with the strengths and weaknesses. They were then categorised to provide a comparative analysis, to extract the essential strengths, and reflect on and overcome the weaknesses. The similarities that exist across the literature were outlined to elicit the key findings and identify the outcomes, which would help to develop an assessment that would link BIM maturity and KPI metrics, and identified as a current gap in the literature. As a result, the next step is to formulate the initial development of the assessment for this research, which will be explained in detail in the next chapter.

Chapter 4: A Conceptual BIM Maturity-KPI assessment framework

4.1 Introduction

Having identified the absence of standardised, linked BIM and KPI parameters within an existing assessment to tackle the overall performance of UK clients, this chapter discusses the steps taken to address this. This chapter is structured into four main sections. The first section identifies existing 'dimensions', 'representations' and 'approaches' that support the selection of a theory/concept for a BIM maturity-KPI assessment. The second section will develop the framework, which will represent key factors for UK construction; it will link elements to show relationships, and thus meet the research's aim and objectives. The third section will review previous BIM/KPI frameworks by demonstrating how these are linked to BIM maturity-KPI assessments. Finally, the last section will discuss key factors that have been defined within the literature in order to formulate an initial assessment that explains the links between BIM maturity, KPIs, and their extracted benefits. It will also provide a detailed explanation of how the assessment was developed.

4.2 Management 'Dimensions', 'Representations' And 'Approaches'

'Dimensions', 'representations' and 'approaches' are management issues that represent the means to define complex issues by researchers. They deliver an insight into issues concerning management 'representations' and 'approaches'. According to Shehabuddeen et al. (1999, p. 5) "*Management representations are ways of depicting management issues or problems*." A number of dimensions exist across studies that categorise management representations and approaches. The dimensions, representations, and approaches selected for the theory and concept of BIM maturity/KPI assessment within this research are presented in Figure 4.1.

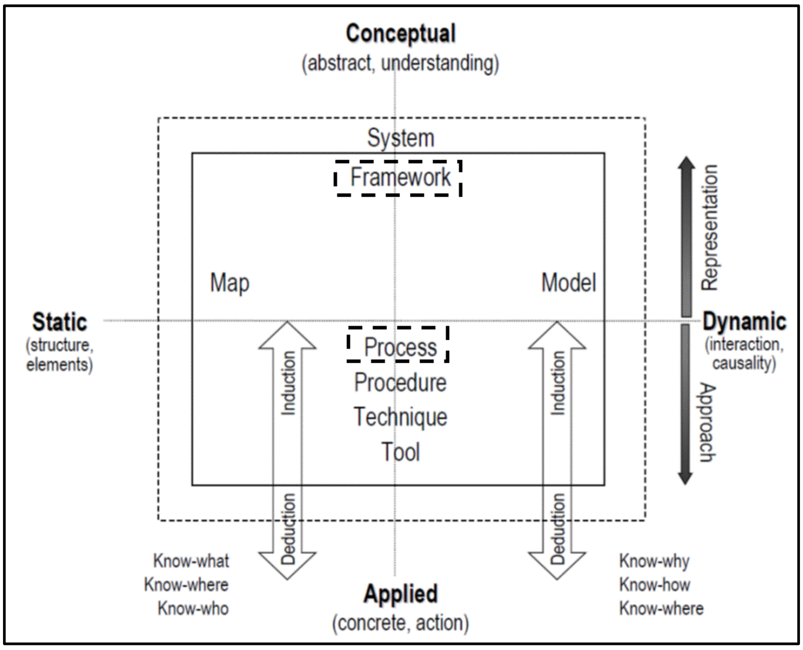


Figure 4.1 Dimensions for categorising management representations and approaches (Shehabuddeen et al., 1999)

Management dimensions depict management issues or problems. Figure 4.1 presents two main dimensions that structure the meaning of management representations and approaches. They are as follows:

1) **Static-Dynamic:** Concerned with the structure and position of elements within a system, and the causality and interaction between the elements of a system.
2) **Conceptual-Applied:** Deals with the abstraction or understanding of a situation and aligns with concrete action in a practical environment.

Both dimensions (Figure 4.1) help to deliver a structured illustration on a Static-Dynamic and Conceptual-Applied axis that resolves management issues. These dimensions can be used to then structure and understand the four different representations concerning the conceptualisation of management issues. The relationship of representation to each dimension is shown in Figure 4.1. The management representation is as follows:

1) **Model:** Supports the understanding of the dynamic interaction between the elements of a system. This is aligned to the Static-Dynamic dimensional axis. It is necessary to signify the possible relationships between BIM maturity and KPI metrics, although this does not require an understanding of the dynamic interaction between the elements of a system. Therefore, model will not be the selected representation used.
2) **Map:** Supports the understanding of the static relationship between elements of a system. This is aligned with the Static-Dynamic dimensional axis. The BIM Maturity/KPI assessment is designed to identify links that could occur between BIM maturity and KPIs through physical attributes. However, this does not require an understanding of the static relationship between elements of a system, and thus a map will not be the selected representation.

Since this research seeks to understand and explore the relationships between BIM maturity and KPI metrics, it will deliver an assessment that can be implemented in a practical environment. Thus both models and maps were not the selected form of representation.

3) **System:** Defines a set of bounded interrelated elements within the context of a paradigm. This is aligned to the Conceptual-Applied dimensional axis. The BIM Maturity-KPI assessment is not required to establish elements and relationships in order to identify what needs to be delivered. Thus, a system will not be the selected form of representation.
4) **Framework:** Supports understanding and communication concerning structure and relationship within a system for a defined purpose. This is aligned to the Conceptual-Applied dimensional axis. An understanding of the relationship between BIM maturity and

KPIs will be presented in an assessment that will examine the data collected. Hence, a framework will be the selected representation. The selection of a framework helps to meet the main aim and objectives to deliver a BIM maturity-KPI assessment for UK clients.

Since this research seeks to understand and explore the relationships between BIM maturity and KPI metrics, and between systems and frameworks, this research will develop a **framework** to assess the performances of UK clients. However, the BIM maturity and KPI metrics relationship first needs to be explored and understood to determine how BIM and KPIs could be linked through the framework and how would the relationships could reflect the overall project and organisational performance amongst UK clients. A framework will be required to deliver a better understanding of the relationships between BIM maturity and KPI metrics, and thereby to ensure these are relevant and applicable to the nature of a conceptual framework.

Moreover, there are four approaches concerned with practical problem solving in the management context, which are as follows:

1) **Procedure:** This is a series of steps to operationalise a process. Although the assessment framework will involve a number of steps that the UK clients will undertake, the framework will depend on the decisions and views of clients, with no transfer of inputs into outputs. Thus, a procedure has not been selected for this research.
2) **Technique:** This is a structured way to complete part of a procedure. The BIM Maturity-KPI assessment will not involve a set of steps to be taken and will not be followed by a procedure concerning activities or tasks. Moreover, it will not include the transfer of inputs into outputs; therefore, a procedure will not be selected for this research.
3) **Tool:** This is used for data collection purposes and as online databases. Tools are presented as a set of instruments (i.e. web-based tool, online database, worksheet, etc.) that supports the collection of data and facilitates the assessment. Tools do not include the transfer of inputs into outputs, and therefore, a tool will not be selected for tis study. While tool was not selected, based on the collected data and the proposed conceptual framework, a tool could be developed, and thereby considered in the future. This would depend on the data collection process based on the needs of UK clients.
4) **Process:** This is an approach to achieve a managerial objective, through the transformation of inputs into outputs. A process will be developed to support the formulation of a BIM Maturity-KPI assessment by transferring data regarding key areas (BIM Maturity, KPIs, combined BIM/KPI), known as the inputs, into an action plan that will be examined by UK clients. This will examine ideas presented in the framework within the context of practic

(known as the outputs). Due to its ability to transfer inputs into outputs, the process was selected for this research.

Since this research considers the transfer of inputs (BIM Maturity, KPIs, combined BIM/KPI) to outputs (the UK Client sector), a process is more suited to this research, which intends to deliver to deliver an assessment of the performance of UK clients. Having selected a framework and process as the main representation and approach, respectively for the assessment, the next section will highlight the importance of developing a framework.

4.3 Differences between three frameworks, and selection of a framework type

As previously discussed, a framework has been selected as the management representation to develop in this research. Frameworks are used in research to give an overall picture of the choices, or to highlight a preferred approach to an idea in providing the overall structure of the research (Yin, 2009). Three main types of frameworks have been introduced, 'practical' (Scriven, 1986) 'theoretical', and 'conceptual' (Eisenhardt, 1991):

1. **Practical framework:** Scriven (1986) stated that a 'practical framework' directs the research in what works in the experience or exercise of doing something by those directly involved in it. According to Lester (2005), findings resulting from use of a practical framework tend to be, only locally generalizable (i.e., the researcher finds out "what works' now under certain specific conditions and constraints, but learns little or nothing that goes beyond the specific context. Furthermore, there has been more focus in academic research towards distinguishing differences between a conceptual and a theoretical framework to select one type to be used for a research. Thus, a practical framework was not selected as the adopted framework for this research.
2. **Theoretical framework:** Imenda (2014, p.189) defined a theoretical framework as: *"the application of a theory or a set of concepts drawn from one and the same theory, to offer an explanation of an event, or shed some light on a particular phenomenon or research problem*". In addition to this, Borgatti (1999) states that *" A theoretical framework guides your research, determining what things you measure, and what statistical relationships you look for."* According to Ngulube et al., (2015), state that *"Theories are tested through propositions or hypotheses using a methodology that fits with the model or theory."* Lester (2005) states that theoretical frameworks *"deals with justification, which is why a particular research question is proposed to be answered in a particular way"*. As such, according to Crawford (2019), it could be seen that theoretical frameworks could be linked to how studies relate to the generation or testing theories being explored within

the literature, where it would undergo a process of identifying a theory cluster group, explore the theories within the cluster group, select the most suitable theory from the group and relate it to the study. This research aims to investigate the potential links and establish proposed relationships between BIM maturity and KPI metrics. Thus, this research will not investigate a particular theory related to BIM maturity and KPI metrics and not undergo the process explained, but rather, will explore how can BIM maturity and KPI metrics be linked together. Thus, a theoretical framework was not selected as the adopted framework for this research.

3. **Conceptual framework:** Miles and Huberman (1994, p.39) defined a conceptual framework as a visual or written product in that it "*explains, either graphically or in narrative form, the main things to be studied the key factors, concepts, or variables and the presumed relationships among them*". Conceptual frameworks provide understanding, rather than offering a theoretical explanation (Jabareen, 2009). According to Ngulube et al., (2015), Conceptual frameworks are also known as *"an analytical framework"*, and finally, Van der Waldt (2020) states that conceptual frameworks have *"the ability to answer the 'what-if', 'what', 'how', 'where' and 'when' questions related to research topics and titles, and the basis of constructing a conceptual framework is often using a cause–effect relationship where the Cause–effect relationships frequently include several independent variables that affect the dependent variable".* The foundation of conceptual framework would rely on three sources: 1) Personal experience, 2) Literature based, and 3) Theoretical framework. This shows that theoretical frameworks would be a part of the conceptual framework in exploring the theories emerging and testing them. There are three key purposes for the need of conceptual frameworks: 1) argumentation, 2) explanation, and 3) generation. Argumentation focuses on the importance of studying the topic, the appropriateness of the design, and the rigor of the methods. Explanation stresses the relationships among who and what will be studied. Generation gives rise to the problem, research questions, and methods of a study.

This research aims to investigate the potential links and establish proposed relationships between BIM maturity and KPI metrics. Thus, it will investigate the cause-effect relationships on how BIM maturity and KPI metrics could be linked together. The construction of the conceptual framework will rely on the researcher's personal experience with the research topic, will include an overview of previous related frameworks in the research field, as those addressed in the literature in Chapter 3, and will include a set of related BIM maturity and

KPI theories that will aid in packing the ideas together to develop the conceptual framework. Finally, the proposed conceptual framework will include a graphical representation on how BIM maturity and KPI metrics would be linked together. Hence, it is proposed that the relationship between BIM maturity and KPIs would best be represented through the adoption of a conceptual framework. This will be based on:

1) The connection of BIM maturity and KPIs within an organisation across clients' needs: this would be achieved through the framework which will provide answers to questions such as 'what' and explanations to 'why' and 'how'.
2) The relationship between BIM and KPIs will be identified by the delivery of relationships between potential variables; these will be presented through the conceptual framework.
3) There is no empirical evidence of a previous relationship between BIM maturity and KPIs; thus, validating the proposed relationship through provision of a conceptual framework can validate existing theory.
4) Due to the subjective relationship between BIM maturity and KPIs, it would be impractical to describe their relationship in quantitative terms only. As a result, conceptual framework will aim to understand the relationships between BIM maturity and KPIs beyond theory.

Having discussed the differences between practical, theoretical, and conceptual frameworks, and selected a conceptual framework for this research, the next section will discuss existing frameworks that combine BIM maturity and KPI metrics. It will also illustrate and explain the process of developing the proposed framework, which will follow the proposed BIM Maturity-KPI assessment framework, and will be based on existing frameworks.

4.4 Existing BIM/KPI frameworks that Support the BIM Maturity-KPI Assessment Framework

As discussed in Chapter 3, 33 studies have previously attempted to link BIM maturity and KPI metrics (Table 3.9). Amongst those studies, five discuss the use of frameworks to link BIM maturity and KPI metrics. The relationship between these studies and the proposed framework will be presented in detail in the next section. The studies are as follows:

1) **Level 2 BIM Maturity/KPI Assessment Framework** (Aboumoemen, 2016). This study was closely linked to the proposed framework through the conceptual framework that connects BIM and KPIs. Due to the scope of the work, the development only focused on BIM maturity (based on Level 2 BIM) and neglected to link this with the KPIs. Due to this limitation, it is necessary to link BIM maturity and KPIs in order to demonstrate how they can enhance adoption across the UK construction sector and assess BIM according to the Level 2 BIM standards and the new BS EN ISO19650 standards (UK BIM Framework, 2019a) (Figure 4.2).

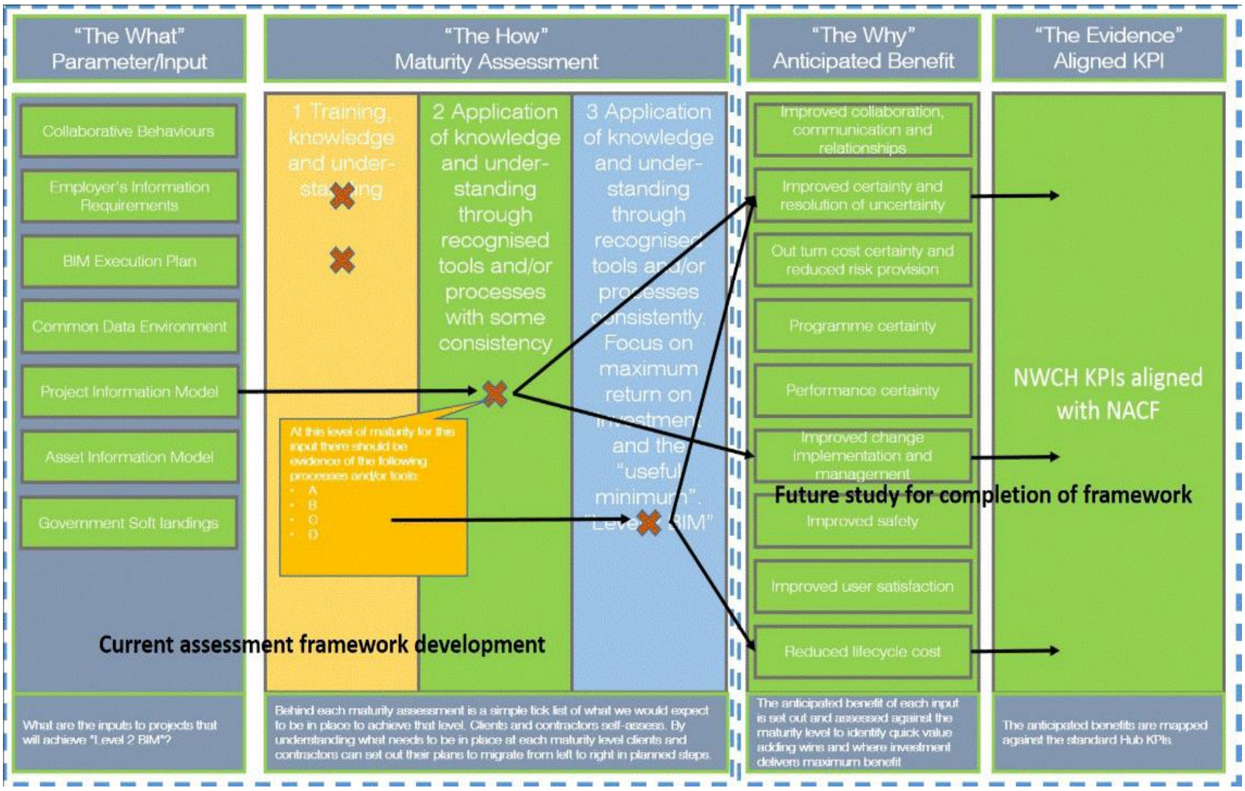


Figure 4.2 Level 2 BIM Maturity / KPI Assessment Framework (Aboumoemen, 2016)

The Level 2 BIM Maturity / KPI Assessment Framework was split into 4 stages.

1. The 1st stage introduces "The What" stage which defines possible inputs of BIM and how they could be used to measure BIM maturity through 7 inputs.
2. The 2nd stage discussed on "The How" stage which defines the possible maturity assessment that could be measured in 3 different maturity assessments; the 1st associated with possible awareness of Level 2 BIM but not being applied necessary, the 2nd related with current application of Level 2 BIM but with minor application, and the last one linked with the 1st 2 assessments and being applied consistently and the use of minimum Level 2 BIM, subjected to transfer to level 3.
3. The 3rd stage presents "The Why" stage that distributes the possible anticipated benefits that could emerge from the BIM inputs and their maturities explained in the 1st 2 stages of the assessment framework.
4. Finally, the last stage displays "The Evidence" which will integrate the 15 NWCH KPIs discussed previously along with all stages of the assessment framework discussed, and how they can collaborate together to develop a complete framework to be used in the platform.

This study have conducted 2 out of the 4 proposed stages, where it conducted a review of the BIM maturity inputs (stage 1) and identified what are the BIM metrics descriptors and their 3 maturity level descriptors (stage 2), and then suggested to review the expected benefits to emerge (stage 3) and the alignment of the previous stages to the KPIs (stage 4) in future studies.

2) **Empirical Approach to Identify Operational Critical Success Factors (CSF) for BIM Projects** (Badrinath et al., 2019). This study conducted an extensive review of existing BIM and CSF assessments, which were re-evaluated and discussed in Chapter Three. An analysis of the relationship between BIM and CSF was presented in this study and the process of the analysis is considered within the proposed framework.
3) **BIM Capability Maturity Model to assess the performance of BIM technology implementations** (Mom & Hsieh, 2012). This study presented the assessment of a BIM capability maturity model and included a list of KPIs. It delivered a BIM performance assessment framework that included three levels (1. Preliminary, 2. Standard, and 3. Comprehensive).
4) **A Study on BIM Performance Assessment Framework for an Architecture Firm** (Shin et al., 2015). This study presented the assessment of 22 KPIs that were presented as BIM metrics across the performance of three firms, and delivered a BIM performance assessment framework. The KPIs assessment was based on a Likert scale that assessed the performance of BIM.
5) **A Relationship Framework for Building Information Modeling (BIM) Capability in Quantity Surveying Practice and Project Performance** (Wong et al., 2016). This study presented 11 BIM capability metrics and their linkages to KPIs (time and cost) through a relationship assessment. This links both BIM capability and KPIs through correlation and regression analysis. Based on both analyses, a relationship framework was presented that illustrated the relationship between the 11 BIM capability metrics and KPIs (time and cost). An extract of the relationship framework is presented in Figure 4.3.

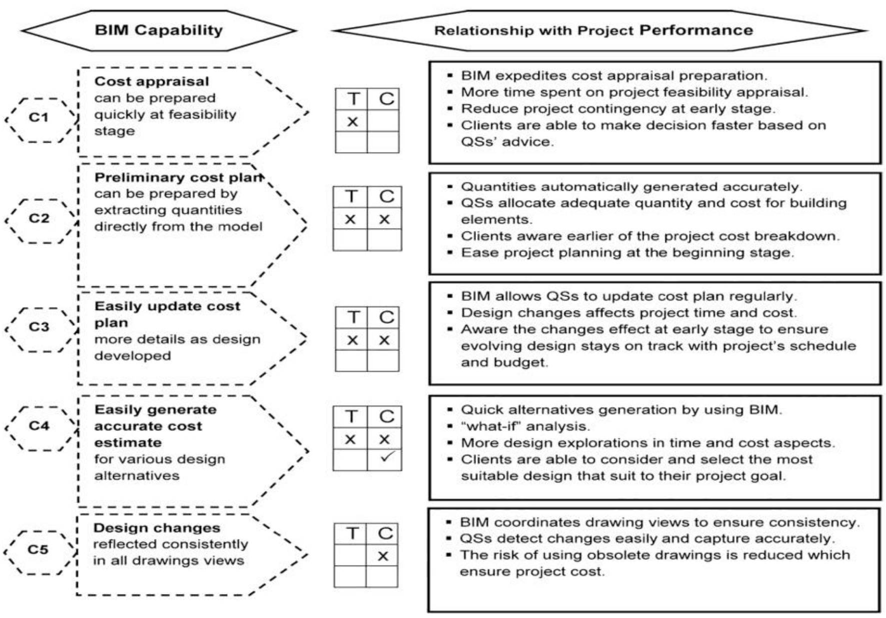


Figure 4.3 Sample of Relationship Framework of BIM Capabilities and Project (Wong et al., 2016).

Having reviewed these frameworks, elements within these frameworks have been selected to develop the proposed framework. However, it was found that different BIM and KPI parameters were used amongst the existing frameworks, which resulted in a delivery that included a varied list of BIM and KPI parameters that suited specific studies, whether in the UK or globally, but not generally. This indicates the need to develop a framework that not only includes a standardised list of BIM maturity and KPI metrics, but also can be used to assess the performance of various clients in general, and in the UK specifically. In the context of this research, a framework will be developed that is tailored to UK construction industry clients. Thus, elements of the previous frameworks have been selected to support the development in this research.

Following a review of the existing combined BIM maturity and KPI frameworks, the next section will present the proposed framework for this research. This will be aligned to the new BS EN ISO 19650 standards, and with the frameworks that were discussed previously (Aboumoemen, 2016; Badrinath et al., 2019; Mom & Hsieh, 2012; Shin et al., 2015; Wong et al., 2016).

4.5 Proposed BIM maturity-KPI assessment framework

A framework has been selected as a management representation for the development of a BIM maturity-KPI assessment framework. Having reviewed the existing frameworks, a new framework will be developed based on the critical review and analysis on the literature and the existing related frameworks. The development process will consist of three stage elements; which is Stage 1: the process to identify the BIM maturity and KPI metrics, Stage 2: to examine the previously identified metrics, and Stage 3: The benefits and evidence from linking BIM maturity and KPI metrics together, which will then help to identify a potential relationship between BIM maturity and KPIs and achieve the aim and objectives of the research.

The aim of the framework is to measure the performance of UK clients and demonstrate how, by linking KPIs with BIM maturity, the benefits of BIM maturity could have an impact on the UK construction industry's performance. Having discussed the process of developing the proposed assessment framework, Figure 4.4 presents the proposed BIM maturity-KPI assessment conceptual framework. It consists of 3 stages:

1. Stage 1 "The What": Identifying BIM maturity and KPI metrics.
2. Stage 2 "The How": Assessing proposed BIM maturity and KPI metrics
3. Stage 3 "The Evidence and The Why": Benefits of the Aligned BIM and KPIs, and the Assessment of their Relationship from "The How" stage.

The next subsections explain each stage of the framework in detail to demonstrate how it was developed and the inclusion of the potential relationships between BIM maturity and KPIs.

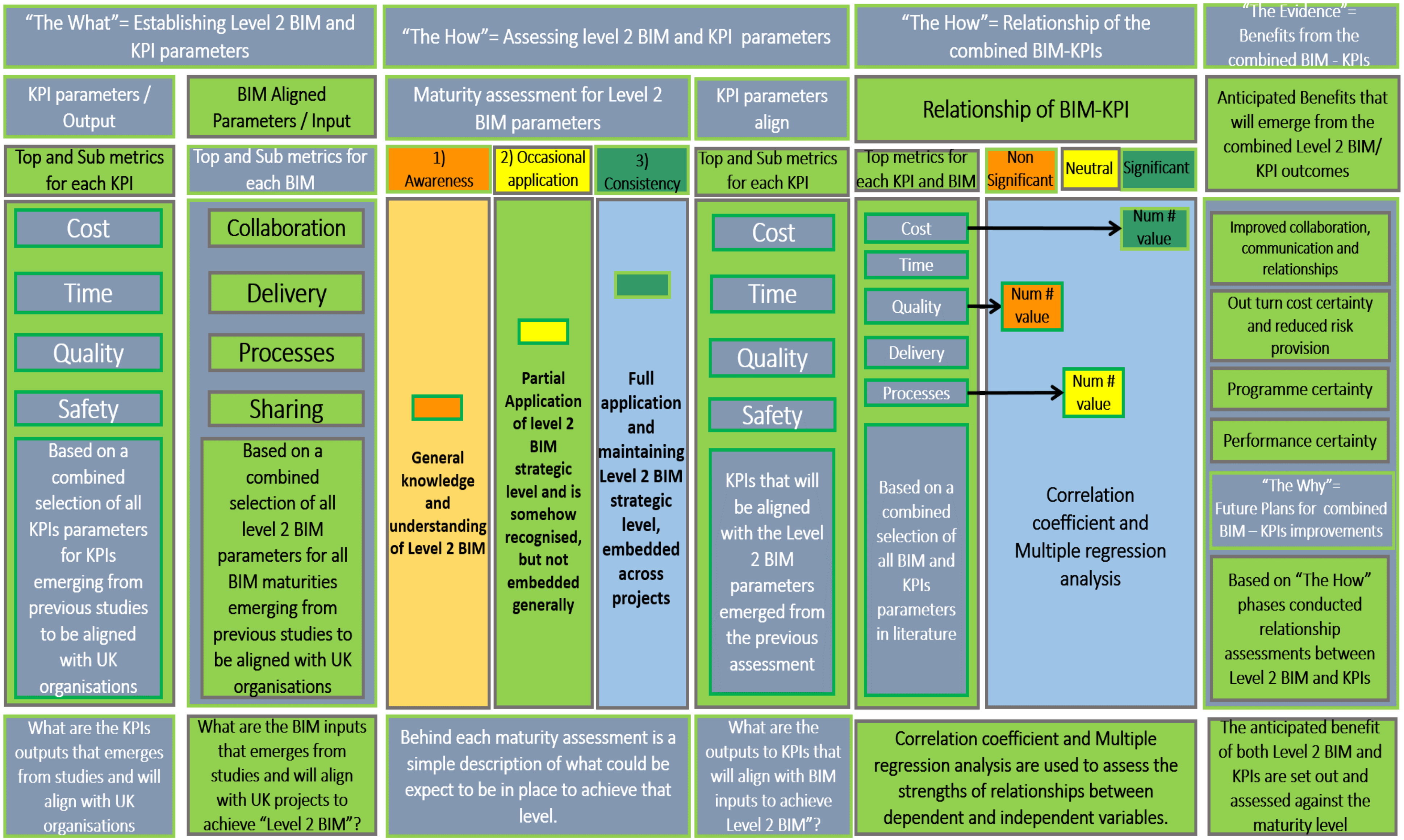


Figure 4.4 Proposed BIM Maturity-KPI assessment conceptual framework (1. "The what", 2. "The How", and 3. "The Evidence and The Why")

4.5.1 Stage 1: Identifying BIM maturity and KPI metrics

The development process of the framework relies on a critical review of the literature by delivering a list of KPI and BIM maturity parameters; these are populated across stage 1 of the framework. The separate identification of BIM maturity and KPI metrics begins in stage 1, which addresses "The What", as it outlines a standardised list for both metrics. Figure 4.5 will discuss stage 1 of the framework development process.

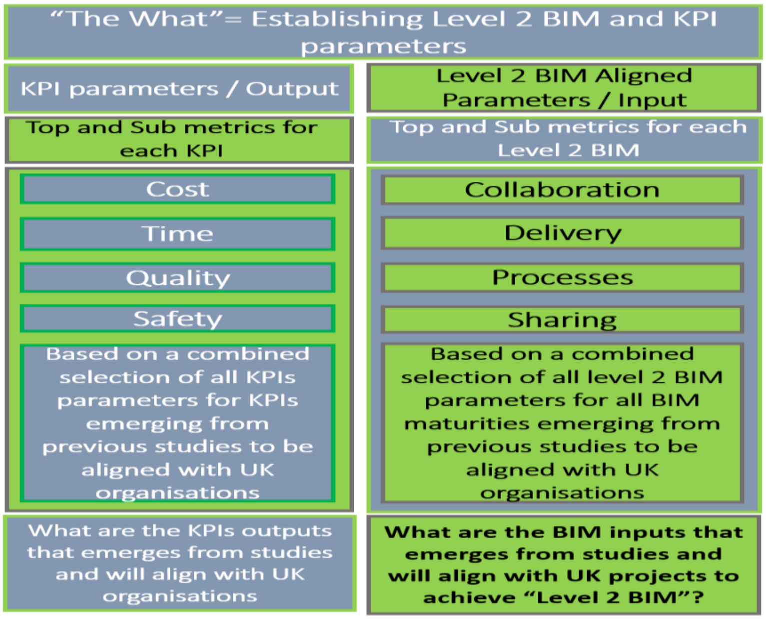


Figure 4.5 "The What: Establishing BIM maturity and KPI metrics

Figure 4.5 presents an extract of stage 1 of the framework. The framework beings with **"The What": Establishing BIM maturity and KPI parameters** stage. The stage has been identified as "The What" since it aims to outline the expected standardised metrics that meet the UK government's transition from Level 2 BIM to the new BS EN ISO19650 standards.

As presented in Table 3.8, nine KPIs emerged from the previous studies, where Cost, Time and Quality were considered the primary KPIs, and Safety, Satisfaction, Performance, Profitability, Productivity and Sustainability were regarded as secondary KPIs. Based on the literature review findings, the data will be collected from a sample of UK construction industry clients, and the KPIs will be aligned to deliver a list of standardised KPIs (Figure 4.6).

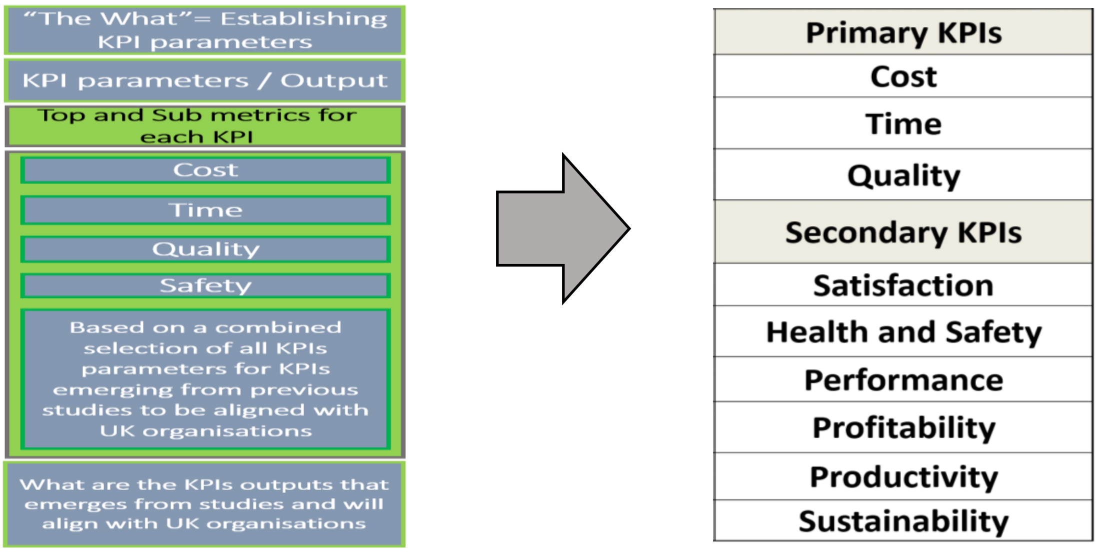


Figure 4.6 "The What"= Establishing KPI metrics sample

Having presented information that covers the KPI metrics presented in this research, the requirements for BIM maturity are presented in Figure 4.7.

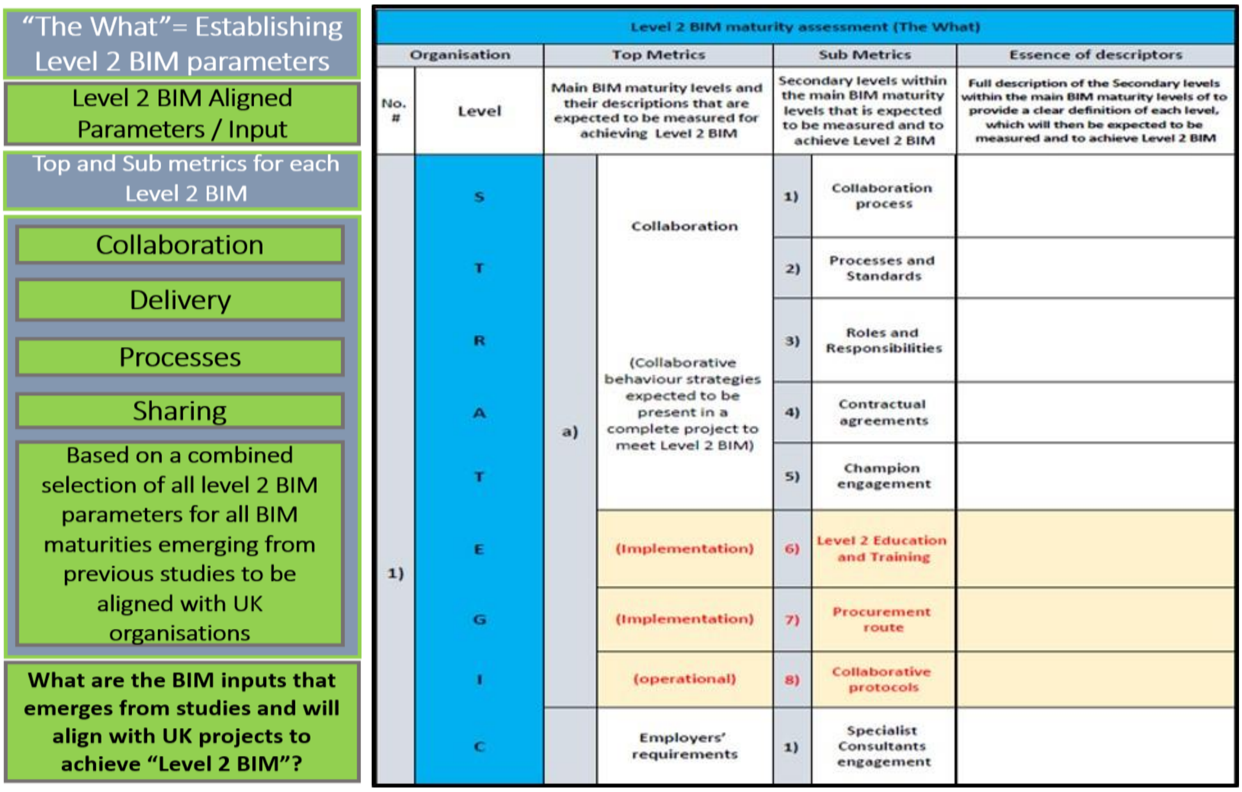


Figure 4.7 "The What": Establishing BIM maturity metrics sample

Following a review of the literature on BIM, as presented in Chapter Three, a number of BIM maturity parameters emerged. Due to the existence of several parameters, a selection criterion was proposed to select those that could be measured and assess the levels of BIM maturity. Therefore, a diverse list of BIM maturity metrics will be reviewed that will focus on BIM maturity outcomes; hence, a standardised list of BIM maturity metrics will be presented.

Aboumoemen (2016) identified the importance of acknowledging the proposed users who would be responsible for understanding how each of the BIM maturity metrics would be conducted. Hence, this study proposed to split the parameters amongst different levels (organisational levels). The organisational levels would include the BIM maturity metrics, which are linked amongst users across each organisational level. Thus, it was proposed to split the organisational levels into three main levels, as follows:

1) **Strategic -** Organisational and project levels that are managed by the organisation team.
2) **Implementation -** Implementing BIM across the organisation, and placing and setting up information.
3) **Operational -** Operating BIM across the organisation, and how the information is collected.

According to Aboumoemen (2016), three organisational levels were proposed amongst which to distribute the BIM maturity metrics. These are believed to assess the degree of BIM maturity across each organisational level.

Several BIM maturity metrics have been identified from the literature, and a list of BIM maturity metrics was identified. These follow the information presented according to the transition from Level 2 BIM standards to the new BS EN ISO19650 standards (Aboumoemen, 2016; BIM Level 2. 2016; UK BIM framework. 2019b).

The BIM maturity metrics are subsequently linked to the information delivery cycle and measure the levels of BIM maturity. The selected metrics using the naming convention metrics as a term being used to identify BIM maturity metrics. Furthermore, it was proposed to split the BIM maturity metrics into three metrics that would fit each organisational level (Aboumoemen, 2016):

1) **Top Metrics:** The main BIM maturity levels and their descriptions that are expected to be measured when adopting BIM.
2) **Sub Metrics:** Secondary levels within the main BIM maturity levels that are expected to be measured when adopting BIM.

In addition to the aforementioned metrics within each organisational level (Aboumoemen, 2016), this research proposes the inclusion of an additional third metric that would feed into the previous two metrics:

3) **Essence of descriptors:** Full description of the secondary levels within the main BIM maturity levels with a clear definition of each level. This will then be measured to demonstrate the adoption of BIM.

The BIM metrics were identified as top levels that would include other BIM metrics, known as sub levels, and a description of what each sub level meant (identified as the essence of descriptors). BIM maturity metrics that emerged from the literature will align with those collected from UK construction industry clients, and enable the development of a list of standardised BIM maturity metrics (Appendix C). Having presented stage 1 of the framework's structure, the next section will outline stage 2.

4.5.2 Stage 2: Assessing proposed BIM maturity and KPI metrics

Following the identification of BIM maturity and KPI metrics, they are then introduced to establish potential relationships and how an assessment of both metrics will deliver a standardised method of assessment. Stage 2 of the framework is "The How" and involves the process of assessment for BIM maturity and the KPI metrics. At this stage, the assessment of the relationship between the metrics is conducted. Figure 4.8 will discuss stage 2 of the framework development process.

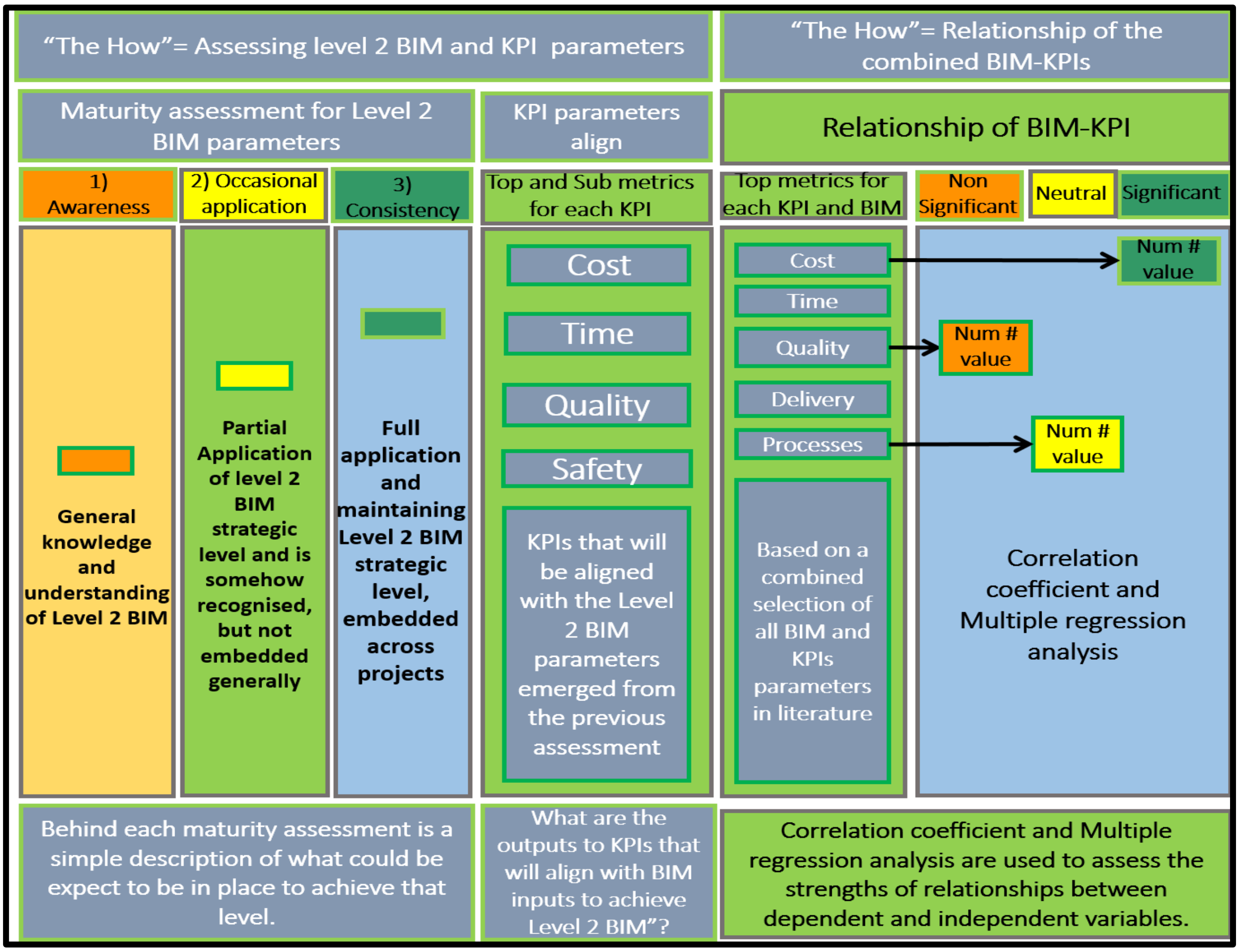
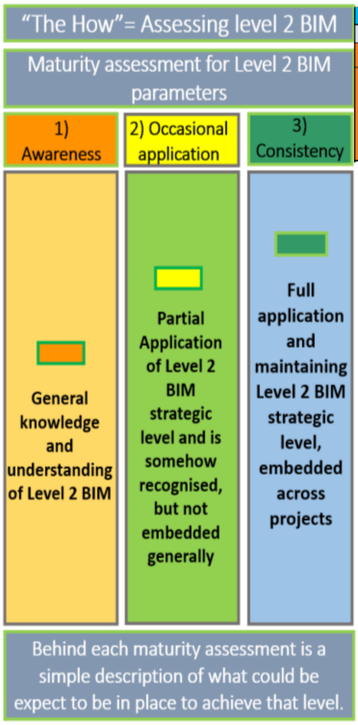


Figure 4.8 "The How": Assessing BIM maturity and KPI metrics

Figure 4.8 presents an extract of stage 2 of the framework. The framework moves on to **"The How" Assessing BIM maturity and KPI parameters.** This stage signifies "The How" as it aims to assess the potential relationship between BIM maturity and KPI parameters to determine their strengths, and how the BIM maturity parameters are acknowledged in projects and organisations within the industry.

As presented in Section 3.4, different BIM maturity assessments exist and, based on the literature review findings and data collected from the UK sample, the emerging BIM maturity metrics and assessment method are expected to align to deliver a standardised assessment for the identified BIM maturity metrics.

According to a review of maturity levels across the literature, BIM maturity assessments delivered a five-level assessment (ARUP. 2014; Change Agent AEC. 2013; CIC. 2013; Succar, 2009), which were based on work by the Software Engineering Institute (SEI. 1993). Nevertheless, Aboumoemen (2016) recommended reducing the maturity assessment from five to three levels in order to provide the necessary distinction between the levels since similarities could be seen (level two being in between levels one and three, and level four being in between levels three and five). This was also achieved in the BIM performance assessment framework study (Mom & Hsieh, 2012) which had three levels (Preliminary, Standard, and Comprehensive), and correlates with Aboumoemen's three-level assessment (Figure 4.9).



Level 2 BIM maturity measurement (The How)		
Maturity level 1	2	3
Awareness	Occasional Application	Consistency
General knowledge and understanding of Level 2 BIM strategic level across organisation	Partial Application of Level 2 BIM strategic level and is somehow recognised, but not embedded generally	Full application and maintaining level 2 BIM strategic level, embedded across projects generally, consistently recognised

This stage proposed three maturity levels:

1) **Awareness (Aw):** General knowledge and understanding of the BIM level 2 strategic level across the organisation.
2) **Occasional Application (Oa):** Partial application of the BIM level 2 strategic level, it is recognised, but not generally embedded.
3) **Consistency (Co):** Full application and maintenance of the level 2 BIM strategic level; it is embedded across projects generally and consistently recognised.

Figure 4.9 "The How": Assessing BIM maturity metrics

Having presented the assessment process of BIM maturity metrics, the next step is to identify how the nine KPI metrics will be linked to the BIM maturity metrics. As presented in Section 3.10, several attempts to link BIM maturity and KPI metrics were proposed. However, as there is currently no standardised method to link BIM maturity and KPI metrics, this research proposes a method to connect them. This method follows similar steps that have been conducted with previous assessments (Section 4.4). A relationship analysis was proposed to assess BIM and CSF (Badrinath et al., 2019).

As a result, Figure 4.10 presents the proposed standardised list of KPIs (Figure 4.6) and a sample of BIM maturity metrics that are aligned to demonstrate the potential relationships of both. As discussed in Section 3.10, across the 33 identified BIM maturity and KPI metric studies, 17 studies presented the existing relationship between various BIM metrics across all primary KPIs (cost, time, quality) but not with the secondary KPIs. This indicates that all BIM maturity metrics would link to all of the primary KPIs; however, 16 other studies have demonstrated links between BIM maturity and KPI metrics across all primary KPIs, but only across some of the secondary KPIs (safety, satisfaction, performance, profitability, productivity and sustainability) are linked to the BIM maturity metrics. This indicates that not all of the secondary KPIs would be linked to the BIM maturity metrics, and a relationship assessment would need to identify the relationship between BIM maturity and the secondary KPI metrics.

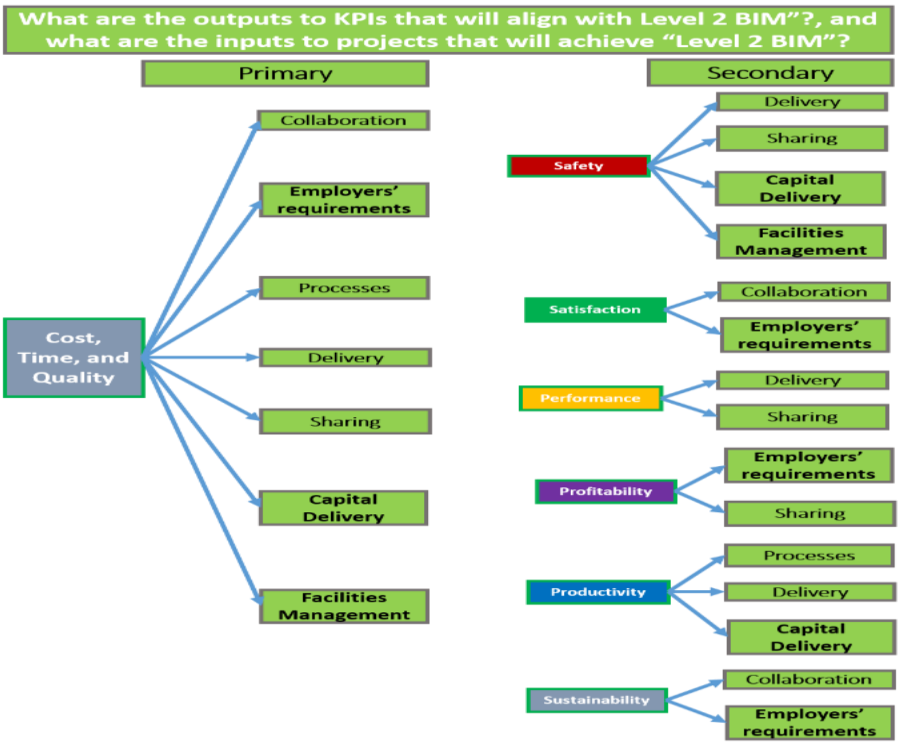


Figure 4.10 "The How": Assessing BIM maturity and KPI metrics proposed relationship

Having presented the proposed relationship assessment between BIM maturity and KPI metrics, the next step will demonstrate how BIM maturity and KPI metrics will be analysed. A BIM performance assessment framework was proposed to measure 22 KPIs that were presented as BIM metrics, and a Likert scale was applied to assess the KPIs across a BIM performance (Shin et al., 2015). The analysis in the literature that considered relationships in frameworks conducted correlation and regression; these analysed the strength of relationship between BIM and KPIs (Wong et al., 2016). This study presents the link between BIM capability metrics and KPIs through a relationship assessment that links BIM capability and KPIs. Figure 4.11 demonstrates the proposed correlation and regression between BIM maturity and KPI metrics.

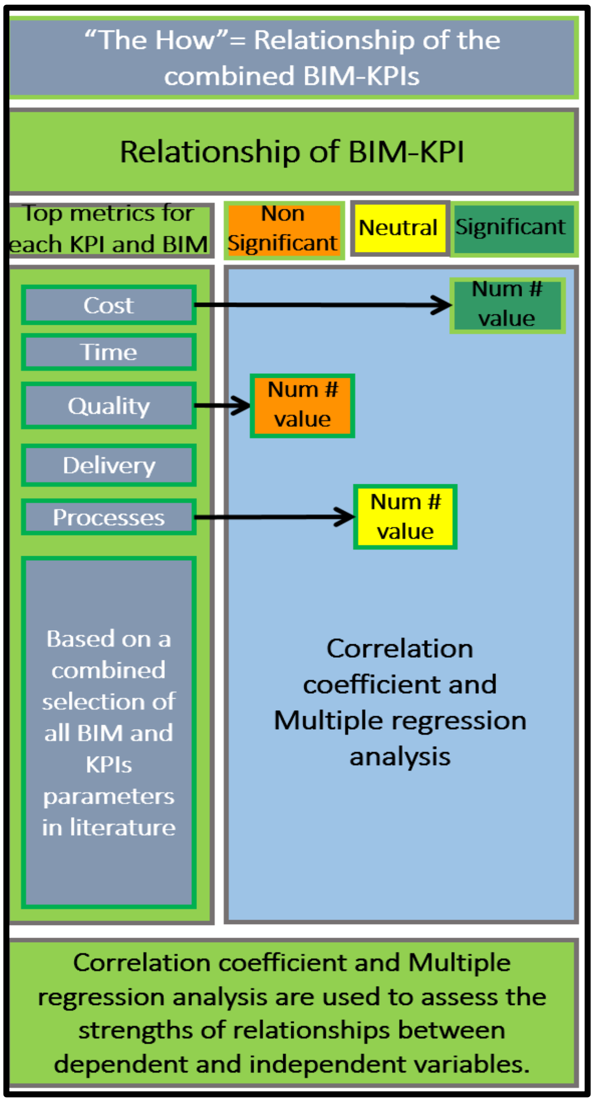


Figure 4.11 "The How": The Relationship assessment of BIM maturity and KPI metrics together

The Likert scale is used with questions that ask participants about areas related to frequencies, level of agreement, and accomplishments. The Likert scale will be used to ask participants about the level of relationship between BIM maturity and KPIs. Likert scales have been used across a number of studies and typically apply a five-point rating. However, similar to the proposed BIM maturity assessment that follows a three-level assessment, a three-point Likert scale relationship is proposed, to provide the necessary distinction between the levels since similarities could be seen across some levels (level two being between levels one and three, and level four being between levels three and five). The three-point Likert scale used to assess the relationship between parameters is as follows: 1. Non significant, 2. Neutral, and 3. Significant.

Having presented stage 2 of the framework's structure, the next section will outline the and final stage (3).

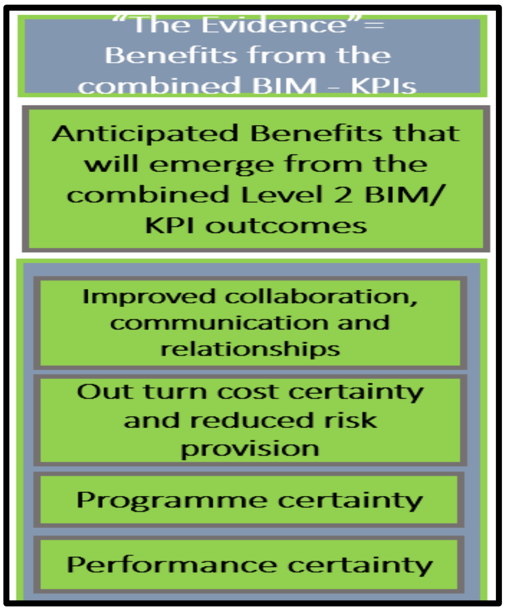
4.5.3 Stage 3: Benefits of the Aligned BIM and KPIs, and the Assessment of their Relationship

Having presented the BIM maturity assessment and the combined BIM-KPI relationship assessment that will be conducted with both separately and together, the final stage of the framework aims to demonstrate the expected benefits from combining BIM maturity and KPI metrics and from the proposed maturity and relationship assessment. This is "The Evidence" stage, and determines the proposed future actions that are expected from the previous maturity and relationship assessment, or "The Why" stage. Figure 4.12 will illustrate the final stage of the framework development process.

Figure 4.12 presents an extract of the final stage of the framework, which is **"The Evidence": Benefits from the combined BIM maturity and KPI parameters.** This stage is called and focused on "The Evidence and The Why"; it aims to consider a number of benefits that are expected to emerge from the proposed BIM maturity assessment and combined BIM-KPI relationship assessment. Moreover, it aims to deliver a number of future improvement strategies on tasks that need to be addressed in order to improve from one level to another.

Figure 4.12 "The Evidence and The Why": benefits of the combined BIM maturity and KPI metrics and proposed future improvements to occur

The final stage of this framework considers the alignment of the three organisational maturity assessment levels (Strategic, Implementation, Operational) alongside the relationship assessment. The intention is to extract the benefits from the BIM maturity-KPI assessments and align them with the benefits noted within the literature. As presented in Sections 2.5 and 2.6, a number of benefits related to BIM maturity emerged from its implementation across projects and the benefits related to clients were noted. The benefits will be collected through the proposed data collection techniques that will be identified from the UK construction industry sample who will focused on the advantages to the client sector (Figure 4.13).



According to Aboumoemen (2016), the benefits that could emerge from combining BIM maturity and KPIs are as follows: Improved collaboration, communication and relationships; improved certainty and reduction of uncertainty; out turn cost certainty and reduced risk provision; programme certainty; performance certainty; improved change implementation and management; improved safety; improved user satisfaction, and reduced lifecycle cost.

Figure 4.13 "The Evidence": Extract of Benefits from the combined BIM maturity and KPI metrics

Some of the BIM benefits that could reflect on clients are as follows (Dakhil, 2017): Improved information control; improved project planning; improved communications; the enhanced integration of processes; improved project quality; improved decision-making process; improved overall project duration control, and improved project cost control. Furthermore, numerous benefits have been identified from the institution of effective Key Performance Indicators (KPIs): An enhanced ability to deliver projects on time; an enhanced ability to deliver projects on budget; a reduced number of defects on projects; optimized processes involved in delivering projects, and raised customer satisfaction levels (M&D Task force. 2014).

Based on the results of the BIM maturity assessment and combined BIM-KPI relationship assessment, a number of actions could be introduced and would help to increase the maturity levels from one level to another, and the relationship assessment from one level to another (Figure 4.14).

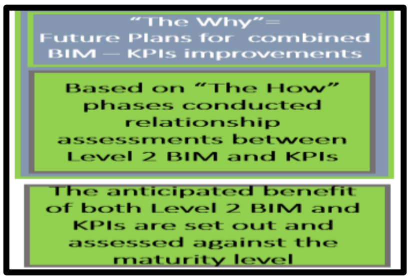


Figure 4.14 Proposed future actions for the Combined BIM-KPI assessment

In addition, based on the assessment in "The How" stage, a list of action plans and future improvement strategies would be provided that would recommend what needs to be undertaken to allow users to move from one level to another and to achieve the benefits previously outlined.

Having presented the structure of the proposed framework and the essence of each stage in order to identify the BIM maturity and KPI metrics, maturity assessment, relationship assessment, anticipated benefits and future actions, a summary of the main purpose of the framework will be discussed.

The proposed BIM maturity-KPI assessment framework will help bridge the missing combination of BIM maturity and KPI metrics that does not exist in the literature. It thus helps to establish how the parameters could be linked within the stage 1 of the framework. Furthermore, the proposed assessment in stage 2 helps to realise the strengths of the potential link between both BIM maturity and KPI metrics. These are based on their assessment and signify the relationship between BIM maturity and KPI metrics. Finally, stage 3 of the framework includes the extracted benefits and recommended actions for future improvements, and outlines the links between BIM maturity and KPI metrics. The actions and benefits in this stage are vital in realising the importance of the previous assessment, as it will offer proposed actions and benefits from stage 2 of the framework. Having presented the three stages of the framework, the next section will deliver the summary of this chapter.

4.6 Summary

A discussion of the development of the BIM maturity-KPI assessment framework was presented in this chapter, which demonstrated the different management dimensions, representation and approaches, and selected those that best fit the proposed assessment (Framework and Process). Furthermore, a justification was offered for the importance of developing a framework in relation to the pre-defined concepts of BIM Maturity, KPIs, and both combined. Moreover, five frameworks were reviewed; these supported the development of the proposed framework and aligned with this research. A proposed framework was presented and the development stages of the framework were outlined through a critical review of the literature and by extracting the main strengths of the proposed framework. The relationship between BIM Maturity and KPI metrics based on the literature review was illustrated in the proposed framework.

Thus, the development of the conceptual framework, and the achievement of the research aim and objectives were discussed, which comprise the research process and associated methodological choices. This chapter is followed by the discussion and validation process (Internal and external), which will form the next chapter.

Chapter 5: Research Methodology

5.1 Introduction

This chapter presents the methodological process that will be conducted to achieve the research aim and objectives. It outlines the research methods that exist, the selected methods that are believed to fit well within this research and provide reasons for not adopting other methods. Furthermore, the adopted data collection techniques are discussed along with the analysis procedures selected. Moreover, a connection between the conducted methods and research objectives will also be distinguished. This chapter discusses various research methods, selects the most suitable for this study and justifies the reasons for selecting these methods in order to meet the research aim/objectives/questions.

5.2 Research and Research methodologies

Effective research relies on an exploration of the methodological techniques that would allow for the exploration of a research problem in order to achieve academic success (Fellows and Liu, 2015). Furthermore, the choice of an appropriate method ensures an ethical approach to the enquiry and supports the analysis of results. This is achieved by considering a set of logical processes within a research methodology, namely principles and procedures, which are subsequently used within the scientific enquiry (Knight and Ruddock, 2008). Hence, a research methodology acts as an overall strategy to investigate the research philosophy, approach and techniques (Haron, 2013).

A number of proposed research methodological models demonstrate the research methods and how a research methodological process could be undertaken. According to Kagioglou et al. (2000) there are three approaches to a research methodology: Research Philosophy, Research Approach, and Research Techniques. These approaches form a nested model where the selection of techniques/tools is reached by a process of narrowing down the philosophical stance to selecting an appropriate paradigm (Figure 5.1). A nested approach has three layers, which can make it easier to follow, but might not cover all essential requirements to meet the research needs (Kagioglou et al., 2000).

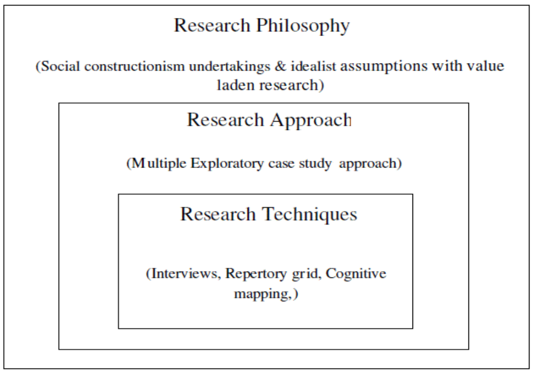


Figure 5.1 Nested research model (Kagioglou et al., 2000)

The second model is a new research proposition *“Research Methodology Life Cycle”* by Dawood and Underwood (2010) (Figure 5.2). Various branches of this model are presented, and the sequence begins by identifying different branches of the Research Philosophy (metaphysics, ethics, logic, aesthetic). This is followed by Research Epistemology (positivism, realism, and interpretivism), after which the next step is Research Ontology (subjectivism and objectivism). Afterwards, the model identifies the Research Approaches (deductive, inductive and abductive), followed by Research Strategies (experiment, grounded theory, case study, action research, and ethnography), Research Choices (mono/mixed/multi methods) and Time Horizon (cross sectional and longitudinal). Finally, Axiology is explored and linked through to the data collection techniques (sample, secondary data, observation, interviews, and questionnaires). Although the model provides a holistic picture through the research methodology and assists researchers with their research process (Dawood and Underwood, 2010), it has not been adopted by previous academic researchers and is thus not reliable on this basis.

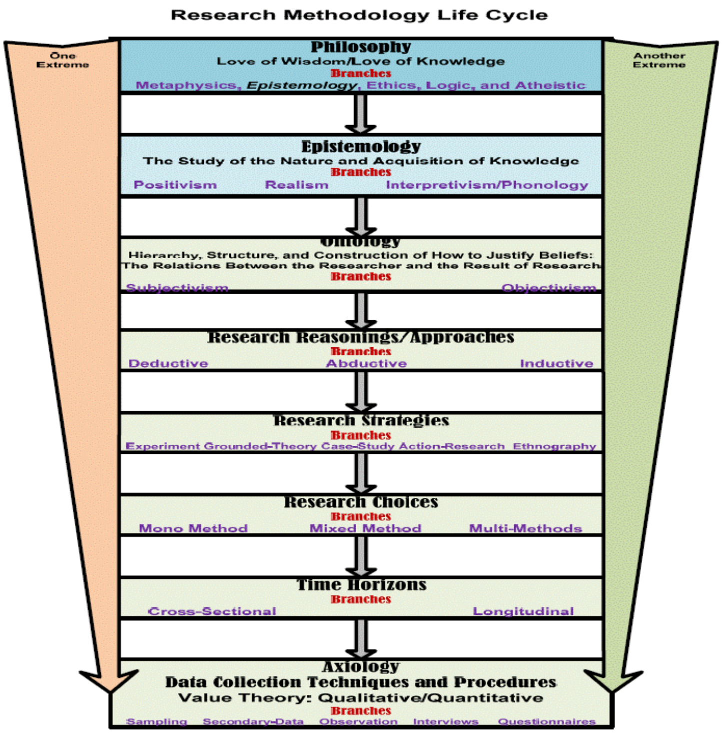


Figure 5.2 Research methodology lifecycle (Dawood and Underwood, 2010)

The third model was proposed by Sexton (2007) (Figure 5.3), but is confusing, especially for researchers who are not native speakers of English (Dawood and Underwood, 2010). Unlike the nested model, this model consists of two approaches:

1) Research Dimensions, which consists of realism and idealism under Ontology; positivism and interpretivism under Epistemology; and value neutral and value- based under Axiology.
2) Research Techniques, which comprises experiment, survey, case study, action research, ethnography (Dawood and Underwood, 2010; Pathirage, Amaratunga, and Haigh, 2005).

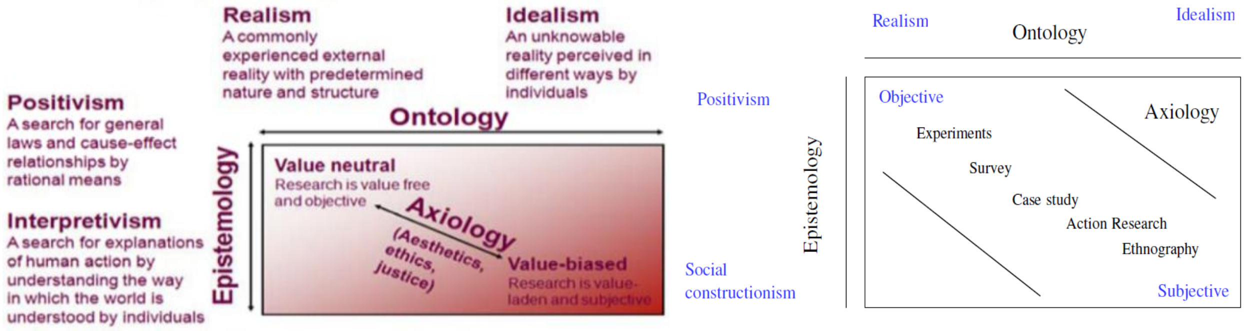


Figure 5.3 Research approach (Pathirage, Amaratunga, and Haigh, 2005; Sexton, 2007)

The last model was proposed by Saunders, Lewis, and Thornhill (2019) and represents six layers of a research methodology, called the "*Research Onion*" (Figure 5.4). The layers consist of: Research Philosophy (positivism, critical realism, interpretivism, post modernism and pragmatism), Research Approach (deductive, inductive and abductive), Research Methodological Choice (mono/multi methods qualitative and quantitative/mixed method simple and complex), Research Strategies (experiment, survey, archival research, grounded theory, case study, action research, ethnography, and narrative inquiry), Time Horizon (cross sectional and longitudinal), and Data Collection and Data Analysis. For this study, the "*Research Onion*" will be adopted as it fully reflects the various research concepts that exist, and on details different methodological approaches that are believed to fit well for this research.

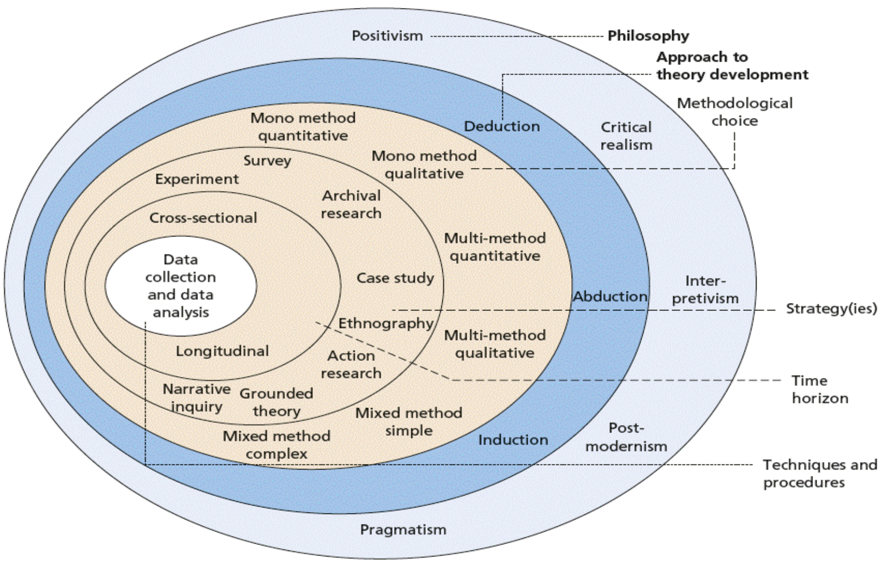


Figure 5.4 Research Onion (Saunders et al., 2019)

The Research Onion provides a complete picture, which offers an understanding of the research components and the appropriateness of various methods when considering the research aim. Furthermore, the "Research Onion" is the main model adopted across various academic research, which contrasts with the other research models that are not being widely adopted, and not completely reliable.

The subsequent sections of the chapter will align to the sequence of the "Research Onion" model by discussing how they support the research aim/objectives and the justification for the methodological choices. Having introduced the different models that exist and the rationale for the adopted model, the next section outlines the research design followed by the research methodological process adopted.

5.3 Research Design

According to Robson (2002), the research design helps to transform the research question into a research project, whereas Gray (2014, p. 128) defines research design as *"the overarching plan for the collection, measurement and analysis of data"*. According to Crotty (1998), methodology is the plan of action, approach, design or process behind the preference and application techniques in research. Yin (2009) describes the research design process as a plan for navigation through the research journey. Research design is therefore the general plan for successfully answering research questions after the identification of a research philosophy, research methods, strategies, and techniques (Creswell *et al.,* 2007). Figure 5.5 presents a summary of the research design, which comprises three phases. The next section will discuss how the phases of the research design relate to the study's research aim and objectives.

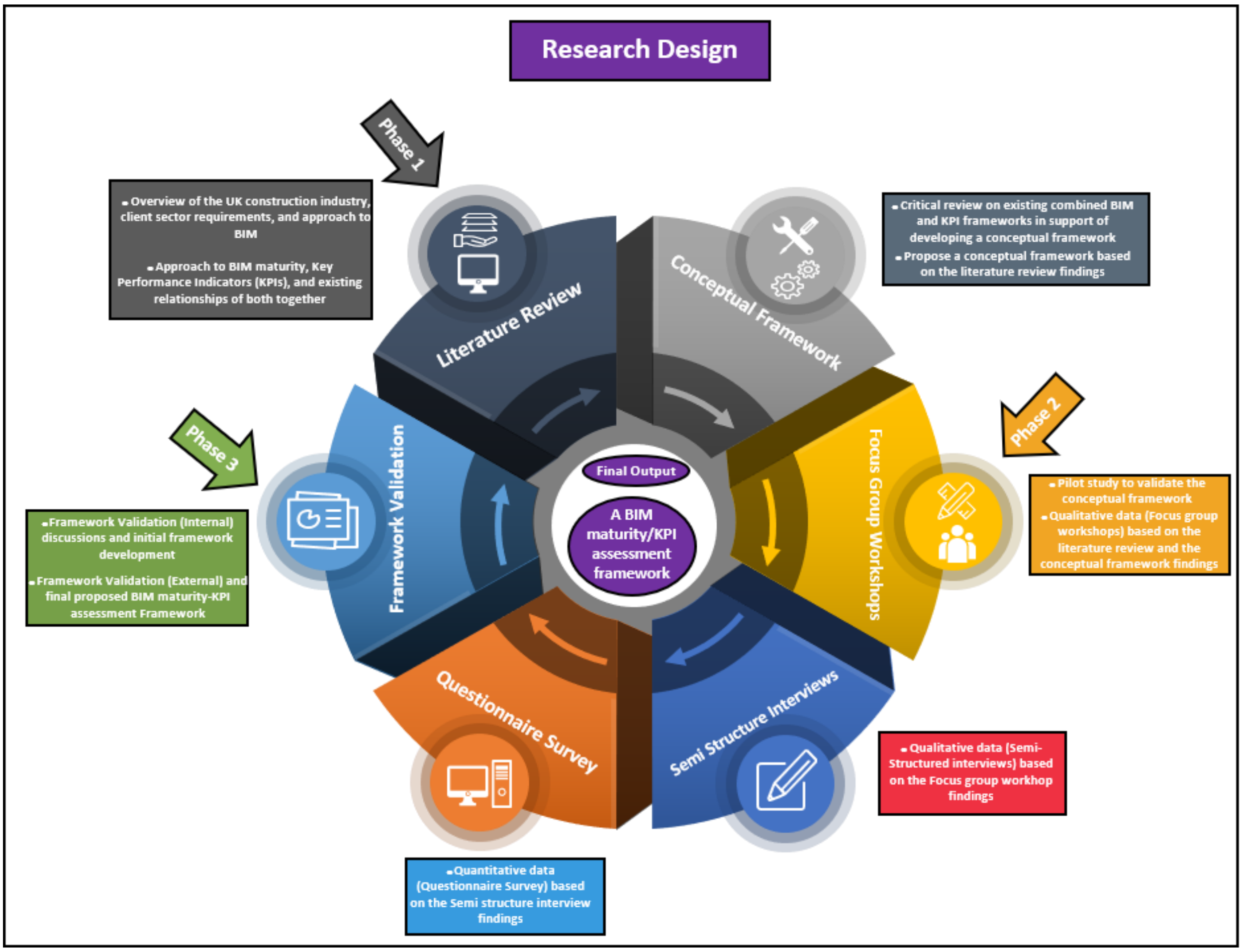


Figure 5.5 Research Design process for this research

5.3.1 Alignment of Research Design phases to Research Aims and Objectives

It is vital to present the relationship between the aim, objectives and research design, and to understand this relationship in order to acknowledge if the proposed objectives align with the adopted research phases (Robson, 2002). Furthermore, different objectives are achieved within different phases. Moreover, a selective data collection technique(s) is required to achieve certain objectives. The alignment between the three research phases of the research design and the research aim and objectives are detailed in Table 5.1:

1) **Phase one (Literature review to establish the conceptual framework):** A critical review of key literature in the field will span all objectives since it will explore and search for information that relates to the overview of the UK construction industry, client sector requirements, and approach to BIM. It will extract the key issues that exist when identifying the research problems and relate them to the objectives. The literature will also conduct a detailed critical review on existing separate BIM maturity and KPI metrics, and both metrics combined. This will assist in developing a draft conceptual framework that examines the proposed metrics and culminates in the presentation of a final conceptual framework. Having proposed a conceptual framework, the literature will be reviewed, and updated based on each of the phases (Figure 5.5). A proposed conceptual framework will meet objectives two-six, since the framework will be initially based on the critical review of key literature.
2) **Phase two (Data collection to examine a proposed conceptual framework):** Prior to the data collection phase, a pilot study will be conducted in order to collect feedback from experts in the field on the framework and thereby check whether it meets the UK client vision for linking BIM maturity and KPI metrics. Furthermore, three data collection methods have been adopted for this research. The first method is a series of focus group workshops, which will meet objectives two-six since it relies mainly on the outcome (findings) from Phase one (critical review of the key literature leading to the proposed conceptual framework). The workshops will collect information as set out in the objectives and further update the proposed assessment framework. The workshop data will be saturated once no further new information is collected. The second method is a set of semi-structured interviews, which will meet objectives four-six by building on the findings of Phase one, and that of the focus group workshop findings, to further develop the proposed assessment framework. The third method will be a questionnaire survey, which will meet objectives five and six by building on from the findings of the semi-structured interviews and inform the design of the questionnaire. The development from the proposed framework (conceptual framework) to the framework stages

(initial framework development) will be provided in the end of each data collection stage.

3) **Phase three (Evaluation and development of the final framework):** The final phase, based on phase one and two findings, aligns to the final objective. Having completed the data collection phase, this phase will review the alignment between the literature review, and data collection findings, and the proposed framework (conceptual framework), which will be achieved through internal discussion (internal validity) that discusses the development of all stages of the framework (initial framework development). In this final phase, the framework will be evaluated within a single focus group workshop (external validity), which aims to further develop and finalise the proposed framework (Final framework). Table 5.1 presents a summary of the research design and objective alignment.

Table 5.1 Alignment of the research design phases and the research aim and objectives

Aim							
"To develop a BIM Maturity-KPI assessment framework for the UK public sector local authority client to assess BIM adoption in line with the UK construction strategy"							
Objectives		**Phase 1 (Literature review and conceptual framework)**	**Phase 1 (Conceptual framework) and Phase 2 (Data collection)**	**Phase 2 (Data collection)**			**Phase 3 (Final framework)**
		Literature review	**Conceptual framework and Pilot study (expert opinion)**	**Focus group Workshops**	**Interviews**	**Questionnaires**	**Validation (Internal and External)**
1	To determine the Building Information Modelling (BIM) approach, its relevance to the **client sector**, and their levels of adoption across the construction industry; globally and UK-specific.	✓ A literature review has been provided that addresses the UK industry, their approach to BIM, Level 2 BIM and BS EN ISO19650, and global approach to BIM	×	×	×	×	×
2	To establish key principles of BIM maturity and evaluate existing BIM assessment frameworks, models, and tools and to understand the principles of existing industry key performance metrics and indicators.	✓ A literature review has been provided that addresses the approach to BIM maturity, KPIs, and evaluation of their existing assessments separately	✓ Developing **"The What"** stage of the conceptual framework, and a presentation of the separate BIM maturity and KPI metrics and existing assessments were provided to experts.	✓ A presentation of the separate BIM maturity and KPI metrics and existing assessments were provided in the focus group workshops	×	×	×
3	To evaluate existing combined BIM-KPI assessment methods, models and tools, and establish the main drivers, barriers and challenges of BIM maturities and KPIs of the UK construction strategy.	✓ A literature review has been provided that addresses the approach of combined BIM-KPIs attempts, and evaluation of their existing assessments together	✓ Developing **"The How", and "The Evidence and The Why"** stages of the conceptual framework, and a presentation of the combined BIM maturity and KPI metrics and existing assessments were provided to experts.	✓ A presentation of the combined BIM maturity and KPI metrics and existing assessments were provided in the focus group workshops	×	×	×
4	To develop a BIM maturity-KPI assessment **framework** for the **UK public sector local authority client** construction industry.	✓ A summary of the literature review was provided that extracted the key elements that existed and resulted in proposing a BIM maturity-KPI assessment **conceptual framework**	✓ A BIM maturity-KPI assessment **conceptual framework** was proposed, the researcher collect some information from experts based on the conceptual framework proposal	✓ The researcher presented the BIM maturity-KPI assessment **conceptual framework**, and explained what information is needed to collect in terms of the BIM maturity metrics across 3 organisational levels **(Strategic, Implementation, Operational).**	✓ **"The What"** stage in terms of the BIM maturity assessment across the 3 organisational levels and 3 level maturity assessment of the conceptual framework will be provided to the interviewees	×	×
5	To examine the relationships between the proposed BIM maturity and the KPIs.	✓ A proposition of a potential relationship between the proposed BIM maturity and KPI metrics in the literature was delivered.	✓ The potential relationships between BIM maturity and KPI metrics would be tested and reviewed before conducting the interviews and questionnaires	✓ The researcher collected some information from the focus group workshops in terms of the descriptions of the BIM maturity metrics across 3 organisational levels and based on a 3-level maturity assessment **(Awareness, Occasional Application, Consistency),** and review on the proposed KPI metrics from the literature.	✓ Interview sessions will be provided to examine the potential relationships between the proposed BIM maturity and KPI metrics through linking the KPIs to the BIM metrics across the 3 organisational levels and 3-level maturity assessment. A final list of KPIs will be agreed on.	✓ A Questionnaire survey will be sent out to the defined sample to examine the potential relationships between the proposed BIM maturity metrics across the 3 organisational levels and 3-level maturity assessment and KPI metrics strength of relationships through a 4-level relationship assessment **(No relationship, Weak, Medium, Strong).**	×
6	To evaluate and propose a final BIM maturity-KPI assessment **framework** to the **UK public sector local authority client** construction industry.	✓ A BIM maturity-KPI assessment **conceptual framework** will be updated based on the BIM-KPI relationships and literature review findings. The framework consists of **"The What", "The How", and "The Evidence and The Why"** 3 stage elements	✓ A BIM maturity-KPI assessment **conceptual framework** was updated based on the expert opinion findings.	✓ **"The What"** stage in terms of the BIM maturity metrics across the 3 organisational levels based on the 3-level maturity assessment of the conceptual framework will be finalised based on the focus group workshops findings	✓ **"The What"** stage in terms of the KPI metrics of the conceptual framework and **The Why"** stage in terms of proposing an action plan will be finalised based on the interview findings	✓ **"The How"** stage of the conceptual framework will be updated, and **"The Evidence"** stage in terms of a list of benefits will be finalised based on the questionnaire findings	✓ An **Initial framework development** will be proposed based on the evolvement of the **conceptual framework** and being compared with the data collection and literature review findings (Internal validation) towards proposing the **Final framework** based on the validation group members (External validation)

There are a number of methods that will be adopted and considered to best fit with the aim and objectives for this research. Figure 5.6 illustrates the adopted research methods for this research.

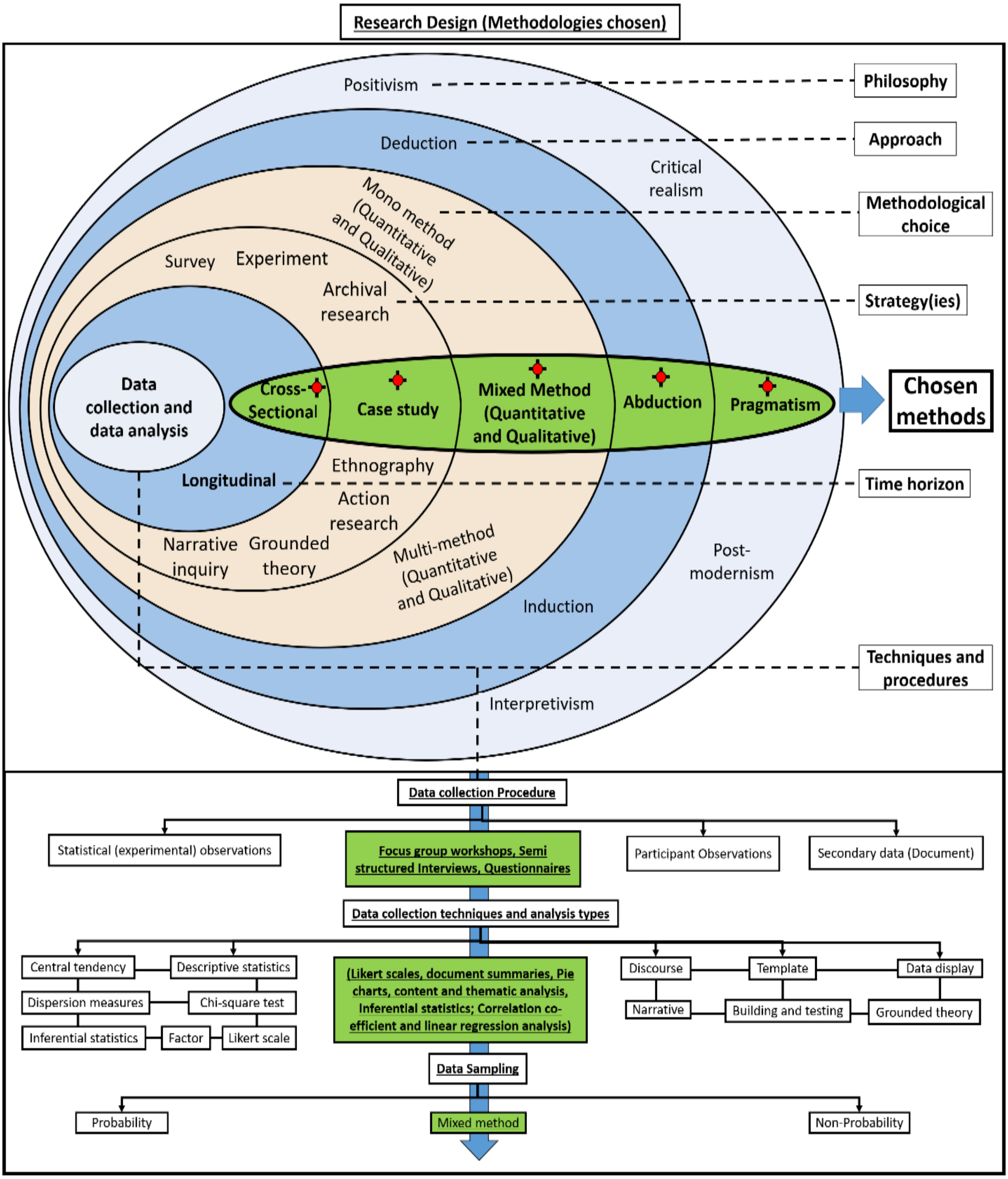


Figure 5.6 Research Design (methodologies chosen) for research

Having presented an outline on the research design, its relationship with the aim and objectives, and a summary of the adopted data collection methods aligned to the three phases of the research design, the next section will discuss the research design in accordance with the methodological layers of the Research Onion.

5.3.2 Research studies associated with the Research Onion layers

Saunders et al. (2019) state that the way in which research questions are asked can determine the research studies. Yin (2018) explains the significant impact of the research studies on the data collection and analysis choices. The research study is associated with all layers of the Research Onion; therefore, different studies will be discussed in order to specify the purpose that best reflects this research. There are four types of research study, which can also be combined in one study (David and Sutton, 2011; Saunders et al., 2019):

1. **Exploratory** (asking open questions to explore a phenomenon): Exploratory studies with ask questions to discover findings and explore a topic. Exploratory research is based on questions that ask “who” and “what” (Yin, 2018). Questions used in this study aim to explore and understand issues. Studies are flexible and adapt to change.
2. **Descriptive** (collecting and describing data): Descriptive studies tend to collect precise information on diverse existing data. Descriptive research poses questions such as “who”, “what”, “where”, “when” and “how” (Yin, 2018). Questions used in this study aim to describe issues in order to have a clearer understanding. This study maintains a high level of persistence from the data collected and aims to describe it in such detail.
3. **Explanatory** (explaining relationships between variables by addressing the current situation): Explanatory studies establish relationships between variables. Exploratory research poses questions such as “how” and “why” (Yin, 2018). These questions aim to identify existing problems to explain these relationships. The data is explained in detail.
4. **Evaluative** (assessing the effectiveness of an organisational or business strategy): Evaluative studies try to recognise if the data collected will be valid and appropriate. Descriptive research considers “who”, “to what extent”, “where”, “when”, “which”, and “how” questions to further evaluate reasons and make comparison between objects (Yin, 2018). The questions used aim to evaluate existing data in order to understand and conduct comparisons.

Based on the nature of the phenomena explored, the adopted research study will be a combination of **exploratory** and **explanatory** as the research seeks to understand what BIM maturity means, what KPI metrics are used, how BIM maturity and KPI metrics can be linked, and why linking them help to tackle existing problems within the UK client sector. The relationships between BIM maturity and KPI metrics will be explained to see if it operates within the framework and how. The framework will be validated across the UK client sector, and the collected data will seek to support the framework development based on the feedback received. Having presented an outline of the research design and the research study, the next section will discuss the adopted research methods, as aligned with the layers of the Research Onion.

5.4 Research Philosophy

When conducting any research, a strategy is a fundamental consideration for the researcher (Gray and Malins, 2004). This is referred to as the 'philosophical paradigm' (Collins, 2010; Fellows and Liu, 2015; Saunders et al., 2019; Trochim and Donnelly, 2006). The research philosophy is conducted by identifying a set of vital assumptions upon which the researcher views the world. These assumptions will help to support the research strategy and methods used to achieve the aim and objectives. Identifying the research philosophy will provide guidance on how the researcher views the world (Collins, 2010). These assumptions underpin the research strategy (Creswell et al., 2007): Ontology (nature of science and truth), Epistemology (what constitutes acceptable knowledge) and Axiology (role of values). Assumptions have been defined by Fumerton (2008) as divisions of a research philosophy; the research philosophy explains how research methods will be adopted and offers reasons why they have been adopted. The next section will discuss the first of these research assumptions (Ontology) and the extreme positions on the continuum.

5.4.1 Ontology

In the context of social research, ontology refers to a theoretical behaviour that is defined by, or comprises, social reality. Bryman (2016) defines 'ontology' as the reflection of reality with respects to social units, while 'epistemology' is a reflection of the adequacy of knowledge. Two concepts define ontology (objectivism and subjectivism) which represent extremes on a continuum. Objectivism is defined by the position that social phenomena exist external to social actors and are related to how they are presented (Crotty, 1998). Constructivism (subjectivism) states that social phenomena are represented by different views that result from the actions of social actor and relate to how they are presented (Saunders et al., 2019). Usually, research adopts philosophical stances that fall between these extremes, which accords with specific a research aim and objectives (Quick, 2014; Uhl-Bien and Ospina, 2012).

This research develops a BIM maturity and KPI assessment framework to assess the levels of BIM adoption and their alignment with the UK construction strategy. This requires the involvement of UK practitioners to reflect from their individual experiences in adopting BIM maturity and KPIs within their working environment. This will be driven by the social reality of organisations, interactions with people and exploring their perceptions and actions. As such, the adopted ontological position will be a variation of **objectivism** and **subjectivism**, since a set of assumptions are made when developing a BIM maturity and KPI assessment framework that requires both extremes.

5.4.2 Epistemology

Epistemology is influenced by what creates satisfactory knowledge in a specific field of study (Saunders et al., 2019). "*Epistemology is the branch of philosophy that concerns the origins, nature, methods, and limits of human knowledge*" (Fellows & Liu, 2008, p. 68). It is vital for a researcher to determine their epistemological position in order to critically select the appropriate methodology in relation to the nature of the research. There are five epistemological positions:

1) **Positivism** (Detached from the participant): The positivist position adopts quantitative experimental methods to test hypothetical-deductive generalisations. Positivism assumes the world conforms to fixed laws of causes and effect, and complex issues can be tackled using simplified and systematic approaches (Crotty, 1998). This research will aim to establish a potential relationship between BIM maturity and KPI metrics (quantitatively), as associated with a positivist strategy. However, the research will not rely solely on these relationships, but also on direct contact with participants and their views on the adoption of BIM maturity and KPI metrics within the UK industry. This requires the involvement of participants' personal views, and the research will not distinguish between feelings and reality. Therefore, this shall not be the adopted epistemological position.
2) **Critical Realism** (reality is vital and seen as external): Similar to a positivist position, the essence of critical realism is what humans' sense as reality and objects have an existence independent of the human mind (Crotty, 1998; Saunders et al., 2019). According to Crotty (1998), realism is different from the concept of idealism, which only describes the existence of the mind and its peculiarities. This position is based on the assumption of a scientific approach to the development of knowledge. This research aims to identify the relationships of BIM maturity and KPI metrics through an assessment framework, which relies on the idea of objectivity, and assesses the levels of BIM adoption within the UK industry, which would link to the human mind. However, the research does not only depend on objectivity and the human mind, but on interactions with participants. There is no control over the data collection process and bias cannot be reduced with the interactions with people. Therefore, this shall not be the adopted epistemological position.
3) **Interpretivism** (open to new knowledge): Interpretivism proposes qualitative and naturalistic approaches to inductively and holistically understand and explain a certain phenomenon. According to Creswell and Clark (2011), interpretivism aims to increase the overall understanding of the subject in which the research develops through the collection and induction of rich data. This position assumes that a researcher should consider the differences

that exist between humans as social actors (Saunders et al., 2019). This research explores the levels of BIM adoption and their alignment to the UK construction industry. This is achieved by developing an assessment framework and identifying the BIM maturity and KPI metrics used (qualitatively), which is associated with an interpretivist position. The researcher will approach participants to understand their requirements, how different groups of people influence each other, and the impact of direct contact with participants. However, the research will not rely solely on participants' views on the adoption of BIM within the UK industry, but on the relationships between BIM maturity and KPI metrics, which will rely on facts and reality. Therefore, this shall not be the adopted epistemological position.

4) **Postmodernism** (no absolute truth to reality): Postmodernism emphasises the role of language and power relations, by seeking to question accepted ways of thinking and give voice to alternative marginalised views. A postmodernist researcher would focus on the ongoing processes of organising, managing and ordering that constitute such entities. As a philosophy, postmodernism rejects concepts of rationality, objectivity, and absolute truth to reality, unlike critical realism, which sees reality as fundamental. Instead, it emphasizes the diversity of human experience and multiplicity of perspectives. There is no in-depth investigation of how the framework is conducted and there is no focus on ongoing processes. However, concepts of rationality, objectivity, and universal truth will be achieved in this research by presenting statistical outcomes on how the BIM maturity and KPI metrics are linked, which will be driven by human experiences of the potential relationship of both within the UK industry. Therefore, this shall not be the adopted epistemological position.
5) **Pragmatism** (problem solving and informed future practice): According to Creswell (2014), pragmatism is seen as a foundation that relies on more than one methodological approach of enquiry, and this allows the strengths of more than one methodological approach to better arrive at results that tackle existing problems and benefits from the extremes of a research continuum (objective and subjective). Therefore, it must be adapted to achieve better outcomes that depend on the nature of the research question (if it is multi-dimensional). Pragmatism deals with reality and truth, rather than theory and opinion, and is assumed by considering competing philosophical worldviews (positivist and interpretivist) (Morgan, 2007). This enables the capture of strengths from each extreme rather than just the adoption of one and neglect of the other. This research aims to explore the potential links of BIM maturity and KPIs in order to overcome existing problems with absence of a link. This aims to reflect on the overall performance of the UK construction industry and better educate the client sector. As

a result, the adopted epistemological position shall be pragmatism, since the research starts with a problem. This will be achieved by adopting both the objective and subjective stances in order to take the strengths of each to better arrive at results that solve the problem. This philosophy is achieved from the mix of inputs that include human experience and statistical evidence regarding the potential relationship between BIM maturity and KPI metrics. Hence, pragmatism aims to achieve this outcome and is best suited for this research that measures the levels of BIM maturity by linking it with KPI metrics in an assessment framework based on the current literature (Bryman, 2016). Figure 5.7 presents a summary of the epistemological positions and highlights the adopted position for this research.

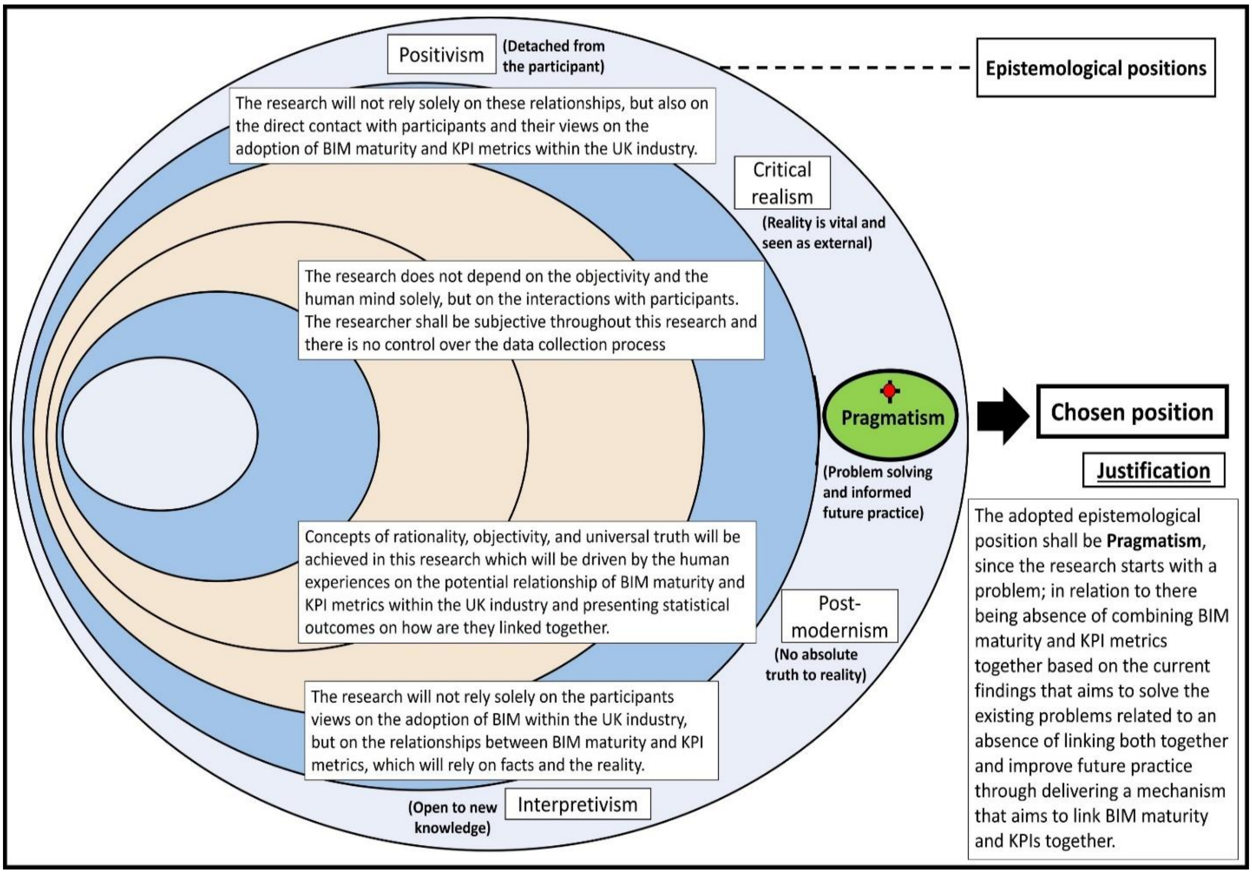


Figure 5.7 Research Epistemological positions and selection of a position (Saunders et al., 2019)

Having described the epistemological position, the next section will discuss the research assumptions (Axiology) and select the position most relevant for this research.

5.4.3 Axiology

Axiology is defined as a branch of philosophy that studies judgment about value. Axiology, in the Research Onion, is viewed as a philosophical branch that emphasises the judgement of research values (Saunders et al., 2019). There are five axiological classifications, which are linked back to each of the epistemological positions (Section 5.4.2) in numbering order. They are:

1) **Value-free** (research is free and detached from social beliefs to avoid bias): The researcher

maintains an objective stance, and will be detached from their research and the presented data (Crotty, 1998; Saunders et al., 2019). As this research investigates a BIM maturity and KPI metrics relationship, the researcher will not be detached from the research and social beliefs. Instead, the research will be based on direct contact with participants and their views on the adoption of BIM maturity and KPI metrics within the UK industry. Therefore, this shall not be the adopted axiological position.

2) **Value-laden** (research is not detached from people (values) and strong views are taken): Similar to value free research, the researcher tries to minimise bias and error, and is as objective as possible; however, value-laden research is not detached from people and the researcher acknowledges bias in their world views and cultural experience (Saunders et al., 2019). This research explores the relationship between BIM maturity and KPI metrics, which is based on arguments and explanations provided by practitioners and authors. The mechanism that structures those arguments and explanations will rely on the researcher's knowledge and expertise in the research area, which will adopt to an objective stance. This relies on the researcher's experience in the field and interactions with other axiological positions, and therefore, will not be the adopted axiological position.
3) **Value Bound** (Researchers are part of what is researched, subjective): Contrary to value-free and laden, researchers are part of what is researched and take a solely subjective stance; moreover, the researcher's interpretations are key to the contribution (Saunders et al., 2019). This research will adopt to a subjective stance, however, this research will not rely solely on the subjective stance when identifying the relationships between BIM maturity and KPI metrics and capturing tacit knowledge and expertise from practitioners on the research area. Rather, it will also depend on the objective stance taken to demonstrate the relationship, which relies on facts, reality, and will rely on the research's expertise on the research area. Since this involves adopting an objective and subjective stance, it will not be the adopted axiological position.
4) **Value Constituted** (researcher and research embedded in power relations): Similar to value-laden research, the researcher and research are embedded in power relations, and some research narratives are silenced at the expense of others. Similar to value bound research, a subjective stance is taken (Saunders et al., 2019), hence, an objectivist stance and universal truth is rejected, and value constituted research challenges ways of thinking and knowing in demonstrating the relationship between BIM maturity and KPI metrics and makes a distinction between feelings and reality. Therefore, this shall not be the adopted axiological position.

5) **Value-driven** (Research initiated and sustained by researcher's doubts and beliefs): Research relies on doubts and beliefs, and the researcher's values drive the reflexive process of inquiry, which is initiated by doubt and a sense that something is wrong or out of place (Saunders et al., 2019). This means addressing the research problem and adopting a mix between the objective (value-free) and subjective (Value bound) stances to reach solutions to those problems and inform future practice, which may contain a mix of feelings and reality.

Having reviewed the different axiological positions, and based on the nature of the phenomena explored and its relationship with the ontological and epistemological positions, a value-driven axiological position will be adopted since the researcher's values drive the reflexive process of inquiry, when proposing an assessment framework that delivers practical solutions that aim to overcome existing problems in the UK. The adoption of value driven would support the ontological position of objectivism and subjectivism by adopting a mix of both reality and social interaction with participants in order to deliver a linkage between BIM maturity and KPI metrics. Having established the research axiological position, the next section will discuss the second Research Onion layer (research approach) and select the approach relevant for this research.

5.5 Research Approach

The Research Approach relies on the use of a theoretical position to build on a research design and formulates the philosophical stance adopted (Saunders et al., 2019). Each study starts with a theory, and it is the clarity of the theory at the outset that most affects the choice of research approach and design. Thus, there are three research approach positions:

1) **Deduction** (testing a theory built from literature to generate it): A deductive approach includes the progress of a theory that is methodically tested. The initial step identifies a theory related to a topic of interest, after which this theory is narrowed down into a more specific hypothesis that can be assessed before narrowing down further. A deductive approach is appropriate when the research topic is supported by extensive literature, where a hypothesis is developed and a research strategy is subsequently used to test this hypothesis, which occurs within the boundaries of existing knowledge (Fellows and Liu, 2008; Saunders et al., 2019). Trochim and Donnelly (2006) believe that deductive thinking works from broader to more particular and could be called a 'top-down' method (Hyde, 2000). The steps of deductive reasoning are available in Figure 5.8.

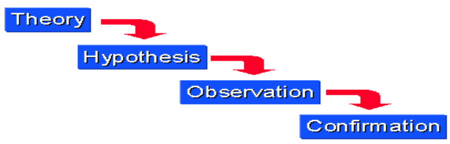


Figure 5.8 Deductive Reasoning (Trochim and Donnelly, 2006)

Although the research will start with a review of literature on BIM maturity and KPIs and how they could be linked within an assessment framework, the framework shall be tested and validated within the UK construction industry. Moreover, the data collected shall be analysed to deliver a final combined framework from the literature (specific) to be examined and subjected to validation by UK clients. Therefore, based on the data collected and the theory developed, the research will conclude with a framework. This would result in the usage of more than one approach and will not rely solely on deduction. Thus, this would not be adopted research approach.

2) **Induction** (generating a theory from data collection and testing it): In contrast, an inductive approach contains perceptions that promote the development of a hypothesis. The inductive approach is frequently used in subjectivist ontology and is often referred to as a 'bottom-up' approach in that it goes from the specific to the general. A inductive approach is appropriate when the research topic is new and there is insufficient literature; thus, data is collected and theory is developed, which extends beyond the boundaries of existing knowledge (Fellows and Liu, 2008; Saunders et al., 2019). Trochim and Donnelly (2006) suggest that inductive reasoning moves from specific observations to broader generalisations and theories. The steps of inductive reasoning are illustrated in Figure 5.9.

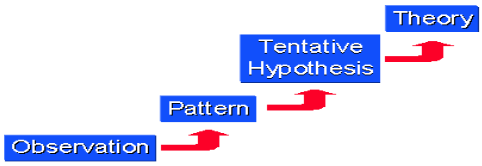


Figure 5.9 Inductive Reasoning (Trochim and Donnelly, 2006)

The critical review of the current literature on BIM maturity and KPIs starts from general information (specific) for both that will guide the development of a framework that will subsequently be tested in relation to its usage in the wider UK construction industry (general). This requires the usage of a deductive approach where the research topic is supported by extensive literature on BIM maturity and KPI metrics (general), but addresses an issue concerning the links and leads to the development of a framework (specific). However, the research will deliver a framework that will be implemented within the UK construction industry. Therefore, since the research will require the interactions between the specific and general context, reviewing the literature means consulting existing knowledge and therefore the study will not rely solely on induction. Thus, this would not be adopted research approach.

3) **Abduction** (generalising from the interactions of theory built from literature and theory tested from data collection): An abductive approach is a mix of both deductive and inductive,

known as the “V” or “W” model or “top-down vs bottom up”. Mixing deductive and inductive may lead to a more significant result. An abductive approach is appropriate when the theory underlining the phenomena is plausible, where data is collected to explore a phenomena and to modify an existing theory, and, as such, it interacts within the boundaries of existing knowledge (Fellows and Liu, 2008; Saunders et al., 2019). Abductive reasoning is a successful way of researching; however, the outcome is satisfactory if a pure inductive or deductive approach were implemented (Bryman, 2016; Teddlie and Tashakkori, 2009; Trochim and Donnelly, 2001). The steps of the abductive reasoning are shown in Figure 5.10.

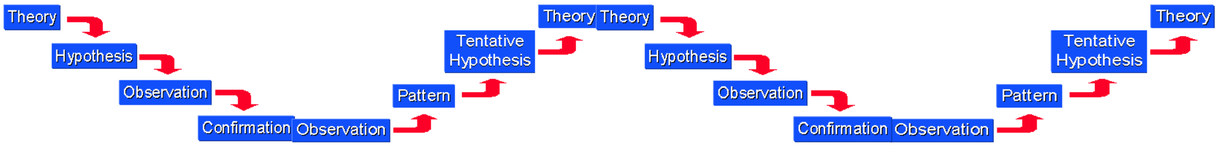


Figure 5.10 Abductive Reasoning (Trochim and Donnelly, 2001)

The adopted research approach will be **abductive**, since it will build on existing literature on BIM maturity and KPIs before developing a theory by combining BIM Maturity-KPI in an assessment framework. The framework will be refined and examined across the UK construction industry, and the results shall be used to generate an update to the existing framework. This will be done through the use of deduction and induction (Bryman, 2016; Gray, 2014), as the framework will be refined, tested and generated from the literature and the data collection.

Figure 5.11 presents a summary of the research approaches and highlights the adopted approach.

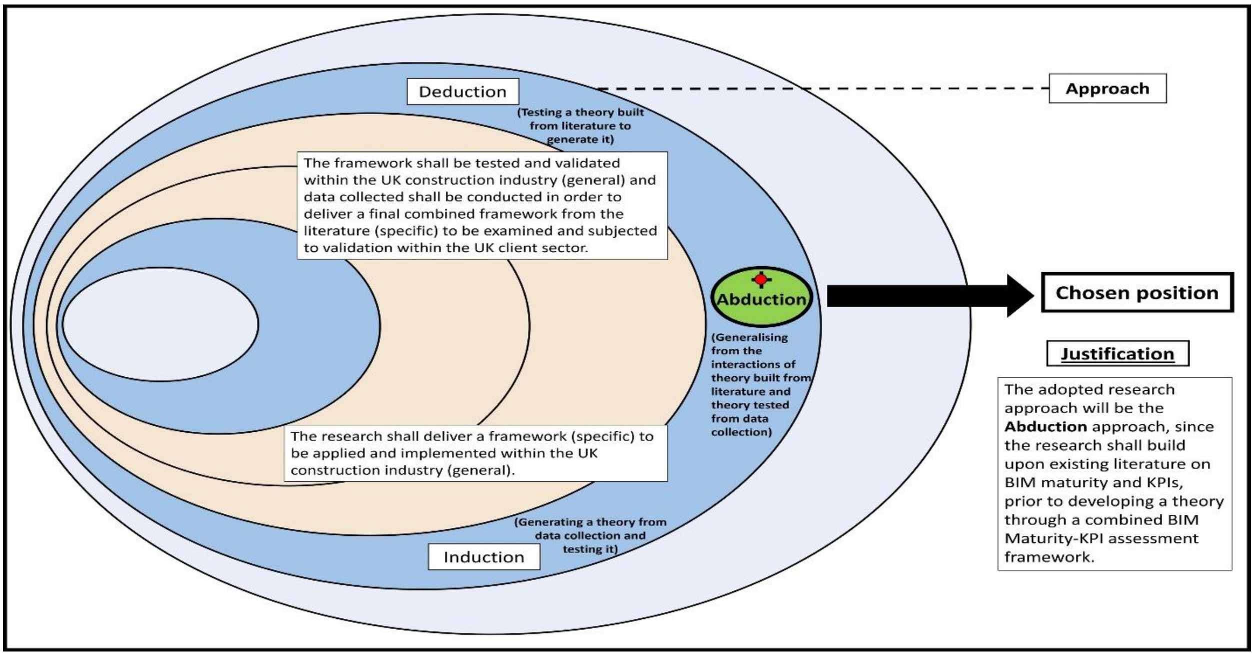


Figure 5.11 Selection of research approach based on research aim and objectives

Having adopted a research approach, the next section will discuss the third Research Onion layer (methodological choice) and select the methodological position relevant for this research.

5.6 Research Methodological choice

According to Crotty (2003) methodology is the plan of action, the approach, design or process behind the preference and application techniques in research. This layer involves the choice between quantitative, qualitative methods, or a mix between quantitative and qualitative (mixed method). The methodological choices outlined include the mono method (usage of a single method in quantitative or qualitative methods), multi-method (usage of multiple methods in quantitative or qualitative methods), and mixed methods (Saunders et al., 2019). Methods used are expected to rely on the philosophical position of the research and the numerical or factual data collected, whether it is numerical, based on personal opinions or both. The methods identified in this layer (Saunders et al., 2019) are:

1) **Quantitative:** Quantitative methods calls for data to be collected in numerical form, where the data presented could include a use of diverse statistical and graphical techniques. Quantitative research is mainly connected with experiments, survey research strategies, archival research, and case studies (Saunders et al., 2019). It has been found to be suitable for addressing research questions relating to what, how much and how many (Fellows and Liu, 2008). Quantitative methods are mainly driven by the objectivism, positivism, value-free, and deduction research continuum since they rely on factual data which requires an objective stance.

The literature shall provide existing data on BIM maturity, KPI metrics and how it has been approached. The data presented will need to establish a potential linkage which would be noted numerically by determining the levels of BIM maturity [Awareness (1) to Consistency (3)] and determining the strength of relationship between the BIM maturity and KPI metrics [No relationship (0) to Significant (3)]. The inputs involve people's opinions on where they score themselves with BIM maturity and how they determine the strength of relationship between BIM Maturity and KPI metrics. This research will not rely solely on quantitative methods, but on UK client views to determine the BIM maturity and KPI metrics used within the industry, if there is a potential linkage between both, and how this linkage would be reflected to the industry. This will require the collection of personal opinion (qualitative data) to further support the numerical data (quantitative). Thus, this requires a mixed use involving numerical facts and personal opinions; as a result, quantitative would not be the adopted research methodological choice.

2) **Qualitative:** Qualitative methods calls for data collection methods that focus on participant opinions, and could thus include a diverse range of data collection techniques in order to contribute to a theoretical position that will not adapt to a regular procedure. It provides the means to explore and understand subjective thoughts that individuals or groups ascribe to a phenomenon (Creswell, 2009). Quantitative methods are mainly driven by subjectivism and interpretivism; moreover, they are value-bound, and since they rely on personal opinions require a subjective stance. A range of strategies are utilised with qualitative research, including action research, case study, ethnography, grounded theory and narrative research.

The literature provides existing data on BIM maturity and KPI metrics and how UK clients see themselves regarding the levels of adoption and BIM maturity, and the KPI metrics used within the UK construction industry. The data collected will then be presented to the UK client sector to collect their opinions on the levels of adoption concerning BIM maturity, the KPI metrics used, whether there is a linkage, and the benefits that could be extracted from a linkage. This research will not rely solely on qualitative methods, but will require these methods to establish a potential linkage. This will be collected numerically by determining the levels of BIM maturity and determining the strength of relationship between the BIM maturity and KPI metrics, which will include collecting numerical facts (quantitative). This will further support the personal opinions (qualitative). Thus, this requires a mixed use between numerical facts and personal opinions, and as a result, which will form the adopted research methodological choice.

Within quantitative and qualitative methods, the following may be used:

- **Mono-method research:** The usage of a single method quantitative or qualitative method. Both research types can also stand on their own before being integrated to form conclusions (Saunders and Tosey, 2012).
- **Multi-method research:** The usage of multiple methods, which are either quantitative or qualitative. In multi-method quantitative studies, the researcher develops their hypothesis based on objectivism, which is validated by implementing different types of quantitative methods (for example, a questionnaire) with associated quantitative analysis procedures (Bryman, 2016; Creswell, 2014; Saunders et al., 2019). For multi-method qualitative designs, the researcher adopts a subjectivist philosophical paradigm to establish their proposed ideas, which will be validated by implementing different types of qualitative method (for example, in-depth interviews) with associated qualitative analysis procedures (Tashakkori and Teddie, 2009).

Table 5.2 presents the differences between quantitative and qualitative research (Bryman, 2016).

Table 5.2 Comparison between qualitative and quantitative research (Bryman, 2016)

Quantitative study	Qualitative study
Numbers	Words
Point of view of researcher	Point of view of participant
Researcher is distant	Researcher is close
Theory Tested	Theory Emergent
Static	Process
Structured	Unstructured
Generalisation	Contextual Understanding
Hard Reliable Data	Rich Deep Data
Macro	Micro
Behaviour	Meaning
Artificial Setting	Natural Setting

1) **Mixed Methods:** Mixed methods combine quantitative and qualitative mono or multi methods in various ways, where the data collected can be presented in different ways from graphical and statistical and meaningful patterns identified. Mixed method research is advocated when the nature of the problem lends itself to use of data collection methods across quantitative and qualitative methods (Amaratunga et al., 2002). Mixed methods are mainly driven by the two objectivist continuums (positivism, value-free, and deduction research) and this is followed by a subjectivist stance (interpretivism and postmodernism, value-bound and value-constituted, and induction research) or vice versa. Alternatively, it can include a combination of objectivism and subjectivism, pragmatism and critical realism, value laden and value-driven, and abduction (Collis and Hussey, 2009; Kothari, 2004; Patton, 2015; Tashakkori and Teddlie, 2009).

   Within **mixed methods (triangulation)**, quantitative and qualitative research are combined within the research design. This generally refers to a research design where qualitative and quantitative strategies are engaged to collect data, either sequentially or concurrently, and the data is integrated at one or more stages in the research process (Creswell et al., 2009). There are three mixed method designs associated with mixed method research as follows:

   a. **Sequential Mixed Method (Exploratory design):** This design allows findings of one method to be verified by another. This may involve beginning with a qualitative strategy followed by a quantitative strategy or vice versa (Tashakkori and Teddlie, 2009). The main strength of this method is down to the fact that exploration may help the researcher to build general knowledge about the proposed variables to be studied, where the findings from one method inform the subsequent method. Moreover, both quantitative and qualitative analysis can be used to provide in depth personal opinion data as well as to contextualise statistical results (Creswell, 2014). However, a key weakness is the huge amount of time it can require to enable completion, since it relies on the usage of both quantitative and qualitative methods,; moreover, both methods may be linked and therefore, one method (i.e. qualitative) may delay the other (i.e. quantitative).

b. **Concurrent Mixed Method (Triangulated or nested)**: otherwise known as parallel design (Tashakkori and Teddlie, 1998) whereby only one data collection phase is used, but both qualitative and quantitative strategies are engaged on the same subject concurrently to collect data and produce results (Amaratunga et al., 2002). The main strength of this method is the shorter data collection time due to the parallel nature of the collection (Creswell, 2014). However, a key weakness is the greater effort and skill required to use two separate methods at the same time. Moreover, it can be difficult to compare the results, which may deliver complex data that may be difficult to analyse and potentially lead to misunderstanding or misinterpretation amongst users (Amaratunga et al., 2002).

c. **Transformative Mixed Method:** This is a combination of sequential and concurrent that relies on a dual theoretical lens within which quantitative and qualitative data can be deployed. The main strength of this method is that the theoretical perspective could be ideological and involve either a sequential or concurrent approach (Creswell, 2014). However, a key weakness is the minimal guidance on this strategy, hence it is unpopular within the mixed method research community (Creswell, 2014).

Having reviewed the different research methodological choice positions, and based on the nature of the phenomena explored, the adopted research methodological choice position shall be **mixed method.** The aim of the research is to develop a proposed BIM maturity-KPI assessment framework for the UK public sector construction client. This involves the interaction of quantitative and qualitative methods by consulting industry practitioners to gather their views on BIM maturity, KPI metrics and their potential relationship (qualitative), and the benefits of a linkage, where participants see themselves within the BIM maturity levels [Awareness (1) to Consistency (3)], and the strength of any relationship between BIM maturity and KPI metrics [Not Significant (1) to Significant (3)] (quantitative). As a result, both objective and subjective stances will be adopted alongside pragmatism, value-driven, and abduction. This will present numerical data and opinions to determine whether there is a linkage between BIM maturity and KPI metrics, and to ascertain the strength of any linkage.

The research type that will be adopted for this research will be **Sequential Mixed Method**. The research aims to develop an assessment framework for UK clients that will require the collection of information from various UK construction organisations. In addition, the information involves numerical relationships, such as those between BIM maturity and KPI metrics, which will examine how both metrics are linked. Furthermore, observations on the presented framework will consider how it could provide a meaningful and applicable framework to UK clients. The information collected will rely on personal views concerning the levels of BIM maturity (sections 4.5.1 and 4.5.2), and through qualitative means (i.e. focus groups or interviews). This will enable an examination of the relationship between BIM and KPIs through numerical measures (section 4.5.3), which collects data by quantitative means (i.e. online questionnaires). This information will be collected one step at a time, (i.e. qualitative through focus groups or interviews) and then will proceed with the next step (i.e. quantitative through online questionnaires). This allows quantitative and qualitative methods to be explored together to consider a potential linkage. Based on the mixed method collected data, the framework shall be updated frequently to enable validation and a mixed analysis will support this process. Figure 5.12 presents a summary of the research methodological choices and highlights the adopted choice.

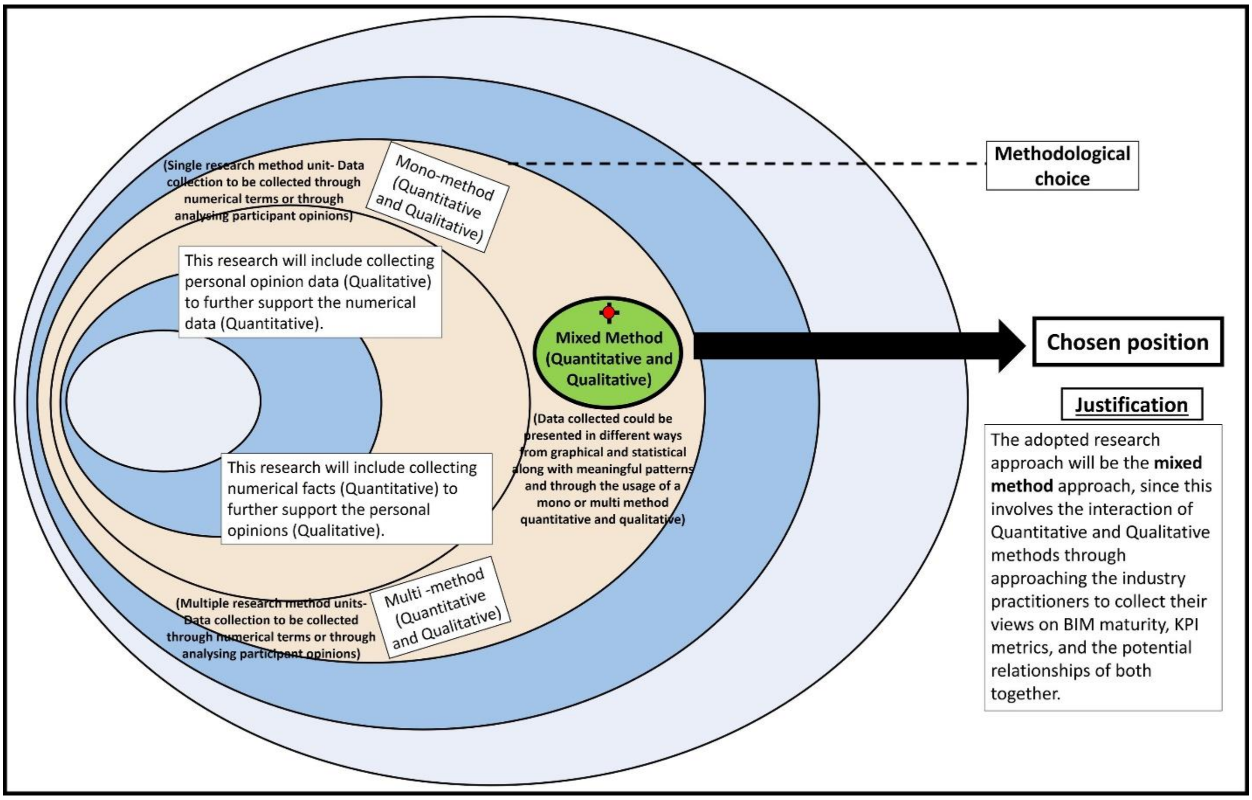


Figure 5.12 Selection of research methodological choice based on research aim and objectives

Having established the research methodological choice, the next section will discuss the fourth Research Onion layer (research strategy) and select the strategy relevant for this research.

5.7 Research Strategy

The Research Strategy refers to *"the logic that links the data collection and analysis to yield results"* (Fellows & Liu, 2008, p. 20). A research strategy refers to the overall logic underpinning the collection of evidence to support an enquiry (Yin, 2018). This layer emphasises that researchers can use one or more strategies within their research design as they plan how to go about answering a research question(s). A Research Strategy aims to achieve the end goal by identifying an action plan on how the data shall be collected (Bryman, 2016; Creswell, 2014; Gray, 2014; Saunders et al., 2019). There are a number of research strategies in this layer as follows:

1) **Survey** (collecting data from a large sample): A 'survey' is a strategy to generalise outcomes, which are grounded by data and result from sampling populations (Creswell, 2014; Saunders et al., 2019). Although a survey strategy could have been adopted, due to the consideration of a numerical relationship between BIM maturity and KPI metrics (Section 4.5.3), a full understanding of BIM maturity and KPI metric outcomes amongst UK clients is the main target. Hence, reaching a number of respondents is not the main requirement, but rather an understanding of the real process. As a result, this will not form the adopted research strategy.
2) **Experiments** (hypothesis to anticipate if a relationship exists): Similar to a survey, an 'experiment' is frequently considered the most demanding strategy to employ due to the need to reduce different explanations of outcomes (Trochim and Donnelly, 2001). Experimental research is more popular among the natural sciences and medical research (Fellows and Liu, 2015; Kumar, 2011). Although the last stage of the framework needs to identify the links between BIM maturity and KPI metrics, no hypothesis will be developed, as the research is not seeking to establish cause/effect. Therefore, this method was not considered appropriate as it based on testing the application of a new entity in a new setting.
3) **Archival research** (usage of community printed archives): Bryman (2016) defines archival research as 'unobtrusive' in nature as the researcher is not personally involved in observing the interactions or events examined. The archival research strategy involves the review and extraction of evidence from archival records (Elder, Pavalko, & Clipp, 1993). Although this research will require access to archives and documents (secondary data) on previous key related literature on BIM Maturity, KPI metrics, and both combined, a framework will be delivered and supported by the publication findings. Due to the nature of this problem, which aims to discover existing (and hitherto unrecorded) links between BIM maturity and KPI metrics, archival research will not be adopted.
4) **Ethnography** (examine the culture of a social group): In 'Ethnographic research', the researcher is included for a specific period in the social life of those being examined and draws conclusions from the observation of these participants (Bryman, 2016). The primary character of ethnographic studies is the direct interaction of the researcher within the natural setting of the research subjects, often over long periods of time (Creswell, 2009). This research, however, aims to deliver an assessment framework to the UK construction industry, hence it shall not deliver insights or in-depth information about the industry in general; instead, the target is to

access organisations that use and understand BIM maturity levels. In addition, this research does not intend to study the behavioural patterns or physiologies of participants, and shall not deliver insights or in-depth information about the industry in general. Therefore, this will not be the adopted research strategy.

5) a) **Action Research** (developing solutions to real organisational problems by collaborative means): The term 'action research' involves the researcher and a client working in partnership to identify and solve a problem (Bryman, 2016). This refers to research within a practical setting with the aim of integrating action and reflection, theory and practice to solve a research problem (Cameron and Price, 2009). It promotes organisational learning by identifying, planning, taking and evaluating action; this known as an action research continuous loop (Figure 5.13).

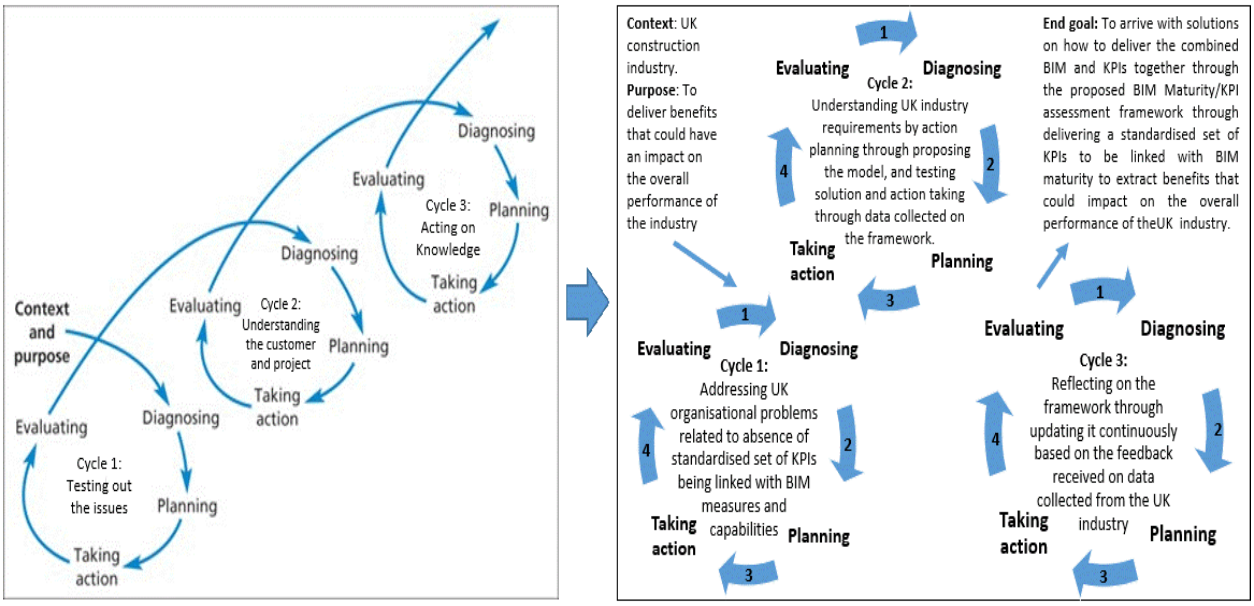


Figure 5.13 Action Research Cycle (left) and proposed cycle (right). (Saunders et al., 2019)

The cycle exists by identifying and testing organisational issues through addressing existing UK organisational problems regarding the absence of a standardised set of BIM maturity and KPI metrics and their link with BIM maturity, which aims to deliver benefits to the performance of the UK industry. Furthermore, this entails understanding UK industry requirements through action planning, proposing the framework, testing solutions and taking action through collecting data on the framework. Finally, this requires action on knowledge by reflecting on the framework and updating it continuously based on feedback from the UK client sector. This cycle would need to be repeated continuously to arrive at solutions on how to deliver the combined BIM maturity and KPI metrics. Although an action research strategy could have been adopted, due to its suitability in addressing the organisational problems associated with a lack of linkage between BIM maturity and KPI metrics, this method was not considered due to the nature of the problem, which aims to identify the links between BIM maturity and KPI metrics. Hence, to select action research, the researcher would play a vital role in influencing the selected organisation. This requires the researcher to act as an active participant within the process, whereas for this study, the researcher will be involved as a passive observer. This study aims to establish a relationship between BIM maturity and KPIs, but does not expect to change the attitudes or behaviours of UK clients, but rather to understand how BIM maturity and KPI metrics could be linked. Therefore, this would not be adopted research strategy.

5) b) **Design Science** (artifact made by human/s to solve problems, and are graphical representations): Similar to action research, Johannenson & Perjons (2014) state that, in design science, the 'technological rule must take the form of what is known as an 'artifact', which are objects made by human to solve problems and are either physical entities or graphical representations.' Voordijk (2009, 2011) describes the 'technological rule' as a general rule that is not a specific solution for a specific problem but a general solution to a type of problem. However, this method was not considered applicable to this study due to nature of the problem. An assessment framework will be presented to clients to help them understand BIM maturity and KPI metrics and how they operate within projects in organisations, to extract benefits by combining both, and to demonstrate how it can enhance the performance of UK clients. An artifact will not be produced; instead, a combined framework will be developed for testing by UK clients. Thus, the proposed framework shall not be considered as an artefact in this context since it does not aim to offer any type of solution to existing problems concerning the absence of combined BIM maturity and KPI metrics. Therefore, this would not be adopted research strategy.

6) **Grounded Theory** (theory that is discovered through systematic data collection): The term 'Grounded Theory' was first presented by Glaser & Strauss in 1967 (Glaser, 2017; Glaser and Strauss, 1967). The primary objective of grounded theory is the development of theory from an inquiry (Creswell, 2009). Although grounded theory provides a systematic way to analyse a qualitative approach through direct analysis, the theory developed does not start from the ground since there is existing literature on BIM maturity and KPI metrics. Rather, this study will adopt both quantitative and qualitative methods to collect and analyse data, and will not aim to generate a new theory. Due to the nature of the problem explored, theory has already been established through the literature. Therefore, the research seeks to validate links between BIM maturity and KPI metrics via mixed methods research. As a result, this will not be the adopted research strategy.

7) **Narrative Inquiry** (interpreting a sequence of events): This is a qualitative strategy, where individual lifestyles are studied through story telling from individual's own perspectives (Creswell, 2009). The stories are then reorganised and presented in a chronological order (Clandinin and Connelly, 2000). As the proposed framework will deliver BIM maturity and KPI metrics, it will not require storytelling, and instead shall require straightforward answers on potential links between BIM maturity and KPI metrics through numerical data and personal opinions from UK clients. Therefore, this will not be the adopted research strategy.
8) **Case study** (in-depth usage of a topic or phenomenon in a real life situation): Yin (2014, p.43) defines a case study strategy as, '*…an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident*'. Case studies are used to develop an in-depth understanding of a phenomenon (Yin, 2014). This is often conducted within a defined context, called the case, which may refer to a specific set of restricting attributes, such as a geographic location, institution or organisation (Fellows and Liu, 2015). Similar to experiment strategy, a case study strategy deals with inquiry from research questions that are associated with "how" and "why" questions, which are associated with explanatory research (Yin, 2018). A descriptive case study is utilised to refer to a phenomenon or processes, whereas an explanatory case study is usually theory driven and may be utilised to develop a hypothesis in a large research project (Fellows and Liu, 2015). An exploratory case study is typically used to test a hypothesis and develop logical conclusions (Yin, 2018).

Having reviewed the different research strategies and based on the nature of the phenomena explored, **case study** will be the adopted research strategy**.** As this research aims to establish an understanding of what BIM maturity means, the KPI metrics used, how both can be linked, and why they would be linked to tackle problems that exist within the UK client sector, a case study will help to meet the aim of this research, and has therefore been selected as the main research strategy. The application of case studies would link back to exploratory and explanatory studies, the combination of objectivism and subjectivism, pragmatism, value-driven, abduction, and mixed method research This will all be adopted within a case study which will deliver primary and in-depth information. Nevertheless, there are a number of case study types within case study research. Thus, the next section explains the different types of case study research, and the main reasons for its selection.

5.7.1 Identification of the case study type and selection criteria

As stated by Yin (2018), case studies can be classified as single or multiple, and then, depending on the number of units of analysis, embedded (more than one unit of analysis) or holistic (one unit of analysis). Four types of case study designs exist (Yin, 2018):

1) **Single holistic case study:** A single case study and uses one unit of analysis.

2) **Multiple holistic case studies:** More than one case study and uses one unit of analysis.

3) **Single embedded case study:** One case study but uses more than one unit of analysis.

4) **Multiple embedded case studies:** More than one case study and uses more than one analysis unit.

Yin (2014, p.80) states that choosing between a single and multiple case studies does not necessarily relate to production of less or more evidence: "*On the one hand, a single case is frequently utilised to present a critical, extreme or unique case. On the other, a single case might be chosen because it is typical or provides a chance to observe and analyse a phenomenon that few have considered*". The rationale for using multiple cases could include the need for replication across cases. Hence, when selecting multiple case studies, they should share the same scale and rank in order for the research to be liable and valid. Cases will be selected on the basis that similar outcomes are foreseen for each (Saunders et al., 2019).

Previous studies reveal common misunderstandings on case studies (Stake, 1995). One of the main misunderstandings is that, "*One cannot generalise on the basis of an individual case; therefore, the case study cannot contribute to scientific development*" (Flyvbjerg, 2006, p.3). "*The view that one cannot generalise on the basis of a single case is usually considered to be devastating to the case study as a scientific method*" (Flyvbjerg, 2006, p.8). According to Flyvbjerg (2006, p.12), "*One can often generalise on the basis of a single case, […] as supplement or alternative to other methods, but formal generalization is overvalued as a source of scientific development […].*". The real process can be understood through an in-depth case study (Fu, 2012).

For this research, **a single embedded case study** will be applied to allow the researcher to identify BIM maturity and KPI metrics, along with the strength of relationships between both, and its implications for UK clients, including different types of clients, within a single case. Since a mixed method choice was chosen that incorporates various types of analysis techniques (numerical and personal views), they will be analysed in different ways and compare BIM maturity and KPI metrics against their emerging benefits. Thus, a single embedded case study design will be selected to generalise the findings of this research across a single case with the usage of multiple unit of numerical and contextual analysis. The selection of a single case study is based on:

a. The organisation type is a main contractor-procurement platform driven by the client sector (a UK public sector local authority client).
b. The focus is on investigating the platform, which is considered a unique case (Yin, 2018), since it will investigate the targeted platform for this research by exploring and studying the current operations of BIM maturity and KPI metrics on their platform, and serve the local authority by delivering a better understanding to clients involved with the platform (Proverbs and Gameson, 2008).
c. Different levels of organisational experience with BIM maturity and KPI metrics are required, since it is essential to explore the levels of understanding of BIM maturity, including the BIM maturity and KPI metrics used in the platform, to establish the strength of relationship between both. Thus it is necessary to approach organisations with an appropriate level of understanding in the research area in order to capture relevant information that will help to meet the research aim and objectives. This will allow the researcher to compare between BIM maturity and KPI metrics being collected, and to determine whether they can be linked.
d. The organisation must be willing to offer access to the data needed for the research in order for the researcher to determine the current state of the platform and support the delivery of a BIM maturity-KPI assessment framework.

Figure 5.14 illustrates the four case study types and highlights the adopted type (Yin, 2018).

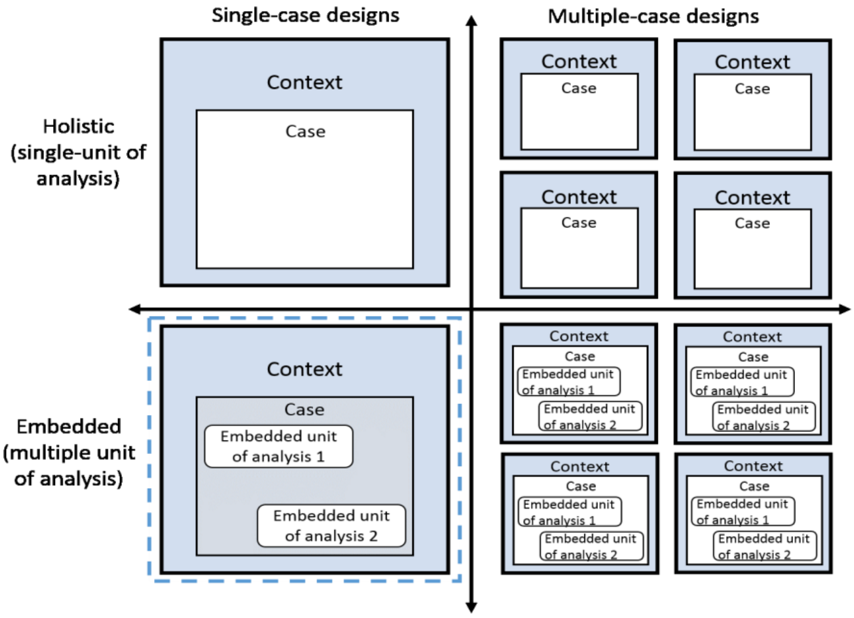


Figure 5.14 Types of case studies based on the number and units (Yin, 2018)

Having selected a single embedded case study as the main case study type, the next section will discuss the selected case study for this research.

5.7.2 The North West Construction Hub (NWCH)

The North West Construction Hub (NWCH) is one of the national main procurement bodies for construction in the UK (NWCH. 2009). They were established in 2009 in response to the Central Government's drive to improve efficiencies within the public sector. The legal entity behind the NWCH is a UK public sector local authority client. NWCH establishes long-term relationships between clients and contractors, such that 98% of their projects are delivered on time and under budget, and 92% of their projects have received client satisfaction scores. NWCH is managed by a small dedicated team of Framework Managers and a series of Special Interest Groups (SIG) are held within the platform. The SIGs are established to deliver the Construction Strategy agenda covering topics such as Supply Chain, BIM/Digital Construction, and Training & Employment.

Over recent years, and as part of the platform targets to meet client BIM needs, the NWCH Working Group have been involved with a number of academic projects. This included support to the University of Salford to explore BIM maturity and the derived benefits for client organisations. Due to nature of this single case study and based on NWCH established contacts, this research will approach multiple companies in the same domain (contracting) of the same industry (UK) located in the same area (Manchester) sharing similar field of expertise (contractors, managers, etc.).

Figure 5.15 presents a summary of the research strategies and highlights the adopted strategy.

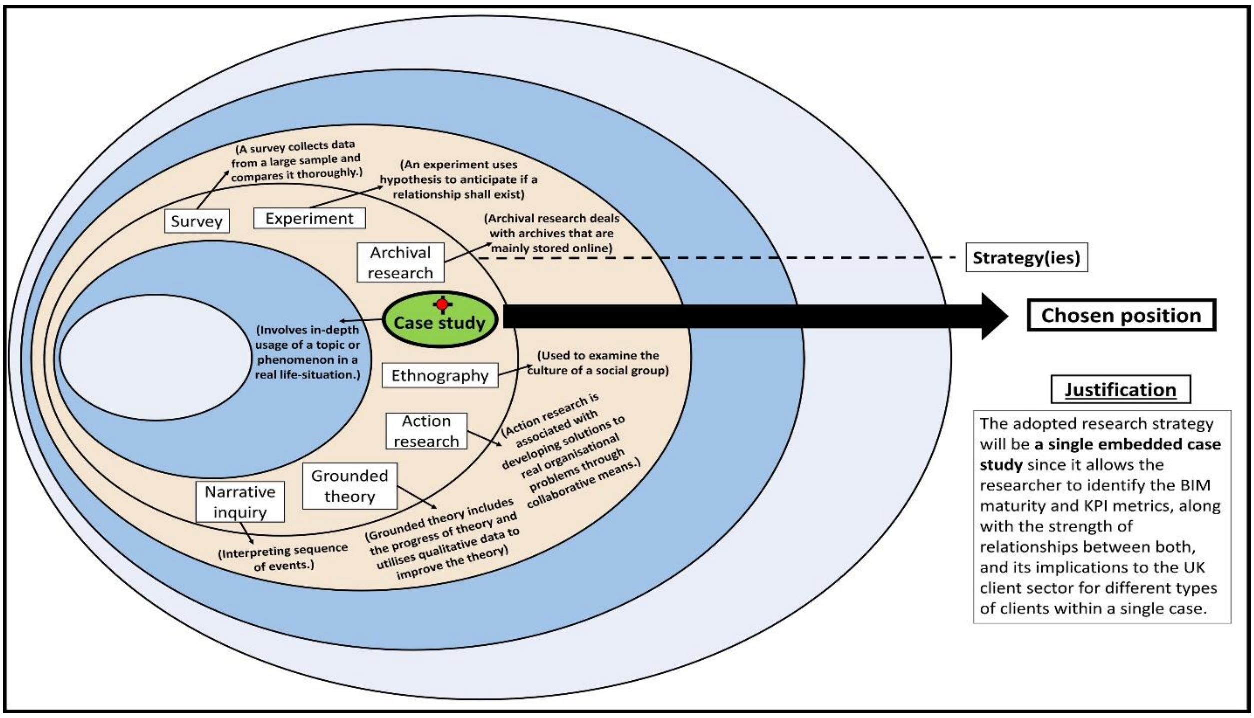


Figure 5.15 Selection of research strategy based on research aim and objectives

Having adopted a research strategy, the next section will discuss the 5th Research Onion layer (research time horizon) and select the research time horizon relevant for this research.

5.8 The Research Time Horizon

The time horizon represents the length of the period within which the research is conducted. This is represented in two ways. The first is known as a "snapshot of time", which represents research undertaken in a controlled timeframe, and the second is the "diary", which represents research conducted in an open timeframe (Saunders et al., 2019). There are two types of time horizon studies (Saunders et al., 2019):

1) **Cross-sectional studies (Snapshot of time):** These resolve research problems and over a controlled amount of time. This involves studying a particular phenomenon, which requires exploration, description, explanation, or evaluation within a given timeframe.

2) **Longitudinal studies (Diary):** This is based on resolving research problems in an open timeframe. This involves studying a particular phenomenon, which requires exploration, description, explanation, or evaluation in an open timeframe. This is only relevant and may be applicable with both action research and design science research since it addresses human behaviour and technological enquiries that could need to review change over a longer period of time. Green et al. (1993) emphasise the need to set a time horizon for research, namely that research cannot run indefinitely. Moreover, Bell (2014) believes that, inevitably, there are deadlines which the research activity must fit, and these must be stated clearly at the outset. Furthermore, a PhD study has a limited time period and therefore all activities and stages of research have to end within the defined time period. Therefore, this shall not be the adopted research time horizon.

The adopted research time horizon will be **cross-sectional**, since the information collected will be grounded in the present day where it addresses a "snapshot" of the levels of BIM adoption and the technological usage of BIM maturity and KPI metrics. Moreover, all activities must end within the allocated timeframe. It restricts an open timeframe to monitor changes to BIM maturity and KPI metrics, and the levels of BIM maturity, since it is beyond the scope to develop further changes and monitor the development and influence of the BIM maturity-KPI assessment framework for UK clients. Thus, a longitudinal horizon was not adopted. Figure 5.16 presents a summary of the research time horizons and highlights the adopted time horizon.

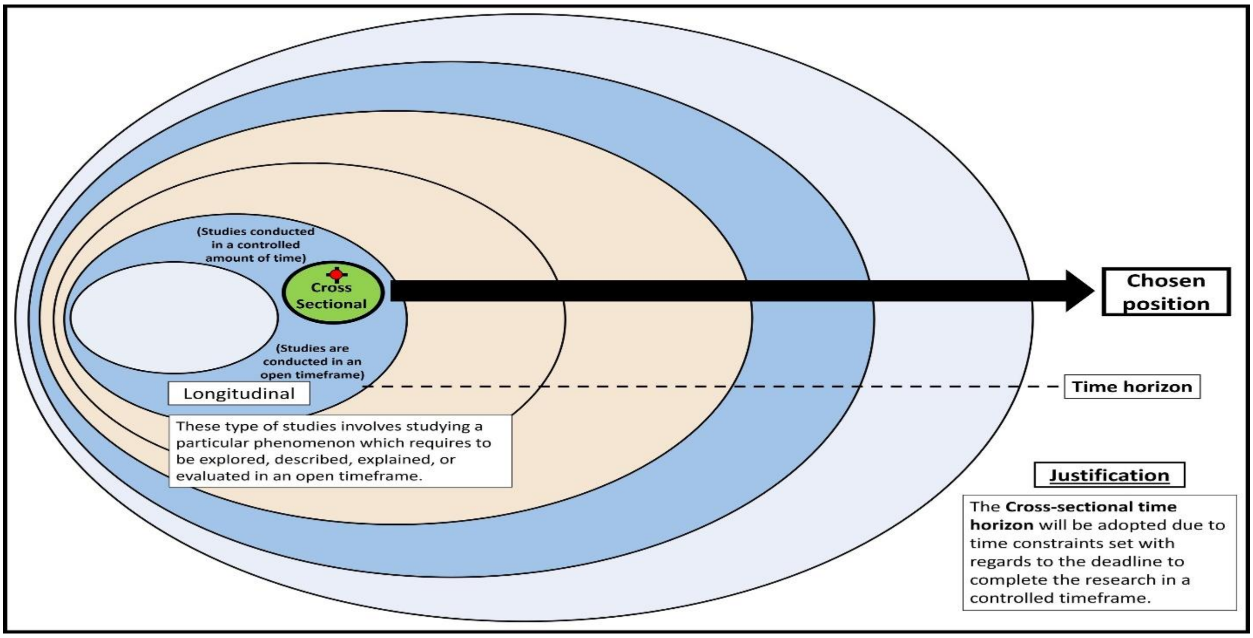


Figure 5.16 Selection of research time horizon based on research aim and objectives

Having adopted a research time horizon, the next section will discuss the final Research Onion layer (data collection types) and select the data collection types relevant for this research.

5.9 Data collection (techniques) and data analysis (procedures)

Saunders et al. (2019) distinguish data collection and analysis as the most vital part of conducting research. Some key issues were identified by Saunders et al. (2019), which consist of 'sampling', 'secondary data' and 'primary data'. These techniques are further expanded and discussed in the context of the research. This refers to techniques that will be engaged to collect the data. According to Kumar (2011), three main types of data collection exist: observations, questionnaires, and interviews. Naoum, (2013) also classified surveys as a data collection technique. Three main research techniques have been adopted for this research: focus group workshops, semi structured interviews, and an (online) questionnaire.

5.9.1 Workshops (Group data collection type)

A workshop is a data collection type that involves a selected group of participants within a study. A workshop technique is useful and effective as it provides an in-depth exploration of a phenomenon and provides a conducive platform for making sense of the various concepts (Gibbs, 1997; Morgan & Kreuger 1993). Workshops are a highly efficient technique for qualitative data collection since the amount and range of data increase by collecting from several people at the same time (Robson, 2004). In addition, workshops are the most appropriate and effective in obtaining information, insight, experience, and knowledge of a large group of industry players in the shortest period of time. This research focuses on dynamic management issues around linking approaches to develop a combined conceptual framework, as discussed. Mixed method techniques are primarily adopted to elicit and analyse stakeholder viewpoints and rich, in-depth data should be collected from group members. However, a main weakness from workshops is that the researcher has less control over the data produced and the sessions can be difficult to assemble (Morgan, 1988). There are two main group data collection types as follows:

1) **Focus group workshops:** Defined as individuals or groups selected by a researcher to conduct further discussions with experts and receive feedback from personal experience on the topic area investigated (Powell, Single and Lloyd, 1996). A group of individuals are selected and assembled by researchers to discuss and comment on the subject of the research. Participants share a common background, which makes the focus group homogenous (Robson, 2011). Numbers may vary; for example, some studies use only one meeting with several focus groups (Burgess, 1996), others meet the same group several times (Gibbs, 1997).
2) **Group Interviews:** Group interviewing involves interviewing a number of people at the same time. The emphasis is placed on questions and responses between the researcher and participants by interviewing a number of people at one time (Gibbs, 1997). In group interviews, a number of people are interviewed at the same time, which could occur in a form of workshop with different groups of people or a number of groups. In comparison, in focus group workshops, the selected individuals or groups will be involved throughout the explored research. Participants may or may not share a common background, which makes the group interview heterogeneous, offering diverse opinions from group members (Robson, 2011).

Focus group workshops will be adopted, and members will all share a common background. The researcher's interactions and discussions with group members will investigate a particular phenomenon to explore and arrive at results (Morgan, 1997). Respondents' interactions gather data concerning attitudes, reactions, experiences, beliefs and feelings. These interactions could depend on the social setting or be independent of a group, but it would be revealed through social interactions in a focus group entity (Gibbs, 1997; Morgan & Kreuger, 1993). Six to ten people per group is the recommended number for a focus group (MacIntosh, 1993), but some could include as many as 15 (Goss & Leinbach 1996), and as few as four (Kitzinger, 1994, 1995). A single meeting with several focus groups may be conducted (Burgess, 1996) or a group could be met several times (Gibbs, 1997). Research topic areas would be explored through the involvement of participants, since they would deliver rich data and responses, and the workshop process would be controlled by the researcher. Potential limitations may include the wide variety of data offered, which may require further explanation and result in additional interruptions; this may prompt conflict and a lack of awareness amongst participants during the sessions. Thus, generalisation will be required from the generated workshops, and there will be limited workshop flow control as a result of the amount of data and number of existing participants (Creswell, 2009). Some conflicts might rise within the group, which will be easy to manage but may consume time. The workshop arrangement process could take longer than usual, as all members have to agree to a certain date and time.

The single embedded case study using focus group workshops with the NWCH forms the focus of the primary data collection techniques. The focus group workshops will qualitatively develop the research's framework proposition, since sessions will be held within the NWCH platform. Personal views will be gathered as a qualitative methodological choice, which would result in multiple data collection and analysis techniques. The validation of the proposed BIM maturity-KPI assessment framework within the platform will be achieved through the proposed workshops at the point that saturation is reached. This could deliver the following outcomes, such as: successful coordination amongst the team, enhancement of the collaboration process, the collection of necessary information relevant for the research topic area. The participation of focus group members will be of key importance to this research, since people's opinions will support the development of the framework, as based on the platform requirements. A number of workshops will be conducted with NWCH focus group members until the data is saturated and no additional data emerges. This will deliver a number of amendments to the framework. It is expected that this will help to finalise the development of the three organisational assessment levels (as discussed in Chapter 4-Section 4.5.1), and present the completed organisational levels. Moreover, an update to the assessment framework in the last workshop will be arranged with the NWCH focus group members. The data collection conducted with the NWCH will be conducted as follows:

1) **Focus group workshops** (Session summary sheet): After the data is collected, the minutes of meeting summary sheet will be prepared. This will summarise the data captured and the progress of each workshop, and set out guidelines for what will occur in upcoming workshops until the data is saturated. Upon completion of the workshops, the summarised minutes will be sent out via email to all members of the NWCH focus group, in order to prompt any important recalled information within the workshops. Any collected documents from the NWCH focus group members will be recorded, and discussions for each workshop will be clarified in the minutes of meeting summary sheet (Gray, 2014; Robson, 2002).

Following the discussion of focus group workshops as an adopted data collection technique, the next section will discuss the second data collection technique (interviews) in further detail.

5.9.2 Interviews (Individual data collection)

Interviews rely mostly on the selected individual or group expertise in capturing relevant data (Saunders et al., 2019). Since it is difficult to access external evidence, records, and company documents that are deemed confidential and outside the researchers' control, it is important to select interviewees with relevant knowledge in the research field and able to offer access to relevant data (Yin, 2018). The complexity of the collected data would call for a detailed description from interviewees (either in person or over a medium such as online or phone) so interviews will be necessary. There are three main types of interview:

1) **Unstructured interviews:** This approach relies on open-ended questions to which interviewees are allowed the flexibility to elaborate in an unrestrictive manner (Denscombe, 2010). Predefined questions are not used as questions but may rather emerge from answers given by interviewees (Thomas, 2003). A main strength of the unstructured interview is that both the interviewer and interviewee have some degree of control over the process. However, a weakness is that the general concept and scope will need to be known in order to prevent total deviation (Saunders et al., 2019).
2) **Structured interviews:** This approach uses questions that are set and relate to the research question or objectives (Denscombe, 2010). They allow a structured approach by asking determined questions to which specific types of answers will be given (Thomas, 2003). A main strength of the structured interview is its suitability when the research objectives are well defined from the beginning. However, a weakness is the general concept and scope, which need to be known in order to prevent total deviation.
3) **Semi-structured interviews:** This incorporates features of both structured and unstructured interviews (Denscombe, 2010). Predefined questions are relied on but not to a great extent as interviewees are given more freedom for further discussion (Thomas, 2003). A main strength of the semi-structured interview is, according to Robson (2002), its programmed questions, but the changeable order depending on the interviewer's perceptions of what seems most suitable. However, a weakness is the greater flexibility in structuring the questions, which this could be seen as a bias since this strategy may direct the interviewee towards the interviewer's desired responses (Saunders et al., 2019). In circumstances when a researcher is familiar with an idea being researched, semi-structured interviews are a recommended data collection technique (Bryman, 2016).

Based on the previous discussion, **semi-structured interviews** will be adopted by presenting a number of questions that collect information on the BIM maturity and KPI metrics used, and how can they both be linked by presenting a BIM maturity assessment to participants who can identify their level of BIM maturity and link it with the KPI metrics (Chapter 4-Sections 4.5.1, 4.5.2, 4.5.3). An update to the framework will be proposed based on the interview findings.

Interview schedule: The interviews will include a set of open and close-ended questions to generate data for the research. The interview will start with close-ended questions to identify the interviewee's current understanding of the adoption and compliance of BIM to the presented KPI metrics, any potential linkage between the two, and whether any benefits exist. This will be supported with open-ended questions to gather an in-depth and rich data. In addition, the interviews will help the researcher to understand the awareness of BIM maturity and KPI metrics amongst organisations, including existing BIM maturity metrics and their assessment, a standardised list of KPI metrics, the linkage between BIM maturity and KPI metrics, and the benefits from linking both through the assessment. Figure 5.17 illustrates the proposed semi structured interview data collection process.

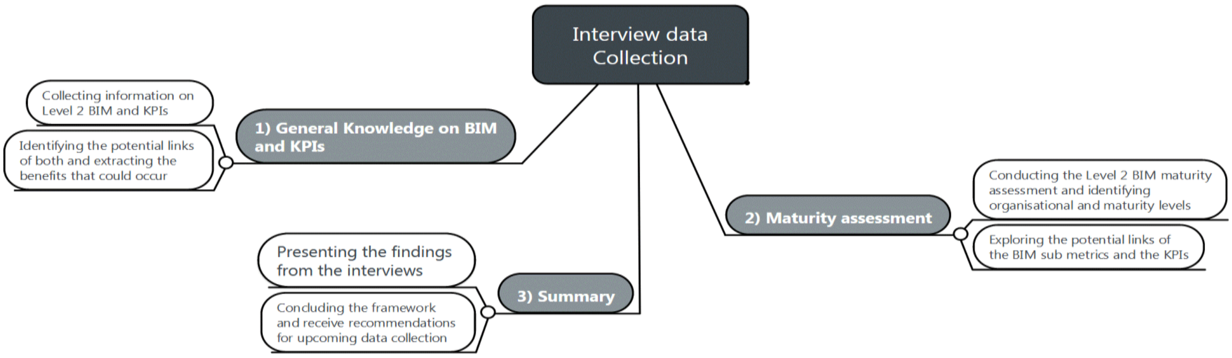


Figure 5.17 Semi structured interview proposed data collection process

The next section will discuss the third data collection technique (questionnaires) in further detail.

5.9.3 Online questionnaires (survey)

According to Saunders et al. (2019), questionnaires are used to gather numerical data, typically through surveys, which may be easier to examine. Collecting objective data on people's behaviour, attitudes and knowledge is possible through the adoption of questionnaires (Oppenheim, 1992). Participant anonymity is maintained, and the generated results are easier to analyse (Denscombe, 2010). A list of questions forms a questionnaire and answers from participants are required. However, the collected responses rely on a similar understanding amongst the participants (Robson, 2002). The questions may vary from open to close-ended and from paragraphs to multiple-choice options. Interview-administered, online and postal, self and delivery/collection are some typical type of questionnaires (Fellows and Liu, 2008). The accepted sample accuracy is be considered for the selection of the appropriate targeted sample. Table 5.3 presents a comparison between workshops, interviews and questionnaires (Naoum, 2013).

Table 5.3 A comparison between workshops, interviews and the questionnaires (Naoum, 2013).

Features	Workshops	Interviews	Questionnaires
Identity of respondents	Known and recognized by researcher and supervision team	Known	Unknown
Interaction between interviewer and respondent	Very close	Close	Distant
Time involving the researcher	All the time	Long time to go through the interview	Short time
Cost	Very high	High	Significantly lower than interviews
Sample	Defined	Small	Large
Quality of Information	Deep and Detailed	Deep and Detailed	Rich
Skill and experience	Minimal skills required, as the researcher will be supported by the team members.	The interviewer needs to have the skill to ask questions, and if necessary, to probe	No skills required
Control of the process	Extremely low as the researcher has to allow participants to talk to each other.	High	Low
Flexibility	High flexibility as the group discussions could be directed to a certain direction and clarifications are made clear.	Allows great flexibility to reword questions and clarify terms that are not clear.	Rigid. The answers are accepted as they are.
Analysis of the results	Easy to analyse.	Difficult and become complicated in the unstructured interviews.	Easy to analyse.
Interviewer bias	The flexibility of focus group workshops allows for bias. A verbal communication exist and will prevent any misleading between interviewer and interviewee.	The flexibility of interviews allows for bias. Sometimes the non-verbal communication or behaviour of the interviewee may mislead the interviewer to incorrect judgement.	If sample is selected appropriately, there should be no bias.

Questionnaires can have a high response rate and may reduce the length of the data collection period. However, distance exists between participants and the researcher, there is less researcher control over the full process, and answers are accepted as received (Naoum, 2013). For this study, an online questionnaire will be adopted, which will include a set of questions related to the strength of relationships between BIM maturity and KPI metrics in a form of a three-five point Likert scale (ranging from strongly disagree to strongly agree).

The questions will follow the same structure as those in the semi structured interviews in order to explore the level of understanding of BIM maturity levels, the usage of BIM maturity and KPI metrics, and the organisational level (Strategic, Implementation, Operational) for each participant. This will be based on the focus group workshop findings, and applied to the BIM maturity assessment, which will be linked with the proposed standardised list of KPI metrics from the semi structured interview findings. This will enable the researcher to extract the benefits of combining both, and would allow for the comparison and contrast between two different audiences (interviewees and questionnaire participants). It will also help to identify the similarities and differences between them, in order to reflect on (and update) the proposed BIM maturity-KPI assessment framework. Figure 5.18 summarises the adopted data collection techniques for this research.

The questions that will be asked during the semi structured interviews and questionnaires will undergo a pilot review, where the list of questions being asked will be reviewed with experts in the field to ensure that the questions make sense and they are collecting the data that meets the aim and objectives of this research. Hence, the final list of questions that will be presented will make sense and will meet the objectives set for this research.

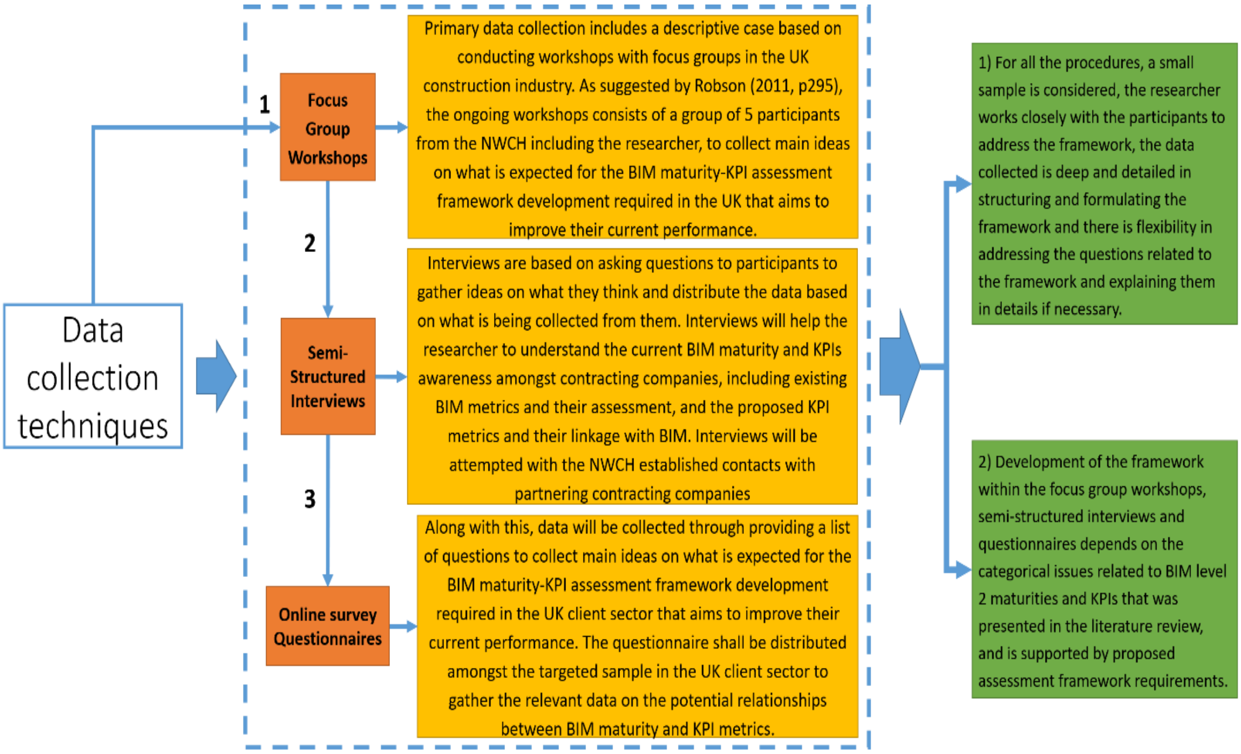


Figure 5.18 Data collection techniques for this research

Having outlined the focus group workshops, semi-structured interviews, and online questionnaires as the adopted data collection techniques, the next section will discuss how each data collection technique will be analysed.

5.10 Data analysis

The data analysis phase investigates the collected data and draws conclusions, which is a vital part of the research (Creswell et al., 2007). Initial study propositions consider the usage of qualitative and quantitative data separately, or in combination, and types, sequences, or patterns of collected data are noted (Yin, 2018). Within this study, the focus group workshops and semi-structured interviews will deliver qualitative data, while the questionnaire survey will deliver quantitative data. Based on the nature of the data collection techniques, this section will address the adopted analysis processes for the qualitative and quantitative data.

5.10.1 Qualitative Data Analysis

Qualitative data analysis focuses on words rather than numbers. Texts are generated either from transcribed recorded data or personal notes and observations, but may include pictures or other images that the researcher examines (Lacey and Luff, 2007). Addressing the initial research propositions requires examination, categorisation, tabulation, or recombining the data analysis (Yin, 2014). Various interpretations may be required which will be achieved through personal experience and the literature review on which the research is based. The development of the framework will rely on a generated set of data analysis (Haron, 2013). The collected data from the focus groups will require analysis after which an updated BIM maturity-KPI assessment framework will be produced. The data will be generated and analysed as follows: First, the qualitative analysis techniques will be presented, followed by the quantitative analysis. Thus, the adopted qualitative data analysis for the focus group workshops and semi-structured interviews includes the following**:**

1) **Thematic analysis:** Braun and Clarke (2006, p. 79) “Thematic analysis is a method for identifying, analysing and reporting patterns within data. It minimally organizes and describes your data set in (rich) detail”. Some of the processes required are:
   a) **Coding Analysis**: (Gray, 2014; Robson, 2011; Saunders et al., 2019): Themes or patterns are searched across a data set (i.e. interviews) that could relate to the research aims and objectives through:
   i. **Open coding:** Finding the categories and developing them into conceptual categories. Working through the process of making constant comparisons, a) Generating initial codes: Coding interesting features of the data in an orderly fashion across the entire data set, collating data relevant to each code.
   ii. **Axial coding:** Linking together the categories developed through the process of open coding. a) Searching for themes: Collating codes into potential themes, gathering all data relevant to each potential theme, and b) Defining and naming themes: Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions for each theme.

The analysis searches for patterns and themes through the top and sub-metrics of BIM maturity and KPI metrics generated in the workshops, and through overarching, main, and sub themes that will be generated from interviewee discussions. The themes will be delivered in a mix of **deductive** (predefined themes) and **inductive** (generating themes), since some of the predefined themes extracted from the literature and previous studies are expected, and accordingly, based on the interview findings, some themes shall be expected to emerge and included with those from the literature.

2) **Content analysis:** Content analysis is a methodology in the social sciences for studying the content of communication. In addition, it is an analytical technique that codes and categorises qualitative data to analyse them quantitatively. Content analysis involves quantifying oriented techniques by which standardised measurements are applied to metrically defined units. These are used to characterise and compare documents that support the research topic area (Haron, 2013). Content analysis of this study requires the

quantification of data concerning the relationship between BIM maturity and KPI metrics and the number of discussions related to each of the distributed themes. Thus, the semi-structured interview data generation type expected includes the following:

Software: Qualitative software Nvivo will be utilised for data coding and analysis for the semi-structured interviews, since it will help to automatically generate nodes (main and sub themes) from the transcribed data. Moreover, it will help to extract the themes and reduce time that would otherwise be spent on manually extracting themes from the transcribed data.

Having discussed the different data analysis processes for qualitative research, the next section shall discuss the adopted quantitative data analysis.

5.10.2 Quantitative Data Analysis

Quantitative data analysis deals with statistical analysis techniques. Such techniques are used to demonstrate results that represent the measurement of variables and summarises a given data set from the representation of samples, whether from the targeted population, the targeted sample or those who participate in the survey (Amaratunga et al., 2002). The quantitative data will aim to present a relationship between BIM maturity and KPI metrics by presenting the BIM maturity assessment across the different organisational levels. This aims to score the maturity level on three levels (awareness, occasional application, and consistency), and determine the strength of relationship between KPI metrics and the levels of BIM maturity through four relationship levels (ranging from no relationship to strong relationship) (Chapter 4, Section 4.5.2). The results will help to validate the proposed conceptual framework. Thus, the adopted quantitative data analysis for the online questionnaire includes the usage of descriptive and inferential statistics. These types of statistics are used to describe data, recognise emerging patterns and generalise the data collected from a known survey population (Laerd. 2013). Two main statistical analysis procedures are adopted to validate the links between BIM maturity and KPI metrics (Chapter 4, Section 4.5.2) (Field, 2017):

1) **Descriptive statistics:** Summarises a given data set from the representation of samples, whether from a targeted population, a targeted sample or from survey participants. The statistics techniques used for descriptive statistics include: Mode (frequency of occurrence), Median (middle value when a data set is ordered from least to greatest), Mean (average), and Standard Deviation [SD] (how much the score deviates from the mean and the minimum and maximum scores). The descriptive statistics for this research will use a mode to determine the most frequent occurrence from the BIM maturity assessment levels (awareness, occasional application, and consistency) to determine current participant BIM maturity levels concerning

the adoption of BIM, and strength of relationships between the BIM maturity metrics and the KPIs (from no relationship to strong relationship) to see if there is an impact by the BIM maturity level on the KPI strength of relationship to each BIM maturity sub metric.

2) **Inferential statistics:** Tend to use more sophisticated analysis techniques when it relies on measurements from a given sample within the delivered population. The inferential statistics for this research will measure the strength of relationship between variables, which will be used through correlation and regression analysis to measure the strength of relationship/association/dependency between BIM maturity and KPI metrics. The data given deals with two main tests (Field, 2017), as follows:

a) Parametric tests: Make certain assumptions about a data set (i.e. mean/SD) drawn from a normal distribution from the entire population and dealing with numerical (quantitative) data. Parametric tests have greater statistical power and present more accurate data. Two different categorical nature data sets exist that deal with parametric tests:

i. **Interval:** Classification with order and distance, but no natural origin. The distance given would be equal. Representation of equality and intervals or differences. [i.e. temperature in degrees, student exam scores, BMI, IQ).

ii. **Ratio:** Classification of order, distance and natural origin. A combination of nominal, ordinal and interval and such a scale would have an absolute zero. Represented by equality of ratios. (i.e. age in years, weight in KG or pounds, height in feet and inches or centimetres and millimetres).

The parametric test will not be adopted in this research since the data that will be drawn from the targeted sample (UK client sector) and their levels of understanding of BIM maturity levels do not require the tests to be normally distributed. This is because the nature of the research suggests the demonstration of a potential relationship between BIM maturity and KPI metrics that does not require statistical power from numerical data that does not use the categorical nature data sets of interval and ratio.

b. **Non-parametric tests:** Does not make assumptions about the entire population on a data set drawn from a non-distribution (distribution free) sample and tends to deal with categorical and continuous (qualitative) data. Two different categorical nature data sets exist that deal with non-parametric tests:

i. **Nominal:** Classification with no order, distance or natural origin. Representation of equality [i.e. 1- Gender; Male or 2- Female; 1- Marital Status; Single, 2) Divorced, or 3) Married].

ii. **Ordinal:** Referred to as an order or categorical measurement and although it has no distance or natural origin, the numerical data is meaningful. Representation of less to greater values. [i.e. level of happiness- one-five very unhappy to very happy, level of agreement- one-five strongly disagree to strongly agree].

The non-parametric test will be adopted in this research since the data that will be drawn from the targeted sample (UK client sector) and their levels of understanding of BIM maturity levels do not require the tests to be normally distributed. This is because the nature of the research suggests a potential relationship between BIM maturity and KPI metrics that will be achieved by collecting data based on the categorical nature data sets of ordinal. The ordinal data in this research is represented through two main sets: 1) BIM maturity levels through three levels (awareness, occasional application, and consistency), and KPI relationship strength through four levels (no relationship to strong), which requires the collection of data based on qualitative interpretations (nominal and ordinal).

As Field (2017) suggests, quantitative analysis is aimed at validating the conceptual framework that will be created from the results of the qualitative analysis involving the focus group workshops, semi-structured interview data and literature. The assessment framework will be refined from the data collected from the online questionnaire concerning how BIM maturity and KPIs can be linked through the demonstration of BIM maturity levels, the strength of the relationship between the BIM maturity and KPI metrics, and the benefits from combining both. Hence, inferential statistics are proposed for interpreting results from the online questionnaire. Inferential analysis will be used to measure the strengths of relationship / dependence between both variables (BIM maturity and KPI metrics). A number of data analysis techniques are associated with inferential statistics that measure the strengths of relationship / dependence between the two variables. The most popular analysis techniques are:

1) **Chi-Square:** Used for testing relationships between categorical variables. The test answers two hypotheses, which are given a Null Hypothesis ($H_{\circ}$) = No relationship between the variables (BIM Sub Metrics and KPIs) and a Hypothesis (H_1) = There is a relationship between the variables. This test is based on values ranging from -1.000_+1.000, and, on the one hand, should the result return a value of 0.000, this would indicate there is no relationship between BIM and KPIs and hence ($H_{\circ}$) would be retained. On the other hand, should the result return a value of ± 0.001_1.000, this would indicate that there is a relationship between BIM maturity and KPI metrics and hence $H_{\circ}$ would be rejected. This test will be conducted with the BIM maturity and KPI metrics as a check to signify the relationship.

2) **One-way ANalysis Of VAriance (ANOVA):** It determines whether there are any significant differences between the means of three or more independent groups within a data set (Field, 2017). This would not be considered since it is not expected to calculate the significance between the average of BIM maturity and KPI metrics. Instead, an alternative test dealing with non-parametric data will be examined. The alternative ANOVA non-parametric tests that exist are detailed as follows (Field, 2017):
   a. **Mann Whitney U test:** The Mann-Whitney U test is *"a statistical test to determine the likelihood that the values of ordinal data variables for two independent samples or groups are different"* (Saunders et al., 2012, p. 674). The test allows two groups or conditions or treatments to be compared without making the assumption that the values are normally distributed. The test will not be undertaken in this research, as the nature of the research does not require a different determination of likelihood for ordinal data values for BIM maturity levels and the KPI strength of relationship. Instead, it requires the researcher to calculate the strength of relationship between both and the dependence levels between both, which do not occur in this test.
   b. **Kruskal-Wallis:** Relies on the rank ordering of data rather than on calculations involving means and variances. It allows a researcher to evaluate the differences between three or more independent samples (Field, 2017). These tests will be used to determine if there is a significance of measures between the BIM maturity levels (awareness, occasional application, and consistency) and the KPI relationship levels (no relationship to strong relationship) based on an alternative Hypothesis (H_1) = there is independence between the variables and their groups. Thus, if the result was found to be significant, then it would reject the (H_1), namely that there is independence between the two groups. This would mean that there is no independence (dependence) between BIM Maturity and KPI metrics. If the result was returned with no significance, then it would accept (H_1) that there is independence between the two groups, which would mean that there is independence between BIM Maturity and KPI metrics.
3) **Relative Importance Index (RII):** Used for generating ranking among variables with cognisance of the relative contribution of frequencies on each scale point of measurement. This test will not be considered since the objectives of this research are not to rate and rank the importance of the variables, ranking the highest occurrence and the importance of either the BIM maturity or KPI sub metrics. Instead, the nature of this research requires an examination of the strength of relationship between both, and RII would not achieve this.

4) **Correlations**: Assesses the strength of relationship between pairs of variables by quantifying the strength of linear relationships between two numerical variables. Similar to all statistical correlation measures, coefficient values (r) lie between +1 and -1 with values closer to +1 denoting a positive correlation, 0 denoting no correlation, while -1 denotes a negative correlation. There are three types of correlation analysis:

   a. **Pearson's correlation coefficient:** A parametric test that is used to establish linear relationships between variables. This is a measure of the linear correlation between two variables X and Y (Field, 2017) that makes assumptions about the frequency distribution of the variables. This test deals with large sample sizes that exceed more than 60 responses (Saunders et al., 2019). This test will not be used since it is necessary to establish the relationship between two categorical variables in an ordinal scale and not an interval scale. It will not make assumptions about the frequency of distribution between BIM maturity and KPI metrics, and it is not necessary to see if the rank order of variables is related. Hence, this test shall not be adopted.

   b. **Spearman's coefficient:** A non-parametric test for statistical dependence between two variables (Jamieson, 2004). The test evaluates the monotonic relationship between two continuous or ordinal variables. The test is based on the ranked values for each variable rather than the raw data (Field, 2017). There are difficulties associated with using Spearman's test with data from either very small samples (less than seven) or large samples (60 and over) (Saunders et al., 2019). This method shall be used because it requires the strength of relationship between the BIM maturity and KPIs metrics in an ordinal scale that will be distributed through the Spearman correlation coefficient, which shows relationships [(no relationship (0), not significant (weak), moderate (medium), and significant (strong)]. The sample size for this research meets the size of 7 – 60 responses and hence this shall be the adopted test.

   c. **Kendall Rank:** A non-parametric test that measures the strength of dependence between two variables. Kendall rank has the ability to measure the strength of association between two ranked variables (Field, 2017). Although the Kendall Rank could have been used as a test of dependence between BIM maturity levels (awareness to consistency) and KPI strength of relationship levels (no relationship to significant relationship), this research aims to measure the strength of relationship between BIM maturity and KPI metrics, and to establish if they are associated and depend on each other. Hence, this shall not be an adopted test.

5) **Regression analysis:** Assesses the strength of cause-and-effect relationship between dependent and independent variables by calculating the co-efficient of determination and regression to distribute significance. There are two types of regression analysis:
   a. **Single or Multiple Linear regression analysis:** Predicts performance across a single or several (multiple) independent variables and a single dependent variable. The regression equation that would be used to demonstrate the results is $\hat{y}=a+bX$ (Field, 2017). A single linear regression analysis shall be used to deliver the cause and effect between BIM maturity and KPI metrics through a scatter plot diagram that will use the regression equation to indicate the regression between BIM maturity and KPI metrics. Should the result return a positive linear relationship, it is going in the same direction so that if a score in one variable (BIM maturity) increases/decreases the other variable (KPI) will also increase/decrease. However, should the result return a negative linear relationship, this indicates it is going in the opposite direction so that if the score in one variable increases/decreases, then the score in the other variable will decrease/increase. Therefore, this shall be the adopted test.
   b. **Ordinal regression:** Describes data and explains the relationship between one dependent variable and two or more independent variables. The dependent variable is ordinal (statistically it is polytomous ordinal) and the independent variables are ordinal or a continuous level (ratio or interval). A few tests are conducted in the regression analysis. This is based on an odds ratio but attempted through proportional odds since it is based on more than two variables. If the estimate is bigger than 0, it implies that you are more likely to get a higher response in a variable over the reference. If the estimate is smaller than 0, this implies you are more likely to get a lower response in a variable over the reference (Adejumo and Adetunji, 2013). Although this research uses two ordinal sets of data (BIM Maturity levels and KPI Relationship levels), this test shall not be used in the analysis since the objective set in this research aims to examine the relationship between BIM maturity and KPI metrics and see if there is an association between them. It does not require the delivery of better predictions, the measurement of the strength of association between variables, or the calculation of estimates that a higher or lower response would be given for the BIM Maturity and KPI Relationship levels. Therefore, this test shall not be adopted.

The quantitative analysis will deliver the results of variables and how they could be linked. This will be attempted through the descriptive and inferential statistics that will consider the potential relationships between BIM maturity and KPI metrics, the strength of their relationship, whether there is an association and dependence between them, and how BIM maturity and KPI are linked. This requires the use of a method that will generate such results. Thus, the online questionnaire will generate data for quantitative analysis:

Software: The researcher will use the Quantitative Software Statistical Package for the Social Sciences (SPSS) program to code and analyse the survey data. SPSS avoids time spent on manual numerical data analysis, and delivers the necessary data to support the findings. Thus, helps to meet the aim and objectives of this research since it helps to demonstrate how BIM maturity and KPI metrics are linked by establishing a potential relationship, including the strength of this relationship, whether BIM maturity and KPI metrics are going in the same or different directions, and if they depend on one another. This potential linkage between BIM maturity and KPI metrics will then be updated through the proposed assessment framework. Having presented the types of analysis used for the collected data, the next section will discuss the available and selected samples for this research.

5.11 Data Sampling

Sampling is the technique by which units from a population are chosen to contribute to the data gathering phase of the research (Saunders et al., 2019). According to Gray (2014) and Saunders et al. (2019), there are three sampling research techniques available, which are:

1) **Probability (representative) sampling:** Selected cases from a population that are known. It is more associated with surveys and questionnaire research. Response rates denote the replies received from the sample size targeted. According to Flick (2011), a suitable sample size for a questionnaire survey shall not be less than **30**, since *"this tends to produce results where individual respondents may skew the results".* The formula used to determine the probability sampling size is:

   $$\mathrm{Na} = \frac{\mathrm{n \ x \ 100}}{\mathrm{Re\%}}$$

   where n= minimum sample size, na= sample size required, re%= estimated response rate in percentage.

   The process to detect a suitable sampling size for research depends on the research aims/objectives/questions, the selection of appropriate sampling techniques, and representativeness of the sample in relation to the population. As this research uses an online questionnaire survey, probability sampling will be adopted. This will be achieved by selecting a sample since the population here will be UK construction industry public sector clients and the sample size will be the sample targeted amongst this group. Thus, a systematic sampling formula will be used to identify the relevant response rates, and to appropriately distribute questionnaires to the UK client sector sample. Krejcie & Morgan (1970), and Sekaran & Bougie (2013) have developed statistical tables outlining the expected numbers for samples (Appendix D). They used a probabillity sampling formula to calculate the sample size, where N is the sample population, and S is the sample size (also known as the confidence level) and represents 1% to 5% of the total population. Therefore, the sample size could be formed into groups (i.e. architecture, structure, real-estate, etc.), which could form a list (Cluster Sampling) on relevant groups from which to collect data.

2) **Non-probability sampling:** Selected cases from a population that are not known. In this technique, no statistical data is generated, which makes it suitable for case study research (Saunders et al., 2016). A sample size is given for each study. For interviews the suggested sample size would be 5-25 interviews; for grounded theory, it would be 20-25, and for a homo/heterogeneous population this would be 4-12 and 12-30. As this research adopts a case study research strategy, then non-probability sampling will be selected. There are five techniques of non-probability sampling:
    a. **Quota:** Non-random used for structured interviews in a survey strategy. The selection of cases within the strata is non-random.
    b. **Convenience:** Gaining access to accessible subjects, such as known contacts, to complete a survey. Interviews could be conducted with this sample.
    c. **Purposive:** Judgement used to select cases to meet the research objectives. Theoretical sampling is used for grounded theory strategies based on the categories and coding.
    d. **Volunteering:** 2 sampling techniques: 1) Snowball: When it is difficult to identify members of population; therefore, there is a need to contact selective cases. 2) Self-selection: This allows each case to identify their interest.
    e. **Haphazard:** Cases are selected without the principles of organisation. This is easily obtainable, such as pre-planned interviews, but may involve bias.

The non-probability sample techniques that will work in this research are **convenience and volunteering**. There are well known contacts that exist in this research and therefore the researcher shall gain access to a sample of UK local authority clients from whom to collect data, within focus group workshops, semi-structured interviews, and questionnaires. The data collected from the semi-structured interviews will use convenience sampling, in which the researcher expects to gain access to interviewees from workshops focus group contacts. Furthermore, the proposed interviews will use a non-probability sampling range of five to 25.

Moreover, snowballing will used by inviting members based on personal contacts; since it is difficult for the researcher to identify members of population there is a need to contact selected cases identified by focus group members. A self-selection process amongst UK construction practices and clients will be adopted, which will help to reduce bias.

Having mentioned that UK clients are the main targeted population sample, it is important to identify the selection criteria for the samples, and how they shall be approached. This will be discussed in the next section.

5.12 Selection criteria

The process of selecting participants for involvement in a study is important since it is vital to deliver information that would help achieve the proposed aim and objectives (Gray, 2014; Robson, 2002). Thus, it is vital to understand and explain how the researcher shall approach the targeted sample. It is mentioned that UK clients represent the targeted sample from the UK construction industry. The focus group workshops will be conducted with NWCH, the researcher shall rely on NWCH personal contacts with existing clients in the UK local authorities. The selection of participants and organisations will be based on multi-level experiences (i.e. participant awareness with BIM and organisations working with Level 2 BIM) to support their transformation towards Level 2 BIM (superseded by BS EN ISO19650 standards). The criteria for selecting participants and organisations for the focus group workshops, interviews, and questionnaires will rely on the following:

1) **Level of experience and knowledge of BIM in general and Level 2 BIM/ BS EN ISO19650 specifically:** It is necessary for participants to have some relevant knowledge of BIM so they can share their experiences and identify BIM maturity metrics. Since this research aims to deliver a proposed BIM maturity-KPI assessment framework to UK clients that follows the governmental mandates for Level 2 BIM (NBS. 2016) (later superseded by BS EN ISO19650 standards), it is important to select participants with a good understanding of Level 2 BIM/ BS EN ISO19650. According to the NBS reports (2019, 2020) levels of experience and knowledge of Level 2 BIM were shown as 70% participants involved in the study and 73% adopted BIM within their organisations, which suggests widespread knowledge of his field.
2) **BIM projects:** Since there has been a mandate to use Level 2 BIM (superseded by BS EN ISO19650 standards) it will be appropriate to approach participants involved with delivering projects that follow the level 2 BIM/BS EN ISO19650 standards. This will be helpful in reflecting and enhancing the proposed BIM maturity assessment and its applicability to these projects.

3) **General BIM being applied:** The organisations should be involved with BIM projects since this research proposes a BIM maturity assessment; thus, it is important to approach organisations that work within a BIM environment to collect relevant information that will help to support the development of the assessment.
4) **Projects that work under a Level 2 BIM environment:** Having approached organisations working within a BIM environment, it will be vital to approach those involved with Level 2 BIM/BS EN ISO19650 standards projects to gain knowledge of how Level 2 BIM/BS EN ISO19650 standards are being used across the projects. This will help to transfer knowledge into the assessment framework as a whole and the BIM maturity assessment specifically.
5) **Multi-functional organisations (consultant, contractor):** It is believed that accessing different organisational disciplines (i.e. consultancy, contracting, etc.) would help develop an understanding of the range of experiences amongst these organisations regarding how BIM is used across organisations in relation to each discipline (i.e. the usage of BIM from a consultant or contractor point of view). Since the BIM maturity assessment will have three organisational levels (strategic, implementation, and operational), it will be completed by different disciplines (i.e. senior managers, BIM coordinators, project managers). Thus, it will be vital to approach various organisations with individuals that would hold similar backgrounds to gather relevant data and evaluate these in relation to organisations.

The proposed criteria cover the relevant requirements when selecting the most suitable organisations and participants for collecting the necessary data from. Accessibility to interviewees will rely on identified contacts from the NWCH platform, which will help to identify suitable people for this research. Accessibility to some of the organisations shall also rely on the organisations identified from the NWCH platform, which will identify suitable organisations for this research. Thus, the selection of the main organisational disciplines that will be involved in the proposed framework will be as follows: **Senior managers** for the strategic level, **BIM coordinators** for the implementation level, and **project managers** for the operational level. Having discussed the selection criteria for organisations and participants, it is necessary to consider how the findings of this research will be produced and achieve the aim of this research, which will be discussed in more details in the next section.

5.13 Validity and Rigour

Validation is important in academic research, since it aims to see if the achieved findings are accurate and reflect the nature of the research (Guion, Diehl, & McDonald, 2011; Haidar, 2019). There are two different aspects of validation, which are internal and external validity (Yin, 2018). Internal validity checks the cause-and-effect relationships established by comparing the data collection findings alongside a critical review of the literature to interpret the `effect' or `response' between both. The process of external validation involves the generalisation of research findings through validating research findings with external participants. Its key purpose is to achieve the generalisation and creditability of the results produced. According to Hair *et al.* (2010), *"where findings are derived from statistical models, validation provides an assurance that the models accurately measure the phenomenon they purport to measure".* There are three types of validation for research (Gray, 2014, Robson, 2002; Saunders et al., 2019):

1) **Reliability:** The use of multiple sources of evidence through surveys, where the generated theory will be examined across the selected sample to increase validity levels within the construction industry (Carmines and Zeller, 1979). Moreover, publishing research findings in conference proceedings/journals tests the reliability. Reliability shows that the researcher's approach is consistent across different cases and projects and minimises any error and bias in the study (Amaratunga et al., 2002). Reliability will be achieved in this research through the use of mixed methods, by collecting data from focus group workshops, semi structured interviews, and online questionnaires from different samples (as explained in Section 5.9). This will allow the data collection results to complement the literature review findings and further support the development of the proposed assessment framework. In addition, the literature review and focus group workshop findings were published as conference papers (Aboumoemen and Underwood, 2017, 2019). Aboumoemen & Underwood (2017) presented a critical review of the key literature from which a proposed BIM maturity-KPI assessment framework was proposed (Section 4.5). Furthermore, Aboumoemen & Underwood (2019) presented a critical review of the key literature from which a BIM maturity-KPI relationship assessment was proposed. This presented the process of how individuals would fill out the BIM maturity assessment to determine their current levels of understanding and the applicability of BIM maturity (awareness, occasional application, and consistency) based on the focus group workshop findings (Section 6.9). It considered how BIM maturity and KPI metrics could be linked in a

relationship assessment (Appendix G). The complete list of referenced publications that support the reliability of this research is available (Appendix I).

2) **Saturation:** This is a process described by various authors to ensure qualitative and quantitative rigour (Saunders et al., 2019). This process ensures no further data are required and thus, the data obtained is sufficient to meet the aim of the research. In terms of the focus group workshops, saturation was achieved by developing the BIM maturity assessment across the three organisational levels (strategic, implementation, and operational) and the KPI metrics initially agreed (Sections 6.10-6.13). The completion of the workshops ensured no further information was required in order to populate the BIM maturity assessments. Hence, saturation was achieved with the finalisation of the BIM maturity assessment at this stage. For the interviews, this was met between the lower and upper region of interviewees (5-25), which examined the assessment of different disciplines and demonstrated how KPI metrics could be linked with the BIM maturity metrics to deliver a finalised set of KPI metrics (Section 7.4.4). The data collected from the interviewees ensured no further information was required to determine the potential linkages of BIM maturity and KPI metrics; thus, the data was saturated. For the questionnaires, this was achieved having reached the relevant response rates for the UK sample (Section 8.3.1) and having examined the statistical significance and relationship between BIM maturity assessments across the three organisational levels and the KPI metrics (Section 8.4.2). The data collected from the online questionnaire ensured there is no further information required to examine the relationships/associations/dependence, to determine the strength of relationship between the BIM maturity and KPI metrics and how they are associated (i.e. moving towards the same or opposite direction). Since no further information was required and having established the relationship, the data were saturated.
3) **Triangulation:** Triangulation is the process of improving data consistency by collecting data from multiple sources (Saunders et al., 2019). The consistency of the research direction across various situations and cases minimised errors and biases, and achieved reliability, (Carmines and Zeller, 1979). It ensures that, should similar procedures be followed by a later investigator, then similar findings and conclusions would be drawn (Amaratunga et al., 2002). Validity is enhanced by triangulation, which involves different sources of information, such as different participants or other researchers. The data was collected through:

a. **Literature review:** The data was collected through different sources of literature, which includes the literature review on Level 2 BIM/BS EN ISO19650 standards, existing BIM maturity assessment/KPI assessments/combined BIM maturity and KPI assessments, and the levels of understanding of BIM amongst UK clients.
b. **Fieldwork:** Data from the literature review was applied to the data collection stage through the case study strategy, NWCH, and the focus group workshops, semi-structured interviews, and questionnaires with UK clients, as discussed in Sections 5.5 and 5.8. This examines the objectives of this research and identifies how BIM maturity and KPIs could be linked and compared with the literature.
c. **External Validity:** From the literature review and fieldwork findings, the data was then carried over to the final phase by updating the proposed BIM maturity-KPI assessment framework and presenting it to the UK client sector. Hence, it meets the aim of this research. The final version of the framework will then aim to establish and identify how BIM maturity and KPIs could be linked together and with the literature and fieldwork findings.

Having presented the validity and rigour process for the research, the next section will deliver the summary of this chapter.

5.14 Summary

The adopted research methods for this research were identified and justified in relation to the Research Onion model. The research methods were designed to achieve the aim of this research. A detailed explanation of the selected data collection phases and data analysis techniques was outlined to explain how the data collection would be achieved. The validity and rigour of the research process was explained in relation to the presented research methods. The methodological process is justified through the selection of the most appropriate research methods that meet the aim and objectives of this research and align with the critical review of the literature. Following the selection of the most appropriate research methods for this research, the data collection will be conducted with the aforementioned sample. The next chapter will discuss the analysis of the first phase of the research (focus group workshops).

Chapter 6: Qualitative (Focus group workshops) data findings

6.1 Introduction

This chapter presents the findings of the focus group workshops, which enabled the development of the organisational BIM assessment and established an agreed list of KPI metrics, as initially identified from the literature. A brief explanation of the processes involved in the focus group workshops will be presented. The selected case study for this research will be outlined and analysed. Next, the conduct of a pilot study prior to the workshops will be explained which offered an opportunity to review the proposed framework (Figure 4.3). After this, the data collected from the workshops will be presented, and the final findings analysed; these were taken forward to the next phase of the study. The next section will present an overview of the single case study selected for this research.

6.2 Overview of the Single Case Study Selection

The selected case study is the North West Construction Hub (NWCH), which is a main contractor-procurement platform for a UK public sector local authority client. Their specialisation is to serve public sector clients across the North West, providing them with higher quality facilities that will include added value, which will be measured through their KPIs (as discussed previously). Their platform aims to deliver projects to their public-sector clients. Figure 6.1 demonstrates the NWCH mechanism, its relationship with partnering and with the local authority.

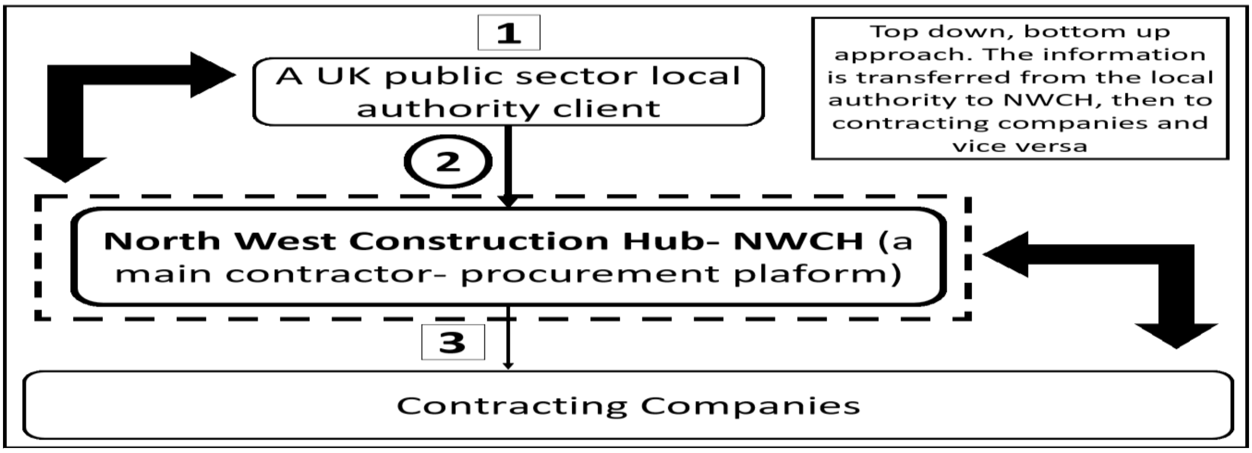


Figure 6.1 The Organisational hierarchy for the NWCH and its role within this research

As shown in Figure 6.1, the NWCH is a key player in the conduct of possible links between local authorities and contracting, partnering companies. The local authority (1 in Figure 6.1) delivers their requirements to NWCH (2 in Figure 6.1), who pass on these requirements to the companies they have contacts with (3 in Figure 6.1). The work planned within the contracting companies will then be transferred to NWCH, who will deliver this to the local authority and receive their feedback. This is illustrated by a top down and bottom up approach that shows how information is passed from one to another. The focus group workshops were conducted within the NWCH platform and based on the framework requirements. The integration of BIM maturity with KPI metrics is proposed to the local authority, and a BIM maturity-KPI assessment framework will be developed with NWCH focus group members, which will subsequently be passed to contracting companies. Currently, the local authority has appointed NWCH to deliver the proposed assessment. Thus, the data collection process for this research will involve the local authority, the NWCH platform and their established contacts with contracting companies. This will increase validity and reliability, as explained in Chapter 5, and allow for the framework to be generalised to other clients. The workshop process will be discussed in more detail in the next section.

6.3 Focus Group Workshops Data Collection Process

A series of focus group workshops will collect information on a list of BIM maturity metrics that need to be populated within each organisational level, and agree a standardised list of proposed KPI metrics (Section 3.7), which would help to finalise the stage 1 of the framework (Section 4.5.1). Upon completion of this stage, the outcomes will feed into the next data collection phases in order to examine and establish the potential links between the two. The focus group workshop process is illustrated in Figure 6.2.

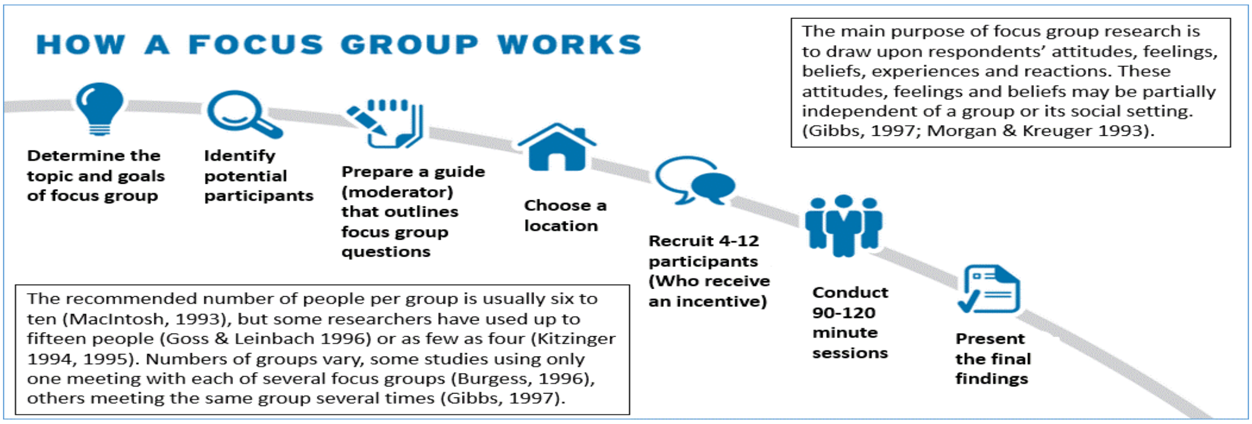


Figure 6.2 Focus group workshops process

The process began by presenting an overview of NWCH that identified the importance of their involvement in this research, and the criteria for the selection of focus group members. Prior to the conduct of the workshops, a meeting was held with NWCH to explain the research requirements, and identify participants best suited for participation. For this, a call for participation was distributed by NWCH, and invitations were distributed to established members. This was based on personal contacts, convenience sampling, snowballing, and members who were believed could usefully contribute to this research. The outcome resulted in the agreement by four members to take part in the focus group discussions. Having recruited the participants, a set of workshops was conducted to discuss the research objectives. The next section will present a summary of the four members who participated in this research.

6.3.1 NWCH Focus Group Members

The research was conducted with the NWCH Digital Construction Working Group that consisted of four members who shared a common background. As such, they are known as a homogenous group, and were identified in this study as P1, P2, P3, and P4. Their roles were as follows: Assistant Framework Manager, BIM Implementation Manager, BIM Co-ordinator, and BIM Manager. A number of workshops was conducted with focus group members, to define the requirements of a BIM maturity-KPI assessment framework; accordingly, the framework was developed. Outcomes relating to BIM maturity were outlined according to the group discussions and findings from the literature on BIM maturity. In comparison, outcomes relating to KPIs were provided by the NWCH platform alongside the literature on KPIs. Emails were distributed to the group to arrange possible dates for workshops; however, these clashed with some group members, so the group had to decide on dates that would suit everyone. Having recruited the focus group members, the researcher checked their background against the criteria on which they were selected (as explained in Section 5.8 in the previous chapter). Table 6.1 presents the complete description of the participants, their background and the criteria used in their selection.

Table 6.1 Background of the selected participants for the focus group workshops

Background and criteria for selecting participants for Focus Group Workshops				
General information	**P1**	**P2**	**P3**	**P4**
Background: (i.e. Architecture)	Public Sector project management, contract & performance management	Architecture and Management	Quantity surveyor	Architectural Technician
Area of expertise: (i.e. Facility Management)	Construction framework management	BIM	BIM	Contractor
Role (i.e. Civil engineer)	Assistant Framework manager	BIM Implementation Manager	BIM Coordinator	BIM Manager
Level of experience with BIM in General: (i.e. Number of years)	< 1	5	3-5	> 5
General Knowledge on Level 2 BIM (i.e. Low, Medium, High)	Low- Good Understanding of the basic principles, benefits and challenges to implement, limited technical knowledge	High	Medium-High	High
Number and types of Projects that you have been involved with that includes level 2 BIM (i.e. 5 Residential projects)	None	2 residential, 4 defence, 5 educational = 11	5 schools, 3 university buildings, 1 mixed use = 9	8 schools (Education), 1 leisure centre (Leisure) = 9
Your personal experience with Level 2 BIM (i.e. enhances delivery of projects, meets projects objectives)	Supporting NWCH manager for the Digital Construction Special Interest Group, made up of representatives from contractors appointed to NWCH frameworks to support clients and drive best practice in BIM delivery within public sector projects. In this case, I am a bridge to the SIG group and NWCH clients.	Provide Asset Information (Graphical and non-graphical) that meets clients requirements and provide information for client to improve operation of the building; improve project quality through facilitating collaboration within the project team; provide better understanding of project through better visualisation of project solutions using 3D models.	Outline deliverables against EIR and ensure these are carried out on the project by the project team. Manage clients expectations and ensure the delivery of BIM is achievable for the project team	At present, my experience is the delivery of the facility data, both in 3D geometry and documentation. BIM Level 2 helps with the delivery of projects. It allows for better collaboration within the design teams and allows for better coordination and spends up the design / coordination process.

All participants share a common background in that they are built environment professionals with expertise in the fields of architecture and surveying. Their level of experience within BIM/digital construction varied from less than one year to more than five years, and their general knowledge on BIM maturity varied from low to high. Of the four participants, only three had experience of BIM projects (between nine to eleven projects), which mainly related to educational, residential, or other mixed uses. This indicates that BIM is mostly applied within the education and residential sector and could reflect on this assessment. Finally, each participant brought their own particular view based on their experience of BIM, which mainly related to meeting clients' requirements, helping with the delivery of projects, and enabling better coordination with design teams. These were recognised as benefits driven by the usage of BIM across various projects. Having presented the focus group members, the next section will discuss the outcomes of the workshops.

6.4 Focus Group Workshops: Discussion and Findings

Having recruited the focus group members for this research and presented an overview of NWCH, a number of workshops were conducted with NWCH focus group members to discuss the research's aim, objectives and requirements. The aim was to further develop the first stage of the proposed conceptual BIM maturity-KPI assessment framework by populating the three organisational levels (Section 4.5.1) and agreeing a list of KPI metrics from the literature (Section 3.7). Eight workshops were conducted, which led to a saturation of the findings; Table 6.2 presents a summary of the discussions and findings.

Table 6.2 Focus group workshops discussions

Focus Group Workshop discussions and findings		
Number of workshop	**Workshop discussions**	**Findings**
Workshop process	**a) Presenting the research aim and objectives.** **b) Review on previous BIM and KPI frameworks from literature.** **c) Presenting a BIM maturity- KPI assessment framework and emerged list of KPIs**	**a) Level 2 BIM Maturity-KPI assessment framework.** **b) 3 organisational levels [Strategic-Implementation- Operational] (Aboumoemen, 2016)** **c) Agreement to the list of KPIs**
Workshop 1	**a) The NWCH vision on the BIM-KPI linkage.** **b) The mechanism by which the organisational levels would work (The overall scoring and presentation of the sub metrics and maturity levels).**	**a) The layout by which the organisational levels would be presented.** **b) The legend of the 3 maturity levels (1-1.6= Awareness, 1.6-2.4= Occasional Application, and 2.4-3= Consistency)**
Workshop 2	• **Discussion on the Strategic level (Up to the Collaboration Top metric stage with its sub metrics)**	• **Strategic level draft**
Workshop 3	• **Discussion on the Strategic level (Completion of the Strategic Organisational level)**	• **Strategic level Completed**
Workshop 4	• **Discussion on the Implementation level (Up to the Processes Top metric stage with the sub metrics) and review on the Strategic level**	• **Implementation level draft**
Workshop 5	• **Discussion on the Implementation level (Completion of the Organisational Implementation level)**	• **Implementation level Completed**
Workshop 6	• **Discussion on the Operational level, (Up to the Capital Delivery Top metric stage with the sub metrics) and review on the Strategic and implementation levels**	• **Operational level draft**
Workshop 7	• **Discussion on the Operational level, (Completion of the Organisational Operational level)**	• **Operational level Completed.**
Workshops 8	• **Presentation on all 3 completed levels to agree on the presented findings**	**a) Final agreement on all 3 organisational levels** **b) Confirmation to the set of KPIs to be taken forward**

The workshops were structured to meet stage 1 of the framework development. According to the structure of the workshops (Table 6.2), the data collected were split into four sections:

1) A pilot study was conducted to review and validate the proposed BIM maturity and KPI assessment framework (Section 4.5) and to review the KPIs (Section 4.5.1).
2) **Workshop One:** Addressed the layout of the organisational levels. The first workshop explored a level 2 BIM maturity/KPI assessment framework, which consisted of three organisational levels (Strategic, Implementation, and Operational) and the relationship between BIM maturity and KPIs. A decision on the maturity level scoring was decided the mechanism was explained on how the organisational level spreadsheets would work.
3) **Workshops Two-Seven:** Considered the outcomes of each organisational level. A series of discussions were held to populate the Top and Sub metrics along with their descriptors according to the latest available BIM information. Thus, the maturity level descriptors were populated according to the metrics and descriptors. The process of populating each organisational level was conducted across the six workshops, where two workshops each focused on finalising each organisational level.
4) **Workshop Eight:** Reviewed the workshop findings and their relevance to the new BS EN ISO19650 standards. This session presented the three completed levels; it aimed to finalise and amend any final changes if necessary and confirm the list of KPI metrics from the literature.

Discussions on the framework depended on the information related to BIM maturity and KPIs as presented in the literature review, which supported the development of the framework. The BIM maturity and KPIs findings were presented during the workshops, which helped to generate a standardised list of BIM maturity and KPI metrics, thereby concluding stage 1 of the framework's development. In addition, the benefits that were expected from linking BIM maturity and KPI metrics were explored. A number of questions relating to each organisational level were posed in each workshop, which based on the framework development and the organisational level discussed, differed from one workshop to another.

The workshops were conducted at NWCH, as its location was ideal for focus group members. Each workshop was digitally recorded, and supplemented with note taking to capture relevant information; this helped to avoid the substantial consumption of time consuming involved in transcribing, which could include irrelevant information. Each workshop lasted between one to two hours, and information or documents collected from the workshops were summarised. Each workshop only finished once saturation was reached. An informed consent form and organisational agreement letter were presented to NWCH, and were signed at the first workshop;

this ensured that ethical consideration for the research were met (both are included in Appendix E). Having presented the workshop structure and discussions across the workshops, the next section presents the findings of the pilot study session, which reviewed the framework and collected feedback. This was held prior to the focus group workshops, which subsequently validated stage 1 of the framework (Table 6.2).

6.5 Pilot study to Review the Proposed Framework (Experts' Opinions)

This section presents the outcomes of the pilot study session; it presents the proposed conceptual framework and the feedback offered prior to the workshops, which later populated the three organisational levels, reviewed the list of KPIs, and finalised stage 1 of the framework (Table 6.2). This was conducted with a client organisation when an overview of the organisation was given. The process then proceeded with initial feedback on the current conceptual framework. A quick review of the literature review findings was given, which explained the proposed framework to determine whether it was appropriate or would need adjustments.

6.5.1 Pilot study process

According to Richard et al. (2009), research theories and concerns focus specifically on pilot studies, which help to develop research with experts prior to the full conduct of the study. Illustrative quantitative study pilots are undertaken for qualitative research as, *"many features of … design could not be determined without prior exploratory research"* (Richard et al., 2009). In order to obtain clarification on research design features, it is essential to carry out pilot studies (Yin, 2014). Data was collected from a client organisation as part of the pilot study, identified as organisation C. The next section will present an overview of the organisation.

6.5.2 Organisation C: Background and Feedback

Organisation C is a National Government body for a city council contracting platform. It was selected as part of the validation process for the proposed framework (Figure 4.3). The organisation is a partner with the main contractor-procurement platform, and involved in previous work related to this research (Aboumoemen, 2016). This involved the conduct of a number of focus group workshops with members to collect information on the expected links between BIM maturity and KPI metrics.

A client session was arranged for which the organisation invited clients to a workshop session when the research was explained in detail (Appendix E). The main feedback received on the proposed framework was positive, but clarification was required; for example, one of the clients indicated that: "*it would be better to focus this work on the relationships between outcomes created via the usage of BIM and KPIs within the construction industry*". Therefore, a number of data collection procedures is required with the UK sector to explore and establish the links between BIM maturity and KPI metrics. Having presented the pilot study session's outcome for the framework, the next section will present the workshop process.

6.6 Workshop Process

As the focus group moderator, P1 was responsible for organising and presenting the discussions for each workshop, along with the developed framework. The workshop process presented each organisational level individually in order to eventually populate and finalise the organisational levels, and agree to a standardised list of KPI metrics. For the workshop process, a brief overview of NWCH's specialism was outlined across the group members; a descriptive document that summarises the information to be collected was presented. Furthermore, it was identified that BIM maturity acts as an input for the framework whereas KPIs act as an output, whilst the benefits of BIM across the UK were also recognised.

An explanation was given on previous frameworks and their links with BIM maturity and KPI metrics (Section 4.4); moreover, the framework stages (Sections 4.5.1-4.5.3) for this research were clarified. A list of documents was presented by group members to further supplement the framework, and this supports the development of the proposed framework and based on previous, identified BIM and KPI frameworks (Aboumoemen, 2016; Badrinath et al., 2019; Mom & Hsieh, 2012; Shin et al., 2015; Wong et al., 2016) Those documents are as follows:

- A Level 2 BIM checklist.
- A BIM measurement tool.
- NWCH KPIs (NWCH. 2015) (Appendix E).
- NWCH BIM-KPI vision (Figure 6.3).
- Three Organisational levels (Aboumoemen, 2016).

The next step was to present the developed framework in this research (Section 4.5), to explain the main aim and objectives underpinning the development of a BIM maturity-KPI assessment framework and how it would be met. The same sequence was undertaken to break down the framework and explain its stages (Chapter 4); however, greater emphasis was placed on stage 1, which involved the collection of data that would structure and deliver the complete BIM maturity and KPI metric outcomes.

The three organisational levels were presented and a brief outline was given on the drafted metrics and the users were assigned to fill out the assessments discussed, explain the vision of the previous study and determine how it would reflect on this research. Finally, the KPIs (Section 4.5.1) were presented to explain the main difference between not having a list of KPI metrics to take forward (in accordance with previous studies), and having a standardised list of KPIs (Section 4.5.1), based on the literature findings and determining how they would be linked with BIM maturity metrics. It was recommended that focus group members present their thoughts on the list of KPI metrics, including whether other KPI metrics may be included, existing ones amended, or indicate agreement with the presented list, which would then be taken forward to the next data collection phases.

The next section will present the discussions conducted in the focus group's first workshop, which involves reviewing the framework's first stage. This involved the mechanism by which the organisational level would work, and the findings from the first workshop, which consisted of the three organisational levels, along with the list of KPIs (Section 4.5.1).

6.7 Workshop 1: Analysis and findings

At the start of the first workshop, focus group members presented a list of documents to support the proposed framework:

- Fifteen NWCH KPIs that are currently used in the platform (Appendix E).
- The potential benefits of BIM maturity and KPI metrics with previous client and stakeholder studies (Figure 4.12).
- A checklist used for BIM and how it could support the development of BIM maturity.
- A BIM measurement tool that explains how it could help support development of BIM maturity and KPIs, and how it could work within the platform.
- The organisational levels: Strategic, implementation, and operational (Aboumoemen, 2016).
- A vision of NWCH's BIM-KPI approach (Figure 6.3).

The NWCH's vision of BIM-KPI (Figure 6.3) indicates how it sees links through a proposed framework, (understanding), how this would be linked with industry disciplines (input) what are the achieved outcomes in relation to BIM maturity and KPI metrics (outputs), and how would be industry disciplines involvement and ideas reflect towards the outcomes related to the BIM maturity and KPI metrics towards establishing a link between both and illustrating this through a proposed framework (mapped inputs against outputs). This vision reflects back to a previous study (Aboumoemen, 2016) where it was expected to present a Level 2 BIM maturity and KPI framework to the NWCH and how it will operate within the platform.

The elements in this vision offers a general overview of NWCH and, for this research, more emphasis is placed on the client (input), and the BIM maturity and KPIs (outputs), since these represent the main aim and objectives. Figure 6.3 demonstrates the complete vision of the BIM-KPI approach by NWCH.

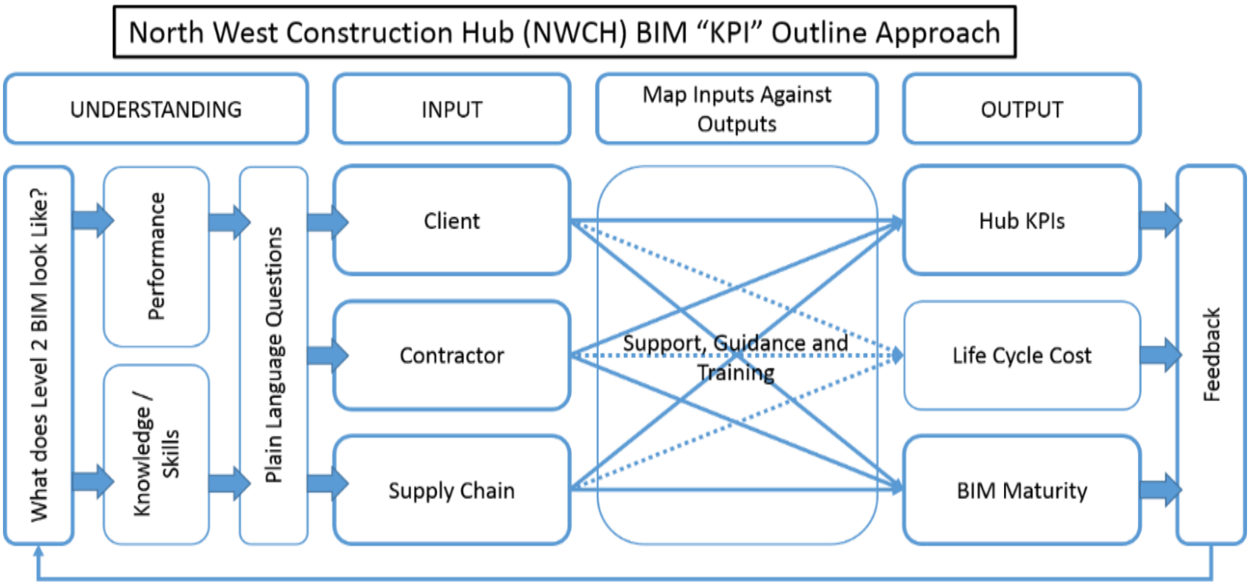


Figure 6.3 NWCH BIM-KPI vision

The layout of the organisational levels was presented, i.e. the mechanism by which the organisational levels were completed, and how would the organisational levels look after completion. Based on the previous discussion, changes to the strategic level spreadsheet were made to address the feedback. A sample of how the spreadsheet will work is shown in Figure 6.4, and the mechanism showing how the spreadsheet will work is based on the following steps:

1) The user will review the BIM maturity descriptors, as shown in step 1, where the description for each sub metric in terms of its maturity level will appear as hidden comments.
2) After the user decided on their current level, the user clicks on a drop-down list cell, as shown in step 2, which will bring up the maturity levels 1-3.
3) Based on the colour coding given in "The how" stage for each maturity level, the selected number should automatically convert to that colour (i.e. Awareness=Orange) as shown in step 3.
4) Since the comment is hidden, the user will be required to right click on the coloured cell and select 'Show Comment' as shown in step 4.
5) After the previous step, the description of each cell should appear (step 5).
6) Finally, all the previous steps are repeated in the same sequence, and upon completion of the strategic level, the calculation of the maturity level in total will appear (step 6).

The formula that the user chose was: 1) The average of all the numbers, and 2) The total will then be: a) From 1-1.9=Awareness, b) From 2-2.7= Occasional Application, and c) From 2.7-3= Consistency. A summary is shown (Figure 6.4 below).

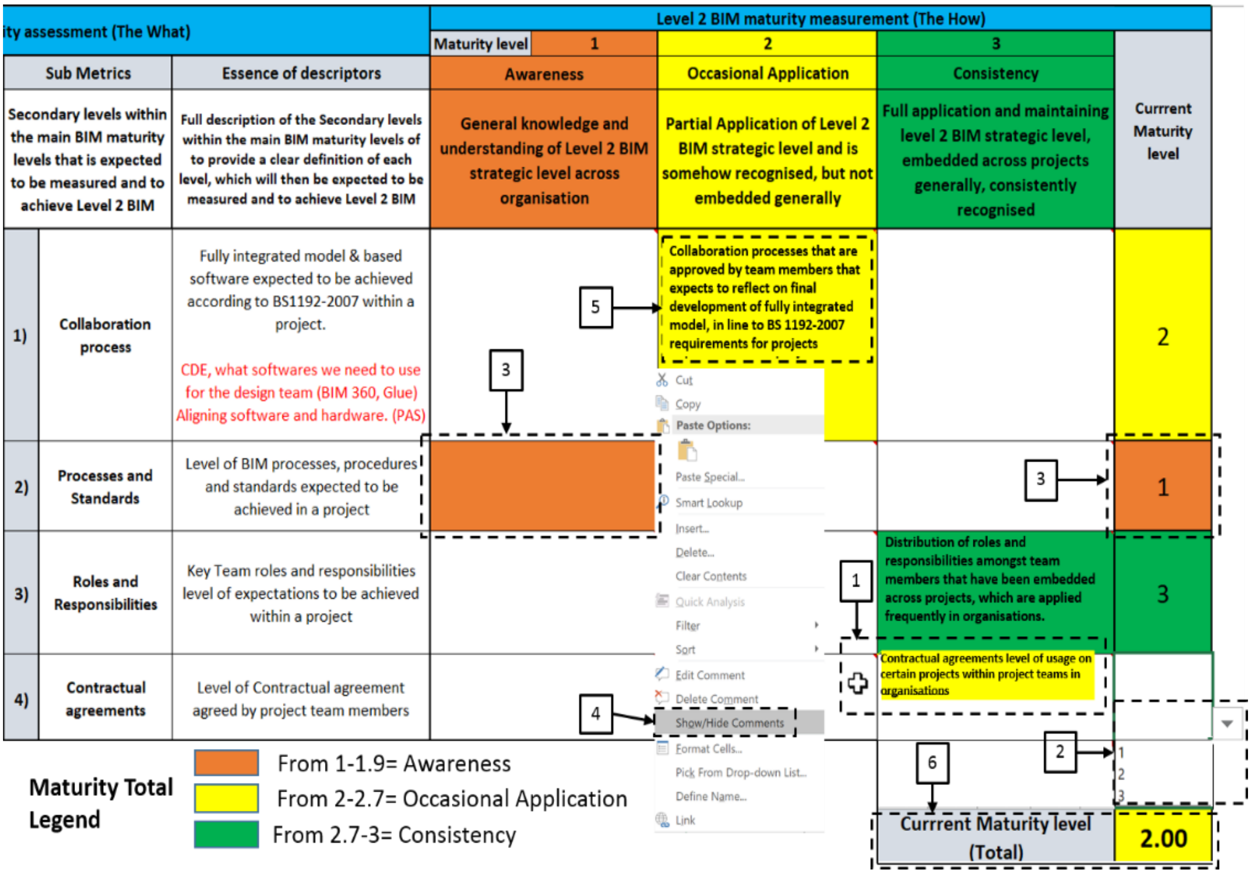


Figure 6.4 Sample of the Organisational level layout development process

6.7.1 Workshop 1 Feedback

After presenting the list of supporting documents for the proposed framework, the focus group provided their feedback. It was acknowledged that:

- The organisational levels: BIM top metrics were targeted for the UK sector in general, but not the client specifically; as a result, the current top metrics need revision in order to meet the client sector demand.
- Furthermore, it was agreed that each organisational level is discussed separately to make it easier for everyone to provide their inputs on what is required. In relation to the strategic level, P3 recommended that "*There is a need to include a formula for the maturity level calculation*". P3 also added that "*The current descriptors are too much for the assessment and causes a confusion for the reader, and thus they need to be hidden, and the duplications that existed (i.e. implementation) needs to be removed*".
- P2 and P4 explained how current KPIs will be measured and related to clients.
- A general proposition was considered on the need to consider the Level 2 BIM standards, such as the BS1192. This would involve the development of a BIM maturity tool for application within a company and as part of the company's strategy to adopt BIM. The tool would be used to educate clients in the adoption of BIM maturity.

- It was recommended that the main contribution of this work would be to deliver this assessment to the client sector.
- All participants were involved in discussions on the BIM measurement tool (Figure 4.2), for which they were required to access the Excel spreadsheet and insert some adjustments to the current descriptors.
- It was proposed that participants offer some ideas on relevant information for the strategic level. Based on the discussions, information at the strategic level was changed, such as: 1) Roles and responsibility, 2) Procurement routes, and 3) EIRs, in terms of descriptors and maturity descriptors.

After the layout of the organisational levels was presented, the focus group provided their feedback. They recommended the following:

- To review a maturity assessment conducted with a similar local authority to see how the assessment was conducted and how it may reflect on the proposed assessment. Based on the descriptors for Top, Sub Metrics, and maturity levels, participants proposed the revision of terminology to fit with the spreadsheet and allow better understanding amongst different users and clients.
- All participants agreed to the concept used that allowed users to simply understand each sub metric and their descriptors in the spreadsheet.
- However, participants suggested lowering the numbers in the formula chosen for the total maturity, as not all users would score within the provided range. Hence, it was agreed that the formula should be changed to the following: **1-1.6= Awareness (Aw)**, **1.6-2.4= Occasional Application (OA)**, and **2.4-3= Consistency (Co)**, and P3 indicated that: "*Usually whoever undertakes the assessment will score up to 2.4. BIM guide, BIM co-ordinator, design manager will probably score highly, whereas the technical guide could score up to 1.6, and other managers could score below than 1.6*".

Discussions in the next workshop aimed to start populating the spreadsheet, for example, by adding some sub metrics, and adjusting the descriptors. The sub metrics related to the collaboration top metric were reviewed and comments were addressed, but participants proposed that the spreadsheet could be populated by adding or removing sub metrics and adjusting the maturity level descriptors within forthcoming workshops. Towards the end of the workshop, some information on existing BIM maturity assessments was presented, and a list emerged in this research (Section 3.4), which was reviewed and analysed for the next workshop. The next section presents findings from the discussion across all organisational levels.

6.8 Workshops 2-7: Key Discussions on Organisational Levels

Having discussed the layout of the organisational levels and presented the NWCH BIM-KPI vision, discussions were subsequently held on each separate organisational level. However, a review of more than one level was conducted where necessary (i.e. BIM metrics that would overlap the three levels). The key topics covered focused on the final outcomes (Table 6.3). These outcomes would be the discussions covered since they provided full coverage of how the organisational levels would be filled and tailored to clients.

Table 6.3 Organisational levels workshop Key discussions areas

Final Outcome
Populating each organisational level according to Level 2 BIM standards (BIM Level 2. 2016; NBS. 2016).
This would require amending the existing information on the organisational levels (Awareness, Occasional Application, Consistency) where necessary (Top and Sub metrics, along with their descriptors)
The same process would be conducted with the maturity level descriptors
Where overlaps may occur (i.e. Sub metrics in Implementation level to exist in the Strategic / Operational level), a comparison would be made, and information provided was to be tailored for each organisational level to differentiate between their existence in more than 1 organisational level.
Further information may be provided for each Sub metric to give a better understanding on how it works and examples of how the sub metrics are used within practices.

As presented in Table 6.2, the structure of the workshops focuses on the participants to revisit the relevant BIM standards to review the presented Level 2 BIM metrics and amend where possible to address the relevant Level 2 BIM top and sub metrics according to each organisational level (Strategic, Implementation, Operational). This will include providing a description to each of the top and sub metrics and providing a maturity descriptor to each of the sub metrics based on 3 maturity levels (Awareness, Occasional Application, Consistency). This will be conducted by populating the metrics alongside with their descriptors according to the available BIM standards, where each of the organisational levels will be conducted across 2 workshops as follows:

1) **Workshops 2 and 3**- The development process of the Strategic level will be conducted and the final maturity assessment for this level will be presented in the end of workshop 3.
2) **Workshops 4 and 5**- The development process of the Implementation level will be conducted and reviewed with the Strategic level's maturity assessment (where necessary), and the final maturity assessment for this level will be presented in the end of workshop 5.
3) **Workshops 6 and 7**- The development process of the Operational level will be conducted and reviewed with the Strategic & Implementation levels' maturity assessment (where necessary), and the final maturity assessment for this level will be presented in the end of workshop 7.

Having explained the process of the workshops and the findings that will be generated from the completion of each workshop, the next section will present the analysis and findings related to the Strategic level.

6.8.1 Workshops 2 and 3: Analysis and Findings for the Strategic Level

The second workshop focused on discussions on the strategic level and its components, which meant participants revisited the previously completed information concerning the top and sub metrics, their descriptions, and maturity level descriptors. For this workshop, discussions covered the Collaboration Top Metric, and the sub metrics were populated and amended alongside their descriptors and maturity level descriptors. Towards the end of the workshop, comments were noted that addressed on some of the sub metrics for the collaboration top metric. They were reviewed and analysed in the next workshop when the strategic level (Appendix E) was also discussed in detail. The previous conducted strategic level (Appendix C) was discussed in detail in the third workshop. Figure 6.5 presents the first development process of the strategic Level. This included the findings of the existing metrics, their descriptors, and the overlaps of the metrics with the organisational levels (Highlighted in red); presented in the top layer of the figure, and the finalised outcomes of the assessment, which demonstrates the update from just having the metrics and their descriptors, towards having the 3 level maturity descriptors for each sub metric; presented in the bottom layer of the figure. The same development process will be repeated across all the workshops towards presenting the final assessment for each organisational level.

BIM Level 2 maturity assessment (The What)			
	Top Metrics	Sub Metrics	Essence of descriptors
	Main BIM maturity levels and their descriptions that are expected to be measured for achieving BIM level 2	Secondary levels within the main BIM maturity levels that is expected to be measured and to achieve BIM level 2	Full description of the Secondary levels within the main BIM maturity levels of to provide a clear definition of each level, which will then be expected to be measured and to achieve BIM level 2
a	Collaboration	1) Collaboration process	• Fully integrated model & based software expected to be achieved according to BS1192-2007 within a project
		2) Processes and Standards	• Level of BIM processes, procedures and standards expected to be achieved in a project
	(Collaborative behaviour strategies expected to be present in a complete project to meet BIM level 2)	3) Roles and Responsibilities	• Key Team roles and responsibilities level of expectations to be achieved within a project
		4) Contractual agreements	• Level of Contractual agreement agreed by project team members
		5) Champion engagement	• Presence of a BIM champion (advisor) within a project and levels of engagement expected.
	(Implementation)	6) Level 2 Education and Training	• Level of education and training expected to be present within a team to achieve BIM level 2
	(Implementation)	7) Procurement route	• Expected procurement route related to BIM to be achieved in line with project needs
	(operational)	8) Collaborative protocols	• Level of collaborative protocols being applied within projects by team members

Level 2 BIM maturity assessment (The What)					Level 2 BIM maturity measurement (The How)			
				Maturity level	1	2	3	
	Top Metrics		Sub Metrics	Essence of descriptors	Awareness	Occasional Application	Consistency	
	Main BIM maturity levels and their descriptions that are expected to be measured for achieving Level 2 BIM		Secondary levels within the main BIM maturity levels that is expected to be measured and to achieve Level 2 BIM	Full description of the Secondary levels within the main BIM maturity levels of to provide a clear definition of each level, which will then be expected to be measured and to achieve Level 2 BIM	General knowledge and understanding of Level 2 BIM strategic level across organisation	Partial Application of Level 2 BIM strategic level and is somehow recognised, but not embedded generally	Full application and maintaining level 2 BIM strategic level, embedded across projects generally, consistently recognised	Currrent Maturity level
a)	Collaboration	1)	Collaboration process	Common Data Environment (CDE), Softwares required for the design team to use (BIM 360) and aligning softwares with the hardware (BS 1192:2007, PAS 1192-2:2013, PAS 1192-3:2014)	No awareness of systems to be used	Common Data Environment (CDE) identified that are compliant with Level 2 BIM standards and free viewer	Systems that are able to integrate the BIM models (CDE) that are compliant with Level 2 BIM standards into operations.	1
		2)	Processes and Standards	Level of BIM processes, procedures and standards expected to be achieved in a project. Some UK Level 2 BIM standards examples to follows are: (BS 1192:2007, PAS 1192-2:2013, PAS 1192-3:2014, PAS 1192-5:2015, BS 8541-1:2012) More information is available at: [https://www.bre.co.uk/page.jsp?id=3508]	Aware and understand what the UK BIM Level 2 standards are, but not embedded. Minimal understanding of the CAPEX and OPEX	Understanding and partially implementing the UK BIM Level 2 standards. Partial understanding of the CAPEX and OPEX	Understanding and fully implementing the UK BIM Level 2 standards. Fully understanding and application of the CAPEX and OPEX	
		3)	Roles and Responsibilities	Key Team roles and responsibilities level of expectations to be achieved within a project	Minimal understanding of roles defined in PAS 1192-2:2013 and no internal resources	Partial understanding of roles defined in PAS 1192-2:2013 and have limited internal resources	Distribution of roles and responsibilities amongst team members that have been embedded across projects which are applied frequently in organisations.	
	(Collaborative behaviour strategies expected to be present in a complete project to meet Level 2 BIM)	4)	Contractual agreements	Level of Contractual agreement agreed by project team members	Minimal Understanding of how form of contracts are some awareness of alignment and no previous experience with Level 2 BIM.	Good understanding of how form of contracts are and alignment of standards with Level 2 BIM projects (i.e. 1 to 2 project).	Full understanding of how form of contracts are and alignment of standardised clauses to contract document (i.e 5+ projects).	
		5)	Level 2 Education and Training	Level of education and training expected to be present within a team to achieve Level 2 BIM	No internal or staff training on Level 2 BIM, and no awareness of roadmap required.	Awareness training required and producing a roadmap, and some staff training in the basics.	There is a full training strategy for the Level 2 BIM and a metrics of (minimum of 50-60% of relevant staff).	
		6)	Procurement route	Client fully understand how each procurement route will impact on the BIM deliverables	Not aware which route is the best for the client and the project.	Some confidence in a particular procurement route and how Level 2 BIM is being implemented from stage 1.	Full confidence in correct procurement routes for the client in particular projects and how Level 2 BIM will be used from stage 1.	

Figure 6.5 Strategic Level: First development process [Existing findings (top layer), and adjusted (bottom layer)]

The third workshop continued discussions on the strategic level. Participants reviewed the metrics populated in the previous workshop, and completed the organisational level with inputs concerning “The What stage- BIM top and sub metrics, and essence of descriptors”, and “The How stage- maturity levels descriptors for the awareness, occasional application, and consistency level”. Discussions reviewed findings from the previous workshop and specifically considered the top metrics for employers’ requirements and facilities management. Participants populated and amended the sub metrics associated with each top metric, and provided sub metric descriptors and maturity level descriptors. A number of adjustments were conducted where some sub metrics were removed and replaced by others, and the descriptors used for the maturity levels were adjusted to reflect clients’ and users’ understandings. Figure 6.6 presents the second and final development process of this level.

BIM Level 2 maturity assessment (The What)			
	Top Metrics	Sub Metrics	Essence of descriptors
	Main BIM maturity levels and their descriptions that are expected to be measured for achieving BIM level 2	Secondary levels within the main BIM maturity levels that is expected to be measured and to achieve BIM level 2	Full description of the Secondary levels within the main BIM maturity levels of to provide a clear definition of each level, which will then be expected to be measured and to achieve BIM level 2
b	**Employers' requirements** (Defining stakeholder needs for projects to be able to achieve BIM level 2) **(Implementation)**	1) Specialist Consultants engagement	• Engagement levels achieved by Specialist Consultants to support the Employers Information Requirements
		2) Design elements	• Design elements requirements expected to be achieved by contractor to be included in the EIRs.
		3) Information Requirements (EIR)	• Presence of Employers Information Requirements and level of requirements expected for Employers
g	**Facilities Management**	9) GSL champion engagement	• Presence of a GSL champion (advisor) within the FM stage and levels of engagement expected.

Level 2 BIM maturity assessment (The What)					Level 2 BIM maturity measurement (The How)			
					Maturity level 1	2	3	
	Top Metrics		Sub Metrics	Essence of descriptors	Awareness	Occasional Application	Consistency	Currrent Maturity level
	Main BIM maturity levels and their descriptions that are expected to be measured for achieving Level 2 BIM		Secondary levels within the main BIM maturity levels that is expected to be measured and to achieve Level 2 BIM	Full description of the Secondary levels within the main BIM maturity levels of to provide a clear definition of each level, which will then be expected to be measured and to achieve Level 2 BIM	General knowledge and understanding of Level 2 BIM strategic level across organisation	Partial Application of Level 2 BIM strategic level and is somehow recognised, but not embedded generally	Full application and maintaining level 2 BIM strategic level, embedded across projects generally, consistently recognised	
b)	Employers' requirements (OIR)= Organisation information requirements, and (AIR)= Asset Information Requirement (Defining stakeholder needs for projects to be able to achieve Level 2 BIM)	1	Design elements	Design elements requirements expected to be achieved by contractor to be included in the EIRs.	No awareness and nothing included in the EIR.	Some understanding of the main packages (i.e groundworks, structure, MEP and architecture, external works) covered.	Full understanding and inclusion of a standardised matrix table that covers all contractor design portions (2D and 3D).	
		2)	Information Requirements (EIR)	Presence of Employers Information Requirements and level of requirements expected for Employers	No ability to develop an EIRs or no abillity to assess the quality of an EIR.	There is a basic understanding of the quality and what should be an EIR, and the ability to develop an EIR with or without the help from a consultant.	Ability to Complete EIRs specific identifies which the clients need for thir facilities.	
		3)	Asset Information Requirement (AIR)	Presence of Asset Information Requirements and level of requirements expected for project team	No ability to develop an AIRs and no understanding of Asset requirements to run and manage a facility.	Understanding of the Asset requirements and basic outline of them and some understanding of COBie.	Full COBie asset registered and submitted as part of the EIR documentation.	
c)	Facilities Management (Operational, maintenance, and lifecycle building performances that is expected to be conducted by the FM team for asset management to achieve Level 2 BIM)	1)	GSL champion engagement	Presence of a GSL champion (advisor) within the FM stage and levels of engagement expected.	Traditional system and no awareness of COBie and BIM models & use.	Able to use model data but not integrated with FM systems and procedures.	Fully integrated systems that can use the model and information contained with for operations and maintenance.	
							Currrent Maturity level (Total)	1.00

Figure 6.6 Strategic Level: Second and final development process [Existing findings (top layer), and adjusted (bottom layer)]

At this stage, the organisational strategic level was completed (shown in Figure 6.7), and it was agreed that Senior Managers were be suited to review this level. Having completed the strategic level, the next workshop involved discussion on the implementation level, and participants recommended considering the strategic level to identify the points at which the populated information would relate to the implementation level.

BIM maturity assessment (Transition from level 2 BIM to the new BS EN ISO19650 standards)											
Organisation		Top Metrics		Sub Metrics			Essence of descriptors	Maturity level	1 = Awareness		Currrent Maturity level
No. #	Level	Main BIM metrics and their descriptions		Secondary metrics associated with the main BIM metrics that is expected to be measured to achieve BIM			Description of the secondary metrics to provide a clear definition of each metric	General Knowledge and understanding of BIM metrics in Strategic level, but is sometimes not being recognised across the organisation 2 = Occasional Application Partial Application of BIM metrics and is somehow being recognised, but is not being embedded generally 3 = Consistency Full application and maintaining BIM metrics, is consistently recognised, and is being embedded across projects generally			
					level 2 BIM	ISO19650					
1)	STRATEGIC	a)	Collaboration (Collaborative behaviour strategies expected to be present in a complete project to meet BIM)	1)	Collaboration process		Common Data Environment (CDE), Softwares required for the design team to use (BIM 360) and aligning softwares with the hardware (BS 1192:2007, PAS 1192-2:2013, PAS 1192-3:2014)	No awareness of systems to be used	Common Data Environment (CDE) identified that are compliant with Level 2 BIM standards and free viewer	Systems that are able to integrate the BIM models (CDE) that are compliant with Level 2 BIM standards into operations.	1
				2)	Processes and Standards		Level of BIM processes, procedures and standards expected to be achieved in a project. Some UK Level 2 BIM standards examples to follows are: (BS 1192:2007, PAS 1192-2:2013, PAS 1192-3:2014, PAS 1192-5:2015, BS 8541-1:2012) More information is available at: [https://www.bre.co.uk/page.jsp?id=3508]	Aware and understand what the UK BIM Level 2 standards are, but not embedded. Minimal understanding of the CAPEX and OPEX	Understanding and partially implementing the UK BIM Level 2 standards. Partial understanding of the CAPEX and OPEX	Understanding and fully implementing the UK BIM Level 2 standards. Fully understanding and application of the CAPEX and OPEX	
				3)	Roles and Responsibilities	Function	Key Team roles and responsibilities level of expectations to be achieved within a project	Minimal understanding of roles defined in PAS 1192-2:2013 and no internal resources	Partial understanding of roles defined in PAS 1192-2:2013 and have limited internal resources	Distribution of roles and responsibilities amongst team members that have been embedded across projects which are applied frequently in organisations.	
				4)	Contractual agreements		Level of Contractual agreement agreed by project team members	Minimal Understanding of how form of contracts are some awareness of alignment and no previous experience with Level 2 BIM.	Good understanding of how form of contracts are and alignment of standards with Level 2 BIM projects (i.e. 1 to 2 project).	Full understanding of how form of contracts are and alignment of standardised clauses to contract document (i.e 5+ projects).	
				5)	Education and Training		Level of education and training expected to be present within a team to achieve BIM	No internal or staff training on Level 2 BIM, and no awareness of roadmap required.	Awareness training required and producing a roadmap, and some staff training in the basics.	There is a full training strategy for the Level 2 BIM and a metrics of (minimum of 50-60% of relevant staff).	
				6)	Procurement route		Client fully understand how each procurement route will impact on the BIM deliverables	Not aware which route is the best for the client and the project based on the BIM deliverables.	Some confidence in a particular procurement route and how Level 2 BIM is being implemented from stage 1.	Full confidence in correct procurement routes for the client in particular projects and how Level 2 BIM will be used from stage 1.	
		b)	Employers' requirements (OIR)= Organisation information requirements, and (AIR)= Asset Information Requirement (Defining stakeholder needs for projects to be able to achieve BIM)	1	Design elements		Design elements requirements expected to be achieved by contractor to be included in the EIRs.	No awareness and nothing included in the EIR.	Some understanding of the main packages (i.e groundworks, structure, MEP and architecture, external works) covered.	Full understanding and inclusion of a standardised matrix table that covers all contractor design portions (2D and 3D).	
				2)	Information Requirements (EIR)	Exchange Information Requirement (EIR)	Presence of Employers Information Requirements and level of requirements expected for Employers	No ability to develop an EIRs or no abillity to assess the quality of an EIR.	There is a basic understanding of the quality and what should be an EIR, and the abillity to develop an EIR with or without the help from a consultant.	Ability to Complete EIRs specific identifies which the clients need for thir facilities.	
	(The Strategic goals and gearing up of the delivery of BIM at the organisation / project Level, and Organisational and project levels that are being managed by the organisation team.)			3)	Asset Information Requirement (AIR)		Presence of Asset Information Requirements and level of requirements expected for project team	No ability to develop an AIRs and no understanding of Asset requirements to run and manage a facility.	Understanding of the Asset requirements and basic outline of them and some understanding of COBie.	Full COBie asset registered and submitted as part of the EIR documentation.	
		c)	Facilities Management (Operational, maintenance, and lifecycle building performances that is expected to be conducted by the FM team for asset management to achieve BIM)	1)	GSL champion engagement		Presence of a GSL champion (advisor) within the FM stage and levels of engagement expected.	Traditional system and no awareness of COBie and BIM models & use.	Able to use model data but not integrated with FM systems and procedures.	Fully integrated systems that can use the model and information contained with for operations and maintenance.	
				2)	Facilities Management Education and Training		Training expected to be presented for the Facilities Management related to BIM	No internal or staff training on Facilities Management, and no full training plan created	Awareness training required, and relevant employees training on the basics.	There is a full training strategy for the Facilities Management and a metrics of (minimum of 50-60% of relevant staff).	
								Currrent Maturity level (Total)			1.00

Figure 6.7 Focus Group Findings for the Completed Strategic Level

6.8.2 Workshops 4 and 5: Analysis and Findings for the Implementation Level

Discussions on the fourth workshop focused on the implementation Level. Discussions were held on the level and its components for which participants needed to revisit previously completed information concerning the top and sub metrics, their descriptions and maturity level descriptors. Participants were also required to review the Strategic level to identify where metrics would reoccur. Discussions reviewed the findings from workshops two and three and covered collaboration, employers' requirements and processes top metrics. These fields were populated and the associated sub metrics were amended alongside their descriptors and maturity level descriptors. The previously conducted Implementation level (Appendix C) was discussed in detail in workshop five. Figure 6.8 presents the first development process of the Implementation Level.

BIM Level 2 maturity assessment (The What)			
	Top Metrics	Sub Metrics	Essence of descriptors
	Main BIM maturity levels and their descriptions that are expected to be measured for achieving BIM level 2	Secondary levels within the main BIM maturity levels that is expected to be measured and to achieve BIM level 2	Full description of the Secondary levels within the main BIM maturity levels of to provide a clear definition of each level, which will then be expected to be measured and to achieve BIM level 2
a	Collaboration (both strategic)	6) Level 2 Education and Training	• Level of education and training expected to be present within a team to achieve BIM level 2
		7) Procurement route	• Expected procurement route related to BIM to be achieved in line with project needs
b	Employers' Requirements	3) Information Requirements (EIR) (strategic)	• Presence of Employers Information Requirements and level of requirements expected for Employers
c	Processes (Defining project needs to identify project requirements to achieve BIM level 2) (operational)	1) Information Management Documentation	• Level of accomplishment of pre-contract, post-contract, Project Implementation Plan, and supply chain reviews expected to be accomplished.
		2) Uses	• Level of primary and secondary BIM uses expected to be achieved for a full BEP.
		3) Supplier assessment forms	• Level of Supplier BIM assessment forms completed for Supply chain to provide understanding of BIM
		4) Implementation Plan (PIP)	• Level of Project Implementation plan data being used to support the BIM Execution Plan
		5) Execution Plan (BEP)	• Level of project information, objectives & goals, resources, and collaborative working expected to be achieved to reveal a Complete BIM Execution Plan.

Level 2 BIM maturity assessment (The What)					Level 2 BIM maturity measurement (The How)			
					Maturity 1	2	3	
Top Metrics		Sub Metrics		Essence of descriptors	Awareness	Occasional Application	Consistency	
Main Level 2 BIM metrics and their descriptions		Secondary metrics associated with the main Level 2 BIM metrics that is expected to be measured to achieve Level 2 BIM		Description of the secondary metrics to provide a clear definition of each metric	General Knowledge and understanding of Level 2 BIM metrics in Implementation level, but is sometimes not being recognised across the organisation	Partial Application of Level 2 BIM metrics and is somehow being recognised, but is not being embedded generally	Full application and maintaining level 2 BIM metrics, is consistently recognised, and is being embedded across projects generally	Current Maturity level
a)	Collaboration (Collaborative behaviour strategies expected to be present in a complete project to meet Level 2 BIM)	1)	Level 2 Education and Training	Level of education and training expected to be taken by an individual to understand level 2 BIM	There is Fundamental training (i.e in house or external)	There is internal training undertaken (i.e. intermediate bim training or system training) CDE, FM, software based training	All systems are applicable (Advanced training on most systems e.g. CDE, FM)	2
b)	Employers' requirements (Defining stakeholder needs for projects to be able to achieve Level 2 BIM)	1)	Information Requirements (EIR)	Ability to understand the project needs and tailor the EIR accordingly. Level of accomplishment of pre-contract, post-contract, Project Implementation Plan, and supply chain reviews expected to be accomplished.	No EIRs presented	Basic template and external procured EIR	Fully developed EIR in the provided documents (AIR)	
c)	Processes (Defining project needs to identify project requirements to achieve Level 2 BIM)	1)	Uses	BIM uses expected to be achieved on a specfic project	No BIM uses are outlined	BIM uses are outlined but not tailored for specific projects	BIM uses are outlined and tailored for specific projects (i.e. school projects)	
		2)	Supplier assessment forms	Supplier BIM assessment forms completed by companies to demonstrate BIM competence	No supply chain forms carried out or completed.	Understanding the need of assessment forms but not in place.	Supply chain forms issued, being corrected and is completed.	
		3)	Execution Plan (BEP)	Level of project information, objectives & goals, resources, and collaborative working expected to be achieved to reveal a Complete BIM Execution Plan.	Understand the need of BEP	Consultant reviews of BEP	Clients are able to review the BEP	

Figure 6.8 Implementation Level: First development process [Existing findings (top layer), and adjusted (bottom layer)].

The fifth workshop continued discussions on the implementation level by reviewing the metrics added in the previous workshop and by populating the organisational level with "The What" and "The How" inputs. For this workshop, discussions reviewed findings of the previous workshop and covered the top metrics for delivery, sharing and facilities management, which populated and amended the associated sub metrics, and provided sub metric and maturity level descriptors. A number of adjustments were made whereby some of the sub metrics were removed and replaced, and descriptors used for the maturity levels were adjusted to meet clients' and users' understandings of this level. Figure 6.9 presents the second and final development process of this level.

BIM Level 2 maturity assessment (The What)			
	Top Metrics	Sub Metrics	Essence of descriptors
	Main BIM maturity levels and their descriptions that are expected to be measured for achieving BIM level 2	Secondary levels within the main BIM maturity levels that is expected to be measured and to achieve BIM level 2	Full description of the Secondary levels within the main BIM maturity levels of to provide a clear definition of each level, which will then be expected to be measured and to achieve BIM level 2
d	Delivery (Setting out all deliverables that are required from team members to achieve BIM level 2) (operational)	1) Master Information (MIDP)	• Level of Master Information Delivery Plan expected to be accomplished for the delivery stage
		2) Task Team Information (TIDP)	• Level of Task Team Information Delivery Plan expected to be achieved in support of the MIDP
		3) Responsibility Matrix (RM)	• Completion of Responsibility Matrix expected to be achieved in support of the TIDP and MIDP
		4) Construction Programme (CP)	• Level of Construction Programme expected to achieve to support the Delivery stage
e	Sharing (Distribution of information amongst stakeholders that is shared effectively amongst them)	1) Document management stage (CDE) (both operational)	• Achievements of File systems, workflows, library, and accessibility in projects' pre-contract and post-contract stage and a post-completion asset management stage for a Common Data Environment
		2) Information Exchange	• Level of Information exchange achieved and validated from one stage to another
g	Facilities Management (All operational)	1) Manuals	• Operational and Maintenance manuals level of attainment for an Asset Information Model
		4) COBie data	• COBie data requirements and reviews expected to be classified for an asset model
		8) Facilities management Training	• Level of training expected to be present for the Facilities Management

Level 2 BIM maturity assessment (The What)					Level 2 BIM maturity measurement (The How)			
					Maturity 1	2	3	
	Top Metrics		Sub Metrics	Essence of descriptors	Awareness	Occasional Application	Consistency	
	Main Level 2 BIM metrics and their descriptions		Secondary metrics associated with the main Level 2 BIM metrics that is expected to be measured to achieve Level 2 BIM	Description of the secondary metrics to provide a clear definition of each metric	General Knowledge and understanding of Level 2 BIM metrics in Implementation level, but is sometimes not being recognised across the organisation	Partial Application of Level 2 BIM metrics and is somehow being recognised, but is not being embedded generally	Full application and maintaining level 2 BIM metrics, is consistently recognised, and is being embedded across projects generally	Currrent Maturity level
d)	Delivery (Setting out all deliverables that are required from team members to achieve level 2 BIM)	1)	Master Information and Task Team Information (MIDP and (TIDP)	Level of Master Information Delivery Plan and Task Team Information Delivery Plan expected to be accomplished for the delivery stage of the MIDP	Understand the need of MIDP and TIDP.	Consultant reviews of MIDP and TIDP.	Clients are able to review the MIDP and TIDP.	
		2)	Model production Delivery Table (MPDT)	Model production Delivery Table detailing Level of Details (LOD) and Level of Information (LOI) at each stage within a project	Understand the need of MPDT	Basic MPDT Template	Project specific	
		3)	Responsibility Matrix (RM)	Responsibillity Matrix clearly outlining roles and responses for outputs and procedures	NO RM produced.	Basic RM template developed but not completed.	Comprehensive RM developed.	
e)	Sharing (Distribution of information amongst stakeholders that is shared effectively amongst them)	1)	Document management stage- Common Data Environment (CDE)	There should be a common data environment (CDE) for the project which should be secure and structured with access managed and data and information clearly categorised and labelled	CDE supplied by you or others - Not aware CDE required	CDE supplied by you or supplied by others - CDE implemented not BIM level 2 compliant / PAS1192-5 compliant	CDE supplied by you or supplied by others - CDE is fully compliant to BIM Level 2 and security requirements	
		2)	Information Exchange	Information exchange achieved and validated from one stage to another	No defined information exchange.	Information exchange is defined with basic requirements.	Clearly defined information exchange with tangible PLQ included.	
f)	Facilities Management (Operational, maintenance, and lifecycle building performances that is expected to be conducted by the FM team for asset management to achieve Level 2 BIM)	1)	COBie data	COBie / asset information data requirements and reviews expected to be classified for an asset information model	No understanding of the use of COBie.	Understanding the use of COBie but not incorporated on the FM.	Fully understand the COBie and fully incorporated on the FM.	
							Currrent Maturity level (Total)	2.00

Figure 6.9 Implementation Level: Second and final development process [Existing findings (top layer), and adjusted (bottom layer)]

At this stage, the organisational implementation level was completed (shown in Figure 6.10), and participants agreed that Information Managers would be best suited to complete this level. Having completed the implementation level, the next workshop involved discussions on the operational level, which was reviewed alongside the strategic and implementation levels to determine whether overlaps arose across the level.

BIM maturity assessment (Transition from level 2 BIM to the new BS EN ISO19650 standards)											
Organisation		Top Metrics		Sub Metrics			Essence of descriptors	Maturity level	1 = Awareness		
No. #	Level	Main BIM metrics and their descriptions		Secondary metrics associated with the main BIM metrics that is expected to be measured to achieve BIM			Description of the secondary metrics to provide a clear definition of each metric	General Knowledge and understanding of BIM metrics in the Implementation level, but is sometimes not being recognised across the organisation 2 = Occasional Application Partial Application of BIM metrics and is somehow being recognised, but is not being embedded generally 3 = Consistency Full application and maintaining BIM metrics, is consistently recognised, and is being embedded across projects generally			Currrent Maturity level
					level 2 BIM	ISO19650					
2)	IMPLEMENTATION	a)	Collaboration (Collaborative behaviour strategies expected to be present in a complete project to meet BIM)	1)	Education and Training		Level of education and training expected to be taken by an individual to understand BIM	There is Fundamental training (i.e in house or external)	There is internal training undertaken (i.e. intermediate bim training or system training) CDE, FM, software based training	All systems are applicable (Advanced training on most systems e.g. CDE, FM)	2
		b)	Employers' requirements (Defining stakeholder needs for projects to be able to achieve BIM)	1)	Information Requirements (EIR)	Exchange Information Requirement (EIR)	Ability to understand the project needs and tailor the EIR accordingly. Level of accomplishment of pre-contract, post-contract, Project Implementation Plan, and supply chain reviews expected to be accomplished.	No EIRs presented	Basic template and external procured EIR	Fully developed EIR in the provided documents (AIR)	
		c)	Processes (Defining project needs to identify project requirements to achieve BIM)	1)	Uses		BIM uses expected to be achieved on a specific project	No BIM uses are outlined	BIM uses are outlined but not tailored for specific projects	BIM uses are outlined and tailored for specific projects (i.e. school projects)	
				2)	Supplier assessment forms		Supplier BIM assessment forms completed by companies to demonstrate BIM competence	No supply chain forms carried out or completed.	Understanding the need of assessment forms but not in place.	Supply chain forms issued, being corrected and is completed.	
				3)	Execution Plan (BEP)	Information Delivery Plan	Level of project information, objectives & goals, resources, and collaborative working expected to be achieved to reveal a Complete BIM Execution Plan.	Understand the need of BEP	Consultant reviews of BEP	Clients are able to review the BEP	
		d)	Delivery (Setting out all deliverables that are required from team members to achieve BIM)	1)	Master Information and Task Team Information (MIDP and (TIDP)		Level of Master Information Delivery Plan and Task Team Information Delivery Plan expected to be accomplished for the delivery stage of the MIDP	Understand the need of MIDP and TIDP.	Consultant reviews of MIDP and TIDP.	Clients are able to review the MIDP and TIDP.	
				2)	Model production Delivery Table (MPDT)		Model production Delivery Table detailing Level of Details (LOD) and Level of Information (LOI) at each stage within a project	Understand the need of MPDT	Basic MPDT Template	Project specific	
				3)	Responsibility Matrix (RM)	Assignment Matrix	Responsibility Matrix clearly outlining roles and responses for outputs and procedures	NO RM produced.	Basic RM template developed but not completed.	Comprehensive RM developed.	
		e)	Sharing (Distribution of information amongst stakeholders that is shared effectively amongst them)	1)	Document management stage-Common Data Environment (CDE)	<CDE> State	There should be a common data environment (CDE) for the project which should be secure and structured with access managed and data and information clearly categorised and labelled	CDE supplied by you or others - Not aware CDE required	CDE supplied by you or supplied by others - CDE implemented not BIM level 2 compliant / PAS1192-5 compliant	CDE supplied by you or supplied by others - CDE is fully compliant to BIM Level 2 and security requirements	
				2)	Information Exchange		Information exchange achieved and validated from one stage to another	No defined information exchange.	Information exchange is defined with basic requirements.	Clearly defined information exchange with tangible PLQ included.	
	(Implementing BIM across the organisation / project level, in line with the organisation / project strategic goals in relation to BIM implementation.)	f)	Facilities Management (Operational, maintenance, and lifecycle building performances that is expected to be conducted by the FM team for asset management to achieve BIM)	1)	COBie data		COBie / asset information data requirements and reviews expected to be classified for an asset information model	No understanding of the use of COBie.	Understanding the use of COBie but not incorporated on the FM.	Fully understand the COBie and fully incorporated on the FM.	
								Currrent Maturity level (Total)			2.00

Figure 6.10 Focus Group Findings for the Completed Implementation Level

6.8.3 Workshops 6 and 7: Analysis and Findings on the Operational Level

Discussions on the sixth workshop focused on the operational level. Discussions were held on the level and its components, and participants needed to revisit the previously completed information for the top and sub metrics, along with their associated descriptions and maturity level descriptors. Participants also needed to review the strategic and implementation levels to determine where metrics would recur. Discussions reviewed the findings of the previous workshop and covered the top metrics for employers' requirements, sharing, and capital delivery, following which participants populated and amended the associated sub metrics, and provided sub metric and maturity level descriptors. The previous conducted operational level (Appendix C) was discussed in detail in the seventh workshop. Figure 6.11 presents the first development process for the operational level.

BIM Level 2 maturity assessment (The What)			
	Top Metrics	Sub Metrics	Essence of descriptors
	Main BIM maturity levels and their descriptions that are expected to be measured for achieving BIM level 2	Secondary levels within the main BIM maturity levels that is expected to be measured and to achieve BIM level 2	Full description of the Secondary levels within the main BIM maturity levels of to provide a clear definition of each level, which will then be expected to be measured and to achieve BIM level 2
a	Collaboration (Strategic)	8) Collaborative protocols	• Level of collaborative protocols being applied within projects by team members
b	Processes (Implementation)	4) Implementation Plan (PIP)	• Level of Project Implementation plan data being used to support the BIM Execution Plan
d	Delivery (Implementation)	4) Construction Programme (CP)	• Level of Construction Programme expected to achieve to support the Delivery stage
e	Sharing (both implementation)	1) Document management stage (CDE)	• Achievements of File systems, workflows, library, and accessibility in projects' pre-contract and post-contract stage and a post-completion asset management stage for a Common Data Environment
		2) Information Exchange	• Level of Information exchange achieved and validated from one stage to another
f	Capital Delivery (Model inputs, simulation and analysis for the Design and construction stages that is expected to be reviewed and verified by the project team to transfer to the next phase and achieve BIM level 2)	1) 3D – 6D inputs	• 3D - 6D analysis and simulations' level of achievability within the design and construction stage
		2) Component Drawings	• Expected Component drawings to be achieved within the design and construction stage
		3) Level of Details (LoD)	• Level of Details required to be maintained within the design and construction stage
		4) File transfer standards	• Expected File transfer standards required to be accomplished for BIM within design and construction stages
		5) Project reviews	• Project reviews required to be checked and notified within design and construction stages
		6) Lifecycle Analysis	• Variety of analysis expected to be reviewed and performed by project team within a 3D model
		7) Modelling simulations	• Level of Modelling simulations required to be performed by project team within a 3D model
		8) Project Information Model (PIM) exchanges	• Level of model definition expected in brief, concept, definition, design, build and commission, handover and closeout, operation and in use stages.

Level 2 BIM maturity assessment (The What)					Level 2 BIM maturity measurement (The How)			
					Maturity 1	2	3	
	Top Metrics		Sub Metrics	Essence of descriptors	Awareness	Occasional Application	Consistency	
	Main Level 2 BIM metrics and their descriptions		Secondary metrics associated with the main Level 2 BIM metrics that is expected to be measured to achieve Level 2 BIM	Description of the secondary metrics to provide a clear definition of each metric	General Knowledge and understanding of Level 2 BIM metrics in operational level, but is sometimes not being recognised across the organisation	Partial Application of Level 2 BIM metrics and is somehow being recognised, but is not being embedded generally	Full application and maintaining level 2 BIM metrics, is consistently recognised, and is being embedded across projects generally	Currrent Maturity level
a)	Employers' requirements (Defining stakeholder needs for projects to be able to achieve Level 2 BIM)	1)	Information Requirements (EIR)	Presence of Employers Information Requirements and level of requirements expected for Employers	No EIRs presented	Basic template and external procured EIR	Fully developed EIR in the provided documents (AIR)	3
b)	Sharing (Distribution of information amongst stakeholders that is shared effectively amongst them)	1)	Document management stage-Common Data Environment (CDE)	Achievements of File systems, workflows, library, and accessibility in projects' pre-contract and post-contract stage and a post-completion asset management stage for a Common Data Environment	CDE supplied by you or others - Not aware and CDE required	CDE supplied by you or supplied by others - CDE implemented but not Level 2 BIM compliant / PAS1192-5 compliant	CDE supplied by you or supplied by others - CDE is fully compliant to Level 2 BIM and security requirements	
c)	Capital Delivery (Model inputs, simulation and analysis for the Design and construction stages that is expected to be reviewed and verified by the project team to transfer to the next phase and achieve Level 2 BIM)	1)	3D – 6D inputs	Usage and achieving 3D, 4D, 5D and 6D elements in projects	Simply Identified 3D-6D elements, but not fully followed	Identified but not used in a certain degree over projects	Identified and used in multiple projects.	
		2)	Level of Development (LoD)	The ability to check if the Level of Details and Level of Information (LoD and LoI) are set up as stated in the MPDT	Basic understanding of the Level of Development that is relevant for projects	Good understanding of the LoD and basic abillity to check (Visual checks) the models	Full understanding the LoD and capability to use the models (Visualise and check the information)	
		3)	Project reviews	Project reviews in specified gateway intervals defined within the project	Basic understanding of the roles and responsibility for the clients on the gateway reviews	Good understanding of the roles and responsibility and acknowledging the clients on the gateway reviews to be applied	Clients Carring out responsibilities on the gateway reviews	
		4)	Lifecycle Analysis	Lifecycle analysis (6D) expected to be reviewed to achieve lifecycle on the project	No capability to operate on the lifecycle.	Basic Usage of the Lifecycle but not fully managed	Fully integrated lifecycle using BIM as a model.	
		5)	As built model	As built model expected to be reviewed for the projects attempted in organisations	As built model is being developed and prepared for review by project team members.	As built model is acknowledged by project team members in line with BIM level 2, and ready to be used.	As built model reflected what is being constructed and bein able to check and confirm	
		6)	Project Information Model (PIM) exchanges	Model definition expected in brief, concept, definition, design, build and commission, handover and closeout, operation and in use stages.	Information model is being developed and prepared for review by project team members.	Information model is acknowledged by project team members in line with BIM level 2, and ready to be used.	Information model have been applied across design and construction stages, in line with the PAS 1192-2 requirements.	

Figure 6.11 Operational Level: First development process [Existing findings (top layer), and adjusted (bottom layer)].

Discussions for the seventh workshop focused on the operational level, during which participants reviewed the metrics considered in the previous workshop and populated the organisational level with "The What" and "The How" inputs. Discussions reviewed findings from the previous workshop and covered the top metric for facilities management, populated and amended the associated sub metrics, and provided the sub metric and maturity level descriptors. A number of adjustments were made, which meant that some sub metrics were removed and replaced, while descriptors used for the maturity levels were adjusted to meet of clients' and users' understandings. Figure 6.12 presents the second and final development process for this level.

BIM Level 2 maturity assessment (The What)		
Top Metrics	Sub Metrics	Essence of descriptors
Main BIM maturity levels and their descriptions that are expected to be measured for achieving BIM level 2	Secondary levels within the main BIM maturity levels that is expected to be measured and to achieve BIM level 2	Full description of the Secondary levels within the main BIM maturity levels of to provide a clear definition of each level, which will then be expected to be measured and to achieve BIM level 2
(implementation)	1) Manuals	• Operational and Maintenance manuals level of attainment for an Asset Information Model
Facilities Management	2) Information Delivery (AIM)	• Expected Documentation, Non-graphical data, and Graphical Model achieved in Operation stage
	3) FM and OM use	• FM and OM use requirements needed to be achieved for the Facilities Management
(implementation)	4) COBie data	• COBie data requirements and reviews expected to be classified for an asset model
(Operational, maintenance, and lifecycle building performances that is expected to be conducted by the FM team for asset management to achieve BIM level 2)	5) Asset Reviews	• Asset reviews required to be checked and notified within an asset model for completion
	6) Handover requirements (GSL)	• Presence of Hand-overs from consultants and levels of requirements expected for the GSL to transfer from the design and construction phase to operational phase.
	7) Post Occupancy Evaluation	• Level of POE's required to be evaluated within the GSL for the Facilities Management
(implementation)	8) Facilities management Training	• Level of training expected to be present for the Facilities Management
(Strategic)	9) GSL champion engagement	• Presence of a GSL champion (advisor) within the FM stage and levels of engagement expected.

Level 2 BIM maturity assessment (The What)					Level 2 BIM maturity measurement (The How)			
					Maturity 1	2	3	
	Top Metrics		Sub Metrics	Essence of descriptors	Awareness	Occasional Application	Consistency	
	Main Level 2 BIM metrics and their descriptions		Secondary metrics associated with the main Level 2 BIM metrics that is expected to be measured to achieve Level 2 BIM	Description of the secondary metrics to provide a clear definition of each metric	General Knowledge and understanding of Level 2 BIM metrics in operational level, but is sometimes not being recognised across the organisation	Partial Application of Level 2 BIM metrics and is somehow being recognised, but is not being embedded generally	Full application and maintaining level 2 BIM metrics, is consistently recognised, and is being embedded across projects generally	Current Maturity level
d)	Facilities Management (Operational, maintenance, and lifecycle building performances that is expected to be conducted by the FM team for asset management to achieve Level 2 BIM)	1)	Information Delivery (AIM)	Operational and Maintenance data for an Asset Information Model	Basic understanding of AIM but not aware what needs to be done	Good Understanding of AIM and using it in the basic level but is not fully level 2 BIM	Fully understand the AIM scheme and is full compliant to the Level 2 BIM requirements	
		2)	COBie data	COBie data requirements and reviews expected to be handed over for an asset model	Basic understanding but not aware what needs to be done for the data	Good Understanding and using it in the basic level but not fully integrated in the system	Fully understand the Cobie scheme and full capability to integrate the asset data into the operation and maintenance process	
		3)	Handover requirements (GSL)	Presence of Hand-overs from consultants and requirements expected for the GSL to transfer from the design and construction phase to operational phase.	Basic understanding of Hand-overs and its requirements for the GSL, but is not presented	Good understanding of the Hand-overs required for the GSL, and is being used but not fully Level 2 BIM compliant	Fully understanding the Hand-overs required for the GSL, and is fully compliant to the Level 2 BIM requirements	
		4)	Post Occupancy Evaluation (POE)	POE's required to be evaluated within the GSL for the Facilities Management	Basic understanding of Post Occupancy Evaluation, but is not presented	Good understanding of the Post Occupancy Evaluation, and is being used but not fully Level 2 BIM compliant	Fully understanding the Post Occupancy Evaluation, and is fully compliant to the Level 2 BIM requirements	
							Current Maturity level (Total)	3.00

Figure 6.12 Operational Level: Second and final development process [Existing findings (top layer), and adjusted (bottom layer)].

At this stage, the organisational operational level was completed (shown in Figure 6.13), and participants agreed that Project Managers would be best suited to undertake this level. Having completed the operational level, a review of all three organisational levels was conducted to determine how assessments were structured and whether any amendments were required. The list of KPIs (Section 4.5.1) was confirmed for adoption at the next stage. The next section will discuss the findings of the three organisational levels following their review.

BIM maturity assessment (Transition from level 2 BIM to the new BS EN ISO19650 standards)											
Organisation		Top Metrics		Sub Metrics			Essence of descriptors	Maturity level		1 = Awareness	Currrent Maturity level
No. #	Level	Main BIM metrics and their descriptions		Secondary metrics associated with the main BIM metrics that is expected to be measured to achieve BIM			Description of the secondary metrics to provide a clear definition of each metric	1 = Awareness: General Knowledge and understanding of BIM metrics in the Operational level, but is sometimes not being recognised across the organisation	2 = Occasional Application: Partial Application of BIM metrics and is somehow being recognised, but is not being embedded generally	3 = Consistency: Full application and maintaining BIM metrics, is consistently recognised, and is being embedded across projects generally	
					level 2 BIM	ISO19650					
3)	OPERATIONAL	a)	Employers' requirements (Defining stakeholder needs for projects to be able to achieve BIM)	1)	Information Requirements (EIR)	Exchange Information Requirement (EIR)	Presence of Employers Information Requirements and level of requirements expected for Employers	No EIRs presented	Basic template and external procured EIR	Fully developed EIR in the provided documents (AIR)	3
		b)	Sharing (Distribution of information amongst stakeholders that is shared effectively amongst them)	1)	Document management stage-Common Data Environment (CDE)	<CDE> State	Achievements of File systems, workflows, library, and accessibility in projects' pre-contract and post-contract stage and a post-completion asset management stage for a Common Data Environment	CDE supplied by you or others - Not aware and CDE required	CDE supplied by you or supplied by others - CDE implemented but not Level 2 BIM compliant / PAS1192-5 compliant	CDE supplied by you or supplied by others - CDE is fully compliant to Level 2 BIM and security requirements	
		c)	Capital Delivery (Model inputs, simulation and analysis for the Design and construction stages that is expected to be reviewed and verified by the project team to transfer to the next phase and achieve BIM)	1)	3D – 6D inputs		Usage and achieving 3D, 4D, 5D and 6D elements in projects	Simply Identified 3D-6D elements, but not fully followed	Identified but not used in a certain degree over projects	Identified and used in multiple projects.	
				2)	Level of Development (LoD)	Level of Information need	The ability to check if the Level of Details and Level of Information (LoD and LoI) are set up as stated in the MPDT	Basic understanding of the Level of Development that is relevant for projects	Good understanding of the LoD and basic abillity to check (Visual checks) the models	Full understanding the LoD and capability to use the models (Visualise and check the information)	
				3)	Project reviews		Project reviews in specified gateway intervals defined within the project	Basic understanding of the roles and responsibility for the clients on the gateway reviews	Good understanding of the roles and responsibility and acknowledging the clients on the gateway reviews to be applied	Clients Carring out responsibilities on the gateway reviews	
				4)	Lifecycle Analysis		Lifecycle analysis (6D) expected to be reviewed to achieve lifecycle on the project	No capability to operate on the lifecycle.	Basic Usage of the Lifecycle but not fully managed	Fully integrated lifecycle using BIM as a model.	
				5)	As built model		As built model expected to be reviewed for the projects attempted in organisations	As built model is being developed and prepared for review by project team members.	As built model is acknowledged by project team members in line with BIM level 2, and ready to be used.	As built model reflected what is being constructed and bein able to check and confirm	
				6)	Project Information Model (PIM) exchanges		Model definition expected in brief, concept, definition, design, build and commission, handover and closeout, operation and in use stages.	Information model is being developed and prepared for review by project team members.	Information model is acknowledged by project team members in line with BIM level 2, and ready to be used.	Information model have been applied across design and construction stages, in line with the PAS 1192-2 requirements.	
		d)	Facilities Management (Operational, maintenance, and lifecycle building performances that is expected to be conducted by the FM team for asset management to achieve BIM)	1)	Information Delivery (AIM)		Operational and Maintenance data for an Asset Information Model	Basic understanding of AIM but not aware what needs to be done	Good Understanding of AIM and using it in the basic level but is not fully level 2 BIM compliant	Fully understand the AIM scheme and is full compliant to the Level 2 BIM requirements	
				2)	COBie data		COBie data requirements and reviews expected to be handed over for an asset model	Basic understanding but not aware what needs to be done for the data	Good Understanding and using it in the basic level but not fully integrated in the system	Fully understand the Cobie scheme and full capability to integrate the asset data into the operation and maintenance process	
	(Operating BIM across the organisation / project, and how the management of information being collected is achieved.)			3)	Handover requirements (GSL)		Presence of Hand-overs from consultants and requirements expected for the GSL to transfer from the design and construction phase to operational phase.	Basic understanding of Hand-overs and its requirements for the GSL, but is not presented	Good understanding of the Hand-overs required for the GSL, and is being used but not fully Level 2 BIM compliant	Fully understanding the Hand-overs required for the GSL, and is fully compliant to the Level 2 BIM requirements	
				4)	Post Occupancy Evaluation (POE)		POE's required to be evaluated within the GSL for the Facilities Management	Basic understanding of Post Occupancy Evaluation, but is not presented	Good understanding of the Post Occupancy Evaluation, and is being used but not fully Level 2 BIM compliant	Fully understanding the Post Occupancy Evaluation, and is fully compliant to the Level 2 BIM requirements	
								Currrent Maturity level (Total)			3.00

Figure 6.13 Focus Group Findings for the Completed Implementation Level

6.9 Workshop 8: Review of the Three Organisational Levels

In the last workshop, the focus group provided their feedback on the completed organisational levels, and participants stated that:

- “[*The*] *Maturity index looks a good start to formulating/evaluating a Client’s level of understanding at key points of each project and anyone from the supply chain. It could also be applied to Assets and Framework level assessments*” [P2]. This indicates that clients would be well educated by this assessment and that it would help them to assess their projects and identify where they stand.
- “*The assessment should be given to users with some awareness and knowledge on Level 2 BIM for the assessment to be meaningful*” [P4]. This highlights the importance of giving the assessment to the right people since the information relates to Level 2 BIM; if given to someone with limited Level 2 BIM knowledge, the assessment could not be completed to the required level. It was noted that the maturity level descriptors could be changed to meet the client’s understanding; the necessary adjustments were presented in Sections 6.7 and 6.8.
- “*The need to have a tangible metric to score all the sub metrics otherwise they could all be scored as 3*” [P3]. This indicates that the metrics need to be well explained, and whoever completes the assessment should only fill out the sections applicable to them. Thus, the metrics that are not applicable should be omitted.
- *There exist[s] sub metrics related to those in the operational level… For organisational level it could mean if they have collaboration between different platforms and system, where every company will have different platforms such as enterprise systems that are related and not related to BIM*“ [P2]. Thus, P2 stated that the sub metrics relating to the collaboration top metrics could be available within the implementation and operational levels.
- “*Generally the strategic level should be kept to its simplest forms to allow clients and users in that level to assess the sub metrics of Level 2 BIM*” [P1]. Everyone agreed that, for the roles and responsibility sub metric, “*Some overlaps could occur between sub metrics in one top metrics with another one in a different top metric (Roles and responsibilities with Collaboration and Employers requirements*”. This needs all sub metrics to be addressed to avoid unnecessary duplication.
- “*There should be a template that explains that not every part is applied to you; therefore answer the metrics which applies to you so that the average scores will make sense and be meaningful, so where it is not applicable to you leave it blank*” [P3]. Thus, participants requested a set of guidelines prior to the assessment to explain how it works and what needs to be completed.

At this point, the final workshop was complete, and the data collection saturated, meaning that it was necessary to move on to the next stage. The next section provides a summary of the BIM maturity assessment findings, a summary of the KPI findings, and the workshop findings in relation to the BS EN ISO19650 standards.

6.10 BIM Maturity Assessment Focus Group Workshops Summary

This stage concluded the findings from the focus group workshops. The next stage of the research was to examine the organisational level spreadsheets for different clients and users within the UK construction industry's public sector. The disciplines expected to complete each organisational level were identified, and are as follows:

1) **Strategic:** Senior Managers, responsible for setting up the strategic goals and gearing up the department to deliver BIM, are expected to complete the assessment at this level.
2) **Implementation:** Information Managers would be expected to complete the assessment at this level as they are responsible for ensuring delivery of the strategic goals to implement BIM, and systems (i.e. people, processes, technologies) are in place to facilitate this.
3) **Operational:** Project Managers, responsible for day-to-day users operating within a Level 2 BIM environment, would be expected to complete the assessment at this level.

The findings revealed the following points:

1) The top metrics of each organisational level were kept the same, and therefore correlate to the findings from previous BIM maturity related studies, which validates some of the findings and ensures they would cover the Level 2 BIM metrics as set out in the standards.
2) Some sub metrics remained the same, whilst others have been replaced/added - as presented in the previous sections. This ensures that the metrics follow the Level 2 BIM/BS EN ISO19650 standards and are suited to each organisational level.
3) Accordingly, all of the sub metrics and maturity level descriptors have been changed, as shown in the previous sections. This ensures that the research differs from a previous study (Aboumoemen, 2016) and shows that the focus group workshops were vital in reviewing the organisational levels and populating the necessary components.
4) The organisational levels have been assigned to relevant disciplines, as explained previously, and this ensures that clients are able to complete the assessment, as stipulated in the research aim and objectives.
5) Finally, the new BIM maturity assessment would add to existing assessments, as the next stage links it to the aforementioned KPIs (Section 4.5.1).

The next section provides a summary of the KPI metric outcomes.

6.10.1 KPIs focus group workshops summary

The list of KPIs that emerged from the literature (Section 3.7) was presented to focus group members to gather their feedback on the use of KPIs as a standardised set for examination. The group members agreed that the list of KPI metrics could offer an initial list for evaluation. Thus, semi-structured interviews will be with the selected sample (as mentioned in Section 5.11), which will collect information on the possible linkages between BIM maturity and KPI metrics.

This stage concluded the findings of the focus group workshops, which delivered a standardised list of BIM maturity and KPIs. A total of eight workshops were conducted to finalise the BIM maturity assessment for all organisational levels and to agree a list of KPI metrics that determine the BIM maturity/KPI linkages to be taken forward to the interview stage. The next section will discuss the BIM maturity assessment and its relevance to the new BS EN ISO19650 standards.

6.11 BIM Maturity Assessment and its Relation to the BS EN ISO19650 Standards

At this stage, the main aim of the workshops was to firstly, collect information on the required BIM metrics that would be populated within each of the organisational levels and to secondly agree to a list of KPIs that would be taken forward to the next data collection phases and examine the potential links. The workshops were undertaken at a time when more emphasis was placed on Level 2 BIM (related more to BIM maturity), and when no mention was made of the BS EN ISO19650 standards. It is worth mentioning that the data presented in the BIM maturity assessment aligns with the Level 2 BIM metrics, as presented in the BS1192:2007 and PAS1192-Parts 2-5. However, the BS EN ISO19650 standards were released in early 2019, and merged the previous UK guides within an international guide (ISO), which was more closely related to information management. Hence, the information presented in the BIM maturity assessment (top and sub-metrics, descriptors, and maturity level descriptors) are more relevant for both the Level 2 BIM mandate and the new BS EN ISO19650 standards. This ensures that the assessment could be transferred and embedded alongside the BS EN ISO19650 standards, as some of the BIM sub-metrics could include the transition from Level 2 BIM to the BS EN ISO19650 standards, as presented in Section 2.8.3. The information that will be collected from interviews and questionnaires and more closely related to Level 2 BIM; however, it would also be relevant to the new BS EN ISO19650 standards.

Having presented a detailed analysis of the organisational assessments, in terms of the final structure for the assessments (Strategic, Implementation, Operational) and an initial list of KPI metrics, the next section will present an update to the proposed framework that relates to "The What" stage (Section 4.5.1).

6.12 The ‘What’ stage: The evolution of the framework

Based on the conceptual framework and primary data findings, the evolution of the framework from the initial development will be presented, namely the ‘What’ stage. Figure 6.14 presents this development stage, which demonstrates the evolution from the conceptual (Section 4.5) to the initial framework development. This section will demonstrate the findings which lead to the following: 1) Agreement to an initial standardised list of KPI metrics (Section 6.10.1), and 2) the BIM maturity top and sub metrics, which was achieved during the focus group workshops.

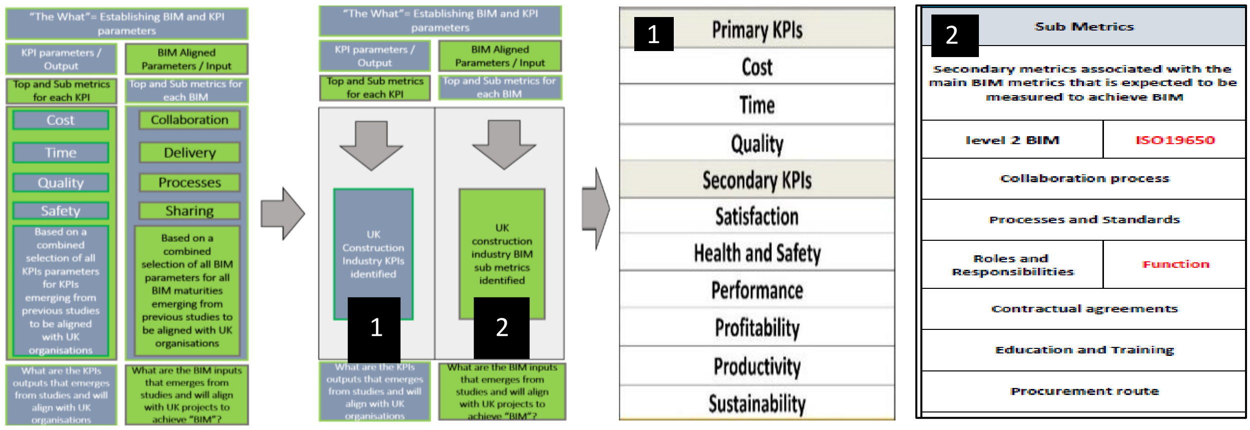


Figure 6.14 The evolution of the ‘What’ stage from the conceptual to the initial framework

The ‘What’ stage identified the required BIM maturity and KPI metrics for the framework and assessments (Section 3.4). The initial framework development evolved from the conceptual framework due to the influence of the primary data collection, it is be necessary to explain the development process and identify the main differences between the two developments. The conceptual framework presented the parameters and inputs that covered the necessary requirements of BIM; these were aligned and merged with the KPI metrics and presented as the ‘What’ stage. The BIM maturity metrics were proposed for inclusion, which act as inputs while the KPI metrics act as outputs. The proposed ten KPI metrics are presented in the framework, and the seven BIM maturity top metrics across all organisational levels are outlined in the framework. Also, given the transition from Level 2 BIM to the new BS EN ISO19650 standards, the BS EN ISO19650 standards will be presented. This denotes the main difference between this research and previous frameworks identified in the literature. The initial framework development emerged as a result of the primary data findings and analysis to include an indication of the expected BIM maturity (aligned to the BS EN ISO 19650 standards) and the KPI metrics included.

Having presented the development of the framework and demonstrated what are the BIM maturity and KPI metrics, the next chapter will discuss the data collected from the next data collection phase (semi structured interviews).

6.13 Summary

This chapter presented the preliminary findings of the framework that was developed with focus group members. The mixed method data collection process for the focus groups, semi structured interviews and questionnaires were described to show how the data was collected at this stage, with a detailed focus on the focus group workshops. An overview of NWCH was given to explain how they operate and the relevance of this research to their business. The criteria for selecting participants for the focus group workshops were identified to show how participants were approached for this research (Table 6.1).

Findings from the previous study (Aboumoemen, 2016) and this research were presented to demonstrate previous insights and what is expected from this research. The organisational levels inputs were provided to outline the necessary requirements for the assessment and how these will be formulated. According to this stage, all organisation level assessments were discussed and completed, and are illustrated in Figures 6.7, 6.10, and 6.13, and agreement on an initial list of KPIs (Section 4.5.1) was achieved. An update to the conceptual framework has been presented, which discussed the findings related to “The What” stage of the framework, and how it has developed from the proposed framework (Section 4.5) towards the initial framework development.

After conducting a number of focus group workshops to generate the BIM maturity assessment, the next step involved the conduct of a number of semi structured interviews to capture more information about the potential links between BIM maturity and KPI metrics, to examine the proposed BIM maturity assessments and to determine how they can be linked with the standardised list of KPI metrics (Section 4.5.1). Having completed the second stage of the BIM maturity and KPI assessment framework development, the next chapter will explain its further development.

Chapter 7: Qualitative (Semi-Structured interview) data findings

7.1 Introduction

The previous chapter presented the BIM maturity assessment development across three organisational levels based on the focus group workshop findings. These findings will be examined through a qualitative enquiry (using semi structured interviews), which represent the second step in the validation process. The focus group workshop findings are examined to determine the relationships between BIM maturity and KPI metrics. This chapter presents the process of validating the assessment and exploring a potential linkage between BIM maturity and KPI metrics, as conducted through semi-structured interviews. The objective in conducting the interviews is to establish an in depth understanding of BIM maturity and KPI metrics and to explore potential links. This will help to validate the workshops findings and the KPI findings from the literature, and present a finalised list of KPI metrics for use in the assessment to establish the potential linkages. The final outcomes of the KPI metrics, and the BIM maturity and KPI metrics linkage will finalise the second stage of the proposed BIM maturity-KPI assessment framework. Similar to the workshops, the aim of the interviews is to meet the study's fourth and fifth objective, by developing the proposed assessment framework and examining a potential linkage.

7.2 Semi structured interview: Data collection and recruitment process

Contact was made with the NWCH to issue a call to participate in interviews for this research. At this stage, a meeting within the platform was conducted and invitations were sent out to the members who attended the meeting. The invitation was to participate in a series of semi structured interviews to collect information related to the data collected from the focus group workshops. The researcher aimed to conducted a number of interviews that fell within the recommended range (5-25 interviews) (Saunders et al., 2016). This stage identified participants who were willing to participate in the interviews, which was based on NWCH contacts (snowballing) and the researcher's personal contacts, some of which may be linked with some of the focus group members.

A client session on BIM was arranged at the University of Salford, where a number of construction professionals were invited to present their findings with BIM case studies related to the NWCH. The researcher was part of the session and distributed a one-page case study that summarised the work and outlined the research aim. This session was a perfect opportunity to identify some contacts who could participate in the interviews. The template of the one pager case study is available in Appendix I. The next section will describe the data analysis process for the interviews.

7.2.1 Semi-structured interviews: Data collection and analysis process

Similar to the workshops, the data collected from the interviews were split into themes in accordance with a thematic analysis process; these themes were also quantified to enable content analysis. Based on the framework findings from the workshops, and on the selected interviewees from NWCH, a number of semi-structured interviews were conducted to explain the proposed framework and collect information on the potential links between BIM maturity and KPI metrics that were presented in the literature review and the focus group workshops. A number of suggestions that helped to generate a potential linkage between BIM maturity and KPI metrics was delivered, which concluded the development of the framework's second stage. In addition, questions were posed on the benefits expected to emerge from the potential linkage between BIM maturity and KPI metrics. The interviews were conducted with NWCH's established contacts via contracting companies and were conducted at the interviewees' workplaces.

The interviews were recorded but, unlike the workshops, instead of also taking notes, detailed transcriptions (verbatim) were undertaken to capture all relevant information on BIM maturity and KPI metrics. Thus, any additional information believed unnecessary for this research will be omitted. A number of questions were asked in each interview around the potential links of BIM maturity and KPI metrics. The links between BIM maturity and KPIs metrics were converted quantitatively to enable measurement, which were subsequently used in the questionnaire. An informed consent form, and an interview invitation letter presented to NWCH were signed as part of the interview process, and templates of these documents are available in Appendix F. Figure 7.1 illustrates the interview data collection process, and Table 7.1 presents the ten questions asked, which were tailored within each interview following the interviewee's identification of their organisational level.

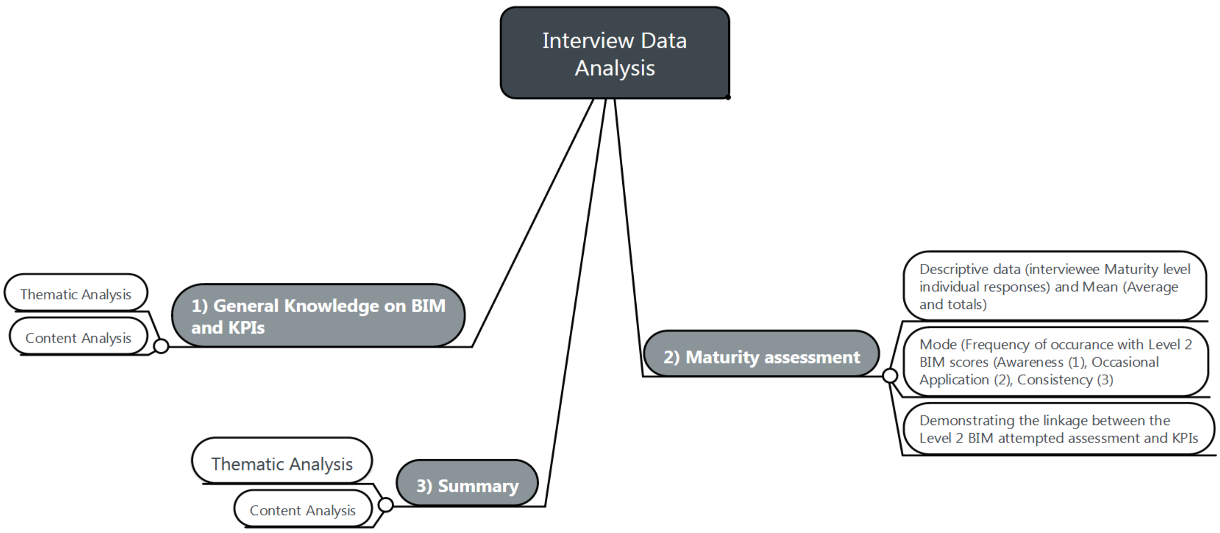


Figure 7.1 Interview data analysis process

Table 7.1 Interview questions

No of question	Questions	Overall Aim	Objective(s) alignment
1	Where does BIM stand in your company in terms of its levels of adoption and Level 2 BIM compliance?	**To investigate the current state of BIM and Level 2 BIM within companies in relation to the UK government mandate**	1
2	a) Are there any BIM maturity assessments/tools/models that are being used within your organisation? If so, what are they? What are the key BIM metrics / parameters that you are currently assessing?	**To identify the awareness with BIM maturity assessment(s) and if there is any that is being used within companies**	2
	b) if not, then why are you not currently using it? What is your BIM maturity assessments when getting into a BIM level 2 project?	**If the previous answer was no, then to explore other alternative BIM maturity assessments being used or if none exist**	
3	In terms of your current assessments, what do you think are the strengths and weaknesses that exists from the usage of the above-mentioned BIM maturity assessments/tools/models?	**To signify the potential strength / weaknesses that exist from the BIM assessment(s) and compare with the literature findings.**	
4	What are your core (Key) KPIs that are being used within your organisation, and how do you measure them? Are they internal or national KPIs? Are you able to assess the impact of KPIs on project / organisational performance? **(If answer= Yes, then answer the question and proceed to question 5),** **(If answer=No, then proceed to Question 6)**	**To investigate the current KPI(s) being used within companies, see how they are being measured and to compare with those that emerged from the literature findings and confirm them.**	
5	5) In terms of both the BIM maturity assessment and your KPIs, currently do you have any mechanism by which you are able to establish the impact of your level of BIM maturity on your standard KPIs? If so, does the BIM maturity give any indication that it impacts on the overall organisational level / project performance?	**To explore the potential mechanism(s) that could be used to establish the impact of the level of BIM maturity on the KPIs, and see if BIM maturity impacts on the overall organisational level / project performance?**	3
6	Do you think that there a link between your level of BIM maturity and its impact on your KPIs? How?	**To determine the possibility of linking both Level 2 BIM and KPIs and see how it impacts**	
7	Based on the given information, could you fill out the spreadsheet template based on your current organisational level (Strategic / Implementation / Operational) and according to the given answers in the spreadsheet and your answers to question 4), can you tell me what you think of the following: In each of those sub metrics and top metrics (If there is more than one sub metric) in the **Awareness level / Occasional application level / Consistency level**, which of the KPIs do you think that could have an impact on the Level 2 BIM metrics? And in what way does it impact on?	**Based on the selected organisational level, to conduct an assessment on the Level 2 BIM maturity that emerged from the focus group workshops and examine what maturity overall levels users score, identify the strengths and weaknesses from the assessment, outline the potential outcomes of it, and determine the potential relationships between the Level 2 BIM maturity assessment and the KPIs that emerged from the literature review and see if they will be linked**	4 and 5
8	Do you feel measuring your Level of BIM maturity allows you to determine its impact on the KPIs? Why?	**To evaluate the outcomes of the previously exercise and see if it met the aim of linking both together.**	5
9	Do you think there is any core benefits that enables you to assess the impact of the level of BIM maturity on the KPIs? If not, then why?	**To explore and identify the potential benefits expected to emerge from the assessment, and align it with the proposed benefits from literature**	5
10	Do you have any comments / Observations / recommendations / any other inputs for bringing this work forward? If yes, then what are they?	**To provide with any further information that could reflect on this assessment, and see if there are any amendments.**	4 and 6

Having presented the list of questions for the interviews, the next section will discuss the process for selecting the interviewees.

7.2.2 Selection of participants for interview

For qualitative research, the selection of participants needs to be precise and based on participants' in-depth knowledge and experience with the content of the research, and with the phenomenon behind it (Robson, 2002). For these reasons, a purposive approach was applied to the selection of participants. NWCH distributed an email to organisations on the database they held, which invited relevant practitioners who met the research background to participate in a semi-structured interview. Additional invitations were also sent to the researcher's personal contacts, who were professionals within the UK sector. The researcher conducted interviews with 15 construction practitioners with at least one year of experience. All interviews took place at the interviewee's workplaces and ranged from 45 mins to 1 hour and 15 mins length. The interviews took place between 23rd May and 19th October 2018, which was also during the timeframe of Level 2 BIM when no mention had been made of the BS EN ISO19650 standards. Although, as previously explained, a transition from Level 2 BIM to the BS EN ISO19650 standards occurred, the interviews findings fit within this transition and were relevant to the standards.

7.2.3 Thematic and content analysis procedure

Ethical consent was granted for the recording of the interviews. After the interviews were completed, transcriptions were undertaken to capture verbatim text data. The transcripts were analysed question by question across all interviewees to extract the main and sub themes related to each question. This involved detailed reading and grouping/categorising to confirm consistency when extracting the themes (Braun and Clarke, 2016; Creswell, 2007) and linking these with the interview outcomes in order to achieve the thematic analysis procedure.

In order to achieves the content analysis procedure, information was imported into NVIVO software to support the analysis, the data was grouped quantitatively, the location of the themes was occurred, the number of discussions relating to each theme were noted, the themes were linked to the interviews, and the data quantified to capture the key topic areas. For question seven, interviewees were asked to identify their organisational level in order to complete the BIM maturity assessment and demonstrate the potential BIM maturity and KPI metrics linkages (these were analysed separately). For this, the thematic analysis focused on links between the KPI metrics and BIM maturity metrics, while the content analysis considered the BIM maturity answers given. The analysis will be presented in the next section.

7.3 Thematic and content analysis findings

This section presents findings from the conducted interviews and presents the extracted themes and sub themes that emerged. Moreover, it presents the quantitative data's links to the themes to signify the importance of key areas in the research.

7.3.1 Interviewee participation

After conducting 15 interviews the data became saturated (Table 7.2 and Figure 7.2). Interviewees were coded to allow anonymity. The interviewees have different levels of experience and work in different roles; this improves the data richness in terms of the range of information and level of detail. Table 7.2 shows that more participants came from an architectural background (six architects were involved), while three strategic contractors also participated alongside three information managers, two project managers, and one building surveyor. All interviewees had between 1-10 years of experience, while four had between 1-5 years, eight had between 6-10, and three had more than 10 years of experience. Having presented the details of the interviewees, the next section will discuss findings from the level of agreement questions (Table 7.1).

Table 7.2 Interviewee list

Interviewees	Personal Professional Background	Years of experience
I01	Strategic contractor	6-10
I02	Information Manager (BIM)	1-5
I03	Architect	1-5
I04	Architect	1-5
I05	Project manager	More than 10 years
I06	Information Manager (BIM)	6-10
I07	Architect	1-5
I08	Project manager	6-10
I09	Strategic contractor	More than 10 years
I10	Building Surveyor	6-10
I11	Architect	6-10
I12	Project manager	More than 10 years
I13	Architect	6-10
I14	Architect	6-10
I15	Information Manager (BIM)	6-10

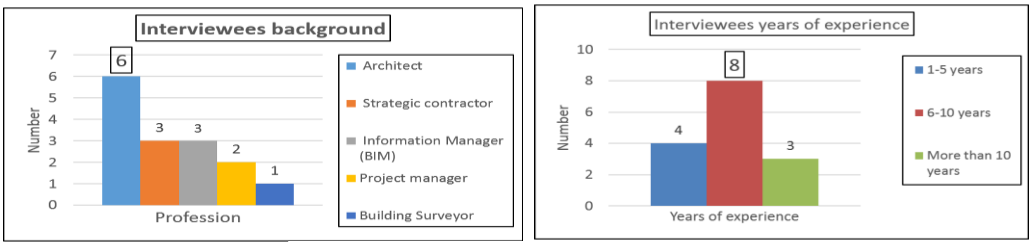


Figure 7.2 Interviewee details

7.3.2 Close ended responses - Level of agreement to questions addressed

This section introduces the findings from the 15 interviewees, in terms of their level of agreement to the questions addressed (Table 7.1). Table 7.3 presents the range of agreement and disagreement by interviewees, along with the individual responses for each statement, and the total percentage distribution of agreement and disagreement across the 15 responses.

Table 7.3 Question outcomes based on fifteen interviewees

Statements outcomes based on 15 interviews																	
Subject area	Agree	Disagree	Interviewees														
			I01	I02	I03	I04	I05	I06	I07	I08	I09	I10	I11	I12	I13	I14	I15
BIM adoption and being compliant to Level 2 BIM	9	6	✓	✓	✓	✓	✓				✓		✓		✓	✓	
Awareness with BIM assessments, none being used in place	12	3	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓
Having a KPI (or BIM related KPI) assessment in practice and impact of KPIs on project / organisational performance	10	5	✓	✓	✓		✓		✓	✓	✓	✓		✓	✓		
Provided KPIs list from research	9	6		✓			✓		✓	✓	✓	✓	✓	✓	✓		
Mechanism to establish an impact of Level of BIM maturity on KPIs (*6 interviewees)	3	3	✓	✓		×	×				✓		×				
Potential link between the Level of BIM maturity and the KPIs (Before assessment)	14	1	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓
Potential link between the Level of BIM maturity and the KPIs (After assessment)	13	2	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓
Benefits of linking BIM and KPIs existing	12	3	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓	✓	✓

The findings showed that:

1) In terms of Level 2 BIM adoption and compliance, nine interviewees agreed to compliance to the government Level 2 BIM mandate, which represents 60% of the sample. Thus, 40% organisations from this sample are not meeting the government Level 2 BIM mandate, which suggests that these organisations may be unaware of the mandate or unclear on what is required for compliance. This correlates with the findings that 39% are not clear on what has to been done to comply with the government mandate (NBS. 2019) and represents an obstacle within these organisations to upskilling to the Level 2 mandate.
2) In terms of awareness of existing BIM assessments, none agreed to the use of assessment within their firms; 12 interviewees stated they were only aware of assessments, while three were not aware of any. Although this aligns with studies that indicate awareness of assessments across organisations with some also applied (Badrinath et al., 2019; Kassem & Li, 2020), this suggests a lack of overall awareness of BIM assessments and thus, the need to educate organisations on assessments to enhance their level of BIM adoption.
3) In regard to KPI metrics in place, ten interviewees agreed to having a number of KPI metrics in used within their organisations citing various reasons, such as measuring the project/organisational performance; in comparison, five disagreed. This suggests that KPI metrics are yet to be made applied within those organisations that disagreed, which could support the development of potential linkages between BIM maturity and KPI metrics.
4) The list of KPI metrics that emerged from the literature was presented to the interviewees. Nine agreed that the presented list of KPI metrics was a standardised list for generalisation, whereas six disagreed. This indicated that the list could be considered a benchmark for use within organisations, although further reviews would have to be conducted to agree on a standardised list of KPI metrics.
5) In determining a mechanism to link BIM maturity and KPI metrics, only six interviewees had knowledge to determine a potential mechanism between both. In comparison, three agreed to a mechanism and provided some examples while three also disagreed and were not able to provide a mechanism. This suggests a struggle to provide a mechanism for both to work together; this needs to be reviewed to see how a mechanism could be achieved.
6) Everyone agreed to a potential link between BIM maturity and KPI metrics except one who disagreed. This indicates there could be potential ways to link them that meets the research objectives and reflect findings from the literature.

7) Moreover, 13 interviewees agreed that this assessment managed to demonstrate a linkage between BIM maturity and KPI metrics, and only two disagreed. This indicates that the assessment succeeds in delivering a linkage and meets the research objectives.
8) Finally, with benefits expected to emerge from this linkage, 12 have agreed that benefits exist, whereas three disagreed. This indicates there are potential benefits from linking both approaches, which meets the research objectives by noting the linkages and potential benefits to users and organisations.

In a nutshell, the findings indicate that 75% of the statements given were agreed to, and only 25% were disagreed, which indicates that the interviewee findings align with the critical review of key literature on BIM maturity, KPI metrics, their linkage, and the benefits to emerge.

Having presented the close-ended responses from interviewees, the next section will present the interviewees' responses to the interview questions, which will help to extract themes and quantify them to meet the selected research analysis.

7.3.3 Extraction of themes based on open ended responses

The next section will present the interviewees' responses to the questions, which contained quotes that were extracted to formulate the thematic analysis. The statements that will be highlighted in bold are directly linked to the question which starts to extract potential themes. The verbatim transcripts of the interviews are available (Appendix F).

1. a) Level 2 BIM adoption and compliance

When exploring the levels of adoption and compliance to Level 2 BIM, responses were given that agreed or disagreed, for example:

> *When it comes to **level of adoption**, then it is **done in a structured way** for the last 10 years, and then we **fall out to be unstructured**, and more of prototyping type of work."* **(Interviewee I01).** *"We are **educating the client on BIM**, and there is an eager to **implement and be compliant with Level 2 BIM** according to the UK government mandate."* **(Interviewee I07).** *"In terms of **adoption with standards**, we're getting on top of it, **finalising our standards and protocols which adopt all the BS standards and the PAS documents**, all the kind of **British Standards** that go alongside with that."* **(Interviewee I14).**

This shows the adoption of Level 2 in accordance to BIM standards that align to Level 2 BIM, and this this also indicated some negative issues related to the adoption of BIM for that specific individual in their organisation, and an unstructured method of working, which has impacted negatively on the organisation's level of adoption of BIM. This aligns with the literature review findings on the awareness of BIM and the levels of adoption (NBS. 2019, 2020). Examples of some themes that could be extracted are: **1. Level 2 BIM protocols and standards, and 2. Introduction to BIM standards amongst clients.**

1. b) BIM maturity assessments/tools/models

When identifying the levels of understanding amongst interviewees on the different BIM assessments and if any exist within their practice, various answers were given, for example:

*"**Resources, software and organisation BIM maturity questionnaire**"* **(Interviewee I02).** *"Looking at how to **create internal checklist**, doing it based on my industrial experience"* **(Interviewee I03)**. *"We know about them and we've been filling them out for years. But when it comes to having a BIM maturity assessment in place, we don't have a standard maturity assessment. That is something that's on the list to do it on **our BIM Level 2 certification with BRE**, on the to do list items….. As a practice, we are in a process of going through a **BIM level 2 certification ourselves**"* **(Interviewee I13).**

This indicated that some interviewees demonstrated their awareness of Level 2 BIM assessments but did not have an assessment in place, although suggested one as a future consideration. However, they had different in-house assessments based on checklists and experience, not related to BIM assessments presented in the literature, and assessments that lead to obtaining a Level 2 BIM certification. This links to attempting an assessment based on self-experience and the absence of existing BIM assessments within practices and shows some lack of awareness of BIM maturity assessments and suggests the need to educate users, which correlates with the research aim and objectives for presenting an assessment. Examples of some themes that could be extracted are: **1. Delivery of Level 2 BIM certifications, 2. Self assessments to measure Level 2 BIM adoption, and 3. Variety of BIM knowledge amongst users.**

In terms of the strengths and weaknesses for the BIM assessments, examples are:

*"General knowledge about BIM **has increased**"* **(Interviewee I06).** *"Most of the maturity assessments are **very technical**"* **(Interviewee I09).** *"Process of disseminating the outcomes **is a manual & time-consuming process**"* **(Interviewee I11).** *"**Sharing knowledge, ideas, aspirations**"* **(Interviewee I12).**

Both noted being more knowledgeable with BIM, the ability to share this knowledge and the concepts generated, and noting the importance of BIM assessment. Some of this resonates with the strengths of BIM assessments noted in the literature.

Both implied some consistency in terms of filling out the assessment and the variation in time taken. This indicates a potential challenge ted alongside the assessments presented earlier in the literature, and could show what might happen with the assessment presented later on. A summary of the strengths and weaknesses that emerged from the interviews are shown in Table 7.4. Examples of some themes that could be extracted are: **1. Collaboration and Sharing, 2. Enhanced Understanding, and 3. Lack of awareness of data.**

Table 7.4 Summary of BIM maturity assessment/tool/model strengths and weaknesses from the interviews

Strengths (Total 15)	Weaknesses (Total 28)
"General knowledge about BIM has increased, and Better engage FM earlier on in a project" **(Interviewee I06)**	*"Very broad, not specific- and don't ask questions relevant to your organisation, and the recording of the data, so where do you keep all the answers" "* **(Interviewee I02)**
"Sharing knowledge, ideas, aspirations" **(Interviewee I12)**	*"Lifecycle request very weak, a gap that needs to be addressed, and We have to extract information and its very difficult."* **(Interviewee I05)**
"It is something useful to have something measure project maturity" **(Interviewee I09)**	*"Most of the maturity assessments are very technical"* **(Interviewee I09)**
"We are dealing with ourselves and we don't have to deal with others to get information" **(Interviewee I11)**	*"Process of disseminating the outcomes is a manual & time consuming process"* **(Interviewee I11)**

2. Key Performance Indicators (KPIs) metrics

When questioning interviewees on their understanding of KPI metrics and on examples they were aware of, a range answers were given; for example:

*"It is difficult to do a KPI on cost, because **what's the benchmark alternative** is very subjective. (i.e. clash) there is a clash there that saves us an X amount of cost, but you might have not had a clash in reality. Expected saving amongst that. So, **it is difficult to put a KPI against cost**"* **(Interviewee I01).** *"We have a **(Closeout 1)**, then we have a **client satisfaction performer** for our clients to give us feedback on our performance"* **(Interviewee I13).**

This indicated that not only do KPIs presented in the literature not align here, but different ways of measuring KPIs and tools exist. This contradicted some of the literature findings and presented an opportunity to develop a standardised list of KPIs for practice. Also, it shows some difficulties with benchmarking KPIs and measuring them, which aligns to some of the literature findings associated with measuring KPIs. Examples of some themes that could be extracted are: **1. Challenges affecting KPIs, and 2. KPIs generated and being used on projects.**

3. a) Linking BIM maturity and KPI metrics (before assessment)

When questioning interviewees on their views on linking BIM maturity and KPI metrics through mechanisms, actions, and the potential link, various answers were given, for example:

*"A methodology for measuring **BIM level 2 benefits along with a SWOT analysis**"* **(Interviewee I09).** *"BIM is how we manage and run the job, KPIs are how we measure the success, and **those 2 things are completely different**"* **(Interviewee I08).** *"Monitor capabilities rather than maturity"* **(Interviewee I01).**

These findings indicated potential mechanisms through different types of analysis (SWOT), the differences between BIM and KPIs, and a greater emphasis on capabilities than on maturity. This indicates that potential methods to link BIM maturity and KPI metrics could vary from one practice to another, meaning that some could identify links while others not. These findings correlate significantly with the literature findings. Examples of some themes that could be extracted are: **1. Capability to extract and / or deliver data, 2. Existence of advanced technology, and 3. Delivery of training facilities.** A summary of the related quotes emerged from the interviews and is available in Table 7.5.

Table 7.5 The mechanism of Level of BIM maturity on the KPIs vs actions required: Interviewee quotes

Mechanism (Total 11)	Actions (Total 11)
"We would monitor a project with no support" **(Interviewee I01)**	*"Monitor capabilities rather than maturity"* **(Interviewee I01)**
"We have series of training offers " **(Interviewee I02)**	*"We could provide training to how to deliver COBie on project"* **(Interviewee I02)**
"A methodology for measuring BIM level 2 benefits, and a SWOT analysis type" **(Interviewee I09)**	*"Use the PWC model for benefits and map the BMAT to it"* **(Interviewee I09)**
"Project Management K Net application manages project resources & PRP costs " **(Interviewee I11)**	*"Project Management K Net application can be used to compare projects differently"* **(Interviewee I11)**

3. b) Linking BIM maturity and KPI metrics (After assessment)

At this stage, the assessment was provided to the interviewees and general feedback was given. Their views were gathered on linking BIM maturity and KPI metrics in terms of the provided assessment, and the associated benefits, which varied between interviewees, for example:

"Yes, there is a direct impact**, if you know someone is not **capable of delivering** something, which has not been implemented, at least you know how to improve it.**" **(Interviewee I02).** ***"**Because you can measure your BIM maturity through **the KPIs and improve your BIM maturity based on the KPIs** that you established**."*** **(Interviewee I04)**. *The more mature the BIM model, if it's in the green column, will give you better data to analyse to get more accurate KPIs.* **(Interviewee I10).**

According to these views, the assessment works in terms of linking BIM maturity and KPI metrics, although some strategies could enable future improvement when implementing the assessment. In terms of the KPI metrics, it would enable measurement and improve the levels of BIM maturity adoption, while scoring in the consistency level would allow for better data analysis and a better delivery of information that aligns with BIM maturity. Examples of some themes that could be extracted are: **1. Enhanced Capabilities, and 2. KPIs outcomes to improve BIM processes.**

4. Actions to link BIM maturity and KPI metrics alongside the potential benefits

Interviewees were asked about the actions required to enable a linkage alongside the potential benefits to occur and various answers were given, for example:

"The process will be** measuring your BIM maturity, create your KPIs, and find out where the problems are, improve it, and then re-measure it.**" **(Interviewee I04).** ***"**I think for clients in general, if you can **link them all together**, then it can make it easier to put a business case for it.**"*** **(Interviewee I15).**

These views show that actions to link BIM maturity and KPI metrics exist, which can act as a continuous cycle of measuring, creating, improving, and then remeasuring. Also, the data could be presented in a matrix or scattered diagram to help explain it to users. Some of the quotes align with the linking actions presented in the literature review and the distribution of BIM maturity and KPI metrics for the framework. Examples of some themes that could be extracted are: **1. Improved collaboration and quality, 2. Developing data based on existing information, and 3. External sources used to ease information transfer.** A selection of key quotes that emerged from the interviewees on the actions, user benefits, and additional information on BIM maturity and KPI metrics are presented in Table 7.6.

Table 7.6 Actions for the linkage and benefits to reflect on users

Actions for link to occur (Total 9)	Benefits on users (Total 7)	BIM and KPIs more info (Total 14)
"The process will be measure your BIM maturity, create your KPIs, and find out where the problems are, improve it, and then re-measure it." **(Interviewee I04)**	*"We want to go to that point, where we have client satisfaction, and we don't have the battles and having to see."* **(Interviewee I01).**	*" I think this assessment is more on project by project basis, since questions are mainly directed to projects status."* **(Interviewee I02)**
"Greater integration of Services & design with the whole supply chain should generate more efficiencies & savings." **(Interviewee I11).**	*"It's doing 3D work upfront, reducing risk on site by improving clash detection process, its removing risks before getting on the site before it gets to cost more"* **(Interviewee I04).**	*"I think one of the drivers that I seem to recall on the early part of the development of BIM, in a strand that we have problem with is Health and Safety."* **(Interviewee I05)**
"Yes it does. By bringing in Culture and Safety into it, I think it is good" **(Interviewee I12).**	*"As long as procurement routes are set up to integrate lifecycle analysis, that could be massive. I think that will be a huge benefit for the construction industry"* **(Interviewee I14).**	*"There is something around collaboration in setting the maturity on a project."* **(Interviewee I09)**
"You can do like a massive matrix or a scattered diagram that shows all of these things down on one side and all of the KPIs, so you can describe to somebody " **(Interviewee I13).**	*"I think for clients in general, if you can link them all together, then it can make it easier to put a business case for it"* **(Interviewee I15)**	*"Its good as a maturity assessment, and a lot easier to fill rather than the lot non-winded ones that you get"* **(Interviewee I13).**

Based on the previous information and questions asked, a list of key words and phrases were repeated and used more frequently in the interviews. The repetition of these words and phrases aims to signify the important areas on which interviewees focused in terms of the BIM maturity assessments, KPI metrics, their linkages, and the benefits to emerge. The key words and phrases linked to these topic areas have been highlighted in bold to subsequently help extract themes related to the research, which was generated from NVIVO software, used to compile the data. The quotes and most frequent words used across the interviewee questions will be discussed in more detail in the next section. Having presented an extraction of the themes, the next section will discuss the hierarchy breakdown of those themes in more details.

7.3.4 Presenting the Overarching, Main, and Sub themes

Themes generated from the interview data were described, and examples identified from quotes were presented; from this, a number of themes were extracted. The themes have been categorised into 3 layers of themes (Braun and Clarke, 2016). Those are presented as follows:

1) **Overarching themes –** which tend to organize and structure an analysis; they capture an idea underpinning a number of themes.
2) **Main Themes –** which report in detail on meaning related to a central organizing concept.
3) **Sub-themes –** which capture and develop an important facet of the central organizing concept of a theme.

Based on the interview quotes (Appendix F), a total of 3 overarching themes, 9 main themes and 39 sub themes were extracted across the interviews and based on the interviewees' responses to the questions (Table 7.1), which helped to identify and quantify the themes. The questions covered in the interviews covered 3 main topic areas (BIM, KPIs, and both combined together), which are identified in the literature and align back to the research objectives. In reviewing those topic areas, 3 overarching themes have formed the basis of the main and sub themes that were identified (People, Process, and Technology). The topic areas, overarching themes, main and subthemes were covered across all the questions in the interviews, except question seven which is presented differently. The main themes include themes that were driven from the 3 overarching themes, which contained a total of 9 main themes (3 main themes each for each overarching theme). The sub themes include themes which are linked to the main themes that were driven from the 3 overarching themes, which contained a total of 39 sub themes (13 sub themes each split amongst the 3 main themes identified for each overarching theme). The layers of categorisation includes 3 layers: 1) The overarching theme with the most total number of discussions (Process) was highlighted in blue (Main themes) and Light blue (Sub themes) which indicated more focus from the interviewees in discussions around the process, 2) The 2nd overarching theme with total number of discussions (Technology) was highlighted in yellow and light yellow, 3) The final overarching with a slightly less total number of discussions (People) was highlighted in green and light green. Figures 7.3-7.5 below illustrates the extraction of the themes from the open-ended questions, and presents the complete picture of the thematic analysis, which will then be detailed by each overarching theme to present the complete picture of the content analysis.

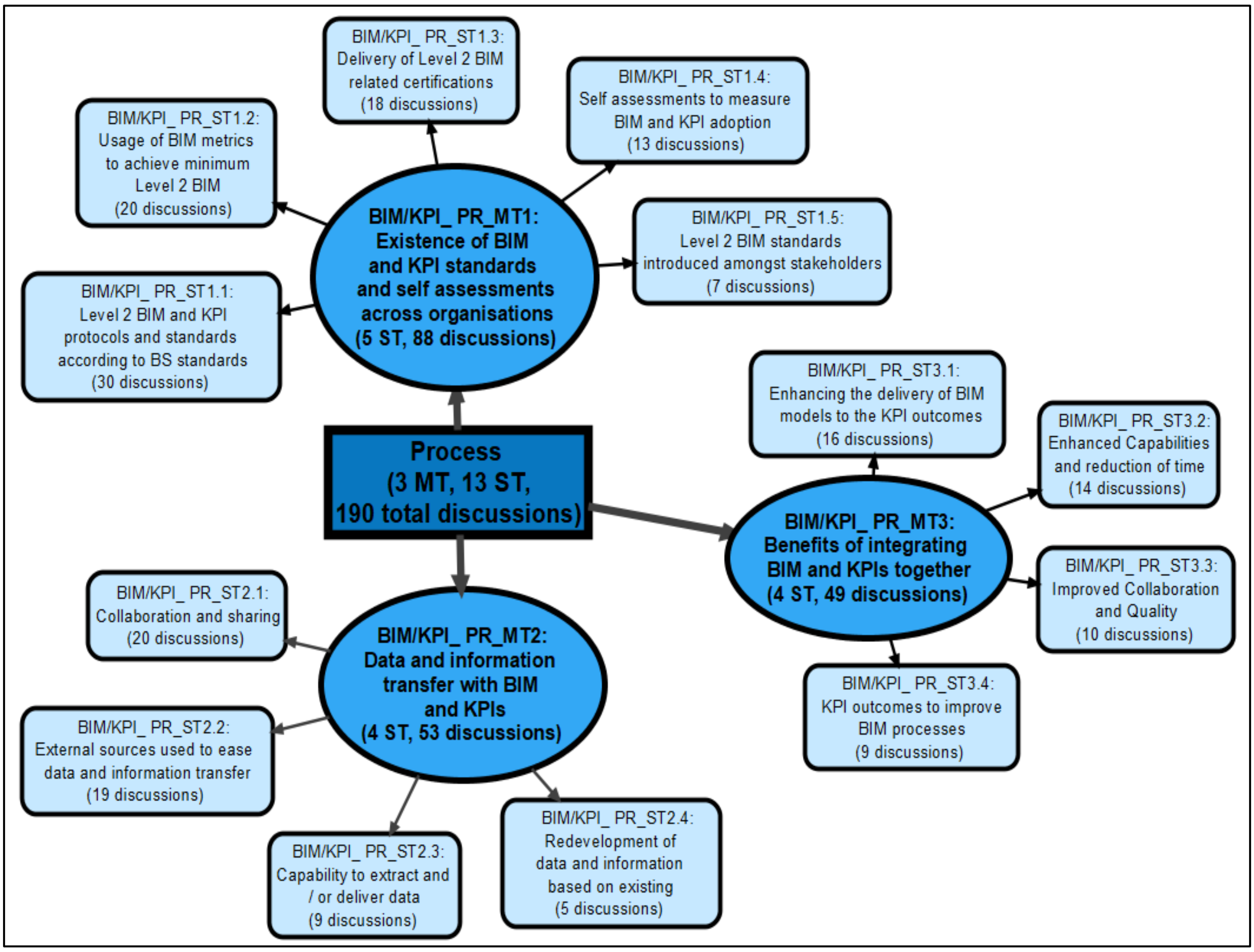


Figure 7.3 Interview thematic map (Process)

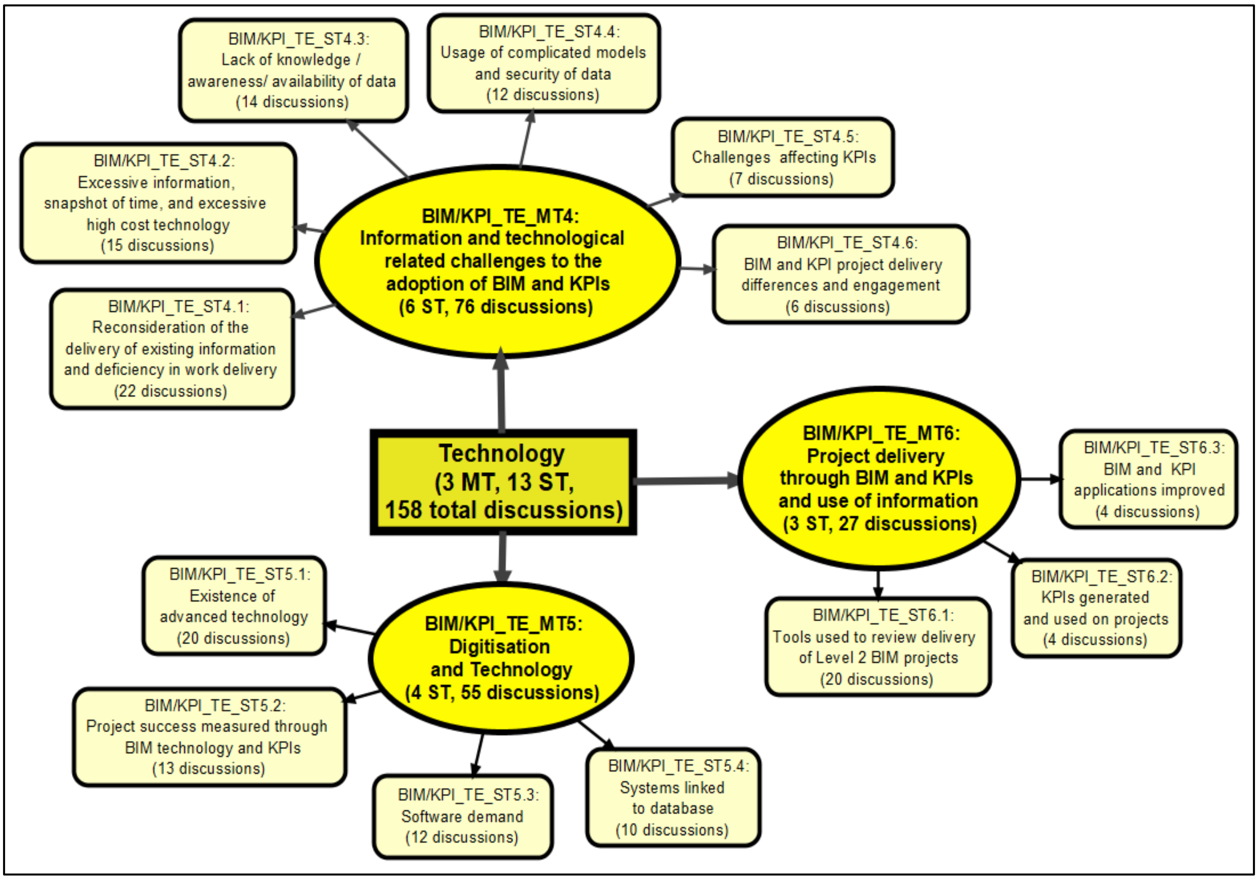


Figure 7.4 Interview thematic map (Technology)

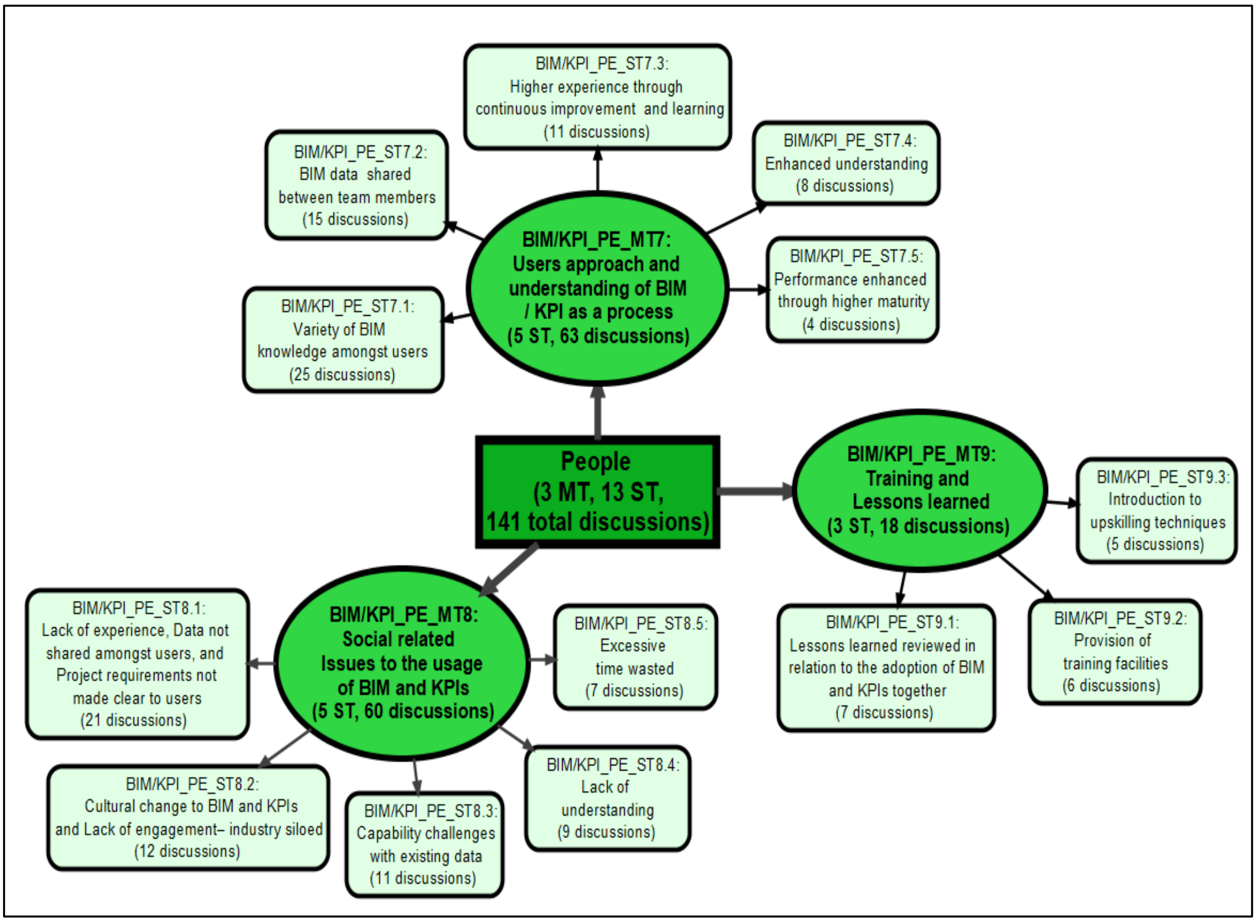


Figure 7.5 Interview thematic map (People)

The next step of the analysis is to present the content analysis and combine this with the thematic findings. For this, the main and sub themes, along with a number of discussions are noted; these are formed as sentences that are compiled to generate sub themes and then linked back to the main themes, which are related back to the overarching themes. These were generated from NVIVO software, which was used to compile this data. The questions were a mix of open and close-ended and offered opportunities to agree/disagree with specific deliverables concerning BIM maturity assessments, KPI metrics, their linkages, and the potential benefits to emerge. Furthermore, a summary of the overarching, main, and sub themes will be delivered in terms of a description for each theme, interview quotes related to the presented themes, discussion outcomes, and the number and percentage of discussions by interviewees associated with these themes. This aims to show how much emphasis in the discussions was placed on the themes mentioned and how the interviewee responded to them. This aims to present discussions related to each sub theme, to outline how much the responses related to each sub theme, what the expected outcomes were from the discussions revolving around these themes, and the number and percentage of discussion linked to each theme. This helped demonstrate the most to the least commonly occurring. The number of discussions, which was based on the verbatim transcripts from the semi structured interviews (Appendix F), were formed and measured as a compilation of sentences of direct quotes from the interviews, and key occurring discussions that starts to form a pattern of interesting and are vital to the research objectives were highlighted in **bold**. These are then linked to sub themes and a sequence of patterns deliver related topics, as this demonstrates a comprehensive meaning to what has been said and how it is linked to occurring sub themes. The same discussions could be repeated that delivers the same sub theme meaning or discussions from different interviewees could deliver the same essence and be similarly linked to sub themes. This emphasises the importance of considering the discussions qualitatively and quantitatively to demonstrate the frequency and number of occurrences of each theme. This helps to recognise areas of strength and weakness (i.e. repetition of sentences about the lack of training suggests that there are issues to do perceived knowledge and competence. The repetition of sentences about existing BIM knowledge demonstrates a good level of BIM knowledge). An initial draft of the identified main and sub themes and the number of discussions, which are based on the verbatim transcripts (Appendix F) and related to each theme, are presented (Figure 7.6).

Nodes (Search Project)

Name	Files	References
i) BIM Implementation (i.e. Users approach to BIM, Understanding, experiences)	1	32
1_b_i 1) Results of Implementing BIM in practices	1	12
1_b_i 2) Results of Applying BIM	1	9
1_b_i 3) Sharing BIM Data	1	2
1_b_i 4) Upskilling and fixing	1	2
1_b_i 5) Meeting users requirements and upskilling	1	2
1_b_i 6) Results of Experience	1	1
1_b_i 7) Existing Knowledge on BIM	1	1
1_b_i 8) BIM Self-assessment	1	1
1_b_i 9) Training	1	1
1_b_i_10) BIM Lessons Learned	1	1
1_b_i_11) Outcomes resulting in better Performance	1	1
1_b_i_12) Understanding and its outcomes	1	1
ii) BIM applications (i.e. Information, Software, Models, tools)	1	20
1_b_ii_1) BIM project delivery	1	5
1_b_ii_2) BIM usage	1	5
1_b_ii_3) Information and its outcomes	1	3
1_b_ii_4) Software demand	1	3
1_b_ii_5) Model outcomes	1	2
1_b_ii_6) Capability to extract or deliver data	1	2
1_b_ii_7) Availability and accessibility to data	1	1
1_b_ii_8) Technology	1	1

Figure 7.6 Main and sub theme grouping and the number of discussions from the interview findings

Having outlined the mechanism to present the thematic and content analysis, the extraction of main and sub themes, the number of discussions (Figures 7.3-7.5), and the list of questions (Table 7.1), the next section will deliver detailed outcomes on the open-ended questions which will help to shape the extracted overarching, main, and sub themes.

7.3.5 Quantifying the Overarching, Main, and Sub themes

After presenting the complete themes, this section presents the detailed findings for each main and sub theme, which were driven by the extraction of the 3 overarching themes. A total of 3 overarching themes, 9 main themes, 39 sub themes, and 489 discussions were identified based on the interviewee discussions on BIM maturity and KPI metrics and how they can be linked together and used in the qualitative analysis. Table 7.7 presents a complete list of the content analysis that shows the breakdown of the themes.

Table 7.7 Summarised list of identified BIM/KPI themes

Code and Main theme name	Code	Sub theme name	Number of Discussions	Total
		Process	**190**	
BIM/KPI_ PR_MT1 Existence of BIM and KPI standards and self assessments across organisations	BIM/KPI_ PR_ST1.1	Level 2 BIM and KPI protocols and standards according to BS standards	30	88
	BIM/KPI_ PR_ST1.2	Usage of BIM metrics to achieve minimum Level 2 BIM	20	
	BIM/KPI_ PR_ST1.3	Delivery of Level 2 BIM related certifications	18	
	BIM/KPI_ PR_ST1.4	Self assessments to measure BIM and KPI adoption	13	
	BIM/KPI_ PR_ST1.5	Level 2 BIM standards introduced amongst stakeholders	7	
BIM/KPI_ PR_MT2 Data and information transfer with BIM and KPIs	BIM/KPI_ PR_ST2.1	Collaboration and sharing	20	53
	BIM/KPI_ PR_ST2.2	External sources used to ease data and information transfer	19	
	BIM/KPI_ PR_ST2.3	Capability to extract and / or deliver data	9	
	BIM/KPI_ PR_ST1.4	Redevelopment of data and information based on existing	5	
BIM/KPI_ PR_MT3 Benefits of integrating BIM and KPIs together	BIM/KPI_ PR_ST3.1	Enhancing the delivery of BIM models to the KPI outcomes	16	49
	BIM/KPI_ PR_ST3.2	Enhanced capabilities and reduction of time	14	
	BIM/KPI_ PR_ST3.3	Improved collaboration and quality	10	
	BIM/KPI_ PR_ST3.4	KPI outcomes to improve BIM processes	9	
		Technology	**158**	
BIM/KPI_TE_MT4 Information and technological related challenges to the adoption of BIM and KPIs	BIM/KPI_TE_ST4.1	Reconsideration of the delivery of existing information and deficiency in work delivery	22	76
	BIM/KPI_TE_ST4.2	Excessive information, snapshot of time, and excessive high cost technology	15	
	BIM/KPI_TE_ST4.3	Lack of knowledge / awareness / availability of data	14	
	BIM/KPI_TE_ST4.4	Usage of complicated models and security of data	12	
	BIM/KPI_TE_ST4.5	Challenges affecting KPIs	7	
	BIM/KPI_TC_ST4.6	BIM and KPI project delivery differences and engagement	6	
BIM/KPI_TE_MT5 Digitisation and Technology	BIM/KPI_TE_ST5.1	Existence of advanced technology	20	55
	BIM/KPI_TE_ST5.2	Project success measured through BIM technology and KPIs	13	
	BIM/KPI_TE_ST5.3	Software demand	12	
	BIM/KPI_TE_ST5.4	Systems linked to database	10	
BIM/KPI_ TE_MT6 Project delivery through BIM and KPIs and use of information	BIM/KPI_TE_ST6.1	Tools used to review delivery of Level 2 BIM projects	20	27
	BIM/KPI_TE_ST6.2	KPIs generated and used on projects	4	
	BIM/KPI_TE_ST6.3	BIM and KPI applications improved	3	
		People	**141**	
BIM/KPI_PE_MT7 Users approach and understanding of BIM / KPI as a process	BIM/KPI_PE_ST7.1	Variety of BIM knowledge amongst users	25	63
	BIM/KPI_PE_ST7.2	BIM data shared between team members	15	
	BIM/KPI_PE_ST7.3	Higher experience through continuous improvement and learning	11	
	BIM/KPI_PE_ST7.4	Enhanced understanding	8	
	BIM/KPI_PE_ST7.5	Performance enhanced through higher maturity	4	
BIM/KPI_PE_MT8 Social related issues to the usage of BIM and KPIs	BIM/KPI_PE_ST8.1	Lack of experience, Data not shared amongst users, and Project requirements not made clear to users	21	60
	BIM/KPI_PE_ST8.2	Cultural change to BIM / KPI and Lack of engagement – industry siloed	12	
	BIM/KPI_PE_ST8.3	Capability challenges with existing data	11	
	BIM/KPI_PE_ST8.4	Lack of understanding	9	
	BIM/KPI_PE_ST8.5	Excessive time wasted	7	
BIM/KPI_PE_MT9 Training and Lessons learned	BIM/KPI_PE_ST9.1	Lessons learned reviewed in relation to the adoption of BIM and KPIs together	7	18
	BIM/KPI_PE_ST9.2	Provision of training facilities	6	
	BIM/KPI_PE_ST9.3	Introduction to upskilling techniques	5	
Total number of discussions for the thematic and content analysis		9 Main themes, 39 sub themes	489	

The next sub sections will present the main and the sub theme findings in relation to the overarching themes.

7.3.5.1 Process

The overarching theme with most discussions related to was **Process**. In the context of this research, Process is defined as the techniques and ways of how is BIM being implemented through the usage of a number of tools and assessments. Hence, the main and sub themes would be linked to Process based on the existing BIM standards, and the data used to implement a number of presented KPIs on projects. As a result, there are 3 main themes, 13 sub themes, and a total of 190 discussions related to the sub themes that have emerged and were linked to Process as a primary overarching theme, and based on the interview questions (Sections 7.2.1-7.2.2) and the verbatim transcripts (Appendix F). The themes have been quantified to rank them based on the number of discussions. The 3 main themes rank order based on the number of discussions are: **1. Existence of BIM and KPI standards and self assessments across organisations (88 discussions), 2. Data and information transfer with BIM and KPIs (53), and 3. Benefits of integrating BIM and KPIs together (49).** The 13 sub themes linked back to the main themes and their related discussions will be discussed in more details in the subsequent sections.

1. Existence of BIM and KPI standards and self assessments across organisations

A total number of 88 discussions have been linked to this main theme, which was the most theme in relation to Process. This theme discusses topic areas related to a number of BIM maturity and KPI standards, assessments and certifications that have been adopted across different organisations. Under this theme, 5 sub themes emerged and linked to their number of discussions after being compiled with the verbatim transcripts. Based on the overall sub themes, the ranking and overall outcomes of the sub themes were as follows (in descending order):

1.1 Level 2 BIM and KPI protocols and standards according to BS standards (**Outlining a number of standards that comply to the BS standards and Level 2 BIM)**; This was the most prevalent sub theme to this main theme which had a total of 30 discussions amongst all interviewees representing 34% of the total discussions related to this theme. Discussions related to this sub theme focused on adoption of BIM standards across practice. Key discussions noted by the interviewees are highlighted in **bold** which focuses on what were the standards being adopted. Those are as follows:

*"Auditing and conducting checks on **whether the folders and files are BS1192-2 compliant** or not."* **(Interviewee I02).** *"It started with the aim to **achieve BIM level 2**, and there are all the **strategic and BIM implementation workflows in place** and implementing it in our projects."* **(Interviewee I04).** *"BIM is about the **feed for these buildings**, it's about managing them and **looking forward** and looking after them. So, you **are building right, so you can manage it right, and maintain right** going forward."* **(Interviewee I08).** *"As a **practice**, we work on the **PAS1192-2, information management structures and***

BIM structures. *The firm has their* ***own BIM guidelines and they are based on PAS1192****."* **(Interviewee I11).** *"In terms of* ***adoption with standards****, we're getting on top of it,* ***coming to the end of finalising our standards and protocols which adopt all the BS standards and the PAS documents****."* **(Interviewee I14).** *"We are trying to* ***implement the standards, our documentation has been reconfigured to BS1192 compliant****, and we are pushing this to make all our projects consistent."* **(Interviewee I15).**

1.2 Usage of BIM metrics to achieve minimum Level 2 BIM (**Implementing a number of BIM metrics that meets the minimum Level 2 BIM requirements)**; This theme had a total of 20 discussions amongst all interviewees representing 23% of the total discussions related to this theme. Discussions related to this sub theme focused on the usage of a number of BIM maturity metrics that meets the Level 2 BIM requirements. Key discussions noted by the interviewees which focuses on what were the BIM maturity metrics implemented to achieve Level 2 BIM are as follows:

"Creation of all the documents required to be Level 2 BIM compliance, all the capability assessments, ***protocols, BIM execution plans template, as well as project execution plan template****."* **(Interviewee I02). "***The* ***own assessment is about the periodic reviews of the project practice****, there is the* ***BIM Execution Project templates and BIM Execution Plan templates****, and there is the* ***BIM information protocol****, which outlines* ***the practice's procedures and how they proceed with training and developments and the speed on BIM projects****."* **(Interviewee I11). "***I think* ***what we've done is we've developed the BIM EIRs****……* ***BEP will be used to a high level****"* **(Interviewee I12). "***We have* ***Master Information Delivery Plan, for the projects, we have our Task information delivery plans on every Workstage*** *of the job."* **(Interviewee I13).** *"I suppose we just try to follow the* ***BEP as part of our self-assessment****.* ***I suppose what will be the Mark Bew's triangle about Level 2 BIM****, which includes everyone working in every 3D environment, that* ***clash detections that coordination and in also the kind of COBie requirements****, the Employers* ***Information Requirement would feed into the model****, and the* ***output is the COBie data*** *in the end. We are following the* ***Information Delivery Cycle****, but nothing on with assessment."* **(Interviewee I14).**

1.3 Delivery of Level 2 BIM related certifications (**The delivery of certifications related to Level 2 BIM for practitioners to be certified on Level 2 BIM);** This theme had a total of 18 discussions amongst all interviewees representing 20% of the total discussions related to this theme. Discussions related to this sub theme focused on the delivery of and the need for BIM certifications that meets the Level 2 BIM requirements. Key discussions noted by the interviewees which focuses on what were the type of certificates awarded and delivered to achieve Level 2 BIM are as follows:

"We ***developed our internal formal one****, and we* ***use our own one****"* **(Interviewee I01).** *"The practice is much more BIM integrated, so that* ***office leads the BIM journey****. They have* ***BRE BIM certification."*** **(Interviewee I11). "***As a practice, we are in a process of going through a* ***BIM level 2 certification ourselves."*** **(Interviewee I13).**

1.4 Self assessments to measure BIM and KPI adoption (**The usage of a number of assessments related to the adoption of BIM and KPIs);** This theme had a total of 13 discussions amongst all interviewees representing 15% of the total discussions related to this theme. Discussions related to this sub theme focused on the usage of a number of self assessments that would measure the adoption of Level 2 BIM and KPIs. Key discussions noted by the interviewees which focuses on what were the self assessments used within practices to measure the adoption of BIM and KPIs are as follows:

*"**Resources, software and organisation BIM maturity questionnaire…** We have **3 forms**, looked at the **Penn state**, and **ARUP** and **different maturities** and we are working with contractors such as Morgan Sindall, b & K**, to develop a tool** that actually makes sense, because some of the **questions** that come out of the **Penn state questionnaire**, does not make sense."* **(Interviewee I02).** *"Looking at and **how to create internal checklist**, so I am **doing it based on my experience** in the industry…. **There is no awareness or knowledge on Level 2 BIM maturity assessments (i.e. Penn state, ARUP)**."* **(Interviewee I03)**. "*What we use now is **documentation within the EU BIM Handbook and the EU BIM assessment is very good.** The website where you can get **addition information about it** and it is considered as the **nearest maturity assessment** is (http://www.eubim.eu/handbook/). **It covers a way of implementing BIM**, so the things you need to put in place as a process to make the implementation."* **(Interviewee I09)**. "*The **own assessment is about the periodic reviews of the project practice…. PQ Questionnaires + BIM Information policies & Review of BEP**. **Pre- Qualifications, Investigated NBS BIM Toolkit"*** **(Interviewee I11)**. "*We work with clients **to develop their BIM maturity assessment."*** **(Interviewee I13)**. "*I suppose we just try to follow the **BEP as part of our self-assessment**."* **(Interviewee I14)**.

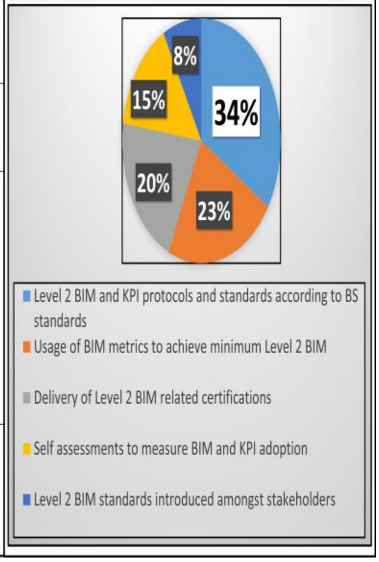
1.5 Level 2 BIM standards introduced amongst stakeholders (**The implementation of Level 2 BIM standards amongst users within practices);** This theme had a total of 7 discussions amongst all interviewees representing 8% of the total discussions related to this theme. Discussions related to this sub theme focused on the Level 2 BIM standards that needs to be introduced and educated to clients to meet their working practices needs in relation to Level 2 BIM. Key discussions noted by the interviewees which focuses on the need to educate clients on BIM and driving their Level 2 BIM requirements are as follows:

*"We are **seeking the delivery of BIM level 2** while having all the processes and documentation in place."* **(Interviewee I04).** *"We say to them you must **provide us with BIM documents** to **cover Level 2 standards**"* **(Interviewee I05).** *"In the minute its more of **overload projects, where we get information on BIM and BIM level 2.**"* **(Interviewee I06).** *"We are **educating the client on BIM**, and there is an **eager to implement and be compliant with Level 2 BIM** according to the UK government mandate".* **(Interviewee I07).**

Table 7.8 presents an overview of the sub themes linked to this main theme and the discussion outcomes linked back to the sub themes which have been detailed through the interviewee quotes and highlighted in **bold**.

Table 7.8 MT1 Existence of BIM and KPI standards and self assessments across organisations

Code	Sub theme name	Discussion outcomes	Rank	Number of Discussions	Code and Main theme name	Total number of discussions and Percentages
BIM/KPI_ PR_ST1.1	Level 2 BIM and KPI protocols and standards according to BS standards	• Adoption of BIM protocols and standards across organisations • Implementation of BIM in a structured way • Introducing the work amongst practices • Outlining the basic needs required to apply BIM	1	$\boxed{30}$	BIM/KPI_ PR_MT1 Existence of BIM and KPI standards and self assessments across organisations	88
BIM/KPI_ PR_ST1.2	Usage of BIM metrics to achieve minimum Level 2 BIM	• Applying some of the BIM metrics that represent minimum level 2 BIM • Introducing the work amongst practices	2	20		
BIM/KPI_ PR_ST1.3	Delivery of Level 2 BIM related certifications	• Having BIM certification in place to allow us to move forward with Level 2 BIM • Outlining the basic needs required to apply BIM	3	18		
BIM/KPI_ PR_ST1.4	Self assessments to measure BIM and KPI adoption	• Scoring Criteria • Usage of surveys, for measuring BIM / KPIs, ROI • Internal in house assessments • EU methodology • Internal checklists • Business plan (KPIs) • Social value and satisfaction • PSP report • Forecast and whole life costs	4	13		
BIM/KPI_ PR_ST1.5	Level 2 BIM standards introduced amongst stakeholders	• The need to educate clients on BIM to allow them to meet their requirements • Clients requesting data which needs to be tailored • Contractors and clients driving level 2 BIM requirements	5	7		



2. Data and information transfer with BIM and KPIs

A total number of 53 discussions have been linked to this main theme. This theme discusses topic areas related to how the related BIM and KPI information will be transferred within practices and the importance of sharing the data. Under this theme, 4 sub themes emerged and linked to their number of discussions after being compiled with the verbatim transcripts. Based on the overall sub themes, the ranking and overall outcomes of the sub themes were as follows:

2.1 Collaboration and Sharing (**Importance of sharing data within practices and enabling collaboration amongst users)**; This was the most prevalent sub theme to this main theme which had a total of 20 discussions amongst all interviewees representing 38% of the total discussions related to this theme. Discussions related to this sub theme focused on the importance of sharing BIM data and collaboration between users within practices. Key discussions noted by the interviewees are highlighted in **bold** which focuses on how users collaborated and shared BIM data across practices. Those are as follows:

*"In terms of the **EIRs, sharing and collaboration**, definitely we are using those because we're trying to ensure that the **design team collaborate** and talk to each other"* **(Interviewee I05).** *"The other thing is **the collaborative approach**, you have **people like ARUP who did work with the MoJ and creating their Learning**, which is a key strength."* **(Interviewee I12).**

2.2 External sources used to ease data and information transfer (**Importance of using and existence of external sources to support information delivery and ease the information**

transfer); This theme had a total of 19 discussions amongst all interviewees representing 36% of the total discussions related to this theme. Discussions related to this sub theme focused on the importance of having external sources in place that could be used to support the information delivery and ease the transfer of information and data related to BIM and KPIs amongst users. Key discussions noted by the interviewees which focuses on what are the different types of sources that existed are as follows:

"We are thinking about it, and ***we do have an insight system (Internal developed tool)." (Interviewee I01)*** *"The KPI template sets up what* ***we have from a modelling perspective."*** **(Interviewee I01).** *"What we use now is* ***documentation within the EU BIM Handbook."*** **(Interviewee I09).** *"The* ***SHARING****, and the* ***information that could be extracted; clash detection, getting FM team on an earlier stage of the project" (Interviewee I07).*** *"The more mature the BIM model, if it's in the green column, will give you better data to analyse to get more accurate KPIs"* **(Interviewee I10).** *"They* ***get a model or a series of models*** *that is* ***easier to federate*** *and* ***easier for them to work with."*** **(Interviewee I14).**

2.3 Capability to extract and / or deliver data (**Ability to extract complex data and deliver the data on time)**; This theme had a total of 9 discussions amongst all interviewees representing 17% of the total discussions related to this theme. Discussions related to this sub theme focused on the ability to deliver data related to BIM models and extract COBie data from those models. Key discussions noted by the interviewees which focuses on how data would be extracted from models and delivered are as follows:

"The guys who are saying yes, ***we can deliver that and deliver on time****, I know they will get the job on the next scheme…..***COBie has to be extracted*** *out of this model…..They need* ***to ensure they can deliver in revit****"* **(Interviewee I02).** *"There are* ***internal QA procedures****. Adapting the internal QA procedures with previous processes. Cultural Digital Construction."* **(Interviewee I03).** "*We are* ***working to put the BIM requirements in the contracts*** *and works information. We have* ***good information requirements for the data****…..We are defining COBie structure, in choosing and locating things"* **(Interviewee I15).**

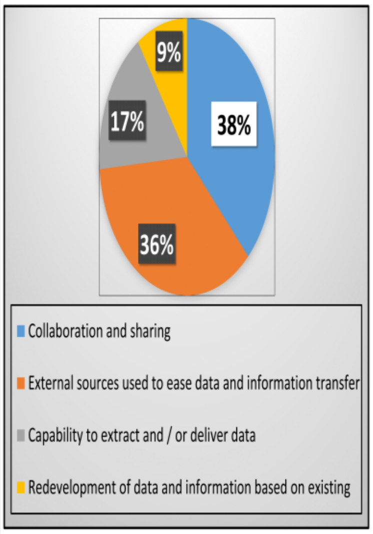
2.4 Redevelopment of data and information based on existing (**To either redevelop based on existing BIM data or to self-develop data based on existing tool and experience**); This theme had a total of 5 discussions amongst all interviewees representing 9% of the total discussions related to this theme. Discussions related to this sub theme focused on the ability to develop additional BIM data based on existing information that would depend on self-development and experience. Key discussions noted by the interviewees which focuses on how the existing data would be redeveloped based on experience are as follows:

"*We* ***don't use anything that is produced by somebody else****, we would* ***look at all of them and make our version on it****"* **(Interviewee I01).** "*There is* ***no formal QA procedure****, so I am* ***looking to develop that*** *at the moment and I am* ***basing it*** *very loosely* ***in terms of the model correctness, basing it on the AEC protocols****"* **(Interviewee I03).** *"****The delivery method*** *tends to be the same, whether its design build or in house, so* ***we elaborated*** *on this and used it to* ***develop our own strategy****."* **(Interviewee I05).** ***"What we've done is we've developed the BIM EIRs where there were gaps."*** **(Interviewee I12).**

Table 7.9 presents an overview of the sub themes linked to this main theme and the discussion outcomes linked back to the sub themes which have been detailed through the interviewee quotes and highlighted in **bold**.

Table 7.9 MT2 Data and information transfer with BIM and KPIs

Code	Sub theme name	Discussion outcomes	Rank	Number of Discussions	Code and Main theme name	Total number of discussions and Percentages
BIM/KPI_PR_ST2.1	Collaboration and sharing	• Collaboration and sharing • Model being mature = better outcomes • Existence of validation checks • Importance of sharing data to extract information to support exist (Clash detection) • FM introduced earlier stage for project.	1	20	BIM/KPI_PR_MT2 Data and information transfer with BIM and KPIs	53
BIM/KPI_PR_ST2.2	External sources used to ease data and information transfer	• Internal KPI tool developed • Model to influence KPIs template • Ease with federation of models. • Usage of external source for feeding information. • Existence of validation checks	2	19		
BIM/KPI_PR_ST2.3	Capability to extract and / or deliver data	• Ability to deliver data on time • Asset data existing. • Level 2 BIM standards in place • Availability of assessments / standards online and easy to access them • Ability to extract COBie data from model • QA procedures adapted with previous processes to assist data extraction	3	9		
BIM/KPI_PR_ST1.4	Redevelopment of data and information based on existing	• Redevelopment of QA procedures through AEC protocols • Elaborating on existing assessments to develop in house tool • Developing of BIM EIRs to address gaps • Relying on self development and not using other produced assessments	4	5		



3. Benefits of integrating BIM and KPIs together

A total number of 49 discussions have been linked to this main theme. This theme discusses topic areas related to the benefits that expects to emerge from linking BIM and KPIs together. Under this theme, 4 sub themes emerged and linked to their number of discussions after being compiled with the verbatim transcripts. Based on the overall sub themes, the ranking and overall outcomes of the sub themes were as follows:

3.1 Enhancing the delivery of BIM models to the KPI outcomes **(How the delivery of BIM models can support the outcomes of KPIs)**; This was the most prevalent sub theme to this main theme which had a total of 16 discussions amongst all interviewees representing 33% of the total discussions related to this theme. Discussions related to this sub theme focused on how if the delivery of BIM models would be enhanced to reflect on the KPI outcomes being represented as a benefit of linking BIM and KPIs together. Key discussions noted by the interviewees are highlighted in **bold** which focuses on how enhancing the delivery of BIM models would impact on the KPI outcomes. Those are as follows:

*“Because you can measure your BIM maturity through the KPIs and **improve your BIM maturity based on the KPIs** that you established.”* **(Interviewee I04).** *“In the perspective of BIM, we are more **focused on outcomes** rather than anything else. We do **see an element of KPIs around cost being measured**.”* **(Interviewee I09).**

3.2 Enhanced capabilities and reduction of time **(Using BIM and KPIs would enhanced capabilities and reduce overall time as benefits to reflect on users)**; This theme had a total of 14 discussions amongst all interviewees representing 29% of the total discussions related to this theme. Discussions related to this sub theme focused on how using BIM and KPIs together would reduce overall project time, would reflect positively on clients and enhanced their capabilities. Key discussions noted by the interviewees which focuses on how using BIM and KPIs together would reduce overall time and enhance their capabilities are as follows:

*“Where you **monitor capabilities rather than maturity, and it should be down in the individual level**.”* **(Interviewee I01).** *“Because you can measure your BIM maturity through the KPIs and improve your BIM maturity based on the KPIs that you established.”* **(Interviewee I04).** *“Clients are **looking for the Return On Investment (ROI)… Getting FM team on an earlier stage of the project”**.* **(Interviewee I07).** *“In the perspective of BIM, we are more focused on outcomes rather than anything else. We do see an element of KPIs around cost being measured… **Capabilities would be here, and the way of getting the benefits**; in terms of outcomes we are using things like BIM uses.”* **(Interviewee I09).**

3.3 Improved collaboration and quality **(Collaboration and quality of BIM models to be improved as a result of linking BIM with KPIs)**; This theme had a total of 10 discussions amongst all interviewees representing 20% of the total discussions related to this theme. Discussions related to this sub theme focused on how linking BIM with KPIs would improve collaboration and quality, enhance productivity, improve profitability and sustainability, and reduce cost certainty and risk. Key discussions noted by the interviewees which focuses on how linking BIM with KPIs together would improve overall BIM model quality and enhance collaboration and productivity are as follows:

*People don’t see the benefits of what BIM is about, in **the collaboration within the team** and the organisation. What information could be extracted, and for the benefits of the clients*.” **(Interviewee I07).** *“We believe its processes will **improve collaboration, coordination and quality with BIM** in terms of in the design, procurement and management of buildings and infrastructure.”* **(Interviewee I11).** *“**Collaborating with the rest of the design team, it will reduce the time upfront**”.* **(Interviewee I14).**

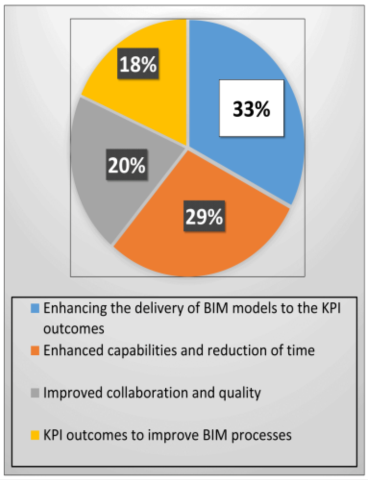
3.4 KPI outcomes to improve BIM processes **(The outcomes of KPIs (i.e. Productivity) would enhance the overall BIM processes);** This theme had a total of 9 discussions amongst all interviewees representing 18% of the total discussions related to this theme. Discussions related to this sub theme focused on adopting BIM to enable the linkage, using BIM to improve design and production quality and linking it with KPIs, and comparing BIM maturity and KPI metrics. Key discussions noted by the interviewees which focuses on how the outcomes of KPIs would improve the overall BIM process are as follows:

"If you're not capable of delivering something (BIM), then it will affect the cost of the delivery and maybe the time and might affect the overall quality (KPIs)" **(Interviewee I02).** *"Depending on your BIM maturity, it will affect the KPI."* **(Interviewee I03).**

Table 7.10 presents an overview of the sub themes linked to this main theme and the discussion outcomes linked back to the sub themes which have been detailed through the interviewee quotes and highlighted in **bold**.

Table 7.10 MT3 Benefits of integrating BIM and KPIs together

Code	Sub theme name	Discussion outcomes	Rank	Number of Discussions	Code and Main theme name	Total number of discussions and Percentages
BIM/KPI_ PR_ST3.1	Enhancing the delivery of BIM models to the KPI outcomes	• Right adoption of BIM enabling the linkage • Improved BIIM maturity outcomes reflect on linkage • More focus on outcomes • Using BIM to improve design & production qualities, and link with CE KPIs • Forecast vs actual (Compare) and refine model outcomes • Speed and Success of handover and measuring it	1	16	BIM/KPI_ PR_MT3 Benefits of integrating BIM and KPIs together	49
BIM/KPI_ PR_ST3.2	Enhanced capabilities and reduction of time	• Reduction of time / cost. • Positive effect on client / Project • Return On Investment (ROI) • Bring FM on early stage • Collaboration with design team to reduce time upfront • Enhanced capabilities • Early engagement of users. • BIM reflect positively on clients • Refer to BIM benefits methodology for measuring benefits and reflect on different users	2	14		
BIM/KPI_ PR_ST3.3	Improved collaboration and quality	• Improved collaboration, coordination and quality • Enhanced productivity • Improved profitability and Sustainability • Reduced cost certainty, risk, programme	3	10		
BIM/KPI_ PR_ST3.4	KPI outcomes to improve BIM processes	• BIM maturity result to reflect on KPIs. • Integrating KPIs outcomes with the BIM processes • Delivery of BIM affecting Cost, Time and Quality • Design + information to affect quality of work • KPIs based on Level 2 BIM requirements • Integrating 3D Models resulting in better reviews and clashes	4	9		



Having discussed the findings of Process, its main and sub themes along with the discussion related, the next section will discuss the findings related to Technology.

7.3.5.2 Technology

The next overarching theme with fewer discussions than Process was **Technology**. In the context of this research, Technology is defined as the various applications related to the existence and number of tools, models, software, etc… when dealing with BIM/KPIs. Hence, the main and sub themes would be linked to Technology based on the existing models, tools, software and related BIM and KPI applications that exist within practices. As a result, there are 3 main themes, 13 sub themes, and a total of 158 discussions related to the sub themes that have emerged and were linked to Technology as a primary overarching theme, and based on the interview questions (Sections 7.2.1-7.2.2) and the verbatim transcripts (Appendix H). The themes have been quantified to rank them based on the number of discussions. The 3 main themes rank order based on the number of discussions are: **1. Information and technological related challenges to the adoption of BIM and KPIs (76 discussions), 2. Digitisation and Technology (55), and 3. Project**

delivery through BIM and KPIs and use of information (27). The 13 sub themes linked back to the main themes and their related discussions will be discussed in more details.

1. Information and technological related challenges to the adoption of BIM and KPIs

A total number of 76 discussions have been linked to this main theme, which was the most theme in relation to Technology. This theme discusses topic areas related to a number of technological challenges that existed and has affected the adoption of BIM maturity and KPI metrics. Under this theme, 6 sub themes emerged and linked to their number of discussions after being compiled with the verbatim transcripts. Based on the overall sub themes, the ranking and overall outcomes of the sub themes were as follows (in descending order):

4.1 Reconsideration of the delivery of existing information and deficiency in work delivery (**The need to redevelop information and existence of rework and work overload)**; This was the most prevalent sub theme to this main theme which had a total of 22 discussions amongst all interviewees representing 29% of the total discussions related to this theme. Discussions related to this sub theme focused on existing work deficiencies such as work overload and the need to redevelop existing information resulting in rework. Key discussions noted by the interviewees are highlighted in **bold** which focuses on what are the problems that existed and resulted in work deficiency and the need to reconsider the delivery of existing information. Those are as follows:

"If you don't have the database, then your kind of screwed…."They ***don't know how to deliver a COBie deliverable****….The 1st time they are going to* ***issue the design + information****, most likely* ***will be incorrect****, so that* ***affects the quality of the work****, because* ***it is not correct****, so we will* ***tell them its not correct*****.** *You will* ***have to correct it****, and that will* ***affect the time scales****, so it all links but its their* ***initial cost*** *that they have to* ***invest in training themselves, Quality and Time****."* **(Interviewee I02).** *"You don't know what you don't know. So if you don't know it's there, then you won't know when & where to look for it."* **(Interviewee I03).** *"There is a* ***problem with the network****, it has been upgraded, the servers have been upgraded, but the way it was set up, it wasn't set up for any graphics to run on any program, and as soon as we started* ***putting our BIM models*** *in it, the network is slowing down…We have a much* ***bigger workload****, we have a much wider base of* ***clients who have different requirements****, so sometimes when we look for a resource in person, it doesn't necessarily mean that what's in market place is what we want."* **(Interviewee I05).** *"No EIRs, CDEs, we are struggling with the electronic communications. We are still in the old-fashioned emails, so as a practice, we don't use proper information transfer methods, BIW conject."* **(Interviewee I08).** *"We are not mandated to Level 2 BIM, but we are technically mandated…. We have not done major assessments, because we only had in* ***deficiencies."*** **(Interviewee I15).**

4.2 Excessive information, Snapshot of time, and excessive high cost technology (**Excessive data given to users, Assessments given that are currently valid at but could be outdated in the future, High cost associated with absence of BIM technology and market fluctuating)**; This theme had a total of 15 discussions amongst all interviewees representing 20% of the total discussions related to this theme. Discussions related to this sub theme focused on excessive data given to users that consumes too much time, outdated assessments being provided and information being snapshot of time in the future, and high cost associated with BIM technology resulting in market fluctuations. Key discussions noted by the interviewees which focuses on the existing problems associated with excessive data given, outdated assessments being given and high costs as a result of the absence of BIM technology are as follows:

*"In a small company, it is **very difficult to spend time creating extra procedures in addition to the normal procedures**, such as making sure we've got all the BIM or KPI documentation".* **(Interviewee I03).** *"So that being the case and being **more than 50% of the workload that we currently have**, we haven't elected to pursue BIM in any great detail."* **(Interviewee I05).** *"Ultimate drawback to BIM is the **cost and the software technology**. There isn't the technology to implement BIM, so they had **to invest a huge amount on the technology to enable them to implement BIM**."* **(Interviewee I07).** *"The problem with that kind of **benchmark is the market fluctuates**. So it's difficult to know where the cost went down or no, because of BIM or the market".* **(Interviewee I09).** *"If we do very strict EIRs, if we did **them back 2 years ago, they will be outdated now**. And if we did it now, it will outdate in 2 years' time…..My conclusion was you can't close them because if you close them, then that's **going to be a snapshot of time**, 2017-2019"* **(Interviewee I12). "***People started throwing BIM **maturity assessments that were like of going out fashioned**…..There is no point in giving them **useless information that will not help them with maintenance**, its got to meet the information provided isn't it."* **(Interviewee I13).**

4.3 Lack of awareness/knowledge/availability of data (**Absence of available assessments and data across organisations);** This theme had a total of 14 discussions amongst all interviewees representing 18% of the total discussions related to this theme. Discussions related to this sub theme focused on the absence of assessments for users to understand BIM maturity, and not being able to adopt Level 2 BIM within practices, although having some awareness with Level 2 BIM. Key discussions noted by the interviewees which focuses on the issues that deal with an absence of understanding Level 2 BIM and no availability with BIM assessments across practices are as follows:

"There is no awareness or knowledge on Level 2 BIM maturity assessments (i.e. Penn state, ARUP). I don't think it is widely known, and not necessary known within the industry" **(Interviewee I02).** *There are **many tools but is not widely known within the industry and limited knowledge on the assessments** taught in the institutions* **(Interviewee I03).** *"There is **no BIM maturity assessment alternative** in place"* **(Interviewee I04).** *"They heard about **the government mandate on BIM, but there was no strategy** in place"* **(Interviewee I07).** *"We've **not got clear EIRs, we don't have clear CDE**, and we're still doing as it's something that the contractor should do. We're just not there. That's why I said people are obsessed with that part"* **(Interviewee I08).** *"So, we are **aware of the Level 2 BIM government mandate, but it was never used** in our projects…..I don't know much about BIM"* **(Interviewee I10).***" We **haven't developed an assessment tool** ourselves."* **(Interviewee I13).** *"We **have not done any assessments yet**, bear in mind that there is no one in house who's got the time to do the assessment, because it's just myself and some others who is driving the business requirements on projects…."* **(Interviewee I14).** *"**We don't have internal KPIs**, not yet. It is not established enough"* **(Interviewee I15).**

4.4 Usage of complicated models and security of data (**Being unable to deal with highly developed models, and security concerns with data storage and limited data server availability);** This theme had a total of 12 discussions amongst all interviewees representing

16% of the total discussions related to this theme. Discussions related to this sub theme focused on absence of models related to BIM and not being able to deal if they are in place, and security concerns with the data storage related to BIM models. Key discussions noted by the interviewees which focuses on the issues on dealing with existing BIM models and the security concerns on those models are as follows:

"*So, anything we want to implement, in terms of* ***software, getting that computer set up, making sure the network is capable of running all these things, takes us a long time****….It's very* ***difficult when we have a model with lots of BIM information*** *to* ***convince people*** *that this is what you need and putting your fingers on any kind of* ***bits of information on this building****…..If* ***we don't allow that for now then we can't add it….****We have a limit on what we can store on our network servers, to be secure.* ***This is another strand, which is security****."* **(Interviewee I05).** *"The problem is as you produce these* ***models in an infinite detail****, you scared that with the IT department,* ***how many amounts of data you need to design and manage the 3D****"* **(Interviewee I08).** *"It's* ***difficult to do so****, we* ***have to think about things in advance****, …. The main focus on it is that yes they will do the model for clash detection, but* ***we said that we will never amend that model****."* **(Interviewee I10).** "*Whether any of the Facilities Management teams across the UK end up using the information that we got into the models the very minute, I doubt it*." **(Interviewee I14).**

4.5 Challenges affecting KPIs (**Unable to benchmark and measure KPIs);** This theme had a total of 7 discussions amongst all interviewees representing 9% of the total discussions related to this theme. Discussions related to this sub theme focused on not being able to benchmark a list of standardised KPIs and measuring them, which is the main aim set for this research on providing a list of standardised list of KPIs to be measured against BIM maturity to reflect back on the UK client sector. Key discussions noted by the interviewees which focuses on the absence of a standardised list of KPIs and difficulties in measuring them are as follows:

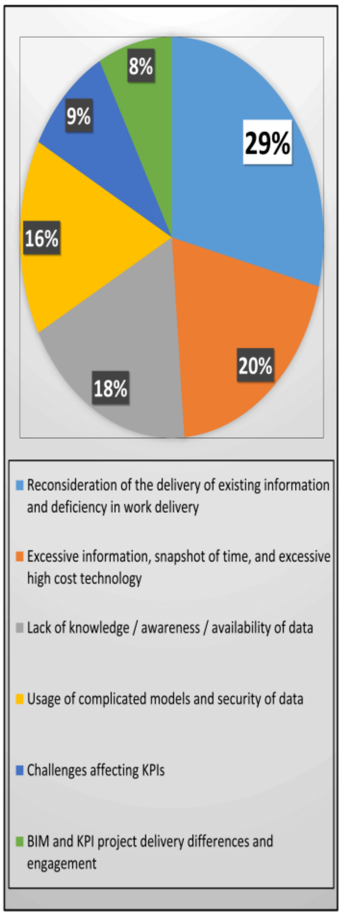
"No formal KPIs, the KPIs are not measured." **(Interviewee I03)**. ***"****How we apply the KPIs is very simplistic, and is it cheaper? On budget? Have you had any accidents? So we are not measuring what impacts the KPIs or what drives the KPIs."* **(Interviewee I08). "***The challenges is the number of other factors that could affect the KPIs, because we don't have that kind of laboratory conditions*." **(Interviewee I09). "***It's only if it doesn't come out of the KPIs, at the end of it, then you can say its by that point that they already lost you millions of pounds through inefficiencies in terms of process delivery and management on any project."* **(Interviewee I13).**

4.6 BIM and KPI project delivery differences and engagement **(Difficulties in linking and measuring BIM and KPIs and absence of engagement with project delivery)**; This theme had a total of 6 discussions amongst all interviewees representing 8% of the total discussions related to this theme. Discussions related to this sub theme focused on difficulties associated with linking and measuring BIM maturity and KPI metrics, which again is the main aim assigned for this research in establishing a mechanism on how can BIM maturity and KPI metrics be linked, and no engagement with the delivery of projects. Key discussions noted by the interviewees which focuses on the difficulties that existed within linking BIM maturity and KPI metrics and the difficulties for them to be measured are as follows:

"But whether it links with the BIM and that side of it, that's what we're focusing on and I'd say not really." **(Interviewee I06).** *"KPIs are covered within the organisation but has to do nothing with BIM, a set of processes set within the organisation standards."* **(Interviewee I07)**. *"We are looking at the traditional KPIs, traditional building industry KPIs, (Time, Cost, Quality, Health and Safety), and BIM is detached."* **(Interviewee I08).** *"I think all BIM related KPIs are difficult to measure, cost is probably the easiest, but it's still difficult because you don't do 2 identical projects, one with BIM and one without, and look at cost's implications….The 1st question is probably the hardest for me to answer because we're not directly engaged on project delivery as such."* **(Interviewee I09).**

Table 7.11 presents an overview of the sub themes linked to this main theme and the discussion outcomes linked back to the sub themes which have been detailed through the interviewee quotes and highlighted in **bold**.

Table 7.11 MT4 Information and technological related challenges to the adoption of BIM and KPIs

Code	Sub Theme name	Discussion outcomes	Rank	Number of Discussions	Code and Main theme name	Total number of discussions and Percentages
BIM/KPI_TE_ST4.1	Reconsideration of the delivery of existing information and deficiency in work delivery	• Absence of database affecting existing data • Not knowing what to search for • Obstacles with external advertising • Working in an old-fashioned way • Asking unnecessary information that wont do any help • Information that needs to be redeveloped • Essential information not being provided properly • Deficiencies with working with data and not knowing what needs to be in place. • Delivering work that is not mandate to Level 2 BIM • Overloaded with work that might not relevant to the market • Deficiencies with some of the existing assessments that are not mandated to Level 2 BIM • Unable to deliver a COBie data • Rework that results in high expenses • Redesigning work that is incorrect as a result of not checking at an early stage	1	22	BIM/KPI_TE_MT4 Information and technological related challenges to the adoption of BIM and KPIs	76
BIM/KPI_TE_ST4.2	Excessive information, snapshot of time, and excessive high cost technology	• High cost associated with absence of BIM and technology and having to invest highly on it • Markets fluctuation as a result of cost drops • Required to check with suppliers on the existing data • Required to integrate discipline to invest in high invested technology properly • Excessive data give to users to consider that requires too much time to follow on. • Having to create extra procedures and this being time consuming • Unless information provided to teams that wont be beneficial • Excessive assessments given and required to be filled. • Information delivered a few years back could be out of date in the present time. • Assessments given that is out of date and therefore cant be used in practice • Current information could be snapshot of time in future	2	15		
BIM/KPI_TE_ST4.3	Lack of knowledge / awareness / availability of data	• Lack of available assessments and not widely known within industry. • Absence of strategies to produce level 2 BIM outcomes in place • Awareness with Level 2 BIM but no usage of it within practice. • No clear level 2 BIM documents in place • No internal KPIs in place and absence of key areas related to KPIs • Unaware of what is happening resulting in not being able to use various existing tools to self assess • Not fully aware of Level 2 BIM resulting in elements in practice that don't follow the UK mandate	3	14		
BIM/KPI_TE_ST4.4	Usage of complicated models and security of data	• No existing model in place • Not able to deal with model and not willing to amend it • Disciplines end up not using the produced models • Deficiencies with model being produced in practices • Excessive data to feed into the models • Users not knowing model outcomes and its requirements • Security concerns with data storage and Limited availability with network servers.	4	12		
BIM/KPI_TE_ST4.5	Challenges affecting KPIs	• Benchmarking KPIs. • Not able to measure KPIs • Difficult to put KPIs against cost • Amount of challenges to affect KPIs negatively • Loss of money as a result of deficiencies with KPIs	5	7		
BIM/KPI_TC_ST4.6	BIM and KPI project delivery differences and engagement	• BIM as a process, KPI as a measure of success. • Difficult to measure BIM or KPIs • KPIs in place that is not related to BIM • Difficult to link KPIs with BIM in general • Absence of engagement with project delivery	6	6		

2. Digitisation and Technology

A total number of 55 discussions have been linked to this main theme. This theme discusses topic areas related to the existence of advanced technology and the utilisation of existing software. Under this theme, 4 sub themes emerged and linked to their number of discussions after being compiled with the verbatim transcripts. Based on the overall sub themes, the ranking and overall outcomes of the sub themes were as follows:

5.1 Existence of advanced technology **(Digital engineering and digital technologies that enhanced implementation of BIM);** This was the most prevalent sub theme to this main theme which had a total of 20 discussions amongst all interviewees representing 36% of the total discussions related to this theme. Discussions related to this sub theme focused on the existence of advanced technology such as digital technologies that enables a more rapid adoption of BIM across practices. Key discussions noted by the interviewees are highlighted in **bold** which focuses on what are the existing technologies that enhances the levels of adoption with BIM across practices. Those are as follows:

"It's fundamentally we go to work, it is ***not digital technology and not necessary using the Level 2 BIM process****, but we use* ***digital technologies with models****."* **(Interviewee I01). "***In terms of documentation, it will be based on technology more, because there is a lot out there to make sure we are compliant…..In terms of* ***documentation****, it will be* ***based on technology more****, because* ***there is a lot out there*** *to* ***make sure we are compliant****"* **(Interviewee I03). "***Basically it revolves around* ***GeoSpace awareness****, the* ***spaces required for materials****, so when tendering takes place, we know how much"* **(Interviewee I05).** "***Digital engineering in the company*** *I work for, we have 4 key drivers of our unique selling point, and* ***digital engineer is one of the things that enable everything*** *in the business"* **(Interviewee I06).** *"BIM is very much based on the technology, even if you know the technology, there needs to be a good level of understanding on what the technology could be done"* **(Interviewee I07).** "*What I know, is it was* ***used for clash detection****; we are aware of that, but* ***it's more of a construction phase.***" **(Interviewee I10).**

5.2 Project success measured through BIM technology and KPIs **(BIM as a process, KPIs as a measure of success, and BIM and KPIs to achieve project success);** This theme had a total of 13 discussions amongst all interviewees representing 24% of the total discussions related to this theme. Discussions related to this sub theme focused on how BIM maturity and KPIs are being approached within practices (i.e. BIM as a process, and KPIs as a measure of success) and how both together achieve overall project success, which is the main aim of this research in having a list of standardised BIM maturity and KPI metrics that aims to measure and monitor overall project success. Key discussions noted by the interviewees which focuses on how BIM maturity and KPIs are being approached to measure project success are as follows:

"BIM is how we manage and run the job, KPIs are how we measure the success, to do with the measuring and the monitoring" **(Interviewee I08).** "*There is a standard* ***set of Level 2 BIM criteria*** *that are required for a* ***Level 2 BIM project in the UK****. So they are the criteria that* ***we will work to if the client says they want it to be Level 2 BIM****. In terms of using* ***data database modelling, agreed depth levels of***

details definition and information, Using PAS1192 – 2 and 3, and specifically PAS1192 – 2 *to make sure our processes of passing data around are in accordance with that……We've developed* ***standard asset information sheet*** *for documenting that as part of our briefing process. So they have a set* ***of asset information with sort of individual type*** *of object that they have in a building, and what* ***sort of information do you want us to provide*** *at the end of the project about each asset."* **(Interviewee I13).** *"There are* ***existing projects which had BIM requirements*** *for level 2 BIM"* **(Interviewee I15).**

5.3 Software Demand **(The need to provide a software delivery to clients (i.e. COBie, Revit);** This theme had a total of 12 discussions amongst all interviewees representing 22% of the total discussions related to this theme. Discussions related to this sub theme focused on the need to utilise existing software (i.e. revit) to the clients as part of project requirements. Key discussions noted by the interviewees which focuses on the need to deliver software to clients for achieving requirements of projects are as follows:

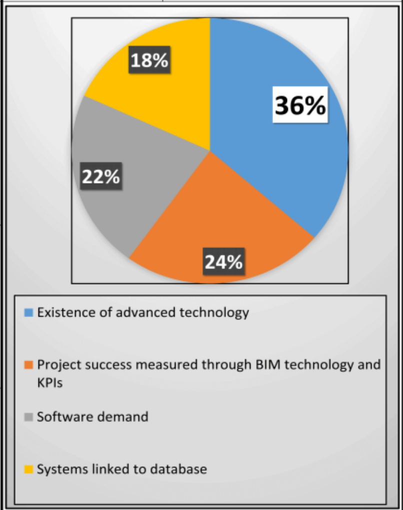
"Specific examples, you say the organisation is using ***a tool (inventor) or Autocad (3D)****…..You are asking for BIM deliverable, which is a federated model, so they can still provide a 3D model"* **(Interviewee I02).** *"The disciplines work together to use the* ***BIM tools (software)****.* ***BIM is considered as a software"*** **(Interviewee I07).** *"We use our model not just for construction detailing or preparation of construction information but goes out on 3rd party pieces of software for rendering, for legalisation, for interactive walk through using BIM 360…..We've been using* ***Revit*** *for the last 10 years,* ***as a piece of software****"* **(Interviewee I13).** *"We are* ***using revit as a tool****……A lot of clients go, yes* ***give us COBie****"* **(Interviewee I14).** *"COBie is* ***delivered to date****"* **(Interviewee I15).**

5.4 Systems linked to a database (**Importance of recording data into a database);** This theme had a total of 10 discussions amongst all interviewees representing 18% of the total discussions related to this theme. Discussions related to this sub theme focused on the importance of having a database in place that records the data given to projects and how the management of these database will help manage project systems in practices. Key discussions noted by the interviewees which focuses on the having a database in place to record project data within them are as follows:

"So we made the forms quite clear so people can fill it out and we could ***record their answers in their databases****"* **(Interviewee I02).** *"The* ***model linked to a database*** *essentially….. We go back to trade staff and* ***someone orders the database****, and we have it* ***integrated with our CaFM system****……When you* ***click on the database****, it will* ***take you somewhere*** *around, and I think that will be a great thing because we* ***will change the database****, because we can* ***import and change the database****, so* ***even if the model might not be up to date****, but the* ***database will be and we can keep up to date…..****All our trade staff have a tablet, if they are going somewhere or a job does pop up,* ***can quickly get it from the database****….Can order it from the tablet, it's that* ***sort of integration of the database*** **(Interviewee I10).**

Table 7.12 presents an overview of the sub themes linked to this main theme and the discussion outcomes linked back to the sub themes which have been detailed through the interviewee quotes and highlighted in **bold**.

Table 7.12 MT5 Digitisation and Technology

Code	Sub theme name	Discussion outcomes	Rank	Number of Discussions	Code and Main theme name	Total number of discussions and Percentages
BIM/KPI_TE_ST5.1	Existence of advanced technology	• BIM to deal with the process • KPIs to do with measuring success • BIM acting as technology outcome. • Documentation based on technology • Usage of certain assessments in the future • Asset information sheet for documenting • BIM tools to be used for technological advancement • Digital technologies with models being used in the practice • Surveys to enhance usage of technology • FM introduced earlier stage for project.	1	$\boxed{20}$	BIM/KPI_TE_MT5 Digitisation and Technology	**55**
BIM/KPI_TE_ST5.2	Project success measured through BIM technology and KPIs	• BIM to deal with the process • KPIs to do with measuring success • BIM acting as technology outcome. • Documentation based on technology • Usage of certain assessments in the future • Digital engineering as key driver for BIM • GeoSpace awareness • Asset information sheet for documenting • BIM tools to be used for technological advancement • Digital technologies with models being used in the practice • Surveys to enhance usage of technology	2	13	 	
BIM/KPI_TE_ST5.3	Software demand	• Utilising software to deliver clients requirement. • Delivering data to date. • Revit as a software demand from users • COBie as a requirement in practices • Inventor and autocad (3D) demands • BIM accredited tools as essential • Almost every practice is using BIM 360 as an essential requirement for clients.	4	12		
BIM/KPI_TE_ST5.4	Systems linked to database	• Linking models to a database • The need to record answers on a database to manage data easier. • Reporting and recording in database • Storage of information in database and continuously being updated • Integration of tables with existing databases • Placing orders on new databases • Integrating CaFM system with database	5	10		

3. Project delivery through BIM and KPIs and use of information

A total number of 27 discussions have been linked to this main theme. This theme discusses topic areas related to the generation of a list of KPIs, and the tools related to BIM maturity and KPIs used for projects delivery. Under this theme, 3 sub themes emerged and linked to their number of discussions after being compiled with the verbatim transcripts. Based on the overall sub themes, the ranking and overall outcomes of the sub themes were as follows:

6.1 Tools used to review delivery of Level 2 BIM projects (**Methods to support project delivery);**

This was the most prevalent sub theme to this main theme which had a total of 20 discussions amongst all interviewees representing 74% of the total discussions related to this theme. Discussions related to this sub theme focused on the different tools and methods that existed and were used to support the delivery of projects. Key discussions noted by the interviewees are highlighted in **bold** which focuses on what are the existing tools that support the delivery of Level 2 projects and review them. Those are as follows:

*"I think its **project based**, its **e-projects** in time. We **drive it on most of our live projects**, the way we look to implement **BIM and digital engineering**."* **(Interviewee I01).** *"An **Audit of all the internal projects**. Auditing and conducting checks on **whether the folders and files are BS1192-2 compliant** or not"* **(Interviewee I03).** *"There are pilot projects being done on 2 projects, to see if the workflows and BIM standards are in place or not"* **(Interviewee I04).** *"We have a means of **auditing when that comes back in.** If we **issue information out in terms of variation on our instruction**, then we have a means of recording that in terms of when, what was said. **Those are a set of KPIs that we have**"* **(Interviewee**

I05). *"Most of the maturity models I mentioned earlier are **about project delivery** and are quite tactical"* **(Interviewee I09)**. *"We've got that kind of strategy in place when it comes with **naming, standards, adoption of BS1192**. All of the projects that will start new, **98% I would say are using revit, so always within that 3D environment**"* **(Interviewee I14).** *"The issues **lie on our ways of working. KPIs are far too much considered on Cost (Project cost)** but they highlight on other issues"* **(Interviewee I15).**

6.2 KPIs generated and used on projects (**New KPIs introduced and are based on organisational KPIs being used**); This had a total of 4 discussions amongst all interviewees representing 15% of the total discussions related to this theme. Discussions related to this sub theme focused on what could be additional KPIs that could be generated to be used on projects, which would add to the current list of standardised KPIs. Key discussions noted by the interviewees which focuses on what could be the additional KPIs that would exist and add to the current list of KPIs are as follows:

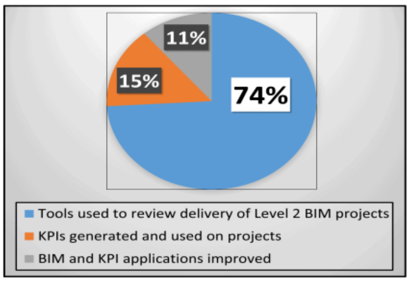
*"I'm assuming there is KPIs that will come out of this, such as **predictability, culture and collaboration, programmes and disputes**. So the current ones are **Profitability and Safety**. I would imagine that **sustainability** will be, and this year it will be definitely in our KPIs"* **(Interviewee I15).**

6.3 BIM and KPI applications improved (**Improved process, collaboration and coordination);** This had a total of 3 discussions amongst all interviewees representing 11% of the total discussions related to this theme. Discussions related to this sub theme focused on how the adoption of BIM and KPI applications would result in collaboration and processes being improved. Key discussions noted by the interviewees which focuses on how the applications of BIM and KPI would improve current processes and coordination between project teams are as follows:

*"But to do that, we need to make sure that **the processes are improved**."* **(Interviewee I06).** "***Improvement in Coordination** through 3D Model, Clash detections & BIM Collaboration products."* **(Interviewee I11).**

Table 7.13 presents an overview of the sub themes linked to this main theme and the discussion outcomes linked back to the sub themes which have been detailed through the interviewee quotes and highlighted in **bold**.

Table 7.13 MT6 Project delivery through BIM and KPIs and use of information

Code	Sub theme name	Discussion outcomes	Rank	Number of Discussions	Code and Main theme name	Total number of discussions and Percentages
BIM/KPI_TE_ST6.1	Tools used to review delivery of Level 2 BIM projects	• Driven on live projects • Audits on Level 2 BIM compliance • Naming conventions in place • E-projects in time • Turn around projects quickly • Maturity models as part of project delivery • Checklist to manage project delivery	1	20	BIM/KPI_ TE_MT6 Project delivery through BIM and KPIs and use of information	27
BIM/KPI_TE_ST6.2	KPIs generated and used on projects	• Predictability • Digital technologies • Culture and collaboration • Programmes and disputes	2	4		
BIM/KPI_TE_ST6.3	BIM and KPI applications improved	• Improved processes • Improved collaboration and coordination	3	3		

Having discussed the findings of Process, its main and sub themes along with the discussion related, the next section will discuss the findings related to People.

7.3.5.3 People

The final overarching theme with a fewer discussions than Process and Technology **was People**. In the context of this research, People is defined as the users approach with BIM maturity and KPIs, their levels of understanding and experiences with both and how they are implementing them within their practices. Hence, the main and sub themes would be linked to People based on the current understanding of the users with BIM maturity and KPIs and how it is being approached and implemented within practices. As a result, there are 3 main themes, 13 sub themes, and a total of 141 discussions related to the sub themes that have emerged and were linked to People as a primary overarching theme, and based on the interview questions (Sections 7.2.1-7.2.2) and the verbatim transcripts (Appendix H). The themes have been quantified to rank them based on the number of discussions. The 3 main themes rank order based on the number of discussions are: **1. Users approach and understanding of BIM / KPI as a process (63 discussions), 2. Social related issues to the usage of BIM and KPIs (60), and 3. Training and lessons learned (18).** The 13 sub themes linked back to the main themes and their related discussions will be discussed in more details in the subsequent sections.

1. Users approach and understanding of BIM / KPI as a process

A total number of 63 discussions have been linked to this main theme, which was the most theme in relation to People. This theme discusses topic areas related to the existing knowledge of BIM maturity across users, how is the data shared amongst projects, the users levels of understanding with BIM maturity, and areas to enhance performance and experience of project team members. Under this theme, 5 sub themes emerged and linked to their number of discussions after being compiled with the verbatim transcripts. Based on the overall sub themes, the ranking and overall outcomes of the sub themes were as follows (in descending order):

7.1 Variety of BIM knowledge amongst users (**Variety of knowledge exists amongst practices and users);** This was the most prevalent sub theme to this main theme which had a total of 25 discussions amongst all interviewees representing 40% of the total discussions related to this theme. Discussions related to this sub theme focused on what current knowledge of Level 2 BIM do the users already know and existing assessments that are being used within organisations. Key discussions noted by the interviewees are highlighted in **bold** which focuses on how is Level 2 BIM being approached, the assessments that are used to measure BIM adoption, and the current understanding of BIM amongst users. Those are as follows:

*"There are around **20 things we measure against on every project**. We **measure it on a monthly basis** on 20 different elements. A **template of the KPIs** and **how it is being measured** was provided….We **developed our internal formal one**, and we **use our own one."*** **(Interviewee I01).** *"Looking at and how **to create internal checklist**"* **(Interviewee I03).** *"So the department has **its business plan, and I have 1 KPI, the business plan**. Along the way to do that, I need to satisfy client on project by project versus….We don't measure the department as KPI, but **we measure the project in a KPI**….I believe we are measuring **[Time, Cost, and Quality]**,* we're measuring social value, we're measuring Customer satisfaction" **(Interviewee I08). "***We are keen to see more emphasis put on whole life costing, because of **being able to measure both forecast and whole life cycle cost**"* **(Interviewee I09).** *"The firm has their **own BIM guidelines** and they are **based on PAS1192**"* **(Interviewee I11).** *"Some examples of that will be we've done in our recent project. That was the **council's first extension of a Level 2 BIM project**…..**So yes, part of our standard systems that we have is standard checklists**, standards that we undertake under 1); at the end of every work-stage (the closeout) and 2); **Client feedback survey**"* **(Interviewee I13).**

7.2 BIM data shared between team members (**Importance of sharing data amongst users and practices);** This had a total of 15 discussions amongst all interviewees representing 24% of the total discussions related to this theme. Discussions related to this sub theme focused on the existing BIM data and how it is being shared amongst users, and the importance of sharing the existing BIM data to enable the adoption of Level 2 BIM. Key discussions noted by the interviewees which focuses on how BIM data was shared amongst users which reflects back to the adoption of Level 2 BIM are as follows:

*"But in terms of you are always **looking at your clients EIRs for what they actually want**, and we've got to **tailor our service depending on what it is that the clients** are actually asking for."* **(Interviewee I13).** *"What we are doing is the project starts off from **a client or a contractor point of view** and its always like we're **going to do it to Level 2 BIM**…..we find **that the contractors and clients do try and drive the requirements of Level 2 BIM**"* **(Interviewee I14).** *"Needing to know the specification of that element, it all **comes down to the client coming up with what do you actually want**"* **(Interviewee I13).**

7.3 Higher experience through continuous improvement and learning (**The need for improved learning to enhance different levels of experience);** This had a total of 11 discussions amongst all interviewees representing 17% of the total discussions related to this theme. Discussions related to this sub theme focused on the importance of improving learning and continuous improvement techniques associated with Level 2 BIM to enhance the levels of experiences amongst users. Key discussions noted by the interviewees which focuses on how the learning techniques would enhanced the levels of experiences within users are as follows:

*"I am **doing it based on my experience** in the industry….With **BIM maturity, the more experience you have, the better you'll perform**"* **(Interviewee I03).** "*So, getting projects going back, which are **starting to be BIM and building upon our BIM library information and experience** using, manipulating and interrogating **BIM models**, so in terms of our maturity, we are doing it kind of a 3rd party through others."* **(Interviewee I05).** *"They **will learn, improve, and refine the way they work**, they'll be **better because it's the way they work…..The 1st BIM project that somebody does,** their **learning is a new way of working, and** they **won't be** as **effective as the 2nd, 3rd or 4th project**"* **(Interviewee I09).** *"We've got*

*to think that **whatever we have to do**, we do very **strict EIRs** , and we are **adopting quite a collaborative approach** to it"* **(Interviewee I12).** *"That's never in the end when somebody goes, well actually **have we achieved the outcome of this project which will fully Level 2 BIM compliant**"* **(Interviewee I14).**

7.4 Enhanced understanding (**Importance of good understanding and different ways to enable better understating amongst users);** This had a total of 8 discussions amongst all interviewees representing 13% of the total discussions related to this theme. Discussions related to this sub theme focused on the various strategies related to enhanced understanding being achieved amongst users, and better performance resulting in improved levels of understanding. Key discussions noted by the interviewees which focuses on the different techniques used to enable better understanding amongst users are as follows:

*"At the moment, based on **me understanding what is required**, it's not necessary **about a set of formal documents…….**The **more mature you are** in the process, the **more you understand the process**, the **better you will perform**…..**With experience that people have on BIM maturity, it will enable better performance**"* **(Interviewee I03). "***Working on **projects to develop a built in BIM, for example**, we have EIR templates, **trying to work with COBie**, and we are getting **some of the documents in place**"* **(Interviewee I15).**

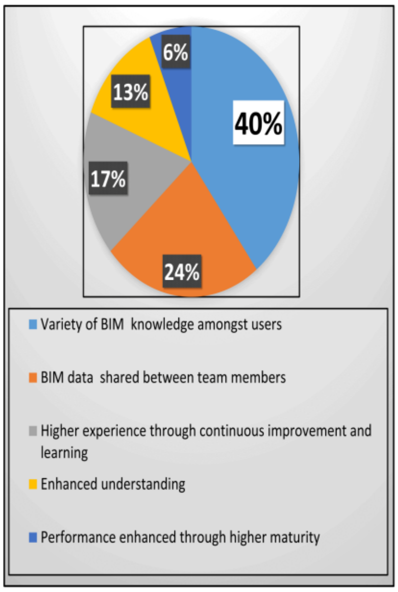
7.5 Performance enhanced through higher maturity (**Enhancing maturity to allow better performance);** This had a total of 4 discussions amongst all interviewees representing 6% of the total discussions related to this theme. Discussions related to this sub theme focused on ways to enhance maturity to allow better performance through management processes and higher experiences amongst users. Key discussions noted by the interviewees which focuses on the ways that could be implemented to enable higher maturity and improve the levels of performance amongst users within practices are as follows:

*"**The design + information**, most likely **will be incorrect**, so that **affects the quality of the work**, because **it is not correct**, so we will **tell them its not correct.** You will **have to correct it**, and that will **affect the time scales**, so it all links but its their **initial cost** that they have to **invest in training themselves**, **Quality and Time**".* **(Interviewee I02).** "*I was asked to produce a strategy document which forecasts some milestones and how long it takes us roughly to a position where **we could stand on our feet and deliver a full Level 2 BIM project**, and I'd say that would take 5 years. Because we have to maintain not only our workload, but also this **new skillset**"* **(Interviewee I05).** *"There is a lot of **talking and trying with this, they want to employ** a BIM manager in the future, as we currently operate with Level 1."* **(Interviewee I06).** *"Yes it gives you a greater appreciation, that could be done as a part of a management process throughout a project that would be ideal and **enhance performance**."* **(Interviewee I11).**

Table 7.14 presents an overview of the sub themes linked to this main theme and the discussion outcomes linked back to the sub themes which have been detailed through the interviewee quotes and highlighted in **bold**.

Table 7.14 MT7 Users approach and understanding of BIM / KPI as a process

Code	Sub theme name	Discussion outcomes	Rank	Number of Discussions	Code and Main theme name	Total number of discussions and Percentages
BIM/KPI_PE_ST7.1	Variety of BIM knowledge amongst users	• Various knowledge on BIM exists amongst users • BIM well known in academia • BIM theories not true • BIM accessed online • Assessments used in organisations	1	25	BIM/KPI_PE_MT7 Users approach and understanding of BIM / KPI as a process	63
BIM/KPI_PE_ST7.2	BIM data shared between team members	• The importance of sharing data across users to enable them with level 2 BIM. • Various ways on sharing BIM data exists amongst users • COBie data shared • Sharing academic work with the practice	2	15		
BIM/KPI_PE_ST7.3	Higher experience through continuous improvement and learning	• Learning is one way that helps users to be better experienced with Level 2 BIM. • Higher experience resulting in better performance with BIM maturity • Improving from one project to another.	3	11		
BIM/KPI_PE_ST7.4	Enhanced understanding	• Different strategies exist for understanding amongst users • Moderated understanding • Good understanding with Level 2 BIM requirements • Better performance as a result of improved understanding • Adequate understanding in terms of technological uses • Visualisation for understanding	4	8		
BIM/KPI_PE_ST7.5	Performance enhanced through higher maturity	• Management process to enhance performance • Enhanced maturity and advanced experience to allow better performance	5	4		



2. Social related Issues to the usage of BIM and KPIs

A total number of 60 discussions have been linked to this main theme. This theme discusses topic areas related to the industry being siloed resulting in BIM data not being shared amongst users, lack of experience and understanding amongst team members, project requirements not made clear to users and excessive time being wasted. Under this theme, 5 sub themes emerged and linked to their number of discussions after being compiled with the verbatim transcripts. Based on the overall sub themes, the ranking and overall outcomes of the sub themes were as follows:

8.1 Lack of experience, data not shared amongst users, and project requirements not made clear to users (**Less compliance and uneducated teams, Lack of data sharing amongst users and an inability to share COBie data, and Various requirements amongst different users and clients who do not know what they are asking for);** This was the most prevalent sub theme to this main theme which had a total of 21 discussions amongst all interviewees representing 35% of the total discussions related to this theme. Discussions related to this sub theme focused on Lack of experience amongst users which did not allow to measure BIM maturity and KPIs, the industry being siloed and not sharing data amongst one another, and clients not knowing what they are asking for. Key discussions noted by the interviewees are highlighted in **bold** which focuses on the current obstacles that resulted in lack of experience, data not being shared, and project requirements not being made clear. Those are as follows:

"We can't deliver compliant COBie** for instance."* **(Interviewee I02).** *"People **don't necessary share** in this industry….**limited knowledge on the assessments taught in the institutions**….The tool **could be available online**, but **due to copyrights and restrictions might not be shared amongst practices**"* **(Interviewee I03).** *"We have a much wider base of clients who have different requirements, so sometimes when we look for a resource in person, it doesn't necessarily mean that what's in market place is what we want."* **(Interviewee I05)**. *"But as far as **being assessed by sharing the data, I'm not sure. **(Interviewee I06).** *"Not all of the organisations are **educated well enough"*** **(Interviewee I07).** *"Because we're not moving forward with BIM, and understanding what it's doing and what it's NOT doing for us, then we are not compliant to measure that impact."* **(Interviewee I08).** *"We are very **high in terms of our level**, but we are **working with lots of clients** that are much of a lower level…..The **other variable** that's **a challenge**, **is people's experience."*** **(Interviewee I09).** ***"None of the people in the working environment have the necessary experience** to enable them to **use Revit to do the BIM model** or change it."* **(Interviewee I10).** *"Because in the end of the day, we find an awful lot of our clients don't really know what they are asking for. Specially in terms of their asset information requirements at the end of the project."* **(Interviewee I13).** *"They've actually **talked to the client and said, do you actually need all of this?"*** **(Interviewee I14).**

8.2 Cultural change to BIM/KPI and Lack of engagement- industry siloed (**Cultural defects and change in organisations concerning approach and when dealing with Level 2 BIM and KPIs** and **Industry siloed, and teams not engaging together);** This had a total of 12 discussions amongst all interviewees representing 20% of the total discussions related to this theme. Discussions related to this sub theme focused on cultural defects towards BIM maturity and KPIs, and industry being siloed resulting in people not collaborating together. Key discussions noted by the interviewees which focuses on the problems with collaboration amongst users and the existing defects in dealing with BIM maturity and KPIs are as follows:

*"The **industry is siloed**. Even with the work that is being done by the digital construction**, it is still traditionally much siloed……**In this context the **culture within the organisation is to work with the cultural digital construction** methodology."* **(Interviewee I03).** ***"Working in siloes**, **no one talks to the other**, **disciplines are segregated and don't collaborate…..**The **mentality of not wanting to use the BIM** in the future from all of the organisation due to **lack of interest** and Change management."* **(Interviewee I07).** *"To get BIM level 2 compliant you need to be there, and your accounting here, but there is a bigger piece which is missing…..So many people think **it's the 3D**, so few people think **it's the value on the future**. We haven't got **a system that's capable of managing this….** We actually **know what's missing at a real problem**, but **its communicating that."*** **(Interviewee I08).** *"I'm not yet **seeing any contractor going back and saying this is the assessment and that was a Level 2 BIM project…..**But these are **projects** in the private sector that **don't have an end user to in mind**, there's **no EIR I suppose**, and there's **no engagement in terms of who's going to be writing the building."*** **(Interviewee I14).**

8.3 Capability challenges with existing data (**Less capability existing amongst users);** This had a total of 11 discussions amongst all interviewees representing 18% of the total discussions related to this theme. Discussions related to this sub theme focused on less people having capability to extract data, poor assessments amongst teams, limited people with knowledge on BIM, and less capability to deal with advanced technology. Key discussions noted by the interviewees which focuses on not having relevant capability to extract data, and users unable to complete assessments are as follows:

"We don't assess ourselves enough. We assess the supply chain. We used to assess our teams more". **(Interviewee I01).** "***COBie has to be extracted*** *out of this model, and* ***they have no capability****."* **(Interviewee I02).** ***"So, what we're left with now are just limited number of people (2) who know about BIM****, which is not enough to drive forward in an organisation this size in a big program"* **(Interviewee I05)**. *"We're* ***a lot way short and being capable*** *to run this"* **(Interviewee I08).** *"It's not* ***in any of our capabilities****, we're just a linked team involves FM and just* ***a small number of our team is involved in the projects*** *around the campus"* **(Interviewee I10)**. *"There are just* ***a few challenges*** *with that point cloud."* **(Interviewee I12).** *"I don't think there is anything we've got within the organisation****. I think we're terrible with assessment, we're very poor".*** **(Interviewee I14).** *"This* ***reflects negatively on the working environment."*** **(Interviewee I15)**.

8.4 Lack of understanding (**Misunderstanding and assessments do not make sense);** This had a total of 9 discussions amongst all interviewees representing 15% of the total discussions related to this theme. Discussions related to this sub theme focused on problems associated to understanding such as reworks and assessments that are unclear, and users not being mature enough with Level 2 BIM. Key discussions noted by the interviewees which focuses on the issues that resulted in lack of understanding are as follows:

"Develop a tool that actually makes sense*, because* ***some of the questions that come out of the Penn state questionnaire, does not make sense."*** **(Interviewee I02).** ***"****If you* ***don't understand BIM*** *as a concept, then there* ***won't be any benefits****, it could* ***result in rework (rewriting documents due to not understanding them*** *well)".* **(Interviewee I03).** ***"Awareness of BIM but no understanding"*** **(Interviewee I07)**. *"That's not just us, because other* ***councils are struggling*** *with the same issue. There is a struggle because* ***you haven't got the understanding*** *and the real senior levels that this is the next stage of investment….Those of us* ***who understand BIM****, will* ***understand how immature we are"*** **(Interviewee I08).** *"If it is just done by a project manager in a local authority who doesn't understand this, the process and have the experience to understand what all these documents are, how they are arranged and how they're updated and reviewed and provided that part of the process."* **(Interviewee I13).** *"Don't know* ***how to fully drive it."*** **(Interviewee I15).**

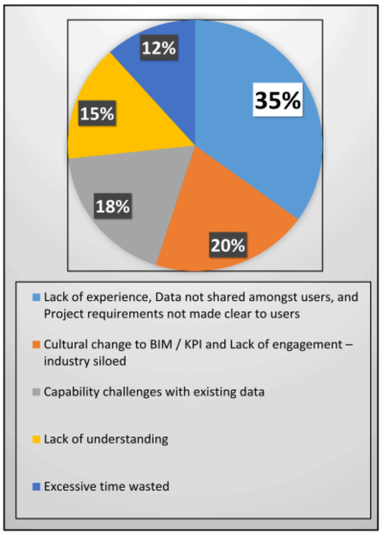
8.5 Excessive time wasted (**Time wasted to collaborate with users and on software);** This had a total of 7 discussions amongst all interviewees representing 12% of the total discussions related to this theme. Discussions related to this sub theme focused on time wasted to collaborate with teams, and no time to teach or educate people. Key discussions noted by the interviewees which focuses on the issues related to time wasting are as follows:

"We ***don't have the time to teach*** *the business, or actually learn. It could help. We know how our businesses is set up."* **(Interviewee I01).** *"To look for the* ***KPIs is a huge time resource****, which will divert us from our current work."* **(Interviewee I03).** *"We* ***spend a lot of time on the start of the projects****, actually more say we spend 2 hours now and collaborating with the rest of the design team…Its almost* ***a complete waste of time doing COBie****, because* ***nobody knows*** *what's it gonna* ***be used for, nobody's got any idea….****It's a* ***pain for us****, we take that* ***approach every time*** *and it's* ***trying to work with organisations*** *to have that* ***similar ethos*** *I suppose****"*** **(Interviewee I14).**

Table 7.15 presents an overview of the sub themes linked to this main theme and the discussion outcomes linked back to the sub themes which have been detailed through the interviewee quotes and highlighted in **bold**.

Table 7.15 MT8 Social related Issues to the usage of BIM and KPIs

Code	Sub theme name	Discussion outcomes	Rank	Number of Discussions	Code and Main theme name	Total number of discussions and Percentages
BIM/KPI_PE_ST8.1	Lack of experience, Data not shared amongst users, and Project requirements not made clear to users	• Less educated teams resulting in less experience. • Lack of experience as a challenge • Unable to measure BIM or KPIs • Far away from compliance • Not knowing what data outcomes will be used for in organisation • Lack of sharing amongst users. • Unable to deliver COBie • Lack of knowledge taught in institutions to be shared with practice • Different requirements from users • Clients not knowing what they ask for • NO compliancy to measure impact of BIM on users • Having to convince users on their requirements • Variation of levels between different disciplines	1	$\boxed{21}$	BIM/KPI_PE_MT8 Social related Issues to the usage of BIM and KPIs	60
BIM/KPI_PE_ST8.2	Cultural change to BIM / KPI and Lack of engagement – industry siloed	• Cultural defects with BIM and KPIs • Lack of interest and change management • Cultural change in organisation to work with BIM. • A cultural shift towards BIM that will result in BIM disappearing in future • BIM approached as 3D where it should be the value on future • Industry siloed resulting in people not collaborating together • The need to communicate to resolve missing issues • Undergo process to overcome collaboration step-falls • Lack of engagement between the teams.	2	12		
BIM/KPI_PE_ST8.3	Capability challenges with existing data	• Less people having capability to extract data. • Not enough self assessment • Poor assessment amongst teams • Challenges with Point Cloud • Limited people who are knowledgeable with BIM • No capability to deal with modern technology • Negative effects on working environment • Further actions required if identified in Consistency level	3	11		
BIM/KPI_PE_ST8.4	Lack of understanding	• Not fully driven • Assessment that doesn't make sense and difficult to understand • Not being mature enough • A process to overcome lack of understanding • Councils struggling • Absence of selling BIM as a product for people to understand it. • Rework as a result of misunderstanding.	4	9		
BIM/KPI_PE_ST8.5	Excessive time wasted	• No time to teach and educate people. • Diverting away from work as a result of excessive time spent to review KPIs • Time wasted to collaborate with teams on specific projects • Time wasted on COBie and disciplines not aware of it. • Excessive time spent resulting in poor quality of produced work	5	7		



3. Training and Lessons learned

A total number of 18 discussions have been linked to this main theme. This theme discusses topic areas related to lessons learned available for BIM and KPI adoption, provision of training facilities, and introduction to upskilling techniques. Under this theme, 5 sub themes emerged and linked to their number of discussions after being compiled with the verbatim transcripts. Based on the overall sub themes, the ranking and overall outcomes of the sub themes were as follows:

9.1 Lessons learned reviewed in relation to the adoption of BIM and KPIs together (**Delivery of lessons learned and reviewing it);** This was the most prevalent sub theme to this main theme which had a total of 7 discussions amongst all interviewees representing 39% of the total discussions related to this theme. Discussions related to this sub theme focused on the importance of having lessons learned as a strategy to adopt BIM and KPIs together. Key discussions noted by the interviewees are highlighted in **bold** which focuses on how the lesson learned reviews were important in adopting Level 2 BIM. Those are as follows:

*"We **create our own one from lessons learned** as in **looking at the things on what went wrong**, what is not suitable, or what is more suitable…..It is subjective, we would **assess that** by and then **feeds back to our lessons learned reviews**"* **(Interviewee I01).** *"There will **exist an assessment along with Lessons learned after the pilot projects are completed**"* **(Interviewee I04).** *"That was a bit of the **lessons learned around this project**, what we've come up at the start of the project is with project values, which is an important dialog"* **(Interviewee I12).** *"We sit there and have a view of the **lessons learned** and with our consultants how is that relationship worked, and will we use them in our projects again."* **(Interviewee**

I13). *"We are trying to **learn it based on lessons learned**, an external is **placed and doing BIM strategy**, which is generic and not being used.....We are trying to **learn it based on lessons learned**, an external is **placed and doing BIM strategy**, which is generic and not being used"* **(Interviewee I15).**

9.2 Provision of training facilities (**Various training strategies and the importance of delivering it);** This had a total of 6 discussions amongst all interviewees representing 33% of the total discussions related to this theme. Discussions related to this sub theme focused on the difference training strategies being provided to better educate teams, and cost and time being linked to training. Key discussions noted by the interviewees which focuses on the importance to provide training to educate team members are as follows:

*"We need to provide them the **training**....How much **training is needed** and aid to deliver the KPI"* **(Interviewee I01).***"**For training, they are spending money and time**.....It's their initial cost that they have to invest in training themselves"* **(Interviewee I02).** "*I gave a lecture at the NBS conference in Manchester last week on **our modelling methodologies and our approach to Level of details**, Level of Information, **Level 2 BIM training**, we were responding to EIRs"* **(Interviewee I03).**

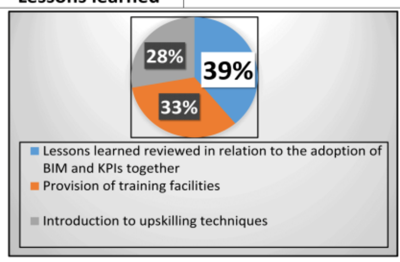
9.3 Introduction to upskilling techniques (**The existence of different upskilling techniques and the need to fix any errors that currently exist);** This had a total of 5 discussions amongst all interviewees representing 28% of the total discussions related to this theme. Discussions related to this sub theme focused on the need to introduce upskilling techniques amongst users and fixing existing errors within practices. Key discussions noted by the interviewees which focuses on how the upskilling techniques were introduced and assist in fixing errors amongst users and within practices are as follows:

*"At the moment, based on **me understanding what is required**, it's not necessary **about a set of formal documents**, but it **needs to be developed**" (***Interviewee I03).** *"There is a lot of **talking and trying with this, they want to employ** a BIM manager in the future, as we currently operate with Level 1."* **(Interviewee I06).** *"Even **if you know the technology**, there **needs** to be **a good level of understanding on what technology could be done** and **what information could be extracted**" (***Interviewee I07).** *"We have a very truthful understanding of **what is required on a Level 2 BIM project.**"* **(Interviewee I13).**

Table 7.16 presents an overview of the sub themes linked to this main theme and the discussion outcomes linked back to the sub themes which have been detailed through the interviewee quotes and highlighted in **bold**.

Table 7.16 MT9 Training and Lessons learned

Code	Sub theme name	Discussion outcomes	Rank	Number of Discussions	Code and Main theme name	Total number of discussions and Percentages
BIM/KPI_PE_ST9.1	Lessons learned reviewed in relation to the adoption of BIM and KPIs together	• The importance of providing lessons learned to adapt to • Create own lessons learned to learn from mistakes • Assessment to support lessons learned • Lessons learned reviews produced • Review lessons learned with various disciplines	1	7	BIM/KPI_PE_MT9 Training and Lessons learned	18
BIM/KPI_PE_ST9.2	Provision of training facilities	• The importance of providing training facilities to users to better educate them. • In house training to support KPIs • Cost and time linked to training • Spending money to train	2	6		
BIM/KPI_PE_ST9.3	Introduction to upskilling techniques	• Upskilling techniques varied from one to another • Strategy documents to forecast milestones with Level 2 BIM • Maintaining workload through skillset • Fixing errors from delivered work to affect cost and time	3	5		



Having presented a detailed analysis of the main and sub themes, the next section will discuss the findings concerning organisational BIM assessments, which is linked to question seven.

7.4 Organisational Level 2 BIM assessments: Analysis

The previous analysis of the thematic and content data considered responses to the close and open-ended questions. This section will present the results concerning BIM maturity assessments within organisations and their potential linkages with KPI metrics to identify how the assessment works and how it links with KPI metrics. Each interviewee was given a template summary with the three organisational levels (strategic, implementation, operational), and were asked to identify the level at which they believe they fit within their organisation. Some interviewees identified with one of the organisational levels, whilst others identified with more than one. The results of the interviewees' BIM assessment scores will be presented first, followed by the extracted linkage between BIM maturity and KPI metrics.

7.4.1 Strategic organisational assessment

This section presents the analysis and findings of the strategic organisational level assessment (Table 7.17).

Table 7.17 Strategic organisational level assessment

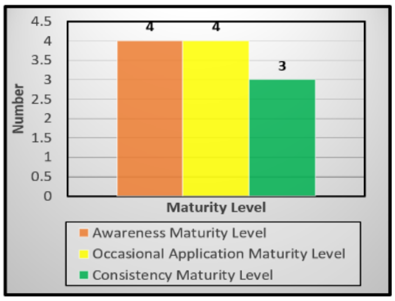
Interviewees	Personal Professional Background	Participant Organisational Position	Maturity Level Average	BIM maturity level (Legend)	Maturity Level Average
I01	Strategic contractor	Strategic Level	Consistency	Awareness (1) Awareness = (1-1.6)	
I03	Architect		Occasional Application		
I05	Project manager		Awareness		
I07	Architect		Awareness		
I08	Project manager		Awareness	Occasional Application (2) Occasional Application (1.6-2.4)	
I09	Strategic contractor		Occasional Application		
I10	Building Surveyor		Consistency		
I12	Project manager		Occasional Application		
I13	Architect		Consistency		
I14	Architect		Occasional Application	Consistency (3) Consistency (2.4-3)	
I15	Information Manager (BIM)		Awareness		
Total		11			

Table 7.17 shows that 11 interviewees identified themselves with the strategic level, and (based on the overall scores given), four identified with **Awareness (Aw)** and with the **Occasional application (OA)** of maturity levels. Moreover, three identified with the **Consistency (Co)** maturity level. This indicated that three users identified with a higher maturity level and perform well within their organisations, whereas eight users were between **Aw** and **OA**, which indicates a requirement to review their current organisational sub metric scores and determine the actions required to move from **Aw** and **OA** to **Co**. Table 7.18 presents a summary of the scoring levels for each interviewee; it shows a matrix of alignment between their overall scores and the individual sub metric score. This helps to identify which sub metrics would be maintained (Co) since this is the highest level of maturity, and the sub metrics that would need to be improved (Aw and OA) to move from one level to another.

Table 7.18 Interviewees' scores and maturity level averages at the strategic level

The Evidence = BIM maturity level at the Strategic level															
BIM maturity level responses based on 11 interviews															
Sub Metrics		I01	I03	I05	I07	I08	I09	I10	I12	I13	I14	I15	Maturity level		Maturity level descriptor
Level 2 BIM	ISO19650												Frequency	Total	
Collaboration process		3	3	3	1	2	2	3	2	3	3	2	3	2.45	Systems that are able to integrate the BIM models (CDE) that are compliant with Level 2 BIM standards into operations.
Processes and Standards		2	1	2	1	2	3	2	2	3	3	2	2	2.09	Understanding and partially implementing the UK BIM Level 2 standards. Partial understanding of the CAPEX and OPEX
Roles and Responsibilities	Function	3	2	2	1	2	3	3	2	3	2	1	2	2.18	Partial understanding of roles defined in PAS 1192-2:2013 and have limited internal resources
Contractual agreements		3	1	2	1	1	2	2	2	3	2	1	2	1.82	Good understanding of how form of contracts are and alignment of standards with Level 2 BIM projects (i.e. 1 to 2 project).
Level 2 Education and Training		3	3	2	1	2	3	3	2	3	2	2	3	2.36	Awareness training required and producing a roadmap, and some staff training in the basics.
Procurement route		3	2	3	1	2	2	2	2	3	2	1	2	2.09	Some confidence in a particular procurement route and how Level 2 BIM is being implemented from stage 1.
Design elements		3	3	3	2	1	2	2	2	3	1	1	2 3	2.09	Some understanding of the main packages (i.e groundworks, structure, MEP and architecture, external works) covered.
Information Requirements (EIR)	Exchange Information Requirement (EIR)	3	1	3	1	1	3	3	2	3		2	3	2.20	There is a basic understanding of the quality and what should be an EIR, and the ability to develop an EIR with or without the help from a consultant.
Asset Information Requirement, (AIR)		3	1	2	1	1	1	2	2	3		2	1	1.80	Understanding of the Asset requirements and basic outline of them and some understanding of COBie.
GSL champion engagement			1	1	1	2	2	3	3	2	2	1	1 2	1.80	Able to use model data but not integrated with FM systems and procedures.
Facilities Management Education and Training		2	1	2	1	2	1	3	3	2	1	2	2	1.82	Awareness training required, and relevant employees training on the basics.
Interviewee maturity level average		2.80	1.73	2.27	1.09	1.64	2.18	2.55	2.18	2.82	2.00	1.55	Occasional Application	2.07	

The matrix indicates that two interviewees (I01, I14) left three BIM sub metric scores blank (EIR, AIR, GSL), which indicated an issue with identifying their position in relation to the sub metrics listed, and an inability to identify their BIM maturity level with those metrics. Only the overall average for the **Collaboration process** was at the **Co** level **(2.45)**, which indicated the **full application and maintenance of the BIM Level 2 strategic level, and its embeddedness across projects generally.** In comparison, the remaining metrics were at the **OA** level, which indicated a **partial application of the BIM Level 2 strategic level, which is recognised, but not embedded generally**. This suggests that users would need to review the sub metrics to determine the action required to allow themselves to move from **OA** to **Co**. Also, it shows that different levels of understanding concerning BIM maturity exists, as the individual scoring for eight interviewees varied from **OA** to **Co**. However, the individual scoring for three interviewees varied from **Aw** to **OA** and did not include **Co**. This indicates the need for these individuals to review and further educate themselves with the BIM metrics, to enable the users to move from the lower levels to the higher levels.

In general, the **Aw** or **OA** scores need to be reviewed to enable users to reach and maintain the **Co** level. From this basis, the potential linkage between BIM maturity and KPI metrics were proposed. For the organisational strategic level, it was difficult to demonstrate a linkage between BIM maturity and KPI metrics at the sub metric level, since participants were unable to establish a linkage. Instead, most interviewees were able to identify the linkage for the top metric, which was easier for them to establish. Thus, the inability amongst some interviewees to recognise the linkage with the KPI metrics in the sub metric level represents a limitation to the BIM assessment.

Based on this constraint, the list of KPI metrics that emerged from the literature (Section 4.5.1), and their potential connection with BIM maturity metrics (Section 4.5.2) were presented to the interviewees to demonstrate how a linkage could occur. As a result, an assessment was conducted to identify the linkage between BIM maturity and KPI metrics at the top metric level. Table 7.19 proposes a linkage between the BIM maturity and KPI metrics at the top metric, based on the assessment and discussions conducted with interviewees at the strategic level.

Table 7.19 The relationship between BIM maturity and KPI metrics at the strategic level

<table>
<tr><th colspan="15">BIM maturity and KPI metrics relationships at the Strategic level</th></tr>
<tr><th colspan="15">BIM maturity and KPI metrics potential relationships based on 11 interviews</th></tr>
<tr><th>Top Metrics</th><th>Sub Metrics</th><th>KPI metrics</th><th>I01</th><th>I03</th><th>I05</th><th>I07</th><th>I08</th><th>I09</th><th>I10</th><th>I12</th><th>I13</th><th>I14</th><th>I15</th><th>KPIs potential relation with BIM Top and Sub Metrics</th></tr>
<tr><td rowspan="6">Collaboration</td><td>Collaboration process</td><td>1) Cost</td><td rowspan="11">No KPIs defined</td><td rowspan="11">No KPIs defined</td><td>2) Time
6) Performance</td><td rowspan="11">No KPIs defined</td><td rowspan="11">The KPIs don't impact with the BIM elements.</td><td rowspan="5">1) Cost
2) Time</td><td rowspan="6">1) Cost
2) Time
3) Quality</td><td rowspan="6">5) Health and Safety
10) Collaborative Culture</td><td rowspan="6">2) Time
3) Quality
11) Others: Clash detection</td><td rowspan="6">1) Cost
2) Time
3) Quality
4) Satisfaction
7) Profitability
8) Productivity</td><td rowspan="6">No KPIs defined</td><td rowspan="6">1) Cost
2) Time
3) Quality
4) Satisfaction
5) Health and Safety
6) Performance
7) Profitability
8) Productivity
10) Collaborative Culture
11) Others</td></tr>
<tr><td>Processes and Standards</td><td>2) Time</td><td></td></tr>
<tr><td>Roles and Responsibilities</td><td>3) Quality</td><td>1) Cost</td></tr>
<tr><td>Contractual agreements</td><td>4) Satisfaction</td><td>11) Others (Disputes)</td></tr>
<tr><td>Level 2 Education and Training</td><td>5) Health and Safety</td><td>5) Health and Safety</td></tr>
<tr><td>Procurement route</td><td>6) Performance</td><td>11) Others (program or a delivery)</td><td>11) Others (potential for better outcomes)</td></tr>
<tr><td rowspan="3">Employers' requirements

(OIR)= Organisation information requirements, and (AIR)= Asset Information Requirement</td><td>Design elements</td><td>7) Profitability</td><td>5) Health and Safety
11) Others (Program)</td><td rowspan="3">1) Cost
9) Sustainability</td><td rowspan="3">3) Quality</td><td rowspan="3">5) Health and Safety
11) Others: "Snap Shot in time".</td><td rowspan="5">No KPIs defined</td><td rowspan="3">1) Cost
2) Time
3) Quality
4) Satisfaction
6) Performance</td><td rowspan="3">No KPIs defined</td><td rowspan="3">1) Cost
2) Time
3) Quality
4) Satisfaction
5) Health and Safety
6) Performance
9) Sustainability
11) Others</td></tr>
<tr><td>Information Requirements (EIR)</td><td>8) Productivity</td><td>11) Others (can we do an EIRs on 10 pages of a spreadsheet)</td></tr>
<tr><td>Asset Information Requirement (AIR)</td><td>9) Sustainability</td><td>5) Health and Safety
11) Others (Number of incidents reports and in use)</td></tr>
<tr><td rowspan="2">Facilities Management</td><td>GSL champion engagement</td><td>*10) Collaborative Culture</td><td>2) Time
3) Quality</td><td rowspan="2">1) Cost
9) Sustainability</td><td rowspan="2">3) Quality</td><td rowspan="2">5) Health and Safety
11) Others "Soft landings implementation plan."</td><td rowspan="2">1) Cost
2) Time
3) Quality
5) Health and Safety
9) Sustainability</td><td rowspan="2">11) Others "asset information".</td><td rowspan="2">1) Cost
2) Time
3) Quality
5) Health and Safety
9) Sustainability
11) Others</td></tr>
<tr><td>Facilities Management Education and Training</td><td>11) Others</td><td>11) Others (please sign and send it back, and we'll see how many we've got back)</td></tr>
</table>

Table 7.19 shows that only one interviewee was able to identify the linkage between KPI and BIM sub metrics, while six interviewees were unable to identify a linkage since they did not possess information on the KPI metrics that could be linked. The linkage presented shows that, across the BIM maturity top metrics, the primary KPI metrics (cost, time and quality) would be linked with the BIM maturity top metrics. This shows that these KPIs would be linked and would correlate with the literature review. For the secondary KPI metrics, it was found that:

1) **Collaboration** would be linked with all of the KPI metrics except sustainability.
2) **Employers' requirements (EIR)** would be linked with satisfaction, health and safety, performance and sustainability.
3) **Facilities management** would only be linked to health and safety, and sustainability.

This shows that interviewees at the strategic level recognise collaboration as a key sub metric and was more frequently linked to the KPI metrics. This indicates the importance of enabling collaboration, as indicated by the KPI metrics. Employers' requirements were relatively frequently linked with the KPI metrics, which indicates that the EIRs would be moderately linked with the KPI metrics in general while some KPI metrics would not have linked EIRs. Facilities management was less frequently linked with the KPI metrics, which suggests a weak linkage and thus difficulties with linking the top and KPI metrics. Furthermore, it will not fit with the other KPI metrics. Finally, collaborative culture was introduced as a new KPI metric and linked with all BIM maturity top metrics. Figure 7.7 illustrates a summary of the BIM maturity and KPI metric relationships at the strategic level.

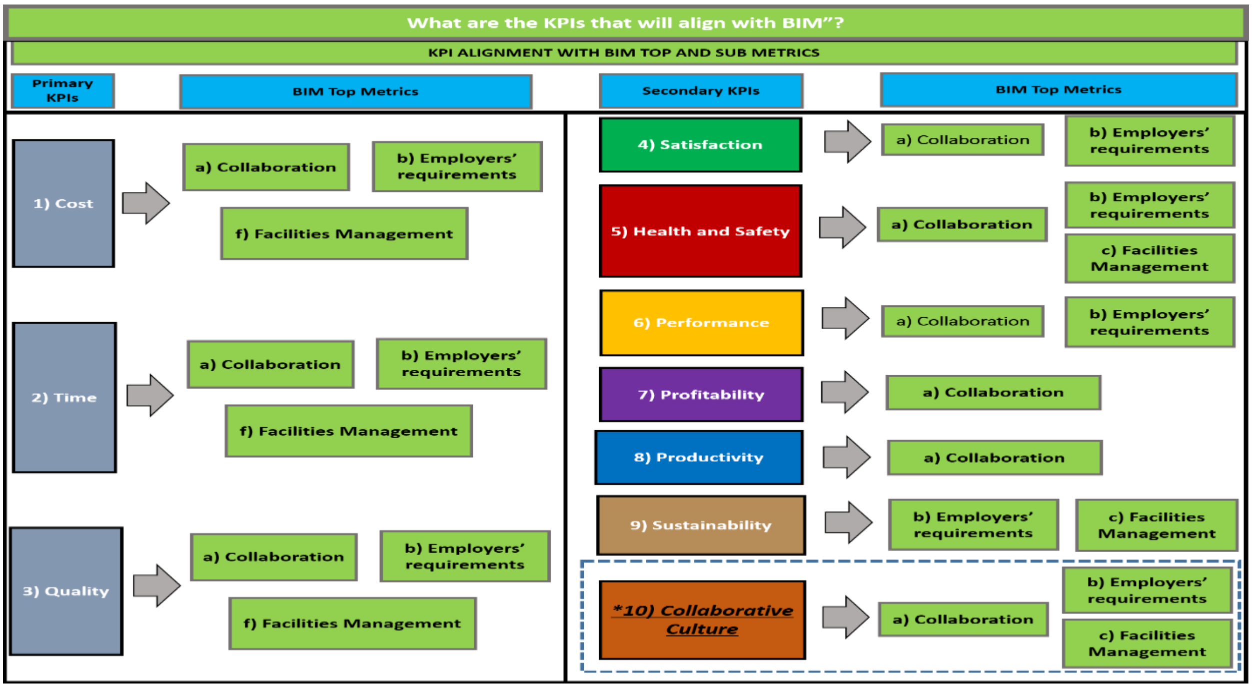


Figure 7.7 Strategic Organisational Level BIM-KPI Linkage

Table 7.20 presents a summary of the nine additional KPI metrics that the interviewees addressed at this organisational level (based on Table 7.19).

Table 7.20 Additional KPIs for the Strategic Level

BIM Sub Metrics	KPIs related to BIM	
Collaboration	**1) Potential for better outcomes, 2) Program, 3) Disputes, 4) Clash Detection**	**Collaborative Culture**
Employers' requirements	**1) Maintainability, 2) Program, 3) Incidents – number of incidents report, 4) Snapshot in time**	
Facilities Management	**1) Capacity, 2) Soft landings Implementation plans**	

The KPI metrics in Table 7.20 represent a proposed list that may be added to the current list of KPI metrics and linked with the BIM maturity metrics. Most interviewees agreed that culture should be included in the previous list of additional KPI metrics, and suggested that this would be linked with all KPI metrics. Thus, **Collaborative Culture** would be introduced as a new KPI metric for inclusion in the initial list of KPI metrics; it will be linked to all BIM maturity top and sub metrics. Having presented the detailed findings of the organisational strategic level, the next section will discuss the findings of the organisational implementation level.

7.4.2 Implementation and organisational assessment

This section presents the analysis and findings of the implementation organisational level assessment (Table 7.21).

Table 7.21 Implementation level organisational assessment

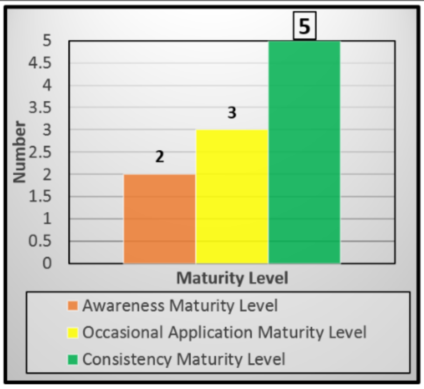
Interviewees	Personal Professional Background	Participant Organisational Position	Maturity Level Average	Maturity Level Average
I02	Information Manager (BIM)	Implementation Level	Consistency	
I03	Architect		Occasional Application	
I04	Architect		Consistency	
I06	Information Manager (BIM)		Awareness	
I07	Architect		Awareness	
I10	Building Surveyor		Consistency	
I12	Project manager		Consistency	
I13	Architect		Consistency	
I14	Architect		Occasional Application	
I15	Information Manager (BIM)		Occasional Application	
Total		10		

Table 7.21 shows that 10 interviewees identified with the implementation level, and (based on the overall scores given), two identified with **Awareness (Aw)**, five with **Occasional application (OA)**, and three with **Consistency (Co)** of maturity levels. This indicated that three users identified with a higher maturity level and perform well within their organisations, whereas eight users were between **Aw** and **OA**, which indicates a requirement to review their current organisational sub metric scores and determine the actions required to move from **Aw** and **OA** to **Co**. Some users identified with both the strategic and implementation levels, which indicates that the assessment would need to work with the same user at multiple levels to determine the maturity level that they would fall under. The overall scores for I03 and I14 were found to be at the **OA** level in both organisational levels. This indicated that users would find themselves at the same maturity level average on multiple levels and thus a consistent scoring average would be adapted. Similarly, I07 experienced the same outcome although their average was at the **Aw** level, while I10 and I13 were at the **Co** level. Conversely, the overall score for I12 was **OA** at the strategic level and **Co** at the implementation level, which indicates different levels of maturity between one organisational level and another for that individual in their organisation. Similarly, I15 experienced the same outcome, but their scoring was **Aw** at the strategic level and **OA** at the organisational level. Table 7.22 presents a summary of the scoring levels for each interviewee, which shows a matrix of alignment between their overall scores, and the individual sub metric score. This helps to identify which of the sub metrics would be maintained (Co), since this is the highest level of maturity, and the sub metrics that would need to be improved (Aw and OA) in order to move from one level to another.

Table 7.22 Interviewees' scores and maturity level average at the implementation level

The Evidence = BIM maturity level at the Implementation level														
BIM maturity level responses based on 10 interviews														
Sub Metrics		I02	I03	I04	I06	I07	I10	I12	I13	I14	I15	Maturity level		Maturity level descriptor
Level 2 BIM	ISO19650											Frequency	Total	
Level 2 Education and Training		2	2	3	1	1	2	2	3	2	1	2	1.90	There is internal training undertaken (i.e. intermediate BIM training or system training) CDE, FM, software based training
Information Requirements (EIR)	Exchange Information Requirement (EIR)	3	2		2	1	3	3	3	2	2	2 3	2.33	Basic template and external procured EIR
Uses		2	2	2	2	1	3	2	3	3	2	2	2.20	BIM uses are outlined but not tailored for specific projects
Supplier assessment forms		3	2	3	1	1	2	2	2		1	2	1.89	BIM uses are outlined but not tailored for specific projects
Execution Plan (BEP)	Information Delivery Plan	3	2	3	1	1	3	3	3	3	2	3	2.40	Clients are able to review the BEP
Master Information and Task Team Information (MIDP and (TIDP)		3	1	2	1	1	2	2	3	3	2	2	2.00	Consultant reviews of MIDP and TIDP.
Model production Delivery Table (MPDT)		2	1	3		1	2	2	3	2	2	2	2.00	Basic MPDT Template
Responsibility Matrix (RM)	Assignment Matrix	3	2	2	1	1	3	3	3	2	1	3	2.10	Basic RM template developed but not completed.
Document management stage- Common Data Environment (CDE)	<CDE> State	3	3	3		1	3	3	3	2	2	3	2.56	CDE supplied by you or supplied by others - CDE is fully compliant to BIM Level 2 and security requirements
Information Exchange		3	3	1	2	1	2	3	3	2	2	2 3	2.20	Information exchange is defined with basic requirements.
COBie data		2	2	2	1	1	3	2	3	2	2	2	2.00	Understanding the use of COBie but not incorporated on the FM.
Interviewee maturity level average		2.64	2.00	2.40	1.33	1.00	2.55	2.45	2.91	2.30	1.73	Occasional Application	2.13	

Table 7.22 indicated that three interviewees (I04, I06, I14) left the scoring for four BIM sub metrics blank (EIR, Supplier assessment forms, MPDT, CDE), which indicated an issue with identifying their position and BIM maturity level on those sub metrics. Both the overall averages for the **BIM Execution Plan (2.40)** and **Common Data Environment (2.56)** were at the **Co** level, whereas the remaining metrics were at the **OA** level. This indicates that users would need to review these sub metrics to determine the actions required to enable them to move from **OA** to **Co**. Also, it shows that different levels of understanding concerning BIM maturity exists, as the individual scoring for five interviewees varied from **OA** to **Co**, whereas for three interviewees it varied from **Aw** to **OA** and did not include **Co**. This suggests the need for further education on BIM metrics for these individual in order to move from the lower to higher levels.

In general, the **Aw** or **OA** scores either need to be reviewed to enable users to move to and maintain the **Co** level. Thus, the potential linkage between BIM maturity and KPI metrics were proposed. Across the organisational strategic level, some of the interviewees found it difficult to demonstrate the BIM maturity and KPI metric linkage at the sub metric level, which represents a limitation to the BIM maturity assessment.

Based on this constraint, the list of KPI metrics that emerged from the literature (Section 4.5.1), and the potential linkage with BIM maturity metrics (Section 4.5.2) were presented to the interviewees to demonstrate how a potential linkage between BIM maturity and KPI metrics could occur. As a result, an assessment was conducted to identify the linkage between the BIM maturity and KPI metrics at the top metric level. Table 7.23 proposes a linkage between the BIM maturity and KPI metrics in the top metrics level according to the assessment and discussions conducted with interviewees at the implementation level.

Table 7.23 The relationship between BIM maturity and KPI metrics at the implementation level

BIM and KPI relationships at the Implementation level													
BIM and KPI expected relationship based on 10 interviews													
Top Metrics	Sub Metrics	KPIs	I02	I03	I04	I06	I07	I10	I12	I13	I14	I15	KPIs potential relation with BIM Top and Sub Metrics
Collaboration	Level 2 Education and Training	1) Cost	3) Quality	No KPIs defined	1) Cost 2) Time	1) Cost 2) Time 3) Quality	No KPIs defined	1) Cost 2) Time 3) Quality	No KPIs defined	2) Time 3) Quality 11) Others "clash detection"	1) Cost 2) Time 3) Quality 4) Satisfaction 7) Profitability 8) Productivity	No KPIs defined	1) Cost 2) Time 3) Quality 4) Satisfaction 7) Profitability 8) Productivity 11) Others
Employers' requirements	Information Requirements (EIR)	2) Time	3) Quality		No KPIs defined	3) Quality		3) Quality 4) Satisfaction		No KPIs defined	1) Cost 2) Time 3) Quality 4) Satisfaction 6) Performance		1) Cost 2) Time 3) Quality 4) Satisfaction 6) Performance
Processes	Uses	3) Quality	1) Cost		1) Cost 2) Time	1) Cost 2) Time 3) Quality		6) Performance 8) Productivity			1) Cost 2) Time 3) Quality 6) Performance 8) Productivity		1) Cost 2) Time 3) Quality 4) Satisfaction 6) Performance 8) Productivity 11) Others
	Supplier assessment forms	4) Satisfaction	3) Quality		1) Cost 3) Quality 11) Others "predictability"	2) Time 3) Quality							
	Execution Plan (BEP)	5) Health and Safety	2) Time 3) Quality		1) Cost 2) Time 3) Quality 4) Satisfaction 11) Others "Delivery and predictability"	1) Cost 2) Time 3) Quality							
Delivery	Master Information and Task Team Information (MIDP and (TIDP)	6) Performance	2) Time 3) Quality		2) Time 11) Others "Resources"	3) Quality		1) Cost 2) Time 3) Quality			1) Cost 2) Time 3) Quality 6) Performance		1) Cost 2) Time 3) Quality 6) Performance 11) Others
	Model production Delivery Table (MPDT)	7) Profitability	3) Quality		2) Time 11) Others "Resources"	No KPIs defined							
	Responsibility Matrix (RM)	8) Productivity	2) Time 3) Quality		11) Others "predictability"	2) Time							
Sharing	Document management stage-Common Data Environment (CDE)	9) Sustainability	1) Cost 2) Time 3) Quality		1) Cost 2) Time	1) Cost 2) Time 3) Quality		No KPIs defined			1) Cost 2) Time 3) Quality 6) Performance		1) Cost 2) Time 3) Quality 6) Performance
	Information Exchange	*10) Collaborative Culture	3) Quality		3) Quality	3) Quality							
Facilities Management	COBie data	11) Others	2) Time 3) Quality		2) Time 11) Others "predictability"	3) Quality		1) Cost 3) Quality			1) Cost 2) Time 3) Quality 5) Health and Safety 9) Sustainability	11) Others "asset information".	1) Cost 2) Time 3) Quality 5) Health and Safety 9) Sustainability 11) Others

Table 7.23 shows that only two interviewees were able to identify the linkage between the KPI metrics and BIM sub metrics, while five interviewees were unable to identify a linkage between the KPI metrics across the BIM maturity top metrics. This was attributed to a lack of information on the KPI metrics that could be linked with the BIM maturity top metrics. The linkage presented shows that, across the BIM maturity top metrics, the primary KPI metrics (cost, time and quality) would be linked with the BIM maturity top metrics. This shows that these KPIs could be linked and correlated with the critical review of the literature. For the secondary KPI metrics, it shows:

1) **Facilities Management** is linked with two KPIs (health and safety, and sustainability), **Collaboration** with three KPIs (satisfaction, profitability, productivity), and **Processes** with three KPIs (satisfaction, performance, productivity).

This indicates that the interviewees recognised a less frequent link as more than one sub metric was linked with these KPIs and interviewees could refer to reviewing the relevant BIM maturity and KPI metrics.

2) Productivity with two BIM top metrics **(Collaboration and Processes).**
3) Satisfaction with three top metrics **(Collaboration, Employer's requirement and Processes)**.
4) Performance with four top metrics **(Employer's requirement, Processes, Delivery, and Sharing)**.

This indicates that performance would be more frequently linked with the top metrics at the implementation level, followed by satisfaction and then productivity. Lastly, similar to the previous organisational level, Collaborative Culture was introduced as a new KPI metric and was linked with all of the BIM top metrics. Figure 7.8 illustrates a summary of the relationship between BIM maturity and KPI metrics at the strategic level.

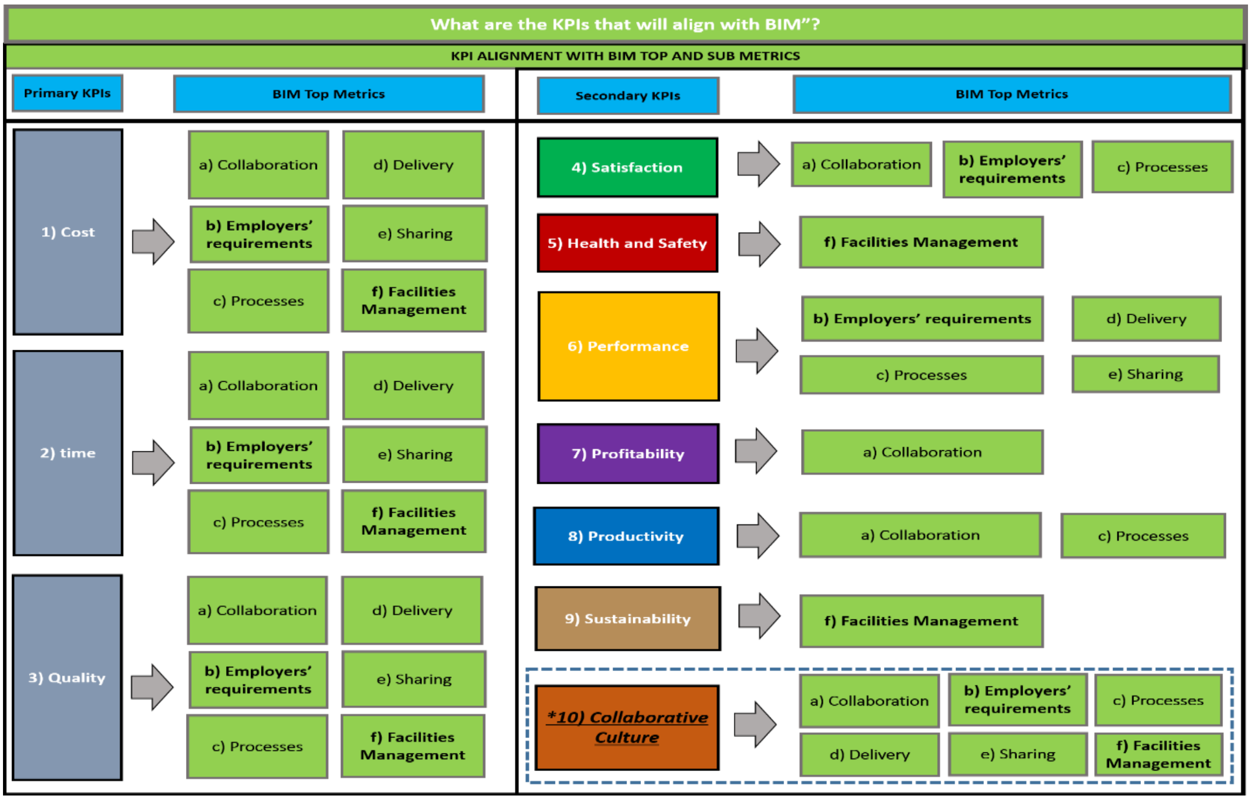


Figure 7.8 Implementation Organisational Level BIM-KPI Linkage

Table 7.24 presents a summary of the five additional KPI metrics that the interviewees addressed at the organisational level (based on Table 7.23).

Table 7.24 Additional KPIs for the implementation level

BIM Sub Metrics	KPIs related to BIM	
Collaboration	Clash detection – technical queries	Collaborative Culture
Processes	1) Validation - Delivery 2) Predictability	
Delivery	1) Resources 2) Predictability	
Facilities Management	1) Asset information 2) Predictability	

These KPIs present a proposed list for consideration. Again, it has been stated that **Collaborative Culture** would be added as a new KPI metric and linked with all BIM top and sub metrics. Having presented the detailed findings of the organisational implementation level, the next section will discuss the findings of the organisational operational level.

7.4.3 Operational organisational assessment

This section presents the analysis and findings of the organisational operational level assessment (Table 7.25).

Table 7.25 Operational Organisational Level assessment

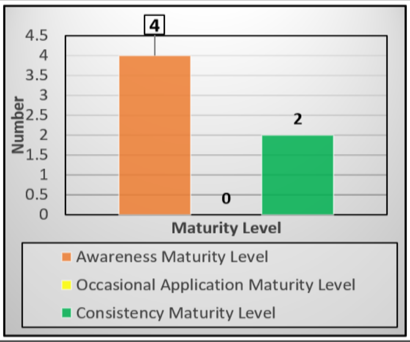
Interviewees	Personal Professional Background	Participant Organisational Position	Maturity Level Average	Maturity Level Average
I03	Architect	Operational Level	Awareness	
I10	Building Surveyor		Consistency	
I11	Architect		Awareness	
I12	Project manager		Consistency	
I14	Architect		Awareness	
I15	Information Manager (BIM)		Awareness	
Total		6		

Table 7.25 shows that only six interviewees identified with this organisational level, which is the lowest number among the levels, and (based on the overall scores given), four identified with **Awareness (Aw)**, none with **Occasional application (OA)**, and two with **Consistency (Co)** of maturity levels. This indicated that two users identified with a higher maturity level and perform well within their organisations, whereas four users were at the **Aw** level, which indicates a requirement to review their current organisational sub metric scores and determine the actions required to move from **Aw** and **OA** to **Co**. Furthermore, only I11 identified with this level, whereas the remaining users identified at both the strategic and implementation levels. This indicates that the assessment would work with the same user at multiple levels and would thus enable the user to determine the maturity level at which they were positioned. Only I10 has a scoring of **Co** across all three organisational levels, which demonstrates consistency, while I11 scored as **Aw.** Moreover, I12 scored at **Co** at the implementation level but **OA** at the strategic level. The remaining interviewees did not score **Co** at any of the organisational levels; instead, I03 previously scored **OA** at the other organisation levels, but at the implementation organisational level scored at **Aw.** Moreover, I14 and I15 scored themselves at **Aw** in this organisational (operational) level and **OA** at the implementation level, but at the strategic level, I14 scored at **OA,** while I15 scored at **Aw.** This indicates variances with the scoring amongst participants who were yet to mature to the **OA** or **Co** levels; this suggests a need for review to enable users to move to the **Co** level. Table 7.26 presents a summary of the scoring levels for each interviewee and shows a matrix of alignment between their overall scores, and the individual sub metric scores. This helps to determine which of the sub metrics would be maintained (Co) since this is the highest level of maturity, and the sub metrics that should need to be improved (Aw and OA) in order to move from one level to another.

Table 7.26 Interviewees' scores and maturity level averages at the operational level

The Evidence = BIM maturity level at the Operational level										
BIM maturity level responses based on 6 interviews										
Sub Metrics		I03	I10	I11	I12	I14	I15	Maturity level		Maturity level descriptor
Level 2 BIM	ISO19650							Frequency	Total	
Information Requirements (EIR)	Exchange Information Requirement (EIR)	2	3	2	2	2	1	2	2.00	Basic template and external procured EIR
Document management stage- Common Data Environment (CDE)	<CDE> State	3	2	2	3	2	2	2	2.33	CDE supplied by you or supplied by others - CDE implemented but not Level 2 BIM compliant / PAS1192-5 compliant
3D – 6D inputs		1	2	1	2	1	2	1 2	1.50	Simply Identified 3D-6D elements, but not fully followed
Level of Development (LoD)	Level of Information need	2	2	3	2	2	1	2	2.00	Good understanding of the LoD and basic ability to check (Visual checks) the models
Project reviews		1	2	1	3	2	2	2	1.83	Good understanding of the roles and responsibility and acknowledging the clients on the gateway reviews to be applied
Lifecycle Analysis		1	2	1	2	1	2	1 2	1.50	No capability to operate on the lifecycle.
As built model		2	3	2	2		1	2	2.00	As built model is acknowledged by project team members in line with BIM level 2, and ready to be used.
Project Information Model (PIM) exchanges		1	3	2	3	2	1	1 2 3	2.00	Information model is acknowledged by project team members in line with BIM level 2, and ready to be used.
Information Delivery (AIM)		1	2	1	3	2	1	1	1.67	Good Understanding of AIM and using it in the basic level but is not fully level 2 BIM compliant
COBie data		1	2	2	3	2	1	2	1.83	Good Understanding and using it in the basic level but not fully integrated in the system
Handover requirements (GSL)		1	3	1	2	1	1	1	1.50	Basic understanding of Hand-overs and its requirements for the GSL, but is not presented
Post Occupancy Evaluation (POE)		1	3	1	2	1	1	1	1.50	Basic understanding of Post Occupancy Evaluation, but is not presented
Interviewee maturity level average		1.42	2.42	1.58	2.42	1.64	1.33	Occasional Application	1.80	

Table 7.26 indicated that one interviewee (I14) left one BIM sub metric scores blank (as built model), which indicated an issue with identifying their position on this sub metric, which meant it was not possible to identify their BIM maturity level for this metric. None of the overall top metrics were found to be at the **Co** level, which indicated an issue with the maturity of the metrics across the organisational levels, while the remaining were distributed between **Aw [3D-6D input, Lifecycle analysis, GSL, and POE, all with (1.50)] (indicating general knowledge and understanding of BIM Level 2 strategic level across the organisation) and OA**. This indicates that users would need to review the sub metrics and determine the actions required to allow the users to move from **OA** to **Co**. Also, it shows that different levels of understanding of BIM maturity exists, as the individual scoring for two users varied from **OA** to **Co**, while the individual scoring for another two users varied from **Aw** to **OA** and did not include **Co**. This suggests a need for these individuals to further educate themselves with BIM metrics, to enable them to move to the higher levels.

In general, the **Aw** or **OA** scores either need to be reviewed to enable the users to move to and maintain the **Co** level. Thus, a potential linkage between BIM maturity and KPI metrics was proposed. Across the organisational operational level, it was difficult for interviewees to demonstrate the linkage between BIM maturity and KPI metrics at the sub metric level, which represents a limitation in being unable to recognise the linkage at the sub metric level.

Based on this constraint, the list of KPI metrics that emerged from the literature (Section 4.5.1), and the potential linkage with BIM maturity metrics (Section 4.5.2) were presented to the interviewees to demonstrate how a potential linkage between BIM maturity and KPI metrics could occur (this was based on the literature review which linked BIM maturity and KPI metrics).

As a result, an assessment was conducted to identify the linkage between the BIM maturity and KPI metrics at the top metrics level. The assessment and discussions were conducted with interviewees at the strategic level, while Table 7.27 proposes a link between the BIM maturity and KPI metrics at the top metrics level.

Table 7.27 BIM maturity and KPI metrics: Relationship across the operational level

<table>
<tr><th colspan="11">BIM and KPI relationships at the Operational level</th></tr>
<tr><th colspan="11">BIM and KPI expected relationship based on 7 interviews</th></tr>
<tr><th>Top Metrics</th><th>Sub Metrics</th><th>KPIs</th><th>I03</th><th>I04</th><th>I10</th><th>I11</th><th>I12</th><th>I14</th><th>I15</th><th>KPIs potential relation with BIM Top and Sub Metrics</th></tr>
<tr><td>Employers' requirements</td><td>Information Requirements (EIR)</td><td>1) Cost</td><td rowspan="12">No KPIs defined</td><td>No KPIs defined</td><td>2) Time
3) Quality</td><td>3) Quality
11) Others "Quality of design and service"</td><td rowspan="12">No KPIs defined</td><td>1) Cost
2) Time
3) Quality
4) Satisfaction
6) Performance</td><td rowspan="8">No KPIs defined</td><td>1) Cost
2) Time
3) Quality
4) Satisfaction
6) Performance
11) Others</td></tr>
<tr><td>Sharing</td><td>Document management stage-Common Data Environment (CDE)</td><td>2) Time</td><td>1) Cost
2) Time</td><td>2) Time
8) Productivity</td><td>11) Others "Co-ordination in sharing the information"</td><td>1) Cost
2) Time
3) Quality
6) Performance</td><td>1) Cost
2) Time
3) Quality
6) Performance
8) Productivity
11) Others</td></tr>
<tr><td rowspan="6">Capital Delivery</td><td>3D – 6D inputs</td><td>3) Quality</td><td>1) Cost
2) Time
5) Health and Safety
11) Others "predictability"</td><td rowspan="6">3) Quality
6) Performance</td><td rowspan="6">5) Health and Safety
7) Profitability
8) Productivity
9) Sustainability</td><td rowspan="6">1) Cost
2) Time
3) Quality
7) Profitability
8) Productivity
9) Sustainability</td><td rowspan="6">1) Cost
2) Time
3) Quality
4) Satisfaction
5) Health and Safety
6) Performance
7) Profitability
8) Productivity
9) Sustainability
11) Others</td></tr>
<tr><td>Level of Development (LoD)</td><td>4) Satisfaction</td><td>No KPIs defined</td></tr>
<tr><td>Project reviews</td><td>5) Health and Safety</td><td>11) Others "predictability"</td></tr>
<tr><td>Lifecycle Analysis</td><td>6) Performance</td><td>4) Satisfaction</td></tr>
<tr><td>As built model</td><td>7) Profitability</td><td>3) Quality
11) Others "predictability"</td></tr>
<tr><td>Project Information Model (PIM) exchanges</td><td>8) Productivity</td><td>No KPIs defined</td></tr>
<tr><td rowspan="4">Facilities Management</td><td>Information Delivery (AIM)</td><td>9) Sustainability</td><td>No KPIs defined</td><td rowspan="4">5) Health and Safety
6) Performance</td><td rowspan="4">4) Satisfaction
5) Health and Safety
6) Performance
7) Profitability
8) Productivity
9) Sustainability</td><td rowspan="4">1) Cost
2) Time
3) Quality
5) Health and Safety
9) Sustainability</td><td rowspan="4">11) Others "asset information".</td><td rowspan="4">1) Cost
2) Time
3) Quality
4) Satisfaction
5) Health and Safety
6) Performance
7) Profitability
8) Productivity
9) Sustainability
11) Others</td></tr>
<tr><td>COBie data</td><td>*10) Collaborative Culture</td><td>2) Time
11) Others "predictability"</td></tr>
<tr><td>Handover requirements (GSL)</td><td rowspan="2">11) Others</td><td>4) Satisfaction
11) Others "predictability"</td></tr>
<tr><td>Post Occupancy Evaluation (POE)</td><td>4) Satisfaction</td></tr>
</table>

Table 7.27 shows that only one interviewee was able to identify the linkage between KPI metrics across the BIM sub metrics, while three interviewees were unable to identify a linkage since they did not possess information on the KPI metrics that could be linked. The presented linkage shows that, across the BIM maturity top metrics, the primary KPI metrics (cost, time and quality) would be linked with the BIM maturity top metrics, which correlates with the literature review. For the secondary KPI metrics, it shows that:

1) Satisfaction and Productivity were linked with most of the BIM top metrics except **Sharing in Satisfaction and Employers requirement in Productivity.**
2) Health and Safety and Sustainability were linked to both **Capital delivery and Facilities management.**
3) Performance was linked with all of the BIM top metrics.
4) Profitability was only linked to **Capital Delivery**.
5) **Facilities Management** was linked with five KPI metrics (Satisfaction, Health and Safety, Performance, Productivity, and Sustainability), and this was the same across both the strategic and implementation levels with two KPIs (Health and Safety, and Sustainability) which sets a generalised link between facilities management and the KPIs across all organisational levels.
6) **Capital Delivery** was linked to all KPI metrics.

This shows that, within the operational level, capital delivery would be linked across all KPI metrics, indicating a more frequent link between BIM maturity and KPI metrics. Facilities management would follow this sequence, as it not linked with profitability, indicating the same reasons previously mentioned. Both sharing and employers' requirements were only be linked with three KPIs each, indicating a lower frequency link between BIM maturity and KPI metrics to those mentioned previously. Finally, similar to both previous organisational levels, Collaborative Culture was introduced as a new KPI metric and linked with all BIM top metrics. Figure 7.9 illustrates a summary of the relationship between BIM maturity and KPI metrics at the operational level.

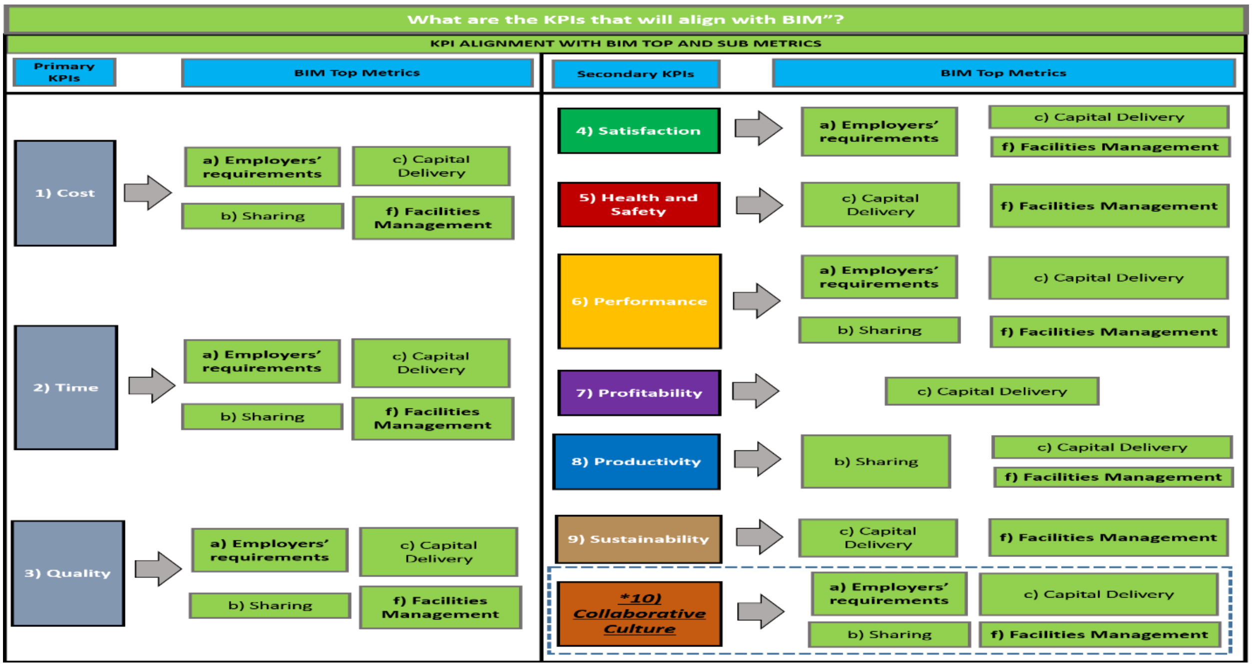


Figure 7.9 Operational organisational level BIM-KPI linkage

Table 7.28 presents a summary of the five additional KPI metrics that the interviewees addressed at this organisational level (based on Table 7.27).

Table 7.28 Additional KPIs for the Operational Level

BIM Sub Metrics	KPIs related to BIM	
Employers' requirements	Quality of design and service,	Collaborative Culture
Sharing	Co-ordination in sharing the information	
Capital Delivery	1) Predictability, 2) Quality of design and service, and service in terms of timescales	
Facilities Management	1) Asset information, 2) Predictability,	

These KPIs presents a proposed list. Again, it has been stated that **Collaborative Culture** would be introduced as a new KPI metric for adding to the initial list previously identified. This would be linked with all BIM top and sub metrics. Having presented the detailed findings of the organisational operational level, the next section discusses the findings of all organisational levels.

7.4.4 BIM-KPI linkage findings across all organisational levels

This section presents the findings concerning the linkage across all the organisational levels and its relation to the literature review findings. After demonstrating the individual linkage between the BIM maturity and KPI metrics at each organisational level, it is useful to determine how this linkage would be mapped across all organisational levels. This could demonstrate a standardised list of combined BIM maturity and KPI metrics for mapping across the organisational level. Figure 7.10 demonstrates the proposed linkage based on the previous findings.

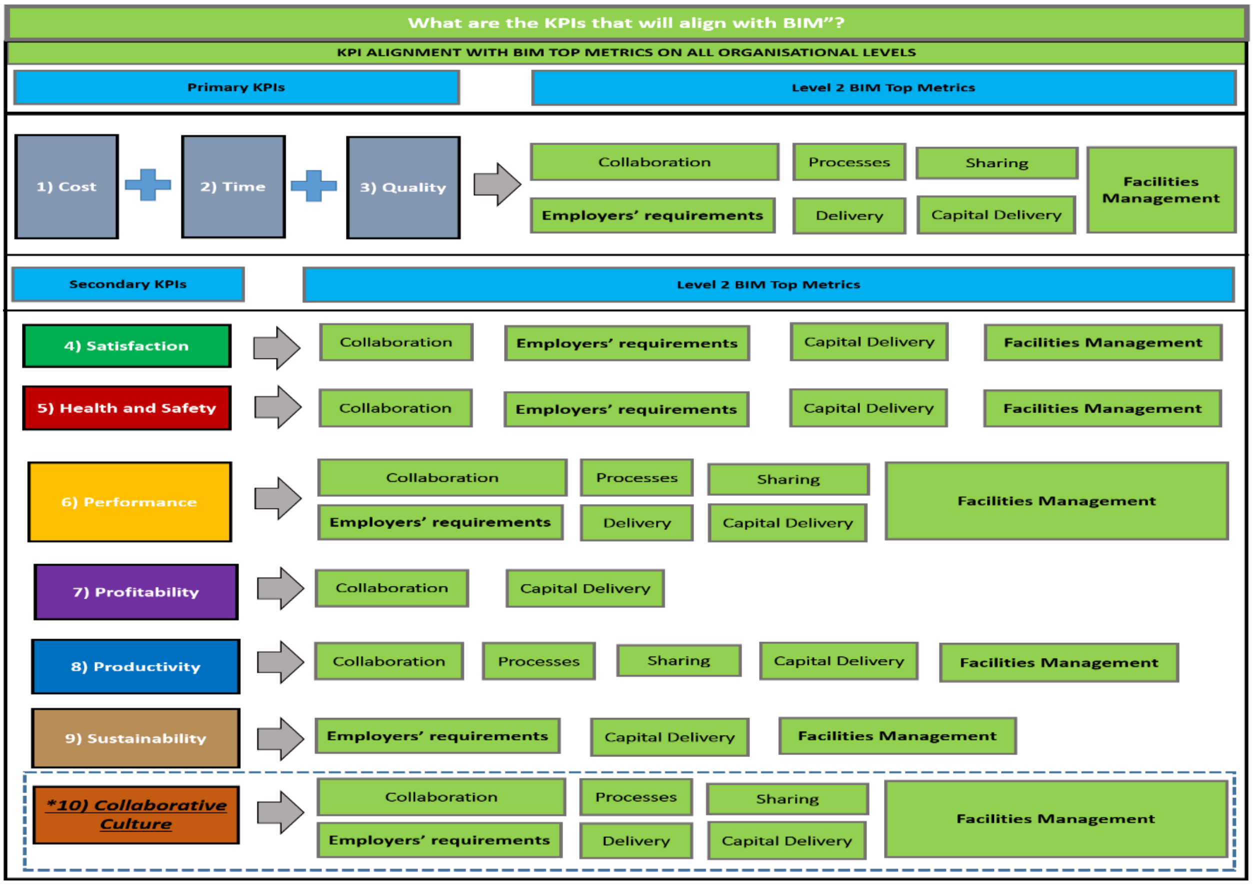


Figure 7.10 Organisational levels BIM-KPI linkage

Figure 7.10 shows that all BIM maturity top metrics would be linked across the three primary KPI metrics (cost, time, quality). This ensures the frequent and potential linkage between BIM maturity and the three primary KPI metrics, which correlate to the KPI metrics identified in the literature and the initial proposition to link BIM maturity and KPI metrics. For the secondary KPI metrics (Satisfaction, Health and Safety, Performance, Profitability, Productivity, Sustainability, and the newly added Collaborative Culture) the linkage with BIM maturity varied from one organisational level to another, which indicated that participants had different views on what linkages would occur. A new KPI is necessary (Collaborative Culture) as it reflects the organisational performance and the need to address cultural behaviours, although this depends on their levels of understanding of BIM maturity and KPI metrics. The findings show that:

1) **Performance** was the most frequent KPI metric in terms of the number of linked BIM maturity metrics. This was linked to all BIM maturity top metrics while collaborative culture, as a new KPI metric, was also frequently linked to all of the BIM maturity top metrics. This indicates that both performance and collaborative culture were seen as the most frequent and important KPI metrics for linking with the BIM maturity top metrics.
2) **Productivity** was the second most frequently linked KPI to all of the BIM maturity top metrics, with the exception being Employers' requirement and Delivery.
3) **Both Health and Safety, and Satisfaction** were linked with four BIM maturity top metrics (Collaboration, Employers requirements, Capital delivery and Facilities Management). This shows that both Health and Safety, and Satisfaction are linked relatively frequently to the BIM maturity top metrics.
4) **Sustainability** was linked with three BIM maturity top metrics (Employers' requirements, Capital delivery and Facilities Management). It is one of the least frequent and least important KPI metric to be linked with the BIM maturity top metrics.
5) Finally, **Profitability** was linked with only two BIM maturity top metrics (Collaboration and Capital delivery), and thus was the least important and least frequent among the KPI metrics.

Based on the previous discussion, Table 7.29 demonstrates the consensus concerning the linking of KPI metrics across all the organisational levels. As collaborative culture was aligned with all organisational levels, 16 new KPI metrics were mentioned and eligible for inclusion when linking to the BIM maturity top metrics.

Table 7.29 All organisational levels: Additional BIM-KPI linkage

BIM Sub Metrics	KPIs related to BIM	
Collaboration	1) Clash detection – technical queries, 2) Potential for better outcomes, 3) Program, 4) Disputes	Collaborative Culture
Employers' requirements	1) Validation – Delivery 2) Quality of design and service, 3) Maintainability, 4) Program, 5) Incidents – number of incidents report, 6) Snapshot in time	
Processes	1) Validation – Delivery, 2) Predictability	
Delivery	1) Resources 2) Predictability	
Sharing	1) Compliance with CDE, 2) Co-ordination in sharing the information	
Capital Delivery	1) Predictability, 2) Quality of design and service, and service in terms of timescales	
Facilities Management	1) Asset information, 2) Predictability, 3) Capacity, 4) Soft landings Implementation plans	

Having presented the findings across all organisational levels, the next section will discuss the findings concerning the benefits and their links to all of organisational levels.

7.4.5 BIM maturity and KPI metrics linkage: Benefits expected to emerge

While Table 7.10 focused on the general benefits associated with the BIM maturity and KPI metrics, this section considers those expected to emerge from linking the BIM maturity and KPI metrics across the three organisational levels, and notes the potential actions needed in order to access these benefits. Table 7.30 presents a summary of the benefits concerning the assessment and actions required to access the benefits.

Table 7.30 Benefits of the assessment

Benefits (related to assessment)
Benefits: There is a list of targets to achieve. Achieving maturity 3 (consistency) all the time. To achieve consistency, what needs to be done to get there? There is a training requirement, people got too much work to do, to measure these against the targets. Beneficial. **(Interviewee I03)**
"Such as improve overall project delivery, add value to the client, spreading more knowledge across the project team, spreading more BIM related stuff and they will be more aware." "The provided list of benefits does align with this, but they will not be measured." **(Interviewee I04)**
*"These are some of the benefits that we've got from that particular project. Complex design solutions, sequencing and programming, *visualisation to support decision making and *improved clash detection. The list of benefits will match and fit with those. [*Refer to Manchester Town tall complex study for a list of benefits. Section 4.7; BIM benefits expected for clients, and Section 4.8; BIM benefits explored in the MCC project"* **(Interviewee I06)**
"Such as working collaboratively, there will be openness, projects will work on a smoother pace" **(Interviewee I07)**
Refer to benefits methodology report to see how you can measure the presented benefits (Benefits measurement methodology report) **(Interviewee I09)**
'Safety and change management and things like that definitely comes in the construction period, along with the KPIs. Based on the list, some relate more to the construction period, so like improved communication and collaboration that would be construction phase, improved certainty and reduction and programme certainty is construction phase, performance certainty comes after, it's a KPI that we can put on the contractor and say we want to achieve coordination of this. Performance and Improved user satisfaction- as an occupancy KPIs." **(Interviewee I10)**
"Assess time savings or cost saving benefits of BIM and reflect this in more competitive quotes to clients to extra business." **(Interviewee I11)**
"As long as the procurement routes are set up to integrate lifecycle analysis, that could be massive. I think that will be a huge benefit for the construction industry as a whole CAPEX, not OPEX." **(Interviewee I14)**

Actions (Total 11)
"To make a positive change, you need to measure maturity" **(Interviewee I01)**
"You need to implement this in an organisation, for instance, even with this spreadsheet; how would you identify the KPIs on having a BEP." **(Interviewee I02)**
I would agree that if there is a BIM project, then all the provided benefits will be achieved **(Interviewee I07)**
"If the benefits could be tied to the KPIs, then that could improve the KPIs. if you can link them all together, then it can make it easier to put a business case for it" **(Interviewee I15).**

Eight benefits would occur from the proposed linkage, which are linked to two key topic areas: Firstly, benefits to projects and organisations, and secondly, benefits to users (i.e. clients, project teams). Benefits related to projects and organisations were identified as follows:

1) Achieving consistency throughout,
2) Improving overall project delivery,
3) Improving clash detections,
4) Those from the MCC projects,
5) The benefits methodology report (PwC. 2018), which presents a list to be measured related to projects and organisations in general, and
6) Integrating lifecycle analysis through the procurement route.

Benefits that are related to clients and project teams were: Adding value to clients and spreading more knowledge to project teams; enabling visualisation to support decision making; working collaboratively to allow openness; supporting safety and change management, and assessing tailored time and cost savings to clients and enabling extra business. Actions required to facilitate these benefits would be: Measuring maturity; implementing linkages in the organisation; examining this across BIM projects, and bonding the benefits to KPIs. This shows that mainly the benefits would vary between clients and projects, and in order for the benefits to occur, these actions need to be addressed.

The interview findings revealed the need to redress the final outcome of the assessment in order to better understand scoring at the lower levels and provide actions to enable users to score from one level to another. Based on this, Figure 7.11 proposes an action plan that highlights the steps to be taken to understand what is needed to achieve consistency.

BIM maturity assessment (The What) (Transition from level 2 BIM to the new BS EN ISO19650 standards)				BIM maturity measurement (The How) (Transition from level 2 BIM to the new BS EN ISO19650 standards)									
				Maturity level 1	2	3						3	
Top Metrics	Sub Metrics		Essence of descriptors	Awareness	Occasional Application	Consistency						Consistency	
Main BIM metrics and their descriptions	Secondary metrics associated with the main BIM metrics that is expected to be measured to achieve BIM		Description of the secondary metrics to provide a clear definition of each metric	General Knowledge and understanding of BIM metrics in operational level, but is sometimes not being recognised across the organisation	Partial Application of BIM metrics and is somehow being recognised, but is not being embedded generally	Full application and maintaining BIM metrics, is consistently recognised, and is being embedded across projects generally	Current Maturity level	Weight	Action plan / Training	Responsibility to meet plan	Responsibility to handle payments and expenditures	Full application and maintaining BIM metrics, is consistently recognised, and is being embedded across projects generally	Target Maturity level
	level 2 BIM	ISO19650											
a) Employers' requirements (Defining stakeholder needs for projects to be able to achieve BIM)	1) Information Requirements (EIR)	Exchange Information Requirement (EIR)	Presence of Employers Information Requirements and level of requirements expected for Employers	No EIRs presented	Basic template and external procured EIR	Fully developed EIR in the provided documents (AIR)	2	1	Software, BIM Authoring, Clash Detection,	Architect 3rd Party Contractor	In house Project (external) Project (external)	Fully developed EIR in the provided documents (AIR)	3
b) Sharing (Distribution of information amongst stakeholders that is shared effectively amongst them)	1) Document management stage- Common Data Environment (CDE)	<CDE> State	Achievements of File systems, workflows, library, and accessibility in projects' pre-contract and post-contract stage and a post-completion asset management stage for a Common Data Environment	CDE supplied by you or others - Not aware and CDE required	CDE supplied by you or supplied by others - CDE implemented but not Level 2 BIM compliant / PAS1192-5 compliant	CDE supplied by you or supplied by others - CDE is fully compliant to Level 2 BIM and security requirements	1	0.8	CDE, BIM launch, COBie MasterClass	Contractor 3rd Party BIM Consultant	Project (external) In house In house	CDE supplied by you or supplied by others - CDE is fully compliant to BIM and security requirements	3
Current Maturity level (Total)							1.5	Target Maturity level (Total)					3.00

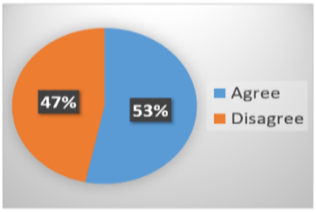
Figure 7.11 Action Plan for future

A number of actions suggested by the interviewees were:

To have a weighing scheme, check back on the filled spreadsheet for example on how to distribute the KPIs / weight / actions. (Interviewee I02); Action plan to take the levels forward and upgrade from 1 level to another (Awareness to occasional application) (Interviewee I02); Follow-up meetings to preview users progress with maturity upskilling. (Interviewee I03)

Table 7.31 presents the actions required to move from one level to another.

Table 7.31 Action Plan Summary

Proposition of an action plan, further recommendations and actions required.			
Action plan strategy (Total 28)	**Agree**	**Disagree**	
"To have a weighing scheme, check back on the filled spreadsheet for example on how to distribute the KPIs / weight / actions, etc" "Action plan to take the levels forward and upgrade from 1 level to another. (Awareness to occasional application)." "Conducting follow-up meeting with users to follow with their progress and see if they upskilled with their maturity" "Create set of matrices on what I needs to be done to comply with this." "After you submit your work, you can return back to the platform and see if this is being implemented there or not.""	8	7	

A number of interviewees suggested a weight scheme, since each sub metric would differ in terms of importance and the need for it could be followed by a training strategy on the required actions for each of the sub metric, who would be responsible for this action, and who would handle expenses associated with the action. This is believed to help upskill and move users to the consistency level. Eight interviewees agreed with this action plan, and seven disagreed. This indicates that this plan would not work across all users but would be worth considering for future development. It also shows a potential method for improving and elaborating on the assessment and to facilitate it across most organisations. The next section will provide an overall feedback on the BIM maturity assessment and how it could be further developed.

7.4.6 Feedback on the BIM maturity assessment and future development

After presenting the findings, the last question aimed to gather some feedback on the assessment and future developments that could enable action and improvement. Various answers were given, for example:

"It's very good. That's a very interesting piece of work" **(Interviewee I13).** *"I think it's a really interesting piece of research and kind of output I suppose"* **(Interviewee I14).**

On the one hand, this indicated that the interviewees were interested to learn more about the assessment, and they found the work to be interesting and could reflect on it. This suggests a potential assessment to adopt within their practice. However, on the other hand, there were some issues in understanding the assessment:

"For us, if it's just what you say, then that's easy for me to score*, but if it's what I actually believe it to be and it's a broader piece, then it might be a different score."* **(Interviewee I01).**
*"If this could be running in the background****, and not seen as an additional task but managed within a general process of construction."*** **(Interviewee I11).**

This shows there are some issues with the theoretical rather than practice-based background and descriptors. Answers given are based on individuals' interpretations and depend on the context; thus, the answers differ. Table 7.32 presents a summary of the quotes related to this that emerged from the interviews.

Table 7.32 Feedback given on the presented assessment and linking BIM/KPIs together

Theory vs Reality (Total 10)	Positive or negative feedback on work (Total 11)	Eligibility for users to use proposed work (Total 14)
"The action plans could then be linked to training plans, where you have a regular 1 to 1 sessions. You did this project and scored 1 so what could be done to improve this." **(Interviewee I05)**	*"It's very good. That's a very interesting piece of work. It's good that you have a really good part of this to work with. Very knowledgeable in the industry."* **(Interviewee I13)**	*"Speak to BIM Alliance. Carry out the research. "Research and Development on BIM. A government body that could carry out the work and share it with industry."* **(Interviewee I03)**
"Different scores might be given depending on the context. Some of the descriptors are of a theoretical process than an actual" **(Interviewee I01)**	*"The numbers are a bit confusing. Some descriptors need to be reviewed"* **(Interviewee I01)**	*"Speaking with the NBS about this. because we've gone through a process with them; a toolkit which takes you through development of using BIM."* **(Interviewee I05)**
"If this could be running in the background, and not seen as an additional task but managed within a general process of construction." **(Interviewee I11)**	*"People are seeing this from their own benefit, not on your project benefit"* **(Interviewee I04)**	*"This is about BIM implementation, and this focuses on the construction side of it, rather than the operational side. To implement them properly, you need to blend them both together."* **(Interviewee I06)**

Having presented a detailed analysis of the organisational assessments and demonstrated how BIM maturity and KPI metrics would be linked together, the next section will present an update to the proposed framework that relates to "The How" stage (Section 4.5.2).

7.5 The 'How' stage: Evolution of the framework

This section presents the evolution of the conceptual framework to the initial framework in terms of the 'How' stage. Figure 7.12 presents the development step of the 'How' stage, which demonstrates the evolution from the conceptual framework (Section 4.5) to the initial framework development. This section will demonstrate the findings of the semi structured interviews which lead to the following:

1) The BIM maturity assessment across the three organisational levels linking with the KPI strength of relationships back to the BIM maturity levels.
2) Agreement to the final standardised list of KPI metrics and linking them to the BIM metrics.

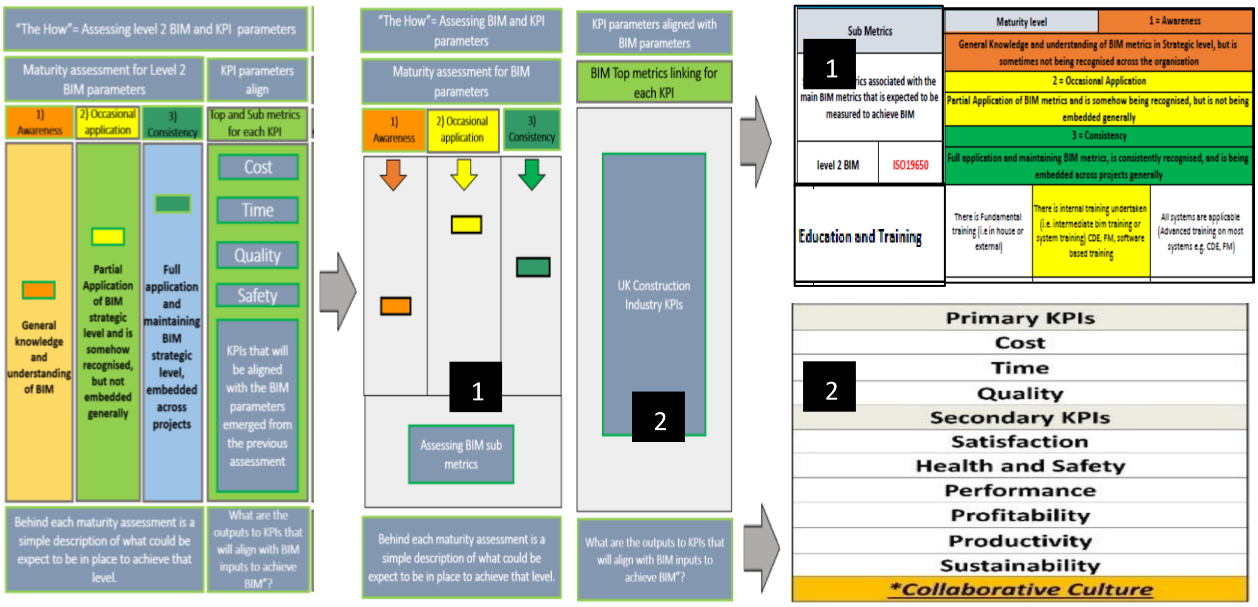


Figure 7.12 The evolution of the 'How' stage from the conceptual to the initial framework

The 'How' stage is presented to identify the potential linkages between BIM maturity and KPI metrics for the framework and for the assessments proposed in this research. The conceptual framework proposed a maturity assessment to be conducted with the BIM maturity sub metrics. The BIM maturity assessment across the three organisational levels (strategic, implementation, operational) was identified, along with a final list of standardised KPI metrics that included collaborative culture as a new KPI metric, and a three-level (awareness, occasional application, consistency) maturity assessment was agreed since it delivers the necessary distinction. As a result, the three-level maturity assessment was used to identify the levels of BIM maturity, but in addition, the linkage between BIM maturity and KPI metrics were established (Figure 7.10). Hence, the initial framework development presents the findings of the maturity levels and how it links back with the KPI metrics.

Having presented the development of the framework and demonstrated how BIM maturity and KPI metrics would be linked together, the next section will provide a summary of the chapter.

7.6 Summary

This chapter presented the findings from the analysis of the semi-structured interviews. Discussions elicited the main and sub themes from the ten questions posed to 15 interviewees, which delivered nine main themes, and 39 sub themes. Thematic analysis was conducted to extract the overarching, main, and sub themes from the discussions with the interviewees. Content analysis was used to demonstrate how many discussions were covered under each sub theme, which helped to emphasise the importance of the main themes, and identified the most commonly occurring themes and patterns to emerge. This was considered in connection with the BIM maturity and KPI linkages. Based on their expertise, interviewees identified with at least one of the organisational levels, which agrees to the workshop findings that advocated three new organisational maturity levels (Awareness, Occasional Application, and Consistency) to assess levels of BIM maturity across the UK client sector. On completion of the maturity assessments, the results showed that all interviewees were positioned across the three maturity levels at the three organisational levels, which shows that levels of BIM maturity differed from one interviewee to another at each organisational level. There were attempts to link the BIM maturity assessments with the KPI metrics provided by the literature while from the semi structured interviews, a new KPI metric (Collaborative Culture) was suggested to reflect the cultural aspects and behaviours amongst UK clients. Further suggested BIM maturity and KPI metrics were identified which could be considered for the upcoming data collection phase (the online questionnaire). An update to the framework which demonstrates how the BIM maturity metrics would link back to the KPI metrics was presented. An update to the conceptual framework has been presented, which discussed the findings related to "The how" stage of the framework, and how it has developed from the proposed framework (Section 4.5) towards the initial framework development.

The next chapter will present the findings and analysis of the online questionnaire data collection phase, in which it will consider the findings of the focus group workshops and semi structured interviews, in terms of the BIM maturity assessment and proposed BIM maturity and KPI metric linkages. These will be examined statistically and the strength of the relationships between the BIM maturity and KPI metrics will be determined. A statistical measure between the levels of BIM maturity and KPI metrics will be conducted to examine the potential relationships and to extract the key benefits expected from this relationship. The data collected and analysed from the interviewees in terms of the organisational levels will be triangulated through comparative analysis with data from the questionnaire participants.

Chapter 8: Quantitative (Questionnaire Survey) data findings

8.1 Introduction

The previous chapter discussed the qualitative findings and analysis (from semi-structured interviews). These findings were tested and examined through a quantitative enquiry, which represents the third step in the process of validating the findings and aimed to achieve a potential linkage between BIM Maturity and KPI metrics. This chapter explores and explains the potential links between BIM Maturity and KPI metrics through a questionnaire survey, which validates the findings from the previous data collection (semi structured interviews). This also finalises this research's mixed method research approach. Similar to the semi-structured interviews, the aim of the questionnaires meets the fourth and fifth objective of this research, in developing a BIM Maturity-KPI assessment framework and examining the potential linkages between BIM Maturity and KPI metrics.

8.2 Questionnaire survey data collection process

The researcher contacted NWCH to distribute a call for participation in the questionnaire survey. The initial step was to identify the criteria under which participants would be selected and the number of participants that would be willing to participate in the survey. This research targeted clients and a number of UK construction organisations. The clients would need some knowledge and previous experience of BIM in order to offer answers to questions on BIM Maturity and KPI metrics. The research aimed to reach as many construction organisations as possible and needed to reach individuals with relevant experience in dealing with BIM Maturity.

Similar to the interview questions, the structure of the questionnaires included three main sections. The first sought information related to participants'/organisations' background and information related to BIM Maturity and KPIs (separately and combined). In the second section, questions sought responses on the potential links between BIM Maturity and KPIs combined from participants and organisations aligned with each of the organisational levels. Thus, the researcher targeted clients and organisations that fit within these organisational levels. The questions first identified whether the participant's answers were based on either a project or an organisational performance level. Then it identified their current maturity level based on three levels (**Awareness**, **Occasional application**, and **Consistency**), and the strength of relationship between BIM Maturity and KPI metrics. This was based on four relationship strengths: No relationship (None), **Not Significant (weak)**, **Moderate (Medium)**, and **Significant (Strong)**. Finally, the last section included feedback on the assessment conducted in the second section and gathered information on the further actions required to support and finalise the proposed assessment framework.

The questionnaire was prepared between October 2018 and January 2019 during which time the BS EN ISO19650 standards were not released. However, the questionnaire was made available online between February 2019 and July 2019, during which the BS EN ISO19650 standards were released. Nevertheless, the questions used would be relevant and related to the new BS EN ISO19650 standards, thus only the Level 2 BIM terminology would be replaced with that of the new BS EN ISO19650 standards. The next section will outline the survey data analysis process.

8.3 Questionnaire survey data analysis process

The questions used in the survey revealed that certain statistical analysis was required to analyse the data and present meaningful results. Such analysis included the use of descriptive statistics (central tendencies, mean/mode/cross-tabulation) to produce numerical data that represented totals and inferential statistics (correlations and regressions). This produced numerical results that represented the level of agreement and degree of association between variables. Table 8.1 presents a summary of the statistical analysis used in this research (Section 5.10.2).

Table 8.1 Quantitative analysis used for the survey analysis

Data analysis types	Purpose of Usage (Objective)
(SPSS software to support the analysis)	
Descriptive statistics	This will deliver results based on summaries for data set given. Cronbach's Alpha is the most common method of checking the internal consistency of scaled data and is used to check for internal consistency of the data (Saunders et al., 2009; Gliem & Gliem, 2003). Central tendency is a main type for this.
Inferential statistics	Inferential statistics are proposed for interpreting the results from the online questionnaire. This is due to the inferential analysis being used to measure the strengths of association between two variables (BIM maturity and KPI metrics), and this will be used to assess the strength of relationships between both variables and represents level of agreement. Correlations and regressions are 2 types that will be used in this research.
Correlation co-efficient analysis (Spearman)	Method shall be used because it will be required to deliver the strength of relationships between BIM maturity and KPI metrics that will be distributed through the spearman correlation coefficient showing the relationships [**(No relationship (None), Not Significant (weak)**, **Moderate (Medium)**, and **Significant (Strong)**]
Linear regression analysis	Method shall be used in the last stage of the model since it shall be required to deliver the cause and effect between the Level 2 BIM and KPIs through a scatter plot diagram.

8.3.1 Questionnaire participants: involvement process

It was necessary to identify the number of participants required to participate in this survey. According to the target population and sample size required (Krejcie & Morgan, 1970; Sekaran & Bougie, 2016), the target population would be the UK construction industry sector. Based on the latest statistical figures published by the UK government (NOMIS. 2018; ONS. 2019; Statista. 2019) the number of people employed in the UK construction sector exceeds three million and the number of organisations working within the construction sector was 314,590. Both represent the population required although very few of these individuals would have experience with BIM and only a few of these organisations may actually be using BIM (BIS. 2013b). the next section will discuss the sample size that was targeted for this research to collect data from.

8.3.1.1 Questionnaire survey sample size selection

According to Flick (2015) a suitable number of survey responses should not be less than **30**, since *"this tends to produce results where individual respondents may skew the results".* Mbugua (2000) similarly suggested that a **minimum of 30** responses would be adequate, which was also supported by Kwak and Kim (2017), who argued that with a sample size of **thirty,** the sampling distribution would be approximated to meet the standard normal distribution according to the central limit theorem. Saunders et al., (2016) presented a table detailing the recommended samples for different target population sizes; it noted the required sample size to distribute a questionnaire based on a 95% confidence level and a margin error of 5%. The response rate is an important factor that needs consideration. The response rate signifies the number of returned questions in a survey that are deemed valid; thus, the higher the response rate, the more power associated with the results returned. It has been stated that no single response rate would be considered standard (Fink, 1995). However, due to the nature of some research areas and based on the density and comprehensiveness of some questionnaires, which is considered the "norm" for this kind of survey, a response rate could decrease severely. According to Soetanto et al., (2001), Sutrisna (2004) and Ankrah (2007), a minimum response rate has been reported as 8.82% although the minimum rates usually fall between 10% and 15%.

Based on the above discussion, the researcher sent out invitations and distributed the questionnaire through an online administered survey website (JISC online survey). This reached the targeted sample; according to Saunders et al., (2016) 100,000+ (N) will require a sample size (S) of **383**, representing a 95% confidence level and 5% margin of error. This was based on a list of BIM practitioners provided by the NWCH (150-200 members), online databases for BIM representative from UK organisations (100-150 organisations), and the researcher's personal contacts from professional social media website contacts and relevant groups (i.e. LinkedIn, BIM relevant websites and professional forums, and relevant LinkedIn BIM professional groups such as "BIM4SME" "BIMexperts" "BIM engineers", and hashtags to reach participants in BIM related groups such as #Cdbb #UkBimAlliance #Level2Bim #NBS #BSI #BRE #ISO19650). This ensured the survey would reach the designated 383 construction professionals from various organisations who represent the sample in terms of BIM knowledge and organisations that use BIM. These groups had individuals that varied from 100 in number to as high as 100,000 individuals representing the UK construction sector. As a result, the survey was distributed and accessed by **500** individuals, which met the required number **(383)**. During a timeframe of five months, a total of **120** professionals were involved throughout the whole survey; however, a few responses were not returned. Specifically,non-responses were defined on **Complete refusal** where **20** disagreed to participate, while **100** agreed to participate, representing 20% participation (**100/500**).

However, of the **100** professionals who agreed to participate, some participants decided not to complete the survey for various reasons, such as: **break off or a lack of interest in the topic** (**25**/**100** participants did not complete questions related to that section representing a 25% drop rate); **being unable to select the organisational levels** proposed (**15** participants and a 15% drop rate), and an **inability to determine the relationships between BIM maturity and KPI metrics** across the three organisational levels. **Partial responses** were also received (Strategic = **10** participants meaning a 10% drop rate; Implementation = **four** participants thus a 4% drop rate, and Operational = **three** participants meaning a 3% drop rate). Finally **complete responses were also received but some were unable to determine the benefits and provide feedback** on the given assessment (**three** participants and a 3% drop rate). Hence, of **120** participants, **eighty** dropped out of the survey.

Thus, the researcher received a total of **40** completed responses from individuals and different organisations, which according to the response rate presents **10.44%** (**40/383**). This rate (10.44%) is within an acceptable range and falls between the previously identified response rates (Ankrah, 2007; Soetanto et al., 2001; Sutrisna, 2004), and in addition the number of responses meets the minimum responses required (30) for an online questionnaire (Flick, 2015, Kwak and Kim, 2017; Mbugua, 2000). Although the online survey would not allow the researcher to access incomplete responses, the **40** responses were valid meaning a **100%** valid ratio. Without answering all questions, it is impossible to run a correlation analysis to identify the potential relationships between BIM Maturity and KPI metrics. Having presented the number of participants involved in the survey, the next section will discuss how the statistical analysis was conducted through descriptive and inferential statistics.

8.3.2 Statistical analysis for the survey (descriptive statistics)

Descriptive statistics summarise a given data sample from the representation of samples, whether from the targeted population, the targeted sample, or those who participated in the survey. The most familiar methods used with the descriptive statistics are the central tendency, as represented by the mode and cross tabulation (frequency of occurrence and cumulative percentages), and mean (average and totals). It is used to identify response points from the survey (Denscombe, 2010). Internal consistency is a process to check for correlations between the responses and the questions represented by Cronbach’s alpha, which checks for internal consistency with scaled data (Gliem and Gliem, 2003; Saunders et al., 2016).

8.3.3 Statistical analysis for the survey (inferential statistics)

This type of analysis tends to use more sophisticated techniques, which rely on measurements from a given sample and are based on the specific population, as it is not possible to measure single items from an entire population. Thus, inferences on the given population need to be drawn. This is achieved by conducting a test of agreement that measures the strength of relationship between given variables. Due to the nature of this research, it is necessary to conduct a number of statistical analysis relevant to the non-parametric data represented within the BIM maturity levels and KPI strength of relationships. For this, the following analysis was conducted: Chi Square, Kruskal Wallis, Spearman Correlation, and Linear regression. While the analysis aimed to find the relationship between BIM Maturity and KPI metrics, which are classified as ordinally scaled, Spearman's correlation coefficient and Kendal rank. These have the ability to measure the strength of association between two ranked variables, which is represented by the BIM Maturity and KPI metrics. According to Saunders et al. (2016), there are difficulties associated with using Spearman’s test as data from either very small (namely less than seven) or large samples, (larger than sixty). For this research, the data sample collected was 40, which fell between 7-60. As such, the above-mentioned inferential analysis was suitable for delivering the analysis to meet the research aim and objectives. The next section will discuss how both statistical types (descriptive and inferential) were conducted.

8.4 Descriptive and Inferential Statistics (Analysis)

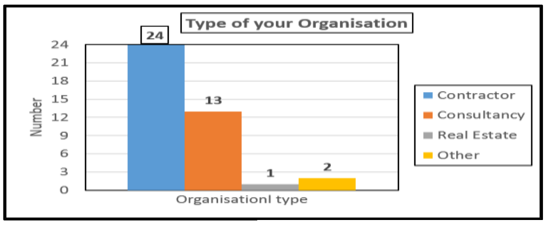
Results that are presented through descriptive statistics may produce an excessive amount of irrelevant information. Thus, it is necessary to summarise the data in order to make sense of it and demonstrate this to the audience. The main idea behind this type of statistics is to produce summaries of the data collected via the questionnaire, which was achieved by producing the frequency distribution (bar and pie charts), along with the mean (averages and total) and mode, which were presented through summarised tables. This was applied to the whole questionnaire, and followed by inferential statistics that presented more intensive data to demonstrate the potential relationships between BIM Maturity and KPI metrics. The software used to present the complete data structure was SPSS version 25.

8.4.1 Section 1: General information

The first section of the questionnaire collected general information from participants. This section gathered data on participants’ professional background to enable a better understanding of where they currently stand within their organisations and to recognise their experience in the industry. This reflects the first section of the interviews in reviewing the current levels of adoption and understanding of BIM maturity and the usage of KPI metrics, and by identifying a potential linkage between BIM maturity and KPI metrics. This helped to establish an enhanced understanding of how participants view these key topics and enable a complete picture of how these topics are embedded within their organisations. The participant identified their organisational position (strategic, implementation, operational) in which they would be expected to conduct the assessment and demonstrated linkages to KPI metrics. A total of 17 questions were asked in this section, which are presented in detail in the following sub sections.

8.4.1.1 Background information

A total of four questions were asked in this section in order to collect information on the participants' backgrounds. This helped to identify the levels of knowledge and experience amongst participants in relation to BIM maturity and KPI metrics. Figure 8.1 presents a summary of the different types of organisations involved. The results show that more participants were classed as working in contractor organisations (24 participants, representing 60% of the sample), followed by 13 who worked for a consultancy (32.5%), two selected 'others' (5%, namely an academic institution and architect practice] and one real estate (2.5%). This suggests that contractors were more interested and knowledgeable in this research area and thus able to offer their understanding of BIM maturity and KPI metrics. This also indicates that other disciplines may lack relevant knowledge on BIM maturity and KPI metrics, and there may be no client demand for BIM, which would complement the literature findings which noted no client demand for BIM (NBS. 2020).

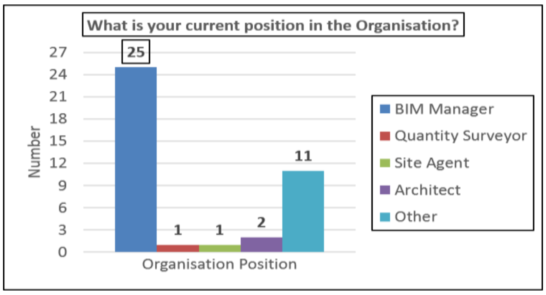


Type of your Organisation

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Consultancy	13	32.5	32.5	32.5
	Contractor	24	60.0	60.0	92.5
	Real Estate	1	2.5	2.5	95.0
	Other	2	5.0	5.0	100.0
	Total	40	100.0	100.0	

Figure 8.1 Type of organisation

Figure 8.2 presents a summary of the different types of positions existing in organisations. The results show that, from these organisations, more participants were BIM managers (25 participants representing 62.5% of the sample). Moreover, 11 selected 'others' representing 27.5% (four of which were design managers representing 10%), two were BIM coordinators, and one was in each for the following positions: Researcher, Technologies Research Development & Innovation, Owner, BIM designer and Global BIM Lead. Moreover, two were architects, one was a quantity surveyor and one a site manager. This suggests that BIM managers had a greater interest in this research.



What is your current position in the Organisation?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Quantity Surveyor	1	2.5	2.5	2.5
	BIM Manager	25	62.5	62.5	65.0
	Architect	2	5.0	5.0	70.0
	Site Agent	1	2.5	2.5	72.5
	Other	11	27.5	27.5	100.0
	Total	40	100.0	100.0	

Figure 8.2 Current position in the organisation

Figure 8.3 presents a summary of participants' roles in relation to BIM. Since this was an open-ended question, various answers were given. By grouping the answers, it shows that more participants were involved in the roles related to BIM processes, implementation and adoption at 11 participants (28%). This was followed by management-related with eight participants (20%), while seven selected 'others' (17.5%), for example a 3D modeler, Enabler, Influencer. Three had coordinator roles and the same number were leaders of companies (7% each), while the remaining participants held the following roles (two for each): BIM managers, Designer manager, Pivotal, and BIM Champion. This shows that various roles exist in relation to BIM and a variety of BIM knowledge existed amongst the participants. It also indicates that BIM managers are more likely to be involved in this work, since they have the knowledge of, and expertise in, BIM.

	Name	Examples	Number of discussions	Percentage
1)	Related to BIM process, implementation and adoption	*"Supporting BIM Implementation and Delivery during Capital Delivery of Construction Projects"*	11	
2)	Management related	*"Digital transformation and information management"*	8	
3)	Others	*"3D Modeler", "Enabler", "Influencer"*	7	
4) a)	Coordinator	*"As a BIM coordinator"*	3	
b)	Lead / Leader	*"As a thought and process leader for our company"*	3	
5) a)	BIM Manager	*"As a BIM Manager"*	2	
b)	Design manager related	*"As a Design Manager"*	2	
c)	Pivotal	*"As a Pivotal"*	2	
d)	BIM Champion	"Business Unit BIM Champion"	2	

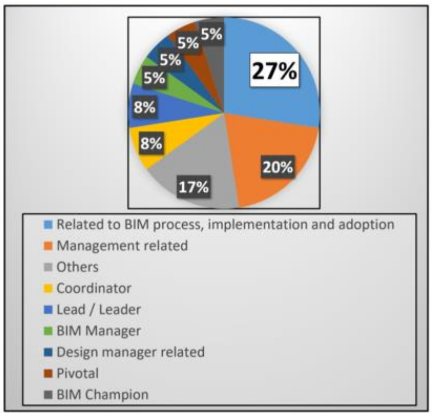
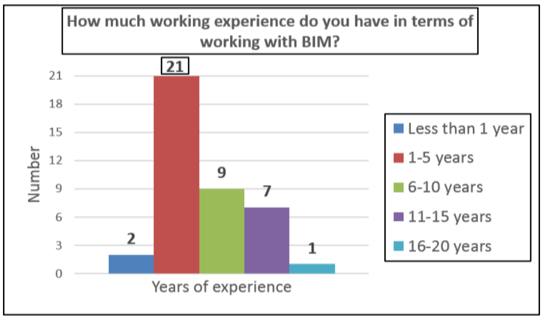


Figure 8.3 Roles in relation to BIM

Finally, Figure 8.4 presents a summary of participants' years of experience with BIM. The results show that 21 participants (52.5%) had at least one to five years of experience, followed by nine (22.5%) who had between six to ten years, then seven (17.5%) who had between 11-15 years, two who had less than a year, and one who had between 16-20 years' experience. This shows that all participants were sufficiently experienced in BIM with at least one year of experience. This also correlates with the NBS survey (2020) in terms of the current levels of BIM adoption over time, which demonstrates that participants have developed knowledge on BIM adoption and indicates that this research will obtain information from users with levels of BIM experience.



How much working experience do you have in terms of working with BIM?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 1 year	2	5.0	5.0	5.0
	1-5 years	21	52.5	52.5	57.5
	6-10 years	9	22.5	22.5	80.0
	11-15 years	7	17.5	17.5	97.5
	16-20 years	1	2.5	2.5	100.0
	Total	40	100.0	100.0	

Figure 8.4 Years of experience

8.4.1.2 General information on BIM Maturity, KPI metrics, and both combined

A total of 12 questions including three sub questions, were asked in this section to collect information from participants on their experience in dealing with BIM maturity and KPI metrics and their personal views on whether they could be combined. This helped to identify the levels of knowledge and experience amongst participants in relation to BIM maturity and KPI metrics and to identify how both could be combined.

Figure 8.5 presents a summary of Level 2 BIM adoption in organisations from the participant's point of view. Since this was an open-ended question, various answers were given. By grouping the answers, it shows that six key topic areas of adoption were provided, and 20 participants (50%) were considered as adopting Level 2 BIM across BIM projects. This was followed by ten participants (25%) actively working on BIM, five had adopted BIM as authoring tools (12.5%), two participants considered that BIM was a requirement (they relied on clients and partially adopted BIM), and one applied it in decision-making. This shows that varying methods of adoption of Level 2 BIM existed amongst the participants in different organisations and greater emphasis was placed on BIM usage across multiple projects in these organisations. It also indicates that Level 2 BIM was applied to BIM projects, which compliments the NBS survey (2020) on the usage of BIM across projects, which also suggests the potential for the use of the proposed BIM maturity assessment across multiple projects.

	Name	Description	Examples	Number of discussions
1)	**BIM projects**	**Information on how is BIM being used (i.e. projects, process)**	*"Organisation is working on BIM Projects", "We are currently working in BIM projects developing our internal 3D protocols, processes and procedures."*	**20**
2)	**Adoption of Level 2 BIM (Actively working)**	**Discussions that revolves around how Level 2 BIM is being implemented within organisations and across projects**	*"We are aiming BIM LEVEL 2", "We are adopting Level 2 BIM principals across all Projects" "BIM level 2", "full adoption"*	**10**
3)	**Adoption of BIM as authoring tools**	**Discussions on adopting BIM as a software tool or related authoring tools across organisations**	*"BIM Adoption is a priority. BIM tools are used on majority of projects", "We have used BIM authoring tools since ~2000."*	**5**
4) a)	**BIM not being a requirement or relying on Client**	**Users who signified that BIM is either not required from Clients or Level 2 BIM not required**	*"BIM is not a client requirement on private projects, hence lack of uptake."*	**2**
b)	**Partial (start) adoption**	**Users who identified themselves as partially adopting Level 2 BIM or just about to adopt**	*"Early stages", "Starting to adopt"*	**2**
5)	**Decision making**	**BIM as part of decision making process**	*"BIM is a factor in our strategic decision making"*	**1**

Percentage

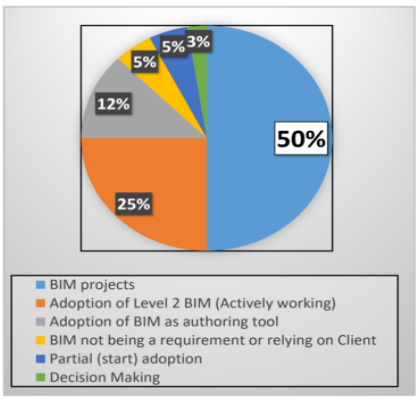
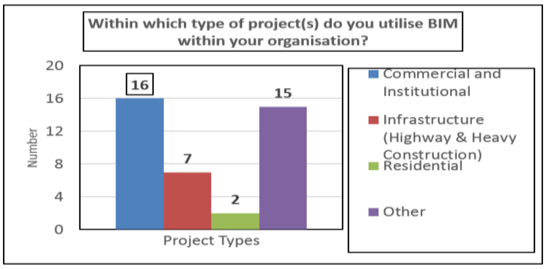


Figure 8.5 Level 2 BIM adoption

Figure 8.6 presents a summary of the different types of project types that exist and the type of BIM usage amongst participants. The results show that more participants (16 or 40%) would use BIM across commercial and institutional projects, while 15 (37.5%) selected others, eight indicated usage across all project types, and one across the following: commercial / education / residential / healthcare, commercial, institutional, and industrial, Residential, commercial, hospitality, transportation, education, education, residential and leisure, and educational, nuclear, and oil and gas. This indicated the possible application of the proposed BIM maturity assessment across commercial and institutional projects to measure the levels of BIM maturity across these types of project.



Within which type of project(s) do you utilise BIM within your organisation?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Residential	2	5.0	5.0	5.0
	Commercial and Institutional	16	40.0	40.0	45.0
	Infrastructure (Highway & Heavy Construction)	7	17.5	17.5	62.5
	Other	15	37.5	37.5	100.0
	Total	40	100.0	100.0	

Figure 8.6 Types of projects operating BIM

When asked about their awareness pf BIM maturity assessments, the results showed that 30 participants agreed to having an awareness of BIM assessments (75%), whereas eight were not] aware (20%), and two stated maybe with reasons given as: *"I think we are BIM Level 2 "capable" but do not always have the obligation to demonstrate that capability if the client does not require BIM level 2 delivery"*, and *"Some Projects are"*. This shows a relatively high level of awareness of BIM assessments and would provide a supporting guide through the assessment developed for this research.

Figure 8.7 presents a summary of the BIM maturity assessments, the different types that exist and the type of assessment usage amongst participants. The results show that amongst all participants (40), more used the CPIx BIM assessment form (15 participants representing 19% of the presented BIM assessments), followed by BIM certification (BRE), which was used by 13 participants (17%). Furthermore, nine participants indicated usage of the Maturity Index and likewise, Arup's BIM maturity assessments (12% each), and eight participants selected others (10%) with five indicating usage of internal, in house assessment tools, capability assessments, capability questionnaires, BMA templates, and a scoring matrix (7%). One participant mentioned each of the following: BSI, Bespoke, and utilisation processes in accordance with PAS1192-2. Moreover, six participants indicated that no BIM assessments existed or were being used in their organisation, while five indicated the usage of Bilal Succar's BIM maturity assessment (7%), four each indicated the use of MoJ BIM assessment and the Scottish future trust BIM ROI and grading tool (5%), three indicated the usage of Atkins BIM capability model (4%), and finally, one indicated that the BIMTaskforce capability compass and upskilling tool was used. These assessments align with those emerging from the literature; they assure that BIM maturity assessments are adopted within organisations, and that the proposed BIM maturity assessment developed from the presented assessments in the literature would be eligible for use and potentially adopted within these organisations.

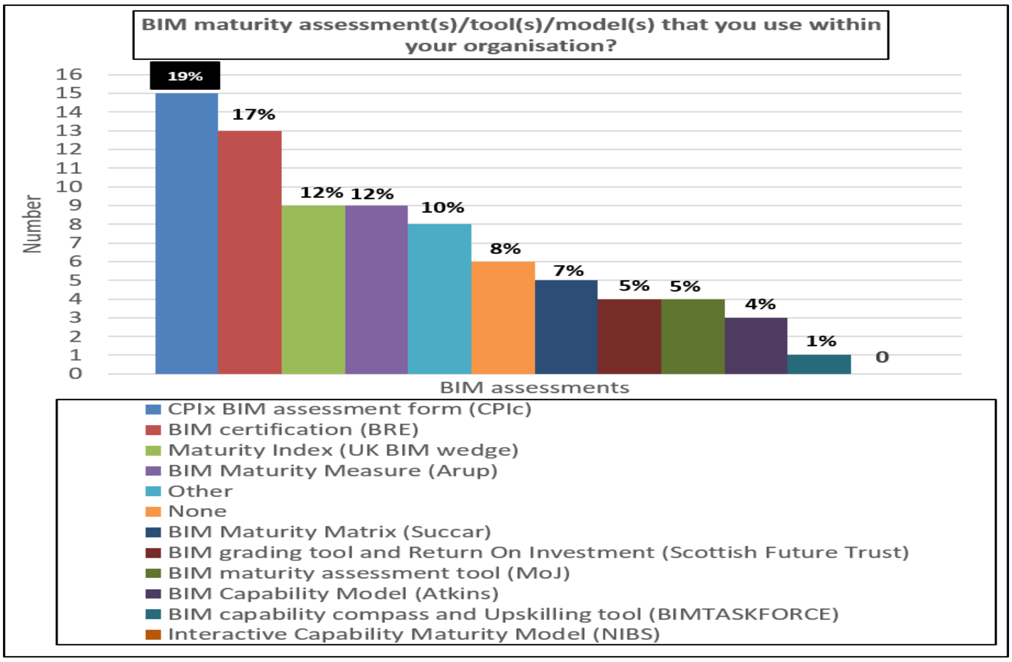


Figure 8.7 BIM maturity assessment(s)/ tool(s)/ model(s)

Figure 8.8 presents the seven BIM top metrics for the BIM maturity assessment across the three organisational levels that were presented in the focus group workshops and interviews. It also notes the type amongst participants in terms of the usage with the top metrics. Based on the responses from all participants, more participants (35 or 87.5%) used employers' requirements (EIR, OIR, AIR) across the organisation, followed by 33 (or 82.5%) participants each indicating the usage of Delivery, Processes, and sharing. Furthermore, 32 participants selected collaboration (80%), 29 selected capital delivery (72.5%), 24 indicated facilities management (60%), two indicated none of the BIM metrics were used, and finally, two indicated others. They stated, "*We outsource to Specialist to support us with Facilities Management and support for EIR review and Delivery and the 3D - 5D; If required*", and "*I'm familiar with the above but unsure how they are specific to maturity….*" This confirms the findings of the workshops and interviews by ensuring that users are considered under the three organisational levels, that the proposed BIM maturity assessment with its top metrics are relevant and that the assessment is relevant and applicable across organisations since the BIM maturity elements are already in use.

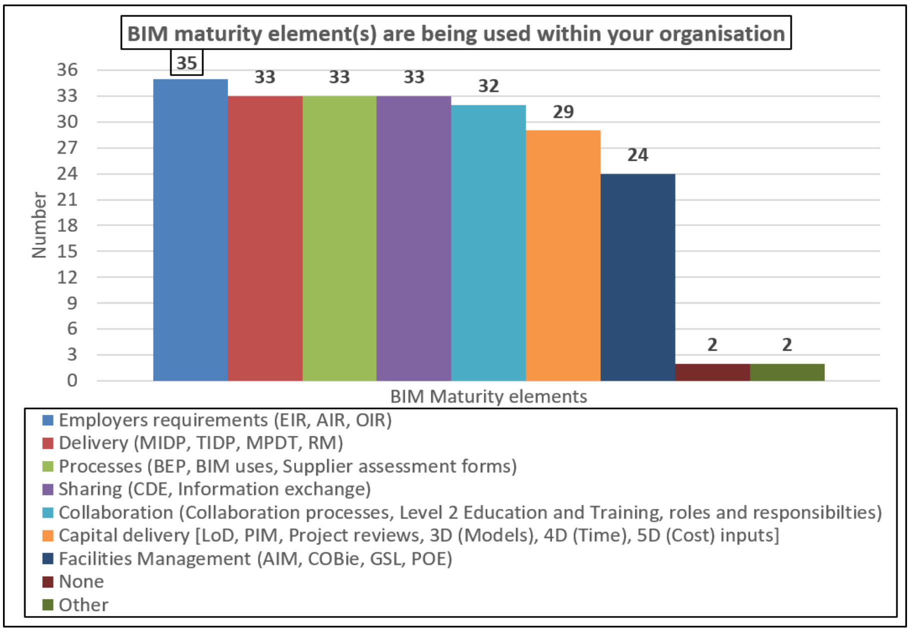


Figure 8.8 BIM top metrics being used in organisation

Figure 8.9 presents a summary of the potential challenges that exist from using the BIM top metrics across the organisation and where participants are positioned within these challenges. Thus, 38 participants indicated a number of challenges that currently exist and two left it blank, which could indicate that there are either no existing challenges, or the participants were unable to indicate the challenges. Based on the responses from 38 participants, the results show 16 key challenges, and most challenges related to client understanding and requirements (11 participants indicated this representing 21% of the total challenges that exist). Meanwhile, eight indicated challenges with a lack of understanding (15%). Furthermore, seven indicated problems with the existence of advanced expensive technology (13%), five noted challenges with information being misfed or absent (10%), and four commented on cultural change towards BIM and a lack of awareness/knowledge or availability of data. Moreover, two participants indicated each the following topics: A lack of engagement, capability issues, and excessive time wasted. Finally, one participant each noted the following: A lack of support, excessive BIM information, deficiencies in work delivery, the spread of data, BIM's need for information, change management, and the challenges faced with BIM adoption across the key areas of people, process, and technology. The results suggest that most challenges are associated with the client understanding of BIM and the need to make BIM clear, whilst a number of challenges align with those presented in the interviews, such as a lack of understanding, capability issues and excessive BIM information. The challenges reflect those that emerged from the literature review and interview findings indicating that the same challenges occur across the UK client sector, from one organisation to another, and amongst different participants across the UK.

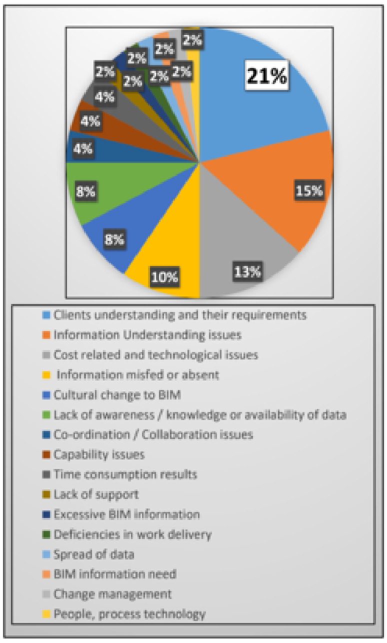
	Name	Examples	Number of Discussions	Percentage
1)	Clients understanding made clear	"Client requirement and understanding. Financial cost. End user understanding."	11	
2)	Lack of understanding	"We need clear definition from Employers information requirements."	8	
3)	Existence of advanced expensive technology	"Increased early stage project costs", "Financial cost"	7	
4)	Information misfed or absent	"absence of standards or incomplete standards in relation to open BIM and product templates"	5	
5) a)	Cultural change to BIM	"Lack of willingness to change"	4	
b)	Lack of awareness / knowledge or availability of data	"lack of overall design team knowledge of the BIM process is always a challenge. i.e. some people simply think its a pretty model."	4	
6) a)	Lack of engagement	"We need wider collaboration amongst the supply chain"	2	
b)	Capability issues	"Skill gaps"	2	
c)	Excessive time wasted	"perhaps time and resource"	2	
7) a)	Lack of support	"You need top down support from the senior management team."	1	
b)	Excessive BIM information	"Specifying a lot of data requirements that will not / can not be used"	1	
c)	Deficiencies in work delivery	"The application of BIM across the Construct and FM lifecycle is varied "	1	
d)	Spread of data	"We are looking to expand our BIM maturity wherever possible."	1	
e)	BIM information need	"getting the required knowledge of BIM to the people working in our field"	1	
f)	Change management	"You need to develop training plans that support effective change management"	1	
g)	People, process technology	"Challenges faced with BIM adoption always come in 3 key areas. People, process and Technology. "	1	

Figure 8.9 Challenges to implementing BIM elements in organisation

Participants were asked about the use of KPI metrics and how they would be measured. The list of KPIs driven by the interviews was used to question and determine various measurement techniques. In terms of KPI use across organisations, 33 participants confirmed the application of quality (82.5%), 31 noted time (77.5%), and 29 stated cost (72.5%). Furthermore, 26 selected health and safety (65%), 21 each for profitability and productivity (52.5% each), 20 each for performance and sustainability (50% each), and 18 each for satisfaction and collaborative culture (45% each). Finally, one selected 'others' (EBITDA and Return customers) (Figure 8.10). Moreover, the use of the primary KPI metrics (cost, time, quality) confirms their importance across organisations, whilst the application of the secondary KPIs (satisfaction, health and safety, performance, profitability, productivity, sustainability), confirms the proposed standardised list of KPIs. This corresponds with Ofori-Kuragu et al., (2016) who outlined both primary and secondary KPI as a standardised list of metrics for application across organisations. Furthermore, collaborative culture emphasises the importance of addressing the cultural aspect as a KPIs, which similarly compliments the interview findings.

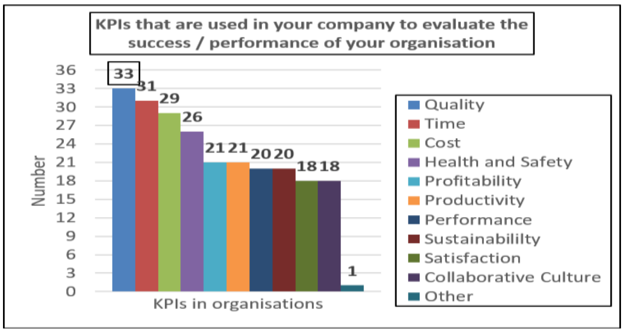


Figure 8.10 KPIs to evaluate the success/performance of an organisation

Various techniques were presented to measure KPIs (Figure 8.11). By grouping the answers, it demonstrates 11 key topic areas for this measurement, and most participants would measure KPIs through different scoring criteria (12 indicated this, representing 30% of the existing measuring techniques). This was followed by the application of ROI and measuring tools, such as the usage of annual surveys to assess employee engagement, client feedback, time sheets and assessments (noted by five (12.5%) participants each). Furthermore, four participants indicated each of the following: constant reviews and recording, and not being able to measure them (10% each). Moreover, three indicated senior management level process, company turnover and half year audits for compliance checking (7.5%), while two indicated the process itself, and profits and targets. Finally, one participant (for each) indicated internal, BIM benefits/lessons learned, and compare and contrast. This indicates that, in order to measure the KPIs, organisations tend to apply a scoring criterion and a percentage indication of fulfilment, which correlates with the findings from Constructing Excellence (2004b) and Kiew, Ismail, & Yusof (2012) in applying a process of calculating, reporting, and remeasuring KPIs.

	Name	Description	Examples	Number of discussions	Percentage
1	Scoring Criteria	Percentage or a scoring strategy	*" scoring criteria within our company's 2020"*	12	
2) a)	Measuring tools	Usage of surveys, assessments	*"There are annual employee engagement surveys"*	5	
b)	ROI tools	Return On Investment	*"By using the CDBB BIM ROI tool ...... The tool is still under development but we are testing it on 2 of our projects."*	5	
3) a)	Unable to measure	Unable to provide a means of measure	*"We haven't really measured them."*	4	
b)	Constant reviews and recording	Recording schemes and reviews	*"Currently under review"*	4	
4)	Others	Additional information related	*"Senior mgt level process"*	3	
5) a)	Process Itself	Process of a workflow or mechanism used to measure KPs	*"Process and efficiencies in relation to quotes"*	2	
b)	Profits and targets	Financial considerations	*"Programme & budget, meeting environmental goals"*	2	
6) a)	Internal	Internally related	*"Internal BIM Project Reviews / Audits"*	1	
b)	BIM benefits / project success and Lessons learned	Benefits / lessons learned / project success	*"Quite useful and really beneficial"*	1	
c)	Compare and Contrast	Comparisons between methods	*"For cost, we analyse the cost of labour vs productivity. "*	1	

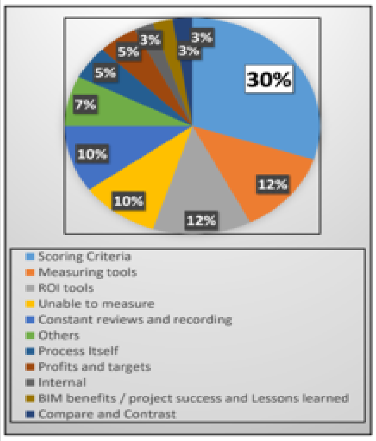


Figure 8.11 Measuring KPIs within organisations

In terms of individual KPI usage, 32 participants confirmed the application of quality (80%), whilst 31 (each) stipulated cost and time (77.5% each). Moreover, 23 selected health and safety (57.5%), 20 (each) for satisfaction and profitability (50%), 17 for performance (42.5%), 16 for productivity (40%), 13 for sustainability (32.5%), and 12 for collaborative culture (30%). Finally, two selected 'others', indicating the previous selection of cost, quality and collaborative culture (Figure 8.12). The results compliments those found on an organisational basis and the literature, which emphasises that the same KPIs (whether primary or secondary metrics) are applied across projects on an individual basis. It also corresponds to the interview findings in noting the need for collaborative culture as a KPI metric.

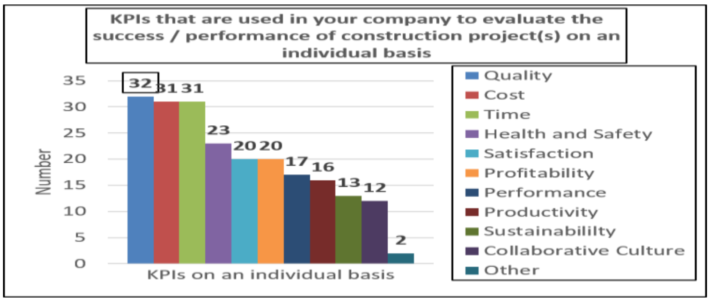


Figure 8.12 KPIs to evaluate the success/performance of construction project on an individual basis

In terms of measuring the KPIs, broadly the same techniques exist, but with slight changes. By Grouping the answers (Figure 8.13) demonstrates that more participants would measure the KPIs through different scoring criteria (ten indicated this representing 25% of the measuring techniques that exist). This was followed by the process itself and being unable to measure the KPIs (at five each representing 12.5% each). Furthermore, four participants indicated constant reviews and recording (10%), three indicated each of the following: Measuring tools, reports and project reviews, BIM benefits, and lessons learned (7.5% each). Moreover, two indicated each profits and targets, compare and contrast, and other techniques (such as traffic lights), while one indicated 'external'. This compliments the findings from an organisational basis which confirms the application of the same mechanism to measure KPIs, and correlates with the literature in ensuring a process to remeasure KPIs.

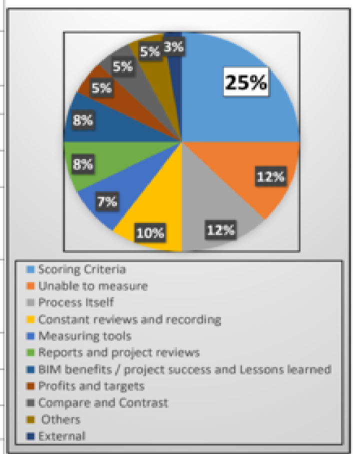
	Name	Description	Examples	Number of discussions	Percentage
1)	Scoring Criteria	....	"Percentage score out of 100".	$\boxed{10}$	
2) a)	Unable to measure	....	"Unsure on how the company measures the remaining KPIs as I am not involved with these processes."	5	
b)	Process Itself	....	"The process in general"	5	
3)	Constant reviews and recording	....	"Record KPIs for every project"	4	
4) a)	Measuring tools	....	"QA assessment"	3	
b)	Reports and project reviews	Reporting	"Based on an initial baseline monthly progress reports incorporate the Reporting KPI's as a contractual requirement."	3	
c)	BIM benefits / project success and Lessons learned	....	"Using a methodology developed in line with BSRIA soft landings principles to evaluate the project success and capture lessons learned"	3	
5) a)	Profits and targets	....	"Profit/Loss on project"	2	
b)	Compare and Contrast	....	"Timesheet data vs invoicing."	2	
c)	Others	....	"Traffic light"	2	
6)	External	Externally related	"External BIM Project Reviews / Audits"	1	

Figure 8.13 Measuring KPIs across construction projects on an individual basis

When questioned about assessing the impact of KPI metrics across project/organisational performance, the results showed that, on the one hand, 36 participants were able to assess the impact of KPIs across project/organisational performance (90%), whilst on the other hand, only four disagreed on assessing the impact (10%). This indicates that most participants are able to assess the impact of KPI metrics and determine their influence across project/organisational performances indicating the importance of the use of KPIs.

Figure 8.14 presents a summary of the views on the possibility of combining BIM maturity and KPI metrics. Three key topic areas were explored and levels of agreement concerning these topic areas were captured. Those are: the ability for BIM maturity and KPIs to work together, the potential benefits from combining both, and the direct impact of BIM maturity on organisation performance. Furthermore, 22 participants (55%) agreed that BIM maturity and KPIs could work together, while 12 (30%) strongly agreed, four (10%) were neutral, two strongly disagreed, and none disagreed. This indicates that 85% either agreed or strongly agreed with the possibility of combining BIM maturity and KPI metrics to assess project/organisational performance, which supports objectives of this study and shows that participants recognised the potential for both BIM and KPIs to work together. In addition, 24 participants agreed with the potential benefits from combining (60%), nine strongly agreed (22.5%), three were neutral, and two each disagreed and strongly disagreed. This indicates that 83% of participants perceive benefits from bringing them together. Finally, 26 participants agreed that BIM assessments have a direct impact on an organisation's performance (65%), six each strongly agreed or were neutral (15% each), while two each disagreed and strongly disagreed. This indicates that 85% of participants perceive a direct impact on organisation when assessing for BIM maturity (Figure 8.14). This supports the importance of BIM maturity assessments, which formed part of the objectives for this research.

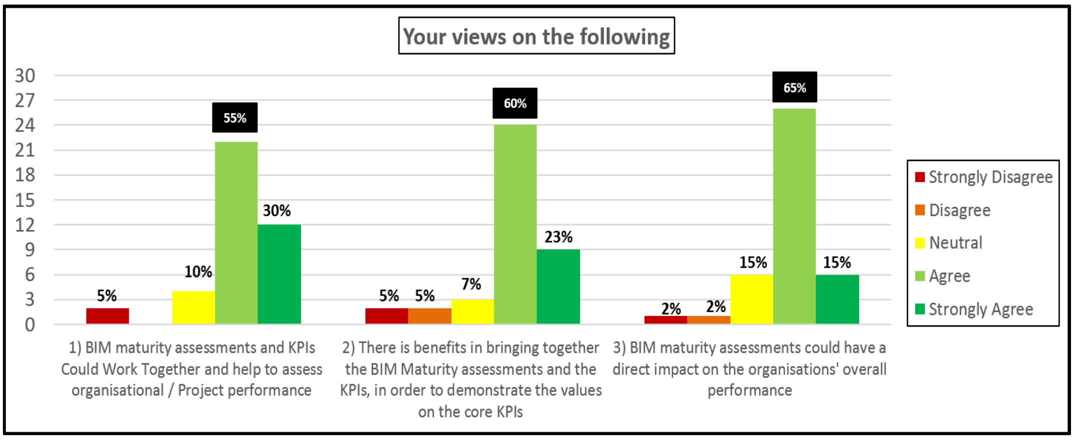


Figure 8.14 Views on combining BIM maturity and KPI metrics (level of agreement)

As an optional question, participants were asked to provide detail to justify their selection on the level of agreement on combining BIM and KPIs. This question was answered by 23 participants (57.5%), while 17 did not elaborate further (42.5%) (Table 8.2). Table 8.2 shows 11 key topic areas that cover the facilitation of BIM implementation with the integration of KPIs, and most discussions (six) were related to linking BIM and KPIs outcomes. Furthermore, three indicating each of the following outcomes: Unable to or experience difficulties in measuring BIM/KPIs, the extraction of benefits, and financial issues. Moreover, two indicated the need to evaluate the impact of BIM maturity on the business, while one indicated each of the following outcomes:

Delivery of a tool *"Industry wide tool"*; clients receiving data on KPIs *"KPIs to provide clients data to be easily understood and promote importance of BIM"*; project performance and organisation influencing on each other *"Project performance and organisation capabilities could work together"*; reviewing and reporting- *"BIM to be an integral part of the review & reporting processes"*; introduction to training *"BIM assessment to asses level of BIM in the organisation so further training could be delivered to bring more values to BIM"*, and ROI *"To demonstrate ROI"*. This indicates that the facilitation of BIM maturity and KPI metrics could work in various ways, and these suggestions could provide a number of guidelines for consideration. This indicates the importance of BIM maturity and KPI metrics working together to allow the integration and reflect the project and organisational performances for UK clients.

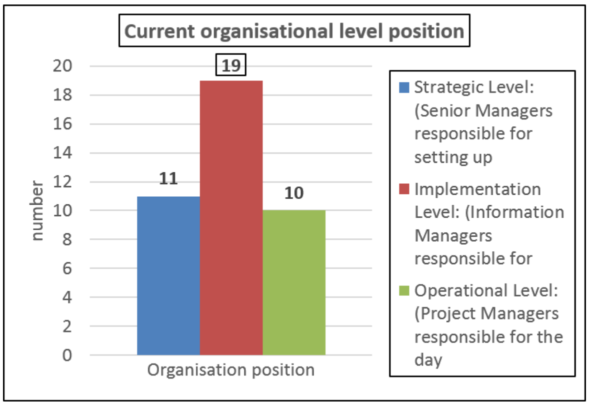
Table 8.2 Facilitating the integration of BIM with KPIs

Name		Examples	Number of discussions
1)	Linking BIM and KPIs outcome	*"BIM maturity assessment and KPIs needs to work in conjunction in order to get a higher benefit"*	6
2) a)	Unable or difficulties to measure BIM / KPIs	*"Measuring performance is not easy. Unless there are clear methods that measure performance KPIs become a hurdle to users trying to evaluate how much work is completed along with quality."*	3
b)	Benefits extract	*"We have to provide a clearer (evidence driven) picture regards the tangible benefits of BIM adoption"*	3
c)	Financial issues	*"It is difficult to assess BIM as if you perform well on a project it is difficult to quantify and assess the time/money saved over the life cycle of a project and the facilities management."*	3
3)	Evaluation of BIM maturity on business	*"KPI's could allow us to evaluate the level of BIM maturity in our business in an ongoing process"*	2
4) a)	Delivery of a tool	*"This would involve an industry wide tool that is used & accepted by the majority"*	1
b)	Clients receiving data on KPIs	*"KPIs would provide clients with data that they can easily understand and would promote the importance of BIM on their projects"*	1
c)	Introduction to training	*"BIM Maturity assessment can assess the level of BIM in the organisation so a further training could be delivered to bring more value of using BIM"*	1
d)	Project performance and organisation influence each other	*"Project performance in terms of BIM can be attributed, to a certain degree, to an organisations capability to work within those processes."*	1
e)	Review and reporting	*"BIM should be an integral part of the review & reporting processes in-particular from a programme & H&S perspective."*	1
f)	ROI	*"To demonstrate ROI"*	1

8.4.1.3 Determining the organisational level

Finally, participants were asked to indicate their organisational level, which would confirm the validity of the proposed BIM maturity assessment. This question would then take participants to the questions related to each organisational level in order to assess their level of maturity, and identify the strength of relationship between KPIs and the BIM maturity sub metrics. As previously mentioned, 15 participants did not answer these questions as they were unable to determine their organisational level, thus this section was answered by 60 participants. However, since some participants did not complete the BIM maturity assessment and determine its linkage to the KPI metrics (ten participants across the strategic level, four at the implementation level, four at the operational level, and three were unable to determine the benefits of the combined BIM Maturity-KPI assessment), only 40 completed responses were returned. Thus, the results are based on these forty responses.

Figure 8.15 presents a summary of the organisational level. The results show that most participants (19 representing 47.5% of those who answered this section) positioned themselves on the implementation level, followed by 11 on the strategic level (27.5%), and ten on the operational level (25%). This suggests that the assessment would be filled out more often with users who would hold positions related to that level, such as Information Managers, which ensures that the strategic goals are outlined, as indicated in the organisational level description.



What is the current organisational level position that best suits you in your organisation?

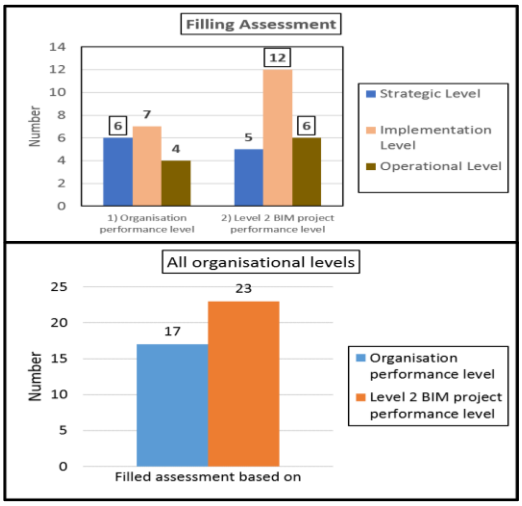
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strategic Level: (Senior Managers responsible for setting up the strategic goals and gearing up the department to delive	11	27.5	27.5	27.5
	Implementation Level: (Information Managers responsible for ensuring that the strategic goals set out in regards to impl	19	47.5	47.5	75.0
	Operational Level: (Project Managers responsible for the day-to-day users operating within a Level 2 BIM environment, wo	10	25.0	25.0	100.0
	Total	40	100.0	100.0	

Figure 8.15 Results of the organisational level position

8.4.2 Section 2: Assessment on BIM Maturity and KPI metrics

Having identified their organisational level position, the second section of the questionnaire examined the potential relationships between the BIM Maturity metrics, as conducted in the interviews, and the KPIs through the list of KPI metrics that were finalised from the interview findings. At this stage, the questionnaire was directed at their particular organisational level, based on their answer to the last question in the previous section. Therefore, for each of the organisational levels participants were required to identify their organisational level performance or their BIM project performance level. This aims to ensure that the assessment would work in either organisational or project levels. Participants were then asked to select their maturity level and then to determine the strength of relationship between each KPI and BIM Maturity metric. For the strategic and implementation levels, 11 BIM Maturity metrics were considered alongside the KPI metrics, while 12 BIM Maturity metrics were included for the Operational level.

Prior to the assessment, participants were asked to note whether they were basing their responses on organisational or project levels; this aimed to determine where the assessment would work best (Figure 8.16). The results show that, at the strategic level, more participants would fill out the assessment based on this organisational level (six out of eleven indicated this, representing 54.5% of those at this organisational level). The remaining five would fill out the assessment out from a BIM performance level (45.5%). For both the implementation and operational levels, more participants completed the assessment on a BIM project performance level. Thus, 12 of 19 indicated the implementation level (63.2%) while seven selected the organisational performance level (36.6%), six out of ten indicate the operational level (60%) and four selected the organisational performance level (40%). The totals indicate that 23 participants across the three organisational levels completed the assessment based on a BIM project performance level (57.5%), and 17 from an organisational performance level (42.5%) This confirms and validates the findings that the presented would work across both the organisational and project performance levels.



You are filling this assessment (Strategic) based on:

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Organisation performance Level	6	15.0	54.5	54.5
	Level 2 BIM Project performance Level	5	12.5	45.5	100.0
	Total	11	27.5	100.0	

You are filling this assessment (Implementation) based on:

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Organisational Performance Level	7	17.5	36.8	36.8
	Level 2 BIM project Performance Level	12	30.0	63.2	100.0
	Total	19	47.5	100.0	

You are filling this assessment (Operational) based on:

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Organisation performance Level	4	10.0	40.0	40.0
	Level 2 BIM Project performance Level	6	15.0	60.0	100.0
	Total	10	25.0	100.0	

Figure 8.16 Completing the assessment across three organisational levels (project/organisational)

The findings show that 40 participants agreed that the proposed BIM maturity assessment was valid and could be used across their working practices whether at a project or organisational level, or across one of the three organisational levels (strategic, implementation, operational) to determine the potential links between BIM maturity and KPI metrics. This aligns with the research aim in developing an assessment to determine the linkage and enhance UK clients performance. The next section will present the findings related to the proposed BIM maturity and KPI assessment across the three organisational levels, which will consist of descriptive and inferential statistical analysis.

8.4.2.1 Organisational level: Descriptive and inferential statistics

Similar to the interviews, the participants who assigned themselves to one of the organisational levels were required to assess their level of maturity across the BIM Maturity metrics that were relevant to their organisational level. After this, they were asked to determine the strength of relationship across the identified list of KPI metrics (from the interview findings) with the BIM Maturity metrics, which were aligned to each organisational level. Hence, the results will be analysed through:

1) The mode (frequency of occurrence in BIM Maturity and KPI metrics), and
2) The Mean (averages of the scores for both).

The following analysis will also be demonstrated: Non-parametric tests of ordinal data, which will be analysed through the Chi square and Kruskal Wallis test of relationships and significance, Spearman correlation strength of relationship tables, and linear regression scatter plots. The p (or probability) value obtained is a measure of how likely that any observed correlation is due to chance. Values range from 0 (0%) to 1 (100%), and with a significance level of 0.05; this examines the alternative hypothesis (H_1) that there is a correlation between the BIM maturity and KPI metrics. This will be conducted in three steps;

1) Demonstrate the Chi square and Kruskal Wallis tests of relationship and independence to examine: the Null Hypothesis ($H_{\circ}$)= No relationship and there is no independence (dependence) between the variables and their groups, and Alternative Hypothesis (H_1) = there is a relationship and independence between the variables and their groups (Table 8.3).

Table 8.3 Chi Square and Kruskal Wallis tests assumptions across all organisational levels

Chi square				**Kruskal Wallis**			
$\rho < 0.05$ (0-0.5%)	Null hypothesis ($H_{\circ}$) = there is no relationship between BIM and KPIs	Result is statistically significant	**Accept**	$\rho < 0.05$ (0-0.5%)	Alternative hypothesis (H_1) = there is independence between BIM and KPIs	Result is statistically significant	**Reject**
$\rho > 0.05$ (0.51 - 100%)		Result is not statistically significant	**Reject**	$\rho > 0.05$ (0.51 - 100%)		Result is not statistically significant	**Accept**

2) Determine the strength of relationship results achieved between the variables to identify which has a negative or a positive correspondence and where the relationships fall between ‘no relationship’ to ‘strong’.
3) Illustrate the linear regression results through scatter plots to determine whether there is a linear relationship between the BIM maturity and KPI metrics if positive (BIM maturity levels increase and the KPI relationship increases) or negative (BIM maturity levels increase and KPI relationship decreases or vice versa); to predict how BIM maturity relates to the KPI metrics, and the value change that occurs from BIM maturity levels on the KPI relationship.

The correlation coefficient is used to represent the linear relationship between two variables (BIM maturity and KPI metrics). Correlation indicates the strength of relationship (no, strong, medium, weak) between variables and depicts the degree to which the two variables are correlated. Thus, correlation indicates the extent to which two variables move together and determines a co-relationship between two variables (BIM maturity and KPI metrics). On the contrary, regression estimates if there is a linear relationship that exists between a dependant variable (KPI metrics) on a set of independent variables (BIM maturity metrics). It describes how an independent variable is numerically related to the dependent variable and is used to determine the best line of fit in a scatter plot with an equation of $\hat{y}=a+bX$ and R^2 linear= ±0-1. R^2 linear is considered a measure of the accuracy or prediction power of the regression model (Field, 2017). Hence, regression reflects the impact of the value change in the independent variable (X) on the dependent variable ($\hat{y}$) (Field, 2017; Saunders et al., 2016).

To conduct the different descriptive and inferential analysis techniques assigned to this research, the reliability of the relationships between BIM Maturity and KPI metrics were examined to study the internal consistency and ensure that the results obtained were reliable. Cronbach's alpha is an acceptable and common method for checking the internal consistency of data (Field, 2005). Cronbach's Alpha is a test statistic used to assess the reliability of scales used in the measurement of data (Field, 2005). Based on a numerical scale from 0-1, results returned with a value of >0.9 indicate an excellent internal consistency. Values between 0.8-0.9 would indicate good consistency, 0.7-0.8 acceptable consistency, 0.6-0.7 questionable consistency, 0.5-0.6 poor consistency, and <0.5 an unacceptable inconsistency (Gliem and Gliem, 2003). This research proposes to explore and examine the potential relationships between BIM Maturity and KPI metrics through a proposed BIM maturity assessment that links with the KPI metrics, and checks the reliability of the presented data. Thus, a Cronbach's alpha test is conducted to check the results of the reliability test across the three organisational levels. The test was computed to assess the reliability of the scales used for the measurement of the relationship between BIM Maturity and KPI metrics across all organisational levels. This yielded excellent values for all three levels: 0.978 **(strategic),** 0.977 **(implementation),** and 0.993 **(operational)**. Therefore, the evidence shows that the assessment conducted to test this relationship was valid and reliable (Table 8.4).

Table 8.4 Test of reliability across the Strategic, Implementation and Operational

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.978	.979	122

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.977	.976	122

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.993	.993	133

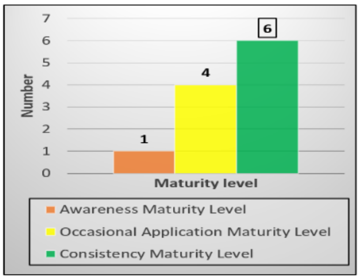
Having presented the descriptive and inferential statistical process to analyse the results of the proposed BIM maturity assessment and its linkage to the KPI metrics across the three organisational levels, the next section will present the results of the descriptive and inferential statistics across the strategic level.

8.4.2.2 Strategic level: BIM maturity and KPI assessment results

This section presents the descriptive and inferential statistical analysis and findings of the strategic organisational level assessment (Table 8.5).

Table 8.5 Strategic organisational level results

Questionnaire participants	Current Organisational background	Participant Organisational Position	Maturity Level Average	BIM maturity level (Legend)	Maturity Level Average
ST_01 (P02)	BIM Manager	Strategic Level	Consistency	Awareness (1) Awareness = (1-1.6)	
ST_02 (P03)	BIM Manager		Consistency		
ST_03 (P06)	(Other) Design Manager		Occasional Application		
ST_04 (P10)	(Other) Design Manager		Occasional Application		
ST_05 (P12)	Quantity Surveyor		Occasional Application	Occasional Application (2) Occasional Application (1.6-2.4)	
ST_06 (P14)	BIM Manager		Consistency		
ST_07 (P19)	(Other) Technologies RD&I		Occasional Application		
ST_08 (P20)	BIM Manager		Consistency		
ST_09 (P23)	BIM Manager		Consistency	Consistency (3) Consistency (2.4-3)	
ST_10 (P26)	(Other) Owner		Occasional Application		
ST_11 (P35)	BIM Manager		Consistency		
Total		11			



Across the 11 participants involved at the strategic level and based on the overall scores, one participant was found to be at the **Awareness** maturity level, four at the **Occasional application** level, and six at the **Consistency** level. This indicates that six participants were already at a higher maturity level and potentially performing well within their organisations, whereas the remaining five users, who were between the **Awareness** and **Occasional application levels,** could need to review their current organisational sub metric scores and determine the actions needed to move from **Awareness** and **Occasional application** to **Consistency**. Table 8.6 presents a summary of the scoring levels for each participant and shows a matrix of alignment between their overall scores and the individual sub metric score. This helps to determine which sub metrics would be maintained (**Consistency**) since this is the highest level of maturity, and the sub metrics that need to be improved (**Awareness** and **Occasional application**) to move from one level to another through a set of actions (Section 7.4.5). A demonstration of the most frequent answers given to each sub metric and the overall frequency are presented below along with the averages and total of the sub metric individual scores.

Table 8.6 Strategic level: Participant scores and maturity level average

The Evidence = BIM maturity level at the Strategic level															
BIM maturity level responses based on 11 Strategic level participant responses															
Sub Metrics		ST_01	ST_02	ST_03	ST_04	ST_05	ST_06	ST_07	ST_08	ST_09	ST_10	ST_11	Maturity level		Maturity level descriptor
level 2 BIM	ISO19650												Frequency	Total	
Collaboration process		3	2	3	2	2	3	2	3	3	1	3	3	2.45	Systems that are able to integrate the BIM models (CDE) that are compliant with Level 2 BIM standards into operations.
Processes and Standards		3	3	3	2	2	3	2	3	3	1	3	3	2.55	Understanding and fully implementing the UK BIM Level 2 standards. Fully understanding and application of the CAPEX and OPEX
Roles and Responsibilities	Function	3	3	1	2	2	3	2	3	3	1	3	3	2.36	Partial understanding of roles defined in PAS 1192-2:2013 and have limited internal resources
Contractual agreements		2	3	2	2	2	3	2	3	3	1	2	2	2.27	Good understanding of how form of contracts are and alignment of standards with Level 2 BIM projects (i.e. 1 to 2 project).
Level 2 Education and Training		3	3	2	2	2	3	1	3	3	1	3	3	2.36	Awareness training required and producing a roadmap, and some staff training in the basics.
Procurement route		2	3	2	2	2	3	2	3	3	1	2	2	2.27	Some confidence in a particular procurement route and how Level 2 BIM is being implemented from stage 1.
Design elements		3	3	2	2	2	3	2	3	3	1	3	3	2.45	Full understanding and inclusion of a standardised matrix table that covers all contractor design portions (2D and 3D).
Information Requirements (EIR)	Exchange Information Requirement (EIR)	3	3	2	2	2	3	2	3	3	1	3	3	2.45	Ability to Complete EIRs specific identifies which the clients need for their facilities.
Asset Information Requirement, (AIR)		3	2	1	2	2	3	2	3	3	1	3	3	2.27	Understanding of the Asset requirements and basic outline of them and some understanding of COBie.
GSL champion engagement		2	2	1	2	2	3	2	3	2	1	3	2	2.09	Able to use model data but not integrated with FM systems and procedures.
Facilities Management Education and Training		2	2	1	1	2	3	2	3	2	1	3	2	2.00	Awareness training required, and relevant employees training on the basics.
Strategic level participants maturity level average		2.64	2.64	1.82	1.91	2.00	3.00	1.91	3.00	2.82	1.00	2.82	Consistency	2.32	

Table 8.6 indicates that participants at the strategic level have maturity scores that are either **Awareness (1-1.6), Occasional Application (1.6-2.4),** and **Consistency (2.4-3)**. The sub metrics with an overall score of **Consistency** were: **Collaboration Process (2.45), Process and Standards (2.55), Design Elements (2.45), and EIR (2.45)**. The descriptor for each sub metric at this level is given. The seven remaining sub metrics were at the **Occasional application** level and no sub metric had an overall level of **Awareness.** Only three participants had individual scores for some sub metrics, which were at the **Awareness** level, whereas the remaining scores ranged from **Occasional application** to **Consistency**. This shows that only a few of the participant's sub metrics scores were categorised as **'General Knowledge and understanding of BIM metrics, but is sometimes not being recognised across the organisation'**, while most sub metrics at the strategic level were either **'Partial Application of BIM and is somehow recognised, but not embedded generally'** or **'Full application and maintaining BIM strategic level, embedded across projects generally, consistently recognised'.** This indicates that most participants at the strategic level are at the second maturity level and that the sub metrics are applied within their organisations, whether partially or fully. As a result, participants showed that the **Collaboration** process and **Processes and Standards**, are fully applied and compliant with BIM standards. Moreover, for **Information Requirements**, both **Design Elements** and **EIRs** are fully understood and meet the BIM standards. In general, the scores that are classed as either **Awareness** or **Occasional application** need to be reviewed to enable participants to move to - and maintain - the **Consistency** level; this would require a set of actions (Section 7.4.5).

1. Descriptive: Frequencies and Relationships between BIM maturity and KPI metrics

Table 8.7 presents results of the KPI metric relationships averages (Mean) with the BIM maturity metrics.

Table 8.7 KPIs strength of relationship frequency and average (Relationship)

Legend	Current KPI relationship legend
No Relationship (None) 0	No Relationship (None)= (0-0.75)
Not Significant (Weak) 1	Not Significant (Weak)= (0.75-1.5)
Moderate (Medium) 2	Moderate (Medium)= (1.5-2.25)
Significant (Strong) 3	Significant (Strong= (2.25-3)

The Evidence = Relationship of BIM and KPIs																							
Strategic Level		KPIs strength of relationship responses based on 11 Strategic level participant responses																					
Sub Metrics		Relationship with KPIs																					
level 2 BIM	ISO19650	Cost		Time		Quality		Satisfaction		Health and Safety		Performance		Profitability		Productivity		Sustainability		Collaborative Culture		KPIs (Total)	
		Frequency	Total	Frequency	Total	Frequency	Total	Frequency	Total	Frequency	Total	Frequency	Total	Frequency	Total	Frequency	Total	Frequency	Total	Frequency	Total	Frequency	Relationship
Collaboration process		2	2.18	3	2.27	3	2.18	2	1.82	2	1.55	2	2.09	2	2.18	2 3	2.36	1	1.27	3	2.45	Moderate (Medium)	2.04
Processes and Standards		2	2.09	2	2.18	3	2.36	1	1.73	2	1.64	2	2.27	1	1.91	2	2.27	2	1.45	3	2.45	Moderate (Medium)	2.04
Roles and Responsibilities	Function	1 2	1.64	2	1.91	2	2.18	2	1.82	1 2	1.64	2	2.18	2	1.91	2	2.00	1 2	1.36	3	2.55	Moderate (Medium)	1.92
Contractual agreements		2	2.27	2	2.09	2	1.73	2	2.00	2	1.55	2	1.82	1	1.73	2	1.91	2	1.55	2	2.27	Moderate (Medium)	1.89
Level 2 Education and Training		2	2.18	2	2.27	2	2.36	2 3	2.00	1 2	1.64	3	2.45	2 3	2.09	2	2.36	2	1.73	3	2.45	Moderate (Medium)	2.15
Procurement route		2	1.91	2	2.00	2	1.82	2	1.73	2	1.55	2	1.82	2	1.55	2	1.82	2	1.64	2	2.27	Moderate (Medium)	1.81
Design elements		2	2.27	2	2.45	2 3	2.27	2	2.27	1	1.55	2 3	2.00	2	1.82	2	2.18	2	1.55	3	2.36	Moderate (Medium)	2.07
Information Requirements (EIR)	Exchange Information Requirement (EIR)	3	2.36	3	2.36	3	2.18	2 3	2.36	1 2	1.64	3	2.09	3	1.91	3	2.00	2	1.73	2	2.27	Significant (Strong)	2.09
Asset Information Requirement (AIR)		2	2.18	2	2.00	2	2.09	2	2.00	1	1.45	2	1.64	1 2	1.36	1 2	1.91	1 2	1.64	2	2.00	Moderate (Medium)	1.83
GSL champion engagement		2	1.64	2	1.55	2	1.91	3	2.18	2	1.64	2	1.91	2	1.27	1 2	1.27	2	1.64	3	2.18	Moderate (Medium)	1.72
Facilities Management Education and Training		2	2.00	2	2.00	1 2	1.91	2	1.91	2	1.55	2	1.91	2	2.00	2	1.82	2	1.64	2	1.91	Moderate (Medium)	1.86
Strategic level KPIs strength of relationship average		Moderate (Medium)	2.07	Moderate (Medium)	2.10	Moderate (Medium)	2.09	Moderate (Medium)	1.98	Moderate (Medium)	1.58	Moderate (Medium)	2.02	Moderate (Medium)	1.79	Moderate (Medium)	1.99	Moderate (Medium)	1.56	Significant (Strong)	2.29	Moderate (Medium)	1.95

The legend for the KPI strength of relationships is as follows: **0= No relationship (None)**, **1= Not Significant(Weak)**, **2= Moderate (Medium)**, **3= Significant (Strong)**. The formula for the averages is as follows: **0-0.75= No relationship, 0.75-1.5= Not Significant (Weak), 1.5-2.25= Moderate (Medium), and 2.25-3= Significant (Strong).** The strength of relationships is split equally since it is predicted that participants would provide average scores that range from '**No relationship'** to **'Significant'**; hence, it was distributed in that manner. However, the majority of the relationships indicate a relationship, whereas minor scores would indicate that there is no relationship.

Table 8.7 indicated that participants gave strength of relationship scores that ranged from '**Not Significant (Weak)'**, **'Moderate (Medium)'**, and '**Significant (Strong)'**, although no scores were given that fell under '**No relationship'**. This indicates a relationship between BIM maturity and all of the KPIs. Across the KPI relationship averages with all of the BIM Maturity sub metrics, **Collaborative Culture** had a frequency and total of **Significant (2.29)**, which indicates that participants see a significant relationship with collaborative culture across all BIM Maturity sub metrics. In comparison, the rest of the KPIs had a frequency and total of **Moderate (1.56-2.10)**, which shows that all participants see a moderate relationship with those KPIs across all of the BIM metrics. In terms of **frequency** with the KPI metrics across all the BIM Maturity sub metrics, Table 8.7 shows that the KPIs with a significant relationship across all of the BIM Maturity sub metrics were:

- **Cost** with **EIR,**
- **Time** with **Collaboration Process** and **EIR,**
- **Quality** with **Collaboration Process, Process and Standards,** and **EIR,**
- **Satisfaction** with **GSL Champion Engagement,**
- **Profitability** with **EIR,**
- **Productivity** with **EIR,** and
- **Collaborative culture** with **Collaboration Process, Process and Standards, Roles and Responsibilities, Level 2 Education and Training, Design elements,** and **GSL Champion Engagement.**

This shows that most of the KPIs had a strong relationship frequency with EIRs indicating a stronger link between EIRs and the KPI metrics. Collaborative Culture had a strong relationship with most of the BIM Maturity sub metrics indicating a stronger link between Collaborative Culture and the BIM maturity metrics and ensuring the importance of Collaborative Culture as a KPI. The remaining BIM Maturity and KPI metrics that had a strong relationship confirm that these metrics are strongly related to one another and it was possible to see which reflected on another

(BIM maturity increase and KPI strength of relationship increases). The KPIs with a '**Not Significant'** relationship frequency across all BIM maturity sub metrics were: **Satisfaction with Process and Standard, Health and Safety with Design Elements and AIR, Profitability with Process and Standards and Contractual agreements,** and **Sustainability with Collaboration Process.** Thus, these KPIs will be reviewed to identify the existing issues that result in this relationship level, and to identify the actions to upskill and move from one level to another, as based on the proposed action plan (Section 7.4.5). The remaining BIM Maturity and KPI metrics had **a moderate relationship**, which indicates stability for both variables. It also suggests a relationship at the same level, which could be reviewed to enable a stronger connection.

Organisations at this level (strategic) would implement the proposed strong relationship and invest more in strong relationships since they help to enhance the organisational performance. Metrics for the medium relationships or below would need to be reviewed to determine the actions required to strengthen this and allow the BIM Maturity and KPI metric relationships to move to the next level.

2. a) Inferential: Chi square test of relationship between BIM Maturity and KPI metrics

An example of Chi square tests across the strategic organisational level is presented in Table 8.8.

Table 8.8 Chi Square tests of collaboration process and the KPIs

Chi Square test between 1.1) Collaboration process and the KPIs in the Strategic Level

	BIM_1.1_Collaboration_process	Cost	Time	Quality	Satisfaction	Health and Safety	Performance	Profitability	Productivity	Sustainability	Collaborative Culture
Chi-Square	3.455[a]	1.273[a]	1.273[a]	2.364[a]	5.364[b]	5.364[b]	7.364[c]	1.273[a]	2.909[a]	3.182[b]	3.455[a]
df	2	2	2	2	3	3	1	2	2	3	2
Asymp. Sig.	.178	.529	.529	.307	.147	.147	.007	.529	.234	.364	.178

a. 3 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 3.7.

b. 4 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 2.8.

c. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 5.5.

The assumptions carried out in the Chi square test will follow those in Table 8.3 in order to examine the Null Hypothesis (H_o) = No relationship exists between BIM maturity and KPI metrics. Table 8.8 shows that, across the selected example from the strategic organisational level, values were returned with a range of scores between **.007_.529**. This shows all values are $p>0.05$ except for performance (0.007), indicating that there is no statistical significance in the result. Therefore, the null hypothesis (H_o) that there is no relationship between Collaboration process and the KPIs was rejected. Only performance (0.007) had a value $\rho<0.05$, indicating that there is a statistical significance in the result, and the null hypothesis (H_o) that there is no relationship between Collaboration process and Performance is accepted. It is predicted that most of the cells would not return significant results, thus rejecting the null hypothesis (H_o) that there is no relationship between BIM maturity and KPI metrics, which validates the research findings that there is a relationship between both variables (BIM Maturity and KPI metrics). Across both variables at the strategic organisational level, similar results were returned with values p>0.05. This shows that there is no statistically significant result and therefore, there is a relationship between BIM Maturity and KPI metrics across all organisational levels, which answers the research question 'is there a relationship between BIM maturity and KPI metrics?'

Table 8.9 Chi Square tests results

KPI		Cost	Time	Quality	Satisfaction	Health and Safety	Performance	Profitability	Productivity	Sustainability	Collaborative Culture
Level 2 BIM	ISO19650	Asymp. Sig									
Collaboration process		0.529	0.529	0.307	0.147	0.147	**0.007**	0.529	0.234	0.364	0.178
Processes and Standards		0.913	0.529	0.178	0.631	0.484	0.132	0.913	0.178	0.801	0.178
Roles and Responsibilities	Function	0.484	**0.029**	0.529	0.147	0.484	0.078	0.029	0.107	0.484	0.763
Contractual agreements		0.178	**0.020**	**0.029**	0.107	0.147	0.147	0.631	**0.029**	0.147	0.178
Level 2 Education and Training		0.078	0.178	0.366	0.484	0.965	0.178	0.913	0.366	0.801	0.178
Procurement route		0.029	0.103	0.631	0.178	0.200	0.078	0.200	0.078	0.107	0.178
Design elements		0.178	0.763	0.234	0.178	0.364	0.484	0.364	0.529	0.801	0.307
Information Requirements (EIR)	Exchange Information Requirement (EIR)	0.307	0.307	0.695	0.234	0.965	0.364	0.200	0.364	0.801	0.178
Asset Information Requirement (AIR)		0.178	0.107	0.200	0.107	0.801	0.484	0.484	0.364	0.965	0.695
GSL champion engagement		0.107	0.078	0.364	0.200	0.484	0.364	0.529	0.178	0.484	0.147
Facilities Management Education and Training		0.103	0.695	0.913	0.307	0.200	0.307	0.695	0.529	0.107	0.307

Table 8.9 demonstrates the results of the Chi square test across the strategic organisational level. Those highlighted are the values which returned p<0.05 indicating that that there is no relationship between BIM Maturity and KPI metrics. These are as follows: Time with Function **(0.029)** and Contractual agreements **(0.020)**, Quality with Contractual agreements **(0.029)**, Performance with Collaboration process **(0.007)**, and Productivity with Contractual agreements **(0.029)**. This indicates that a relationship exists between BIM maturity and KPI metrics.

2. b) Kruskal Wallis test of independence between BIM maturity and KPI metrics

An example of Kruskal Wallis test of independence across the three organisational levels are presented in Table 8.10.

Table 8.10 Kruskal Wallis tests of collaboration process and the KPIs

Kruskal Wallis test between 1.1) Collaboration process and the KPIs in the Strategic Level

	Cost	Time	Quality	Satisfaction	Health and Safety	Performance	Profitability	Productivity	Sustainability	Collaborative Culture
Kruskal-Wallis H	1.539	3.155	2.979	5.080	1.309	1.750	.170	.556	2.453	.893
df	2	2	2	2	2	2	2	2	2	2
Asymp. Sig.	.463	.207	.225	.079	.520	.417	.919	.757	.293	.640

a. Kruskal Wallis Test

b. Grouping Variable: BIM_1.1_Collaboration_process

The assumptions carried out in the Kruskal Wallis will follow those presented in Table 8.3 which examines the Alternative Hypothesis (H_1) = Independence exists between BIM maturity and KPI metrics where the KPI strength of relationship does not depend on the BIM maturity metric levels. Table 8.10 shows that, across the selected example (Collaboration process and the KPIs), values were returned with a range of .079_.919. This indicates that, values $\rho < 0.05$ indicate a statistically significant result, and therefore a rejection of the alternative hypothesis (H_1) that there is independence between Collaboration process and the KPIs metric. In comparison, values $\rho > 0.05$ indicate no statistical significance in the result and therefore the alternative hypothesis (H_1) that there is independence between the Collaboration process and KPI metrics is accepted. Across both variables for this organisational level, similar results have been returned with values $p > 0.05$, which shows that there is no statistically significant result and therefore, there is independence between the BIM Maturity and KPI metrics across all organisational levels. This shows that the KPIs' strength of relationships do not depend on the BIM maturity levels, and thus do not impact on one another. Table 8.11 demonstrates the results of the Kruskal Wallis test across the organisational (strategic) level, and those highlighted are the values which returned $p < 0.05$ indicating that the KPI strength of relationship depends on the BIM maturity levels.

Table 8.11 Kruskal Wallis test results

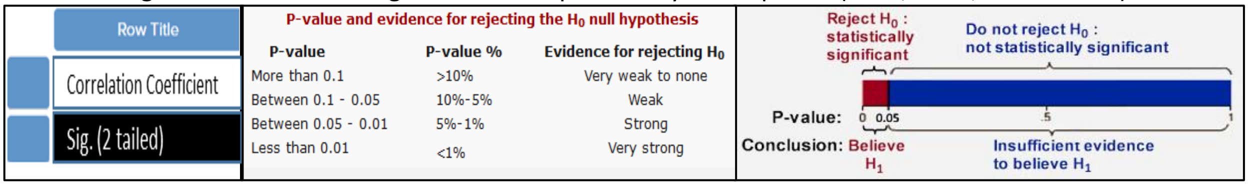
KPI		Cost	Time	Quality	Satisfaction	Health and Safety	Performance	Profitability	Productivity	Sustainability	Collaborative Culture
Level 2 BIM	ISO19650	Asymp. Sig									
Collaboration process		0.463	0.207	0.225	0.079	0.520	0.417	0.919	0.757	0.293	0.640
Processes and Standards		0.955	0.826	0.275	0.631	0.704	0.221	0.503	0.202	0.558	0.134
Roles and Responsibilities	Function	0.969	0.612	0.226	0.374	0.734	0.253	0.612	0.394	0.754	0.264
Contractual agreements		0.162	0.700	0.391	0.872	0.866	0.470	0.591	0.994	0.873	0.659
Level 2 Education and Training		0.070	0.077	0.092	0.500	0.727	0.065	0.032	0.092	0.496	0.189
Procurement route		0.107	0.105	0.442	0.622	0.073	0.656	0.390	0.561	0.272	0.088
Design elements		0.467	0.307	0.269	0.467	0.596	0.504	0.195	0.185	0.092	0.225
Information Requirements (EIR)	Exchange Information Requirement (EIR)	0.459	0.106	0.397	0.727	0.676	0.921	0.359	0.584	0.138	0.868
Asset Information Requirement (AIR)		0.088	0.350	0.055	0.268	0.837	0.215	0.307	0.441	0.622	0.535
GSL champion engagement		0.095	0.061	0.100	0.058	0.216	0.100	0.265	0.166	0.216	0.088
Facilities Management Education and Training		0.513	0.211	0.074	0.025	0.078	0.193	0.211	0.057	0.303	0.451

Table 8.11 shows no highlighted values, which indicates independence between the BIM maturity and KPI metrics and shows that the KPI strength of relationships did not depend on the BIM maturity levels. Thus, they do not impact on one another across the organisational level.

3. Spearman Correlation Coefficient analysis

It is necessary to examine the relationship between the BIM Maturity and KPIs metrics with ordinal data presented in maturity levels and strength of relationships. Thus, a Spearman correlation will be used to demonstrate if the maturity and metrics move in the same direction and to examine the strength of relationship. The analysis will show the strength of correlation between both variables with the significant (2 tailed) values ranging between 0(0%) to 1(100%), corresponding significant (Sig.) **ρ=0.01 (99% probability) level and *ρ=0.05 (95% probability) level, and N (number of participants involved in each organisational level). The null hypothesis ($H_\circ$) assumption is that there is no correlation between the BIM maturity and KPI metrics data sets. A Sig. value close to 1 suggests no correlation other than due to chance and that the null hypothesis assumption is correct. If the Sig. value is close to 0, the observed correlation is unlikely to be due to chance and there is a very high probability that the null hypothesis is wrong. With values ranging from 0 to 1, and with significance levels of **0.01 and *0.05, this test will examine the strength of evidence to reject the null hypothesis ($H_\circ$), as follows (Figure 8.17):

Figure 8.17 Statistical significance and probability assumptions (Field, 2017; Laerd. 2018)



1. Should the results return values at a significance level of *0.05 and more than 0.1 (more than 10% chance), the probability level = BIM maturity and KPI metrics returning correlation values of more than 0.1, which is not statistically significant, and thus there is very weak evidence to reject the $H_\circ$.
2. Should the results return values at a significance level of *0.05 and between 0.1-0.05 (between 10%-5% chance), the probability level = BIM maturity and KPI metrics returning correlation values between 0.1-0.05, which is not statistically significant, and thus there is weak evidence to reject the $H_\circ$.
3. Should the results return values at a significance level of *0.05 and between 0.05-0.01 (between 5%-1% chance), the probability level = BIM maturity and KPI metrics returning correlation values **between 0.05-0.01,** which is **statistically significant**, and thus strong evidence to reject the $H_\circ$.
4. Should the result return values at a significance level of **0.01 and less than 0.01 (less than 1% chance), the probability level = BIM maturity and KPI metrics returning correlation values of **less than 0.01,** which is **statistically significant**, and thus very strong evidence to reject the $H_\circ$.

In other words, a 5% (p= 0.05) probability level or below indicates a statistical significance with at least 95 in every 100 participants who, if undertaking the same investigation, would produce a similar statistically significant correlation from their data analysis (Laerd. 2018).

Table 8.12 Spearman Correlation Coefficient

Correlation between BIM maturity and KPI metrics			Cost	Time	Quality	Satisfaction	Health and Safety	Performance	Profitability	Productivity	Sustainability	Collaborative Culture
Spearman's rho	Level 2 BIM \ ISO19650 Collaboration process	Correlation Coefficient	-0.124	0.536	0.465	.712*	0.349	-0.280	0.000	0.056	0.460	0.071
		Sig. (2-tailed)	0.717	0.089	0.150	0.014	0.292	0.404	1.000	0.869	0.154	0.835
		N	11	11	11	11	11	11	11	11	11	11
	Processes and Standards	Correlation Coefficient	0.096	0.196	0.508	0.028	0.141	-0.303	0.220	0.388	0.338	0.568
		Sig. (2-tailed)	0.779	0.565	0.111	0.935	0.680	0.365	0.515	0.238	0.310	0.068
		N	11	11	11	11	11	11	11	11	11	11
	Roles and Responsibilities \ Function	Correlation Coefficient	0.050	0.210	0.469	0.430	0.217	0.389	0.210	0.424	0.092	0.383
		Sig. (2-tailed)	0.883	0.535	0.146	0.187	0.522	0.237	0.535	0.194	0.787	0.245
		N	11	11	11	11	11	11	11	11	11	11
	Contractual agreements	Correlation Coefficient	0.574	0.250	0.352	0.160	-0.059	0.165	0.306	-0.030	-0.087	0.289
		Sig. (2-tailed)	0.065	0.458	0.288	0.638	0.864	0.628	0.360	0.931	0.800	0.389
		N	11	11	11	11	11	11	11	11	11	11
	Level 2 Education and Training	Correlation Coefficient	.687*	.671*	.670*	0.335	0.236	.714*	.715*	.670*	0.278	0.429
		Sig. (2-tailed)	0.019	0.024	0.024	0.314	0.484	0.014	0.013	0.024	0.408	0.188
		N	11	11	11	11	11	11	11	11	11	11
	Procurement route	Correlation Coefficient	0.461	0.463	0.218	0.300	-0.092	0.276	0.327	0.075	0.130	.696*
		Sig. (2-tailed)	0.153	0.152	0.521	0.371	0.787	0.411	0.326	0.827	0.704	0.017
		N	11	11	11	11	11	11	11	11	11	11
	Design elements	Correlation Coefficient	0.386	0.486	0.507	0.386	0.081	0.174	0.528	0.536	.662*	0.465
		Sig. (2-tailed)	0.241	0.130	0.111	0.241	0.812	0.609	0.095	0.089	0.027	0.150
		N	11	11	11	11	11	11	11	11	11	11
	Information Requirements (EIR) \ Exchange Information Requirement (EIR)	Correlation Coefficient	0.394	.648*	0.273	0.225	0.158	0.000	0.452	0.244	0.159	0.100
		Sig. (2-tailed)	0.230	0.031	0.417	0.505	0.643	1.000	0.162	0.470	0.641	0.770
		N	11	11	11	11	11	11	11	11	11	11
	Asset Information Requirement (AIR)	Correlation Coefficient	0.091	0.276	.689*	0.495	0.099	0.358	0.255	0.344	0.235	0.126
		Sig. (2-tailed)	0.791	0.412	0.019	0.122	0.771	0.280	0.449	0.301	0.487	0.712
		N	11	11	11	11	11	11	11	11	11	11
	GSL champion engagement	Correlation Coefficient	0.355	.695*	0.555	0.389	0.441	0.555	0.480	0.572	0.441	0.548
		Sig. (2-tailed)	0.285	0.018	0.076	0.237	0.175	0.076	0.135	0.066	0.175	0.081
		N	11	11	11	11	11	11	11	11	11	11
	Facilities Management Education and Training	Correlation Coefficient	0.204	0.500	.639*	.753**	.670*	0.559	0.500	.714*	0.472	0.366
		Sig. (2-tailed)	0.547	0.117	0.034	0.007	0.024	0.074	0.117	0.014	0.143	0.269
		N	11	11	11	11	11	11	11	11	11	11

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 8.12 presents the results of the strategic organisational Spearman correlations. The results show that BIM Maturity and KPI metrics reported a number of Sig. values ranging from 0.007 to 0.034, which are highlighted in black. Only a limited number of values were returned at significant ρ=**0.01 (99% confidence levels and this means the value will be considered significant if is between 0.001 to 0.010) and ρ=*0.05 (95% confidence levels and this means the value will be considered significant if is between 0.010 to 0.050) which are highlighted in the table. The KPI returning a ρ=**0.01 level and less than 0.01 indicating very strong evidence to reject the null hypothesis is: Satisfaction with Facilities Management Education and Training **(.753**; ρ=0.007)**. The KPIs that returned a ρ=*0.05 level and between 0.05-0.01 indicated that there is strong evidence to reject the null hypothesis. These are:

- Cost with Level 2 Education and Training **(.687*; ρ=0.019)**,
- Time with the following: Level 2 Education and training **(.671*; ρ=0.024)**; EIR **(.648*; ρ=0.031)**; GSL Champion Engagement **(.695*; ρ=0.018)**,

- Quality with the following: Level 2 Education and training **(.670*; ρ=0.024)**; AIR **(.689*; ρ=0.019)**; Facilities Management Education and training **(.639*; ρ=0.034)**,
- Satisfaction with Collaboration process **(.712*; ρ=0.014)**,
- Health and Safety with Facilities Management Education and training **(.670*; ρ=0.024)**,
- Performance with Level 2 Education and Training **(.714*; ρ=0.014)**,
- Profitability with Level 2 Education and Training **(.715*; ρ=0.013)**,
- Productivity with the following: Level 2 Education and training **(670*; ρ=0.024)**; Facilities Management Education and training **(.714*; ρ=0.014)**,
- Sustainability with Design Elements **(.662*; ρ=0.027)**, and
- Collaborative Culture with Procurement route **(.696*; ρ=0.017)**.

The next step will demonstrate the positive and negative correlations and strength of relationships according to the given numerical values. This information will then be translated to colour coded tables to analyse the presented data, and the range of values will be described to explain the data in more detail. Should the results return positive values across the correlated variables (BIM Maturity and KPIs), this would indicate that, as the level of maturity increases or decreases, the KPI strength of relationships also increases or decreases. Values that are negative indicate that as the level of maturity increases, the KPI strength of relationships decrease, and vice versa. To describe the numerical values clearly, a correlation matrix table was presented. There have been many interpretations across different studies for the correlation rule of thumb. This is described in Table 8.13, which presents eight different interpretations of the correlations.

Table 8.13 Interpretation of correlation coefficient comparisons

Correlation Coefficient		Pearson Product Moment correlation coefficient (*r*)	Spearman (*rho*) correlation coefficient	Pearson and Spearman correlation coefficients					
		Cohen Statistical power analysis (Cohen, 1988, p79-81)	Practitioners effective tool (Hong, 2014, p51)	Guilford Rule of Thumb (Guilford, 1950, 1956)	Statistics without Maths for Psychology (Dancey & Reidy, 2004, p176)	Applied Statistics for the Behavioural Sciences (Hinkle, Wiersma, & Jurs, 2003)	Guide for interpreting Correlation Analysis (Prion & Haerling, 2014)	Correlational analysis Medicine (Chan, 2003)	Quinnipiag university Politics. Guide to correlations (Akoglu, 2018)
+1.000	-1.000	Perfect	Very Strong	Very high relationship, very dependable relationship	**Perfect**	Very high positive / negative correlation	Very Strong	Perfect	Perfect
+0.900	-0.900	Strong / Large			**Strong**			Very Strong	Very Strong
+0.800	-0.800		Strong	High correlation, marked relationship		High positive / negative correlation			
+0.700	-0.700						Strong		Moderate
+0.600	-0.600		Moderate	Moderate correlation, Substantial relationship	**Moderate**	Moderate positive / negative correlation		Strong	
+0.500	-0.500						Moderate		Fair
+0.400	-0.400	Moderate / Medium	Moderate to low			Low positive / negative correlation			
+0.300	-0.300			Low correlation, definite but small			Weak	Moderate	
+0.200	-0.200	Weak / small	.016 - .029 weak to low		**Weak**	Negligible correlation		Weak	Poor
+0.100	-0.100		Below .016 too low to be meaningful	Slight relationship			Negligible correlation	Negligible	
0		None / trival			**None**			None	None

Row Title
Correlation Coefficient
Sig. (2 tailed)

What Happens to Variable X	What Happens to Variable Y	Type of Correlation	Value
X increases in value	Y increases in value	Direct or positive	Positive, ranging from .00 to +1.00
X decreases in value	Y decreases in value	Direct or positive	Positive, ranging from .00 to +1.00
X increases in value	Y decreases in value	Indirect or negative	Negative, ranging from −1.00 to .00
X decreases in value	Y increases in value	Indirect or negative	Negative, ranging from −1.00 to .00

Table 8.13 shows Pearson's correlation (Cohen, 1988), Spearman correlation (Hong, 2014), and a combination of both. A correlation coefficient (ρ value) closer to 1 would indicate a positive (+1) or a negative (-1) correlation, whereas a ρ value closer to 0 would indicate no correlation. Due to the authors' different research areas and the comprehensiveness of their different interpretations, this is based on a non-parametric rule of thumb, since the greatest importance should be given to avoid misunderstanding when reporting correlation coefficients and naming their strengths. For this research, Dancey and Ridey's (2004) statistical interpretation (rule of thumb) was selected for interpretation. The essence of this test is to visualise the strength of relationships (No relationship to Strong) between the BIM maturity and KPI metrics to determine how the KPI metrics relate to the BIM maturity levels. It also enables the researcher to determine the strength of evidence, whereby as the BIM maturity levels increases, the KPIs' strength of relationship increases if values are returned positive. Moreover, the strength of evidence determines that, as the BIM maturity levels increase the KPIs' strength of relationship decreases or vice versa, if values are returned negative. Figure 8.18 illustrates how this data will be described.

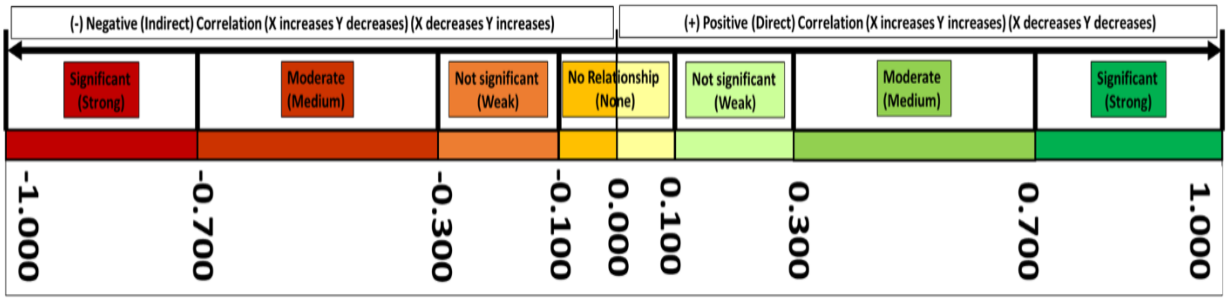


Figure 8.18 Correlations: Strength of relationship

Based on the selected rule of thumb and correlation interpretation, Figure 8.18 indicates that values with a positive correlation occur when the maturity level increases or decreases, and the KPIs relationship moves in the same direction (increase or decrease). The range extends from no relationship (0.000) to strong (1.000) on the right-hand side of the 0.000 value. Values with a negative correlation occur when the BIM maturity level increases, and the KPI relationships decreases, and as the BIM maturity level decreases, the KPI relationship increases. This ranges from no relationship (0.000) to strong (-1.000) on the left-hand side of the 0.000 value, and thus moves in a different direction. The strength of relationship (No relationship to Strong) determines the BIM maturity and KPI metric relationships. Moreover, in order to determine the strength of evidence, the BIM maturity levels increases when the KPIs strength of relationship increases. Figure 8.19 and Table 8.14 demonstrate the results of the strategic level according to this description.

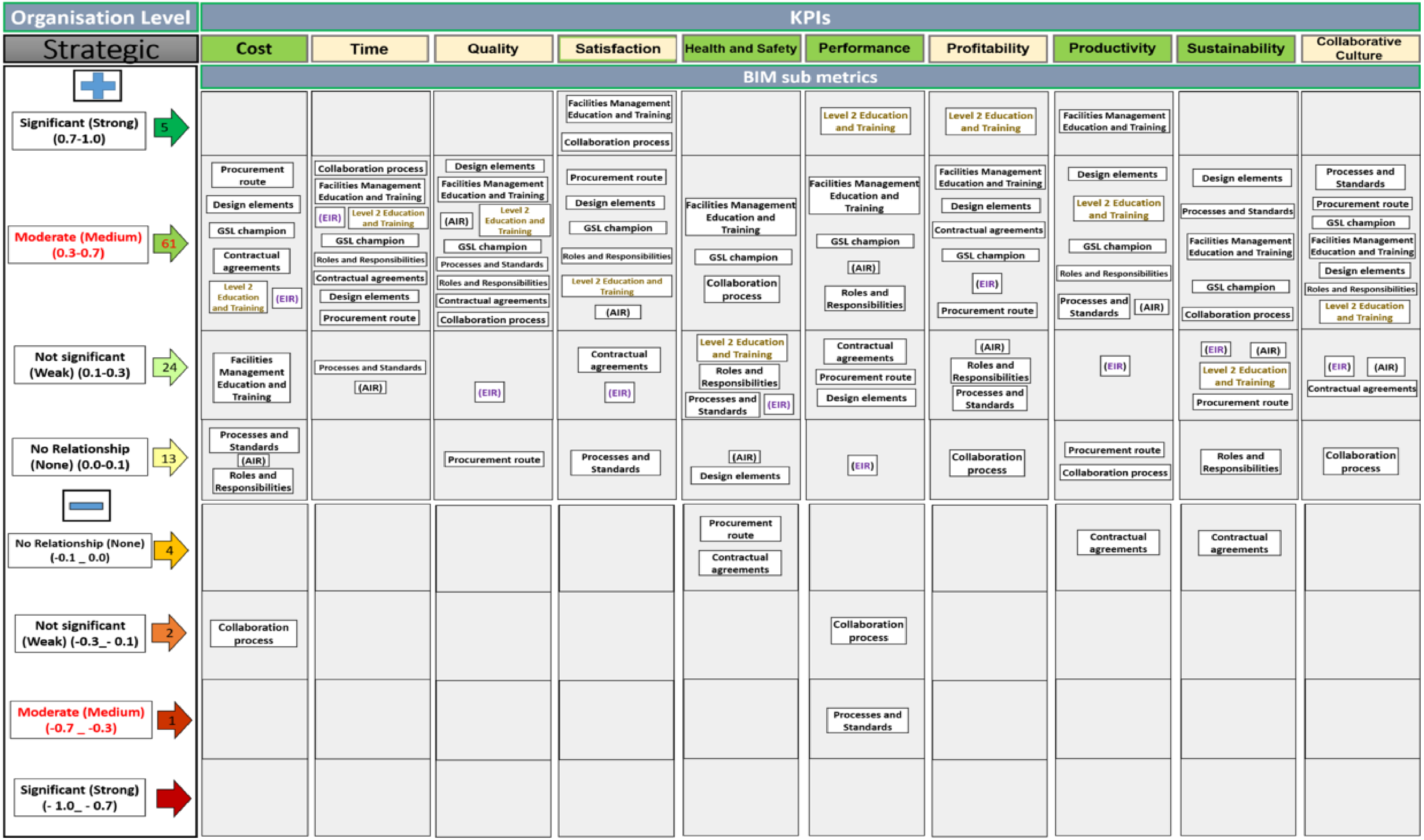


Figure 8.19 Spearman Correlation Coefficient: Strength of relationship

Table 8.14 Spearman Correlation Coefficient: Strength of relationship

The Evidence = Examining the Relationship between BIM Maturity and KPI metrics based on 11 participants								Current BIM Maturity-KPI relationship total					
Sub Metrics		Maturity level	Strategic Level	(The Strategic goals and gearing up of the delivery of BIM at the organisation / project Level, and Organisational and project levels that are being managed by the organisation team.)				Significant (Strong) = (-1.0 _ -0.7)			Significant (Strong) = (0.7 - 1.0)		
								Moderate (Medium) = (-0.7 _ - 0.3)			Moderate (Medium) = (0.3 - 0.7)		
Secondary metrics associated with the main BIM metrics that is expected to be measured to achieve BIM		Awareness	Distributing the correlation between the BIM Maturity and KPI metrics					Not significant (Weak) = (-0.3 _ -0.1)			Not significant (Weak) = (0.1 - 0.3)		
		Occasional Application											
		Consistency						No Relationship (None) = (-0.1 - 0)			No Relationship (None) = (0 - 0.1)		
Level 2 BIM	ISO19650	Maturity level	Cost	Time	Quality	Satisfaction	Health and Safety	Performance	Profitability	Productivity	Sustainability	Collaborative Culture	Correlation
Collaboration process		2.45	-0.124	0.536	0.465	.712*	0.349	-0.280	0.000	0.056	0.460	0.071	0.225
Processes and Standards		2.55	0.096	0.196	0.508	0.028	0.141	-0.303	0.220	0.388	0.338	0.568	0.218
Roles and Responsibilities	Function	2.36	0.050	0.210	0.469	0.430	0.217	0.389	0.210	0.424	0.092	0.383	0.287
Contractual agreements		2.27	0.574	0.250	0.352	0.160	-0.059	0.165	0.306	-0.030	-0.087	0.289	0.192
Level 2 Education and Training		2.36	.687*	.671*	.670*	0.335	0.236	.714*	.715*	.670*	0.278	0.429	0.540
Procurement route		2.27	0.461	0.463	0.218	0.300	-0.092	0.276	0.327	0.075	0.130	.696*	0.285
Design elements		2.45	0.386	0.486	0.507	0.386	0.081	0.174	0.528	0.536	.662*	0.465	0.421
Information Requirements (EIR)	Exchange Information Requirement (EIR)	2.45	0.394	.648*	0.273	0.225	0.158	0.000	0.452	0.244	0.159	0.100	0.265
Asset Information Requirement (AIR)		2.27	0.091	0.276	.689*	0.495	0.099	0.358	0.255	0.344	0.235	0.126	0.297
GSL champion engagement		2.09	0.355	.695*	0.555	0.389	0.441	0.555	0.480	0.572	0.441	0.548	0.503
Facilities Management Education and Training		2.00	0.204	0.500	.639*	.753**	.670*	0.559	0.500	.714*	0.472	0.366	0.538
Current Maturity level (Total)		2.32	0.289	0.448	0.486	0.383	0.210	0.237	0.363	0.363	0.289	0.367	0.343
**. Correlation is significant at the 0.01 level (2-tailed).													
*. Correlation is significant at the 0.05 level (2-tailed).													

Figure 8.19 and Table 8.14 show that, in terms of the correlation coefficient values:

1) All KPI metrics returned a significant correlation with the BIM maturity metrics.
2) The returned significant values were all positive indicating that, as the BIM maturity levels increase, the KPI strength of relationship with BIM maturity increases.
3) The returned positive significant values of BIM maturity and KPI metrics indicate a strong relationship between BIM maturity and KPI metrics and strong evidence that, as the BIM maturity levels increase, the KPI strength of relationship with BIM maturity increases. These are: **Satisfaction with Collaboration process** (.753**; ρ=0.007), **Satisfaction with Facilities Management Education and Training** (.753**; ρ=0.007), **Performance with Level 2 Education and Training** (.714*; ρ=0.014), **Profitability with Level 2 Education and Training** (.715*; ρ=0.013), **Productivity with Facilities Management Education and training** (.714*; ρ=0.014).
4) The returned positive significant values between BIM maturity and KPI metrics indicate a medium relationship between BIM maturity and KPI metrics and medium evidence that, as the BIM maturity levels increase, the KPI strength of relationship with BIM maturity increases. These are: **Cost with Level 2 Education and Training** (.687*; ρ=0.019), **Time with the following: Level 2 Education and training** (.671*; ρ=0.024); **EIR** (.687*; ρ=0.019); **GSL Champion Engagement** (.695*; ρ=0.019), **Quality with the following: Level 2 Education and training** (.670*; ρ=0.024); **AIR** (.689*; ρ=0.019); **Facilities Management Education and**

training (.639*; ρ=0.034), **Productivity with Level 2 Education and training** (.670*; ρ=0.024); **Sustainability with Design Elements** (.662*; ρ=0.027), and **Collaborative Culture with Procurement route** (.696*; ρ=0.017).

5) The results indicated that **Time, Quality, Satisfaction, Profitability, and Collaborative Culture** returned positive values indicating either, as the maturity level increases/decreases the KPI relationships increase/decrease as the strength of relationship and strength of evidence values range from **No relationship (0.000) to Strong (.753)**.
6) The results indicated that **Cost, Health and Safety, Performance, Productivity, and Sustainability** returned negative values indicating opposition. Thus, as maturity levels increase/decrease, the KPI relationships decrease/increase as the strength of relationship and strength of evidence values range from **No relationship (-0.092) to Medium (-0.303)**. Four values were returned as no relationship and with no evidence, which are as follows: **Health and Safety with Contractual agreement and Procurement Route**, **Productivity with Contractual agreement**, and **Sustainability with Contractual agreement**. Two values were returned as a weak relationship and with weak evidence (-0.280_-0.124), which are as follows: **Cost with Collaborative Process**, and **Performance with Collaborative Process**. One value was returned as a moderate relationship and with moderate evidence, which is **Performance with Process and Standards**.
7) The greatest strength of relationship and evidence values were returned in the positive moderate category, and the lowest values returned were in the negative moderate category, which indicates more of a moderate relationship with moderate evidence. Thus, as the BIM maturity levels increase, the KPI strength of relationship with BIM maturity increases.

Having presented the findings of the Spearman correlation coefficient, the next section will discuss the findings of the regression analysis.

4. Regression analysis

As mentioned previously, linear regression analysis is one of the most popular tests for predicting performance across several independent variables and a single dependent variable (Hair et al., 1998). Thus, linear regression helps to identify one or more variables based on their explanatory powers (influence over a dependent variable) (Blaikie, 2003). A linear regression method is used to deliver the cause and effect between BIM Maturity and KPI metrics through a scatter plot diagram, since the data presented should reveal whether there is a linear relationship between BIM Maturity and the KPI metrics, and if the impact of the value change in the independent variable (BIM Maturity) impacts on the dependent variable (KPI metrics). The analysis will display a list of scatter plots which will determine if there is a linear relationship between BIM Maturity and the KPI metrics, which will determine the best line of fit in a scatter plot with a regression equation of $\hat{y}=a+bX$ and R^2 linear= ±0-1 (Field, 2017). The results will predict the overall performance of the BIM maturity and KPI metrics across all organisational levels. The interpretation of the scatter plots is shown in Figure 8.20.

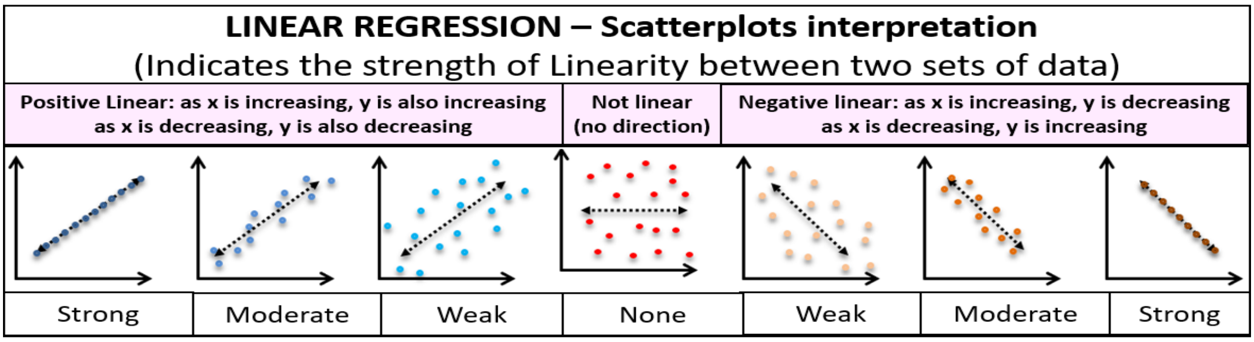


Figure 8.20 Scatterplots interpretation diagram (CQE academy, 2019; Field, 2017; Pythagoras. 2014)

Figure 8.21 presents the results of the linear regression analysis conducted on the maturity level averages and the total KPI relationship averages at the strategic level. The scatter plot tables between BIM maturity and each KPI are available in Appendix G.

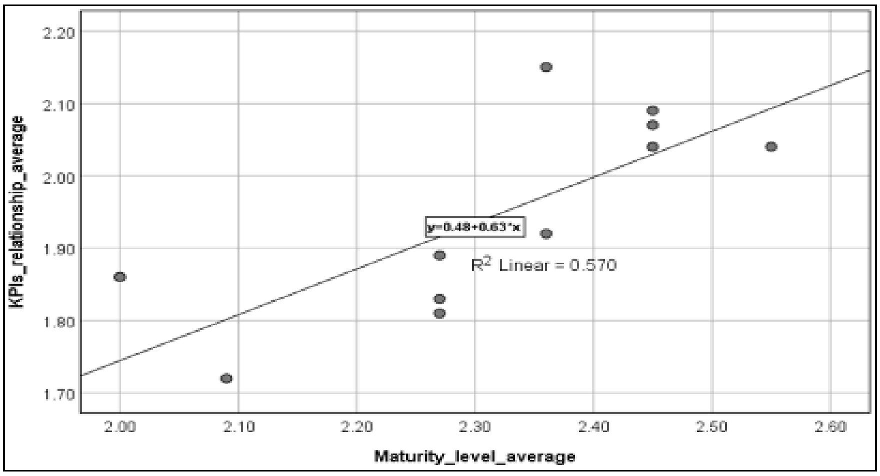


Figure 8.21 Scatter plot between BIM maturity and the KPI relationships at the strategic level

With regard to the BIM Maturity and KPI metrics averages at the strategic level, the regression equation returned after entering the data was: $\hat{y}=0.48+0.63X$, and the R^2 Linear=0.570. According to Figure 8.21, the scatter plot demonstrated a positive linear relationship; thus, as BIM maturity increases, the KPI metrics increase at the strategic level. Table 8.15 presents the complete list of results for the strategic organisational level.

Table 8.15 Scatter plot diagram strength of linearity relationship results

KPI	Regression formula	Scatterplot interpretation
Cost	$\hat{y}$ = 0.49+0.68X, R^2 Linear= 0.208	Weak Positive Linear
Time	$\hat{y}$ = 0.38+1.07X, R^2 Linear= 0.494	Moderate Positive Linear
Quality	$\hat{y}$ = 0.09+0.94X, R^2 Linear= 0.509	Moderate Positive Linear
Satisfaction	**$\hat{y}$ = 2.07+0.04X, R^2 Linear= 8.067E-4**	**Weak Negative Linear**
Health and Safety	$\hat{y}$ = 1.38+0.09X, R^2 Linear= 0.054	Weak Positive Linear
Performance	$\hat{y}$ = 0.33+0.73X, R^2 Linear= 0.269	Weak Positive Linear
Profitability	$\hat{y}$ = 0.04+0.75X, R^2 Linear= 0.181	Weak Positive Linear
Productivity	$\hat{y}$ = 1.37+1.45X, R^2 Linear= 0.578	Moderate Positive Linear
Sustainability	**$\hat{y}$ = 2.38+0.35X, R^2 Linear= 0.152**	**Weak Negative Linear**
Collaborative Culture	$\hat{y}$ = 0.18+0.91X, R^2 Linear= 0.566	Weak Positive Linear
STRATEGIC LEVEL (BIM AND KPIs)	$\hat{y}$ = 0.48+0.63X, R^2 Linear= 0.570	Moderate Positive Linear

Table 8.15 shows that the following KPIs returned a positive regression, indicating that, as the BIM maturity levels increase, the KPI strength of relationship increased across the strategic level:

- Weak= Cost, Health and Safety, Performance, Profitability, Collaborative Culture,
- Moderate= Time, Quality, Productivity, and the total BIM maturity and KPIs.

This shows that the aforementioned KPI strength of linearity would depend on the BIM maturity levels and would move in the same direction, such that as BIM maturity levels increase, the KPI strength of relationship also increases. The following KPIs returned a negative regression indicating the opposite direction; thus, as the BIM maturity levels increases/decreases, the KPI strength of relationship decreases/increases: Weak= Satisfaction and Sustainability. This indicates that the afore-mentioned KPI strength of linearity would not depend on the BIM maturity levels and it would move in a different direction (as BIM maturity levels increases/decreases, the KPI strength of relationship decreases/increases).

Having presented the analysis and findings of the strategic organisational level, the next section presents the analysis and findings of the implementation organisational level.

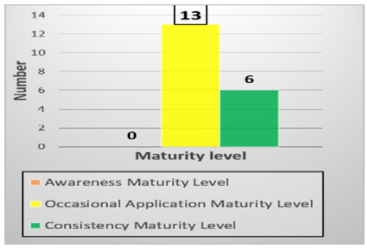
8.4.2.3 Implementation level: BIM maturity and KPI assessment results

This section presents the descriptive and inferential statistical analysis and findings of the implementation level assessment (Table 8.16).

Table 8.16 Implementation organisational level results

Questionnaire participants	Current Organisational background	Participant Organisational Position	Maturity Level Average
IM_01 (P04)	BIM Manager	Implementation Level	Occasional Application
IM_02 (P05)	BIM Manager		Consistency
IM_03 (P07)	(Other) Design Manager		Occasional Application
IM_04 (P08)	BIM Manager		Occasional Application
IM_05 (P09)	(Other) Design Manager		Occasional Application
IM_06 (P11)	BIM Manager		Occasional Application
IM_07 (P13)	BIM Manager		Consistency
IM_08 (P15)	BIM Manager		Occasional Application
IM_09 (P18)	(Other) Researcher		Consistency
IM_10 (P24)	BIM Manager		Occasional Application
IM_11 (P28)	BIM Manager		Consistency
IM_12 (P29)	BIM Manager		Occasional Application
IM_13 (P30)	(Other) Design Manager		Occasional Application
IM_14 (P34)	BIM Manager		Consistency
IM_15 (P36)	BIM Manager		Occasional Application
IM_16 (P37)	BIM Manager		Consistency
IM_17 (P38)	BIM Manager		Occasional Application
IM_18 (P39)	Architect		Occasional Application
IM_19 (P40)	(Other) BIM Coordinator		Occasional Application
Total		19	

Maturity Level Average



Across the 19 participants involved at the implementation level and based on the overall scores, none were at the **Awareness** maturity level, 13 were at the **Occasional application** level, and six were at the **Consistency** level. This indicated that six participants were already at a higher maturity level and potentially performing well within their organisations. The remaining 13 were at the **Occasional application,** which suggests that these users could review their current organisational sub metric scores and determine actions to take to move from **Occasional application** to **Consistency**. Table 8.17 presents a summary of the scoring levels for each participant and shows a matrix of alignment between their overall scores, and the individual sub metric score. This helps to determine which sub metrics should be maintained (**Consistency**) at the highest level of maturity, and the sub metrics that could be improved (**Awareness** and **Occasional application**) to move to the next level (Section 7.4.5). A demonstration of the most frequent answers given to each sub metric and the overall frequency is given along with the averages and total of the sub metric individual scores.

Table 8.17 Implementation level: Participant scores and maturity level average

The Evidence = BIM maturity level at the Implementation level																							
BIM maturity level responses based on 19 questionnaire responses																							
Sub Metrics level 2 BIM	ISO19650	IM_01	IM_02	IM_03	IM_04	IM_05	IM_06	IM_07	IM_08	IM_09	IM_10	IM_11	IM_12	IM_13	IM_14	IM_15	IM_16	IM_17	IM_18	IM_19	Maturity level Frequency	Maturity level Total	Maturity level descriptor
Level 2 Education and Training		3	2	2	2	2	1	3	1	3	2	3	2	1	3	2	2	3	2	2	2	2.16	There is internal training undertaken (i.e. intermediate BIM training or system training) CDE, FM, software based training
Information Requirements (EIR)	Exchange Information Requirement (EIR)	3	2	2	2	1	2	3	2	3	2	3	2	2	3	2	2	2	1	2	2	2.16	Basic template and external procured EIR
Uses		2	3	2	2	3	2	3	2	3	2	3	2	2	3	2	3	3	2	3	2	2.47	BIM uses are outlined but not tailored for specific projects
Supplier assessment forms		2	3	2	2	2	3	3	2	3	1	3	3	3	3	3	2	2	2	1	3	2.37	BIM uses are outlined but not tailored for specific projects
Execution Plan (BEP)	Information Delivery Plan	2	3	2	2	2	3	3	2	3	2	3	2	3	3	2	3	3	1	3	3	2.47	Clients are able to review the BEP
Master Information and Task Team Information (MIDP and (TIDP)		3	3	1	2	2	3	3	2	3	2	1	2	3	3	2	2	2	1	2	2	2.21	Consultant reviews of MIDP and TIDP.
Model production Delivery Table (MPDT)		2	3	1	2	3	1	3	2	3	1	1	1	1	3	2	2	2	2	2	2	1.95	Basic MPDT Template
Responsibility Matrix (RM)	Assignment Matrix	2	3	1	3	3	3	3	2	3	2	2	1	3	3	2	3	2	2	1	3	2.32	Basic RM template developed but not completed.
Document management stage- Common Data Environment (CDE)	<CDE> State	2	3	3	3	3	3	3	2	3	2	3	3	3	3	2	3	2	2	3	3	2.68	CDE supplied by you or supplied by others - CDE is fully compliant to BIM Level 2 and security requirements
Information Exchange		3	3	2	2	2	3	3	2	3	2	3	2	3	3	2	3	2	2	2	2	2.47	Information exchange is defined with basic requirements.
COBie data		1	2	1	2	2	2	2	1	3	2	2	2	2	3	2	2	2	2	1	2	1.89	Understanding the use of COBie but not incorporated on the FM.
Implementation level participants maturity level average		2.27	2.73	1.73	2.18	2.27	2.36	2.91	1.82	3.00	1.82	2.45	2.00	2.36	3.00	2.09	2.45	2.27	1.73	2.00	Occasional Application	2.29	

Table 8.17 indicates that participants at the implementation level have given maturity scores ranging from **Awareness** to **Consistency**. The sub metrics with an overall score of **Consistency** were as follows: **Uses (2.47), BEP (2.47), Design Elements (2.68), and EIR (2.47)**. The descriptor of each sub metric at this level is given. The seven remaining sub metrics were at the **Occasional application** level and no sub metric had an overall level of **Awareness.** Ten participants had individual scores for some sub metrics that were at the **Awareness** level, whereas the remaining scores ranged from **Occasional application** to **Consistency**. This shows that only a few of the sub metric score fell under **Awareness** with most at the implementation level. This indicates that most participants at the implementation level are at the second maturity level and that the sub metrics are applied within their organisations whether partially or fully. As a result, in terms of **Processes**, participants showed that both BIM uses and BEP are fully outlined and not tailored to specific projects, and that clients are able to review them. In terms of **Delivery**, both CDE and Information Exchanges are defined and compliant with BIM requirements. In general, the scores that are either **Awareness** or **Occasional application** need to be reviewed to enable participants to move to - and maintain - the **Consistency** level (Section 7.4.5).

1. Descriptive: Frequencies and Relationships between BIM maturity and KPI metrics

Table 8.18 presents results of the KPI metric relationships with the BIM maturity metrics.

Table 8.18 KPIs strength of relationship frequency and average (Relationship)

The Evidence = Relationship of BIM and KPIs																								
Implementation Level		KPIs strength of relationship responses based on 19 Implementation level participant responses																						
Sub Metrics		Relationship with KPIs																						
level 2 BIM	ISO19650	Cost		Time		Quality		Satisfaction		Health and Safety		Performance		Profitability		Productivity		Sustainability		Collaborative Culture		KPIs (Total)	
		Frequency	Total	Frequency	Total	Frequency	Total	Frequency	Total	Frequency	Total	Frequency	Total	Frequency	Total	Frequency	Total	Frequency	Total	Frequency	Total	Frequency	Relationship
Level 2 Education and Training		2	2.11	2	2.21	2	2.47	2	2.32	2	2.16	2	2.26	2	2.00	2	2.21	1	1.47	3	2.53	Moderate (Medium)	2.17
Information Requirements (EIR)	Exchange Information Requirement (EIR)	2	2.00	2	2.00	3	2.37	3	2.32	2	1.79	2	2.00	2	1.89	2	2.11	2	1.53	3	2.42	Moderate (Medium)	2.04
Uses		2	2.16	3	2.26	2	2.26	2	2.21	2	2.11	2	2.16	2	1.89	3	2.53	2	1.84	2	2.42	Moderate (Medium)	2.18
Supplier assessment forms		2	2.11	3	2.21	2	2.37	2 3	2.21	2	2.05	2	2.21	2	1.84	2	2.32	2	1.89	2 3	2.42	Moderate (Medium)	2.16
Execution Plan (BEP)	Information Delivery Plan	2 3	2.21	3	2.42	3	2.53	3	2.42	2	1.95	3	2.26	2 3	2.00	2	2.26	2	1.84	3	2.58	Significant (Strong)	2.25
Master Information and Task Team Information (MIDP and (TIDP)		2 3	2.21	3	2.42	3	2.32	2	2.21	2	2.05	3	2.42	2	1.79	2	2.26	2	1.74	3	2.47	Moderate (Medium)	2.19
Model production Delivery Table (MPDT)		3	2.11	3	2.32	3	2.32	3	2.26	2	1.68	2	1.95	2	1.63	2	2.32	2	1.53	3	2.26	M S	2.04
Responsibility Matrix (RM)	Assignment Matrix	3	2.05	2 3	2.16	3	2.42	2	2.26	2	2.00	3	2.47	3	2.16	3	2.47	2	1.68	3	2.53	Significant (Strong)	2.22
Document management stage- Common Data Environment (CDE)	<CDE> State	2 3	2.42	2	2.37	2	2.47	3	2.63	2	1.95	3	2.47	3	1.95	3	2.63	2	1.74	3	2.68	Significant (Strong)	2.33
Information Exchange		3	2.37	3	2.58	2	2.47	3	2.53	2	1.74	2 3	2.42	2	2.00	3	2.32	2	1.63	3	2.53	Significant (Strong)	2.26
COBie data		3	2.21	3	2.11	3	2.26	2	2.21	2	1.68	2	2.21	2	1.95	2	2.11	2	1.84	3	2.26	Moderate (Medium)	2.08
Implementation level KPIs strength of relationship average		M S	2.18	Significant (Strong)	2.28	Significant (Strong)	2.39	M S	2.33	Moderate (Medium)	1.92	Moderate (Medium)	2.26	Moderate (Medium)	1.92	Moderate (Medium)	2.32	Moderate (Medium)	1.70	Significant (Strong)	2.46	Moderate (Medium)	2.18

Legend	Current KPI relationship legend
No Relationship (None) 0	No Relationship (None)= (0-0.75)
Not Significant (Weak) 1	Not Significant (Weak)= (0.75-1.5)
Moderate (Medium) 2	Moderate (Medium)= (1.5-2.25)
Significant (Strong) 3	Significant (Strong= (2.25-3)

Table 8.18 indicates that participants have given strength of relationship scores that ranged from **Not Significant (Weak), Moderate (Medium)**, and **Significant (Strong)**, and no scores were classed as **No relationship**. This indicates a relationship between BIM maturity and all KPIs. Across the KPI relationship averages with all of the BIM sub metrics, the following had either a frequency or total of **Significant: Time (2.28), Quality (2.39), Satisfaction (2.33), Performance**

(2.26), Productivity (2.32) and Collaborative culture (2.46), which indicates that participants see **a significant relationship** with the aforementioned KPI metrics across all the BIM sub metrics. The rest of the KPI metrics had a frequency and total of **Moderate (1.70-2.18)**, which shows that all participants perceived **a moderate relationship** with the remaining KPIs across all of the BIM metrics. In terms of the frequency of the KPIs across all BIM metrics, Table 8.18 shows that KPIs with a significant relationship across all the BIM metrics were:

- **Cost** with **MPDT, RM, CDE,** and **Information Exchange,**
- **Time** with **Uses, Suppliers assessment forms, BEP, TIDP, MPDT, Information Exchange,** and **COBie data,**
- **Quality** with **EIR, BEP, TIDP, MPDT, RM,** and **COBie Data,**
- **Satisfaction** with **EIR, BEP, MPDT, CDE,** and **Information Exchange,**
- **Performance** with **BEP, TIDP, RM,** and **CDE,**
- **Profitability** with **RM,** and **CDE,**
- **Productivity** with **Uses, RM, CDE, and Information Exchange,** and
- **Collaborative culture** with **all the BIM sub metrics** except **Uses.**

This indicates that most KPI metrics had a strong relationship with BEP and RM, both frequency and overall average strong relationship with CDE **(2.36)** and Information exchange **(2.26),** and the rest were moderate. **Time, Quality, Satisfaction, Performance, Productivity, and Collaborative Culture** had strong relationships with most of the BIM sub metrics, and the remaining BIM Maturity and KPI metrics with a strong relationship were those BIM Maturity and KPI metrics that were strongly related, which reflects on their maturity levels. The KPI with a '**Not Significant relationship'** across all BIM metrics was **Sustainability** with **Level 2 Education and Training.** This indicates that these KPIs would be reviewed to determine the issues that result in this relationship level, and these KPIs need to be highlighted to determine the actions that could be taken to upskill and move from one level to another (Section 7.4.5). The remaining BIM Maturity and KPI metrics had **a moderate relationship**, which indicates stability with both variables. They are related at the same level and could be reviewed to obtain a stronger relationship.

Organisations at this (Implementation) level would implement the proposed strong relationship and invest more in the strong relationships since it would help to enhance the organisation's performance. Moreover, the metrics in the medium or below relationship would need to be reviewed to determine what needs to be changed to allow the BIM Maturity and KPI metric relationships to move from this level to the next.

2. a) Inferential: Chi square test of relationship between BIM Maturity and KPI metrics

Table 8.19 demonstrates the results of the Chi square test across the implementation level, and those highlighted are values, which returned $p<0.05$ indicating that that there is no relationship between the BIM Maturity and KPI metrics.

Table 8.19 Chi Square tests results

KPI		Cost	Time	Quality	Satisfaction	Health and Safety	Performance	Profitability	Productivity	Sustainability	Collaborative Culture
Level 2 BIM	ISO19650	Asymp. Sig									
Level 2 Education and Training		**0.001**	**0.008**	0.819	**0.018**	**0.002**	**0.039**	**0.024**	**0.008**	**0.008**	0.819
Information Requirements (EIR)	Exchange Information Requirement (EIR)	0.075	0.075	**0.005**	**0.008**	**0.000**	**0.004**	0.109	**0.001**	0.109	**0.029**
Uses		**0.024**	**0.024**	**0.008**	**0.005**	**0.001**	**0.003**	**0.009**	0.819	0.075	0.491
Supplier assessment forms		**0.024**	**0.024**	**0.029**	**0.029**	0.052	**0.005**	**0.043**	0.104	**0.029**	**0.034**
Execution Plan (BEP)	Information Delivery Plan	**0.029**	**0.002**	**0.008**	**0.029**	0.188	0.104	0.224	**0.008**	0.109	0.491
Master Information and Task Team Information (MIDP and (TIDP)		**0.029**	**0.002**	**0.008**	**0.005**	0.052	**0.029**	0.131	**0.008**	0.267	**0.018**
Model production Delivery Table (MPDT)		0.091	**0.014**	0.008	**0.024**	0.801	**0.008**	0.157	**0.029**	0.109	**0.024**
Responsibility Matrix (RM)	Assignment Matrix	0.188	**0.029**	**0.029**	**0.008**	**0.005**	**0.018**	0.075	**0.018**	0.801	**0.008**
Document management stage- Common Data Environment (CDE)	<CDE> State	**0.034**	**0.029**	0.819	0.251	0.075	**0.029**	0.376	0.251	0.052	0.108
Information Exchange		0.143	**0.008**	0.819	0.819	0.157	**0.034**	0.062	0.008	**0.029**	**0.018**
COBie data		**0.024**	0.091	0.104	0.104	0.376	0.104	**0.029**	**0.040**	0.443	**0.024**

Table 8.19 shows that a number of BIM maturity and KPI metric values were $\rho<0.05$ indicating a statistical significance in the results; therefore, this means accepting the null hypothesis (H_o) that there is no relationship between BIM maturity and the KPIs, and a rejection of the alternative hypothesis (H_1) that there is a relationship between BIM maturity and the KPIs. This could indicate that the results given by participants at this organisational (implementation level) did not determine an existing relationship across the highlighted BIM maturity and the KPI metrics. These will be examined further in the upcoming analysis (i.e. Spearman) to indicate whether a relationship exists and the strength of this relationship. However, this indicated that there might not be a relationship between BIM maturity and KPI metrics across the organisational levels, which aligns with the research problem with the absence of a linkage between BIM maturity and KPI metrics. The remaining values were $p>0.05$ indicating that there is no statistical significance in the result and therefore, the null hypothesis (H_o) is rejecting as there is no relationship between BIM maturity and the KPIs. Thus, the alternative hypothesis (H_1) is accepted that there is a relationship between BIM maturity and the KPIs, which answers the research question 'is there a relationship between BIM maturity and KPI metrics?'

2. b) Kruskal Wallis test of independence between BIM maturity and KPI metrics

Table 8.20 demonstrates the results of the Kruskal Wallis across the implementation level, and those highlighted are the values which returned $p < 0.05$ indicating that BIM Maturity and KPI metrics depend on each other.

Table 8.20 Kruskal Wallis test results

KPI		Cost	Time	Quality	Satisfaction	Health and Safety	Performance	Profitability	Productivity	Sustainability	Collaborative Culture
Level 2 BIM	ISO19650	Asymp. Sig									
Level 2 Education and Training		0.711	0.389	0.298	0.638	0.060	0.029	0.161	0.289	0.639	0.204
Information Requirements (EIR)	Exchange Information Requirement (EIR)	0.070	0.070	0.027	0.043	0.457	0.304	0.115	0.258	0.051	0.128
Uses		0.894	0.534	0.665	0.820	0.252	0.367	0.040	0.258	0.204	0.273
Supplier assessment forms		0.490	0.295	0.253	0.285	0.148	0.199	0.088	0.178	0.905	0.229
Execution Plan (BEP)	Information Delivery Plan	0.280	0.159	0.439	0.536	0.576	0.682	0.220	0.719	0.045	0.356
Master Information and Task Team Information (MIDP and (TIDP)		0.783	0.817	0.675	0.602	0.298	0.823	0.377	0.915	0.070	0.733
Model production Delivery Table (MPDT)		0.668	0.802	0.582	0.604	0.516	0.610	0.495	0.543	0.102	0.611
Responsibility Matrix (RM)	Assignment Matrix	0.776	0.800	0.327	0.715	0.378	0.611	0.718	0.990	0.427	0.809
Document management stage- Common Data Environment (CDE)	<CDE> State	0.048	0.234	0.879	0.432	0.962	1.000	0.462	0.228	0.089	0.355
Information Exchange		0.964	0.923	0.509	0.120	0.965	1.000	0.482	0.344	0.228	1.000
COBie data		0.340	0.254	0.403	0.268	0.443	0.768	0.174	0.080	0.398	0.651

Table 8.20 shows that only a few BIM maturity and KPI metric values returned values of $\rho<0.05$ indicating that there is a statistical significance in the result, and therefore, the alternative hypothesis (H_1) is rejected, namely that there is independence between BIM maturity and the KPI metrics (KPI strength of relationship does not depend on BIM maturity level), or that the null hypothesis (H_o) is accepted, that there is no independence between BIM maturity and the KPI metrics (KPI strength of relationship depends on BIM maturity level). These were:

- Cost with CDE **(0.048)**,
- Quality with EIR **(0.027)**,
- Satisfaction with EIR **(0.043)**,
- Performance with Level 2 Education and Training **(0.029)**,
- Profitability with Uses **(0.040)**, and
- Sustainability with Information delivery plan **(0.045)**.

According to the results given by participants at this organisational (implementation) level the KPI strength of relationship would not depend on the BIM maturity level across the non-highlighted values and only the KPI strength of relationship would depend on the BIM maturity level across those highlighted values. Those will be examined further in the upcoming analysis (i.e. regression) to determine whether the KPI strength of relationship depends on the BIM maturity levels and to whether they move in the same or different directions. The remaining values were p>0.05 indicating no statistical significance in the result and therefore, accepting the alternative hypothesis (H_1) that there is independence between BIM maturity and the KPI metrics, or rejecting the null hypothesis (H_o) that there is dependence between BIM maturity and the KPI metrics. These answer the research question of whether there is a relationship between BIM maturity and KPI metrics.

3. Spearman Correlation Coefficient analysis

Table 8.21 displays the results of the implementation organisational correlations.

Table 8.21 Spearman Correlation Coefficient

Correlation between BIM maturity and KPI metrics			Cost	Time	Quality	Satisfaction	Health and Safety	Performance	Profitability	Productivity	Sustainability	Collaborative Culture
Spearman's rho	Level 2 BIM \ ISO19650 Level 2 Education and Training	Correlation Coefficient	0.182	0.197	0.117	0.160	.558*	.590**	0.351	-0.101	-0.071	-0.223
		Sig. (2-tailed)	0.457	0.419	0.634	0.513	0.013	0.008	0.140	0.681	0.773	0.359
		N	19	19	19	19	19	19	19	19	19	19
	Information Requirements (EIR) \ Exchange Information Requirement (EIR)	Correlation Coefficient	0.405	0.265	.544*	0.424	0.237	0.241	0.354	0.197	.498*	0.308
		Sig. (2-tailed)	0.086	0.274	0.016	0.071	0.329	0.320	0.137	0.419	0.030	0.199
		N	19	19	19	19	19	19	19	19	19	19
	Uses	Correlation Coefficient	0.031	0.147	-0.102	-0.054	0.270	0.213	.485*	0.267	0.299	0.258
		Sig. (2-tailed)	0.898	0.549	0.677	0.828	0.264	0.382	0.035	0.270	0.213	0.285
		N	19	19	19	19	19	19	19	19	19	19
	Supplier assessment forms	Correlation Coefficient	0.119	-0.087	-0.204	-0.205	-0.145	-0.194	-0.230	-0.399	-0.101	-0.368
		Sig. (2-tailed)	0.627	0.722	0.401	0.401	0.555	0.427	0.343	0.090	0.682	0.121
		N	19	19	19	19	19	19	19	19	19	19
	Execution Plan (BEP) \ Information Delivery Plan	Correlation Coefficient	0.373	0.375	0.227	0.227	0.232	0.182	0.387	0.177	.588**	0.297
		Sig. (2-tailed)	0.116	0.114	0.351	0.349	0.340	0.455	0.102	0.468	0.008	0.217
		N	19	19	19	19	19	19	19	19	19	19
	Master Information and Task Team Information (MIDP and (TIDP)	Correlation Coefficient	0.164	-0.150	-0.065	0.087	0.367	-0.136	0.043	-0.061	0.131	0.097
		Sig. (2-tailed)	0.503	0.541	0.790	0.722	0.122	0.578	0.862	0.803	0.593	0.694
		N	19	19	19	19	19	19	19	19	19	19
	Model production Delivery Table (MPDT)	Correlation Coefficient	0.022	0.123	0.245	0.233	0.270	0.234	0.226	0.257	.500*	0.119
		Sig. (2-tailed)	0.929	0.615	0.312	0.337	0.264	0.335	0.353	0.289	0.029	0.627
		N	19	19	19	19	19	19	19	19	19	19
	Responsibility Matrix (RM) \ Assignment Matrix	Correlation Coefficient	0.167	0.115	0.019	0.102	0.139	-0.147	0.094	0.011	0.303	-0.059
		Sig. (2-tailed)	0.494	0.639	0.937	0.677	0.571	0.548	0.702	0.964	0.207	0.812
		N	19	19	19	19	19	19	19	19	19	19
	Document management stage-Common Data Environment (CDE) \ <CDE> State	Correlation Coefficient	.465*	0.281	-0.036	0.185	-0.011	0.000	0.173	-0.284	0.401	-0.218
		Sig. (2-tailed)	0.045	0.245	0.884	0.448	0.964	1.000	0.478	0.238	0.089	0.370
		N	19	19	19	19	19	19	19	19	19	19
	Information Exchange	Correlation Coefficient	-0.011	0.023	0.156	-0.367	0.010	0.000	0.166	-0.223	0.284	0.000
		Sig. (2-tailed)	0.966	0.926	0.525	0.123	0.967	1.000	0.498	0.359	0.238	1.000
		N	19	19	19	19	19	19	19	19	19	19
	COBie data	Correlation Coefficient	0.175	0.140	-0.205	-0.227	0.152	-0.056	-0.145	-0.280	-0.043	-0.114
		Sig. (2-tailed)	0.474	0.567	0.401	0.350	0.535	0.819	0.555	0.246	0.861	0.643
		N	19	19	19	19	19	19	19	19	19	19
**. Correlation is significant at the 0.01 level (2-tailed).												
*. Correlation is significant at the 0.05 level (2-tailed).												

The results show that BIM Maturity and KPI metrics reported a number of Sig. values ranging from 0.008 to 0.045, as highlighted in black. Only a limited number of values were returned at a significance of ρ=**0.01 and ρ=*0.05 which are also highlighted (in black) in the table.

1. The KPI that returned ρ=**0.01 level and less than 0.01 indicated very strong evidence to reject the null hypothesis. These are: Performance with Level 2 Education and Training **(.590**; ρ=0.008)** and Sustainability with BEP **(.588**; ρ=0.008)**.

2. The KPIs that returned a ρ=*0.05 level and between 0.05-0.01 indicated strong evidence to reject the null hypothesis are: Cost with CDE **(.465*; ρ=0.045),** Quality with EIR **(.544*; ρ=0.016)**, Health and Safety with Level 2 Education and Training **(.558*; ρ=0.013)**, Profitability with Uses **(.485*; ρ=0.035)**, Sustainability with the following: EIR **(.498*; ρ=0.030)**, and MPDT **(.500*; ρ=0.029)**.
3. The KPIs that did not return significant values ρ= 0.05 and 0.01 (2-tailed) were as follows: Time, Satisfaction, Productivity, and Collaborative Culture.
4. The results did not return values of more than 0.1 (more than 10% chance) had a probability level = very weak to no-evidence to reject the null hypothesis or between 0.1-0.05 (between 10%-5% chance). The probability level = weak evidence to reject the null hypothesis. This indicates that the results that did not return a significance value close to 1, which suggests no correlation other than due to chance and that the null hypothesis is correct.

Table 8.22 and Figure 8.22 demonstrate the results of the implementation level's strength of relationship.

Table 8.22 Spearman Correlation Coefficient: Strength of relationship

The Evidence = Examining the Relationship between BIM Maturity and KPI metrics based on 19 participants								Current BIM Maturity-KPI relationship total					
Sub Metrics		Maturity level	Implementation Level	(Implementing BIM across the organisation / project level, in line with the organisation / project strategic goals in relation to BIM implementation.)				Significant (Strong) = (-1.0 _ -0.7)			Significant (Strong) = (0.7 - 1.0)		
Secondary metrics associated with the main BIM metrics that is expected to be measured to achieve BIM		Awareness	Distributing the correlation between the BIM Maturity and KPI metrics					Moderate (Medium) = (-0.7 _ - 0.3)			Moderate (Medium) = (0.3 - 0.7)		
		Occasional Application						Not significant (Weak) = (-0.3 _ -0.1)			Not significant (Weak) = (0.1 - 0.3)		
		Consistency						No Relationship (None) = (-0.1 - 0)			No Relationship (None) = (0 - 0.1)		
Level 2 BIM	ISO19650	Maturity level	Cost	Time	Quality	Satisfaction	Health and Safety	Performance	Profitability	Productivity	Sustainability	Collaborative Culture	Correlation
Level 2 Education and Training		2.16	0.182	0.197	0.117	0.160	.558*	.590**	0.351	-0.101	-0.071	-0.223	0.176
Information Requirements (EIR)	Exchange Information Requirement (EIR)	2.16	0.405	0.265	.544*	0.424	0.237	0.241	0.354	0.197	.498*	0.308	0.347
Uses		2.47	0.031	0.147	-0.102	-0.054	0.270	0.213	.485*	0.267	0.299	0.258	0.181
Supplier assessment forms		2.37	0.119	-0.087	-0.204	-0.205	-0.145	-0.194	-0.230	-0.399	-0.101	-0.368	-0.181
Execution Plan (BEP)	Information Delivery Plan	2.47	0.373	0.375	0.227	0.227	0.232	0.182	0.387	0.177	.588**	0.297	0.306
Master Information and Task Team Information (MIDP and (TIDP)		2.21	0.164	-0.150	-0.065	0.087	0.367	-0.136	0.043	-0.061	0.131	0.097	0.048
Model production Delivery Table (MPDT)		1.95	0.022	0.123	0.245	0.233	0.270	0.234	0.226	0.257	.500*	0.119	0.223
Responsibility Matrix (RM)	Assignment Matrix	2.32	0.167	0.115	0.019	0.102	0.139	-0.147	0.094	0.011	0.303	-0.059	0.074
Document management stage-Common Data Environment (CDE)	<CDE> State	2.68	.465*	0.281	-0.036	0.185	-0.011	0.000	0.173	-0.284	0.401	-0.218	0.096
Information Exchange		2.47	-0.011	0.023	0.156	-0.367	0.010	0.000	0.166	-0.223	0.284	0.000	0.004
COBie data		1.89	0.175	0.140	-0.205	-0.227	0.152	-0.056	-0.145	-0.280	-0.043	-0.114	-0.060
Current Maturity level (Total)		2.29	0.163	0.130	0.063	0.052	0.189	0.084	0.173	-0.040	0.254	0.009	0.110
**. Correlation is significant at the 0.01 level (2-tailed).													
*. Correlation is significant at the 0.05 level (2-tailed).													

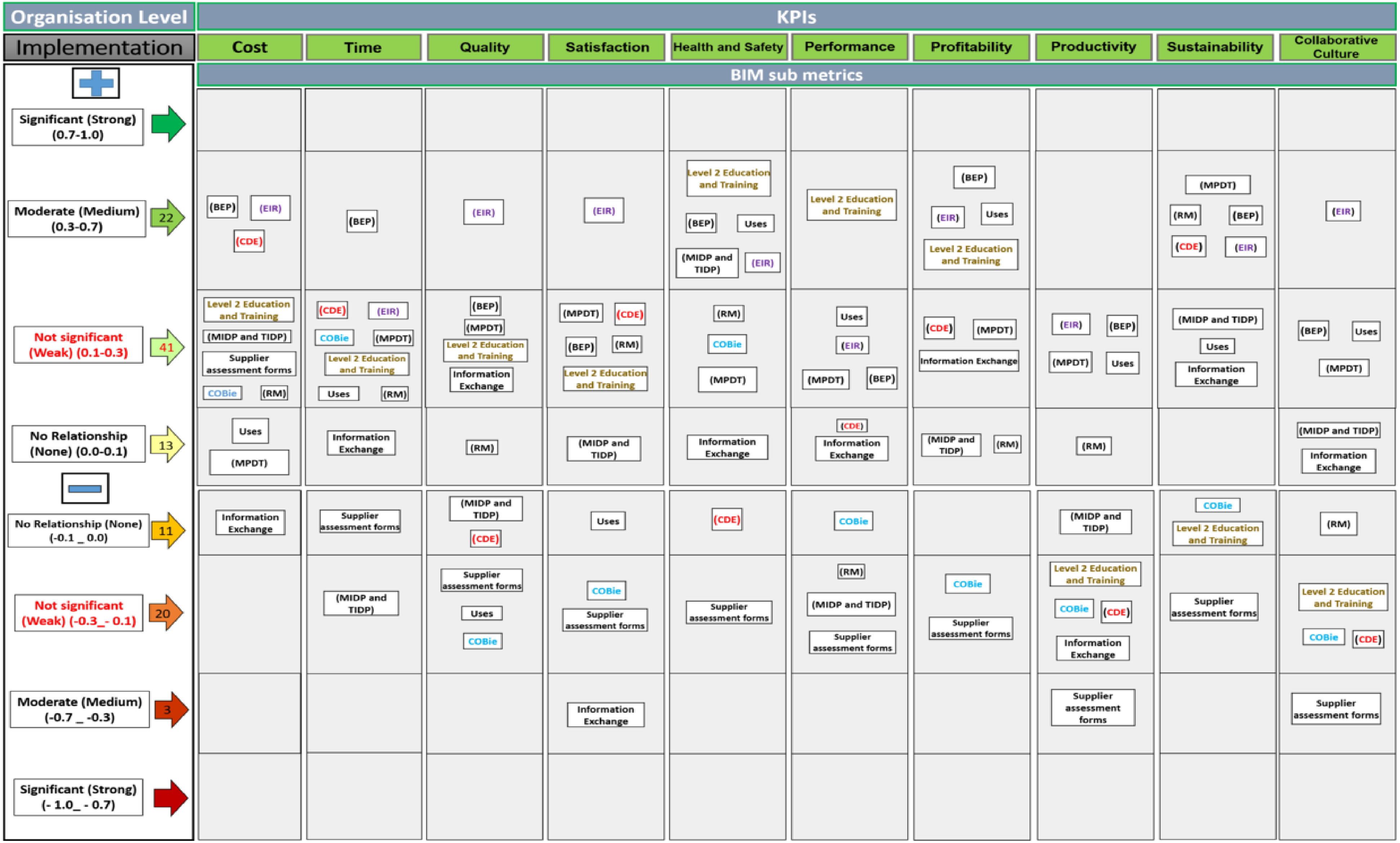


Figure 8.22 Spearman Correlation Coefficient: Strength of relationship

Table 8.22 and Figure 8.22 show that:

1) Unlike the KPIs at the strategic level, which retuned significant correlation values, only **Cost, Quality, Health and Safety, Performance, Profitability, and Sustainability** returned a significant correlation with BIM maturity metrics.
2) The returned significant values were all positive indicating that, as the BIM maturity levels increase, the KPI strength of relationship with BIM maturity increases; moreover, the values returned were all moderate **(0.3000-0.7000)**.
3) The positive significant values between BIM maturity and KPI metrics indicate a moderate relationship between BIM maturity and KPI metrics and moderate evidence that, as the BIM maturity levels increase, the KPI strength of relationship with BIM maturity increases. The include: **Cost with CDE** (.465*; ρ=0.045), **Quality with EIR** (.544*; ρ=0.016), **Health and Safety with Level 2 Education and Training** (.558*; ρ=0.013), **Performance with Level 2 Education and Training** (.590**; ρ=0.008), **Profitability with Uses** (.485*; ρ=0.035), **Sustainability with the following: EIR** (.498*; ρ=0.030), **BEP** (.588**; ρ=0.008), and **MPDT** (.500*; ρ=0.029).
4) Contrary to the KPIs at the strategic level, which did not return negative values across a number of KPIs, the results indicated that all KPIs returned either positive values indicating either, as the maturity level increase/decrease the KPI relationships increase/decrease. Furthermore, the strength of relationship and strength of evidence values ranged from **no relationship (0.000)** to **medium (.590)** or returned negative values indicating opposition whereby, as maturity levels increase/decrease, the KPI relationships decrease/increase with strength of relationship and the strength of evidence values range from **no relationship (-0.011)** to **medium (-0.399)**.
5) In contrast to the strength of relationship and evidence at the strategic level, which returned values in the strong category (0.700-1), there have been no positive or negative values in the strong category across this organisational level, indicating that there are no strong relationships between BIM maturity and KPI metrics and no strong evidence that, as the maturity level increases/decreases the KPI relationships increase/decrease or vice versa.
6) Most 'strength of relationship and evidence' values were found in the positive weak category, and the lowest values were in the negative moderate category, indicating that there are more weak relationships and weak evidence that as the BIM maturity levels increase, the KPI strength of relationship with BIM maturity increases.

Having presented the findings of the Spearman Correlation Coefficient, the next section will discuss the findings of the regression analysis.

4. Regression analysis

Table 8.23 presents the complete list of results for the implementation level, while the scatter plot tables between BIM maturity and each KPI are available in Appendix G.

Table 8.23 Scatter plot diagram strength of linearity relationship results

KPI	Regression formula	Scatterplot interpretation
Cost	$\hat{y}$ = 1.53+0.28X, R^2 Linear= 0.285	Weak Positive Linear
Time	$\hat{y}$ = 1.52+0.33X, R^2 Linear= 0.233	Weak Positive Linear
Quality	$\hat{y}$ = 1.91+0.21X, R^2 Linear= 0.300	Weak Positive Linear
Satisfaction	$\hat{y}$ = 1.45+0.38X, R^2 Linear= 0.411	Weak Positive Linear
Health and Safety	$\hat{y}$ = 1.19+0.32X, R^2 Linear= 0.199	Weak Positive Linear
Performance	$\hat{y}$ = 1.29+0.42X, R^2 Linear= 0.320	Weak Positive Linear
Profitability	$\hat{y}$ = 1.41+0.22X, R^2 Linear= 0.149	Weak Positive Linear
Productivity	$\hat{y}$ = 1.19+0.49X, R^2 Linear= 0.518	Weak Positive Linear
Sustainability	$\hat{y}$ = 1.23+0.21X, R^2 Linear= 0.115	Weak Positive Linear
Collaborative Culture	$\hat{y}$ = 1.44+0.45X, R^2 Linear= 0.701	Moderate Positive Linear
IMPLEMENTATION LEVEL (BIM AND KPIs)	$\hat{y}$ = 1.41+0.33X, R^2 Linear= 0.753	Moderate Positive Linear

Table 8.23 shows that the following KPIs returned positive regression, indicating that as the BIM maturity levels increase the KPI strength of relationship increased:

- Weak= Cost, Time, Quality, Satisfaction, Health and Safety, Performance, Profitability, Productivity, Sustainability, and
- Moderate= Collaborative Culture, and the total BIM maturity and KPIs across the Implementation level.

This shows that the aforementioned KPI strength of linearity depends on the BIM maturity levels and move in the same direction, such that, as BIM maturity levels increase, the KPI strength of relationship increases. In contrast, there has been no negative regression indicating the opposite direction. Thus, as the BIM maturity levels increase/decrease, the KPI strength of relationship decreases/increases. This shows that the KPI metrics depend on the BIM maturity metrics and would move towards the same direction across the organisational (Implementation) level.

Having presented the analysis and findings of the implementation level, the next section will present the analysis and findings of the operational level.

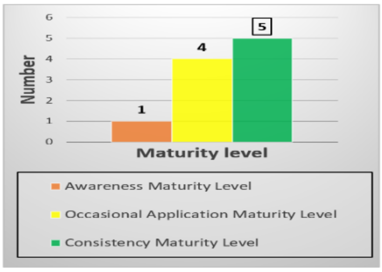
8.4.2.4 Operational level: BIM maturity and KPI assessment results

This section presents the descriptive and inferential statistical analysis and findings for the operational level assessment (Table 8.24).

Table 8.24 Operational organisational level results

Questionnaire participants	Current Organisational background	Participant Organisational Position	Maturity Level Average
OP_01 (P01)	BIM Manager	Operational Level	Consistency
OP_02 (P16)	Site Agent		Awareness
OP_03 (P17)	BIM Manager		Consistency
OP_04 (P21)	(Other) BIM Coordinator		Occasional Application
OP_05 (P22)	BIM Manager		Occasional Application
OP_06 (P25)	BIM Manager		Consistency
OP_07 (P27)	Architect		Occasional Application
OP_08 (P31)	BIM Manager		Occasional Application
OP_09 (P32)	BIM Manager		Consistency
OP_10 (P33)	(Other) BIM Designer		Consistency
Total		10	

Maturity Level Average



Across the ten participants involved in the operational level and based on the overall scores given, one scored in the **Awareness** maturity level, four in the **Occasional application** level, and five in the **Consistency** level. This indicated that five participants were already at a higher maturity level and potentially performing well within their organisations, whereas the remaining five users - being between **Awareness** and **Occasional application -** suggests a need to review their current organisational sub metric scores and to determine the actions that need to be taken to move from **Awareness** and **Occasional application** to **Consistency**. Table 8.25 presents a summary of the scoring levels for each participant and shows a matrix of alignment between their overall and individual sub metric score. This helps to identify which sub metrics would be maintained (**Consistency**) since this is the highest level of maturity, and the sub metrics that would need to be improved (**Awareness** and **Occasional application**) to move to another level through a set of actions (Section 7.4.5). A demonstration of the most frequent answers given to each sub metric and the overall frequency is given along with the averages and totals of the individual sub metric scores.

Table 8.25 Operational level participant scores and maturity level

The Evidence = BIM maturity level at the Operational level

BIM maturity level responses based on 10 questionnaire responses

Sub Metrics: level 2 BIM	Sub Metrics: ISO19650	OP_01	OP_02	OP_03	OP_04	OP_05	OP_06	OP_07	OP_08	OP_09	OP_10	Maturity level: Frequency		Maturity level: Total	Maturity level descriptor
Information Requirements (EIR)	Exchange Information Requirement (EIR)	3	1	3	3	1	3	2	2	2	2	2	3	2.20	Basic template and external procured EIR
Document management stage- Common Data Environment (CDE)	<CDE> State	3	1	3	3	2	3	2	2	3	2	3		2.40	CDE supplied by you or supplied by others - CDE is fully compliant to Level 2 BIM and security requirements
3D – 6D inputs		3	1	1	3	1	3	1	1	3	3	1	3	2.00	Identified but not used in a certain degree over projects
Level of Development (LoD)	Level of Information need	3	1	3	3	2	3	2	3	3	1	3		2.40	Full understanding of the LoD and capability to use the models (Visualise and check the information)
Project reviews		3	1	1	2	2	3	1	2	3	1	1		1.90	Good understanding of the roles and responsibility and acknowledging the clients on the gateway reviews to be applied
Lifecycle Analysis		2	2	3	2	1	3	2	1	3	1	2		2.00	Basic Usage of the Lifecycle but not fully managed
As built model		3	1	3	1	2	3	2	2	3	1	3		2.10	As built model is acknowledged by project team members in line with BIM level 2, and ready to be used.
Project Information Model (PIM) exchanges		3	1	3	1	2	3	2	2	2	1	2		2.00	Information model is acknowledged by project team members in line with BIM level 2, and ready to be used.
Information Delivery (AIM)		3	1	3	1	1	3	2	1	2	1	1		1.80	Good Understanding of AIM and using it in the basic level but is not fully level 2 BIM compliant
COBie data		3	1	1	1	2	2	2	3	3	1	1		1.90	Good Understanding and using it in the basic level but not fully integrated in the system
Handover requirements (GSL)		2	3	3	1	2	3	3	1	1	1	1	3	2.00	Good understanding of the Hand-overs required for the GSL, and is being used but not fully Level 2 BIM compliant
Post Occupancy Evaluation (POE)		2	1	3	1	2	2	2	1	1	1	1		1.60	Good understanding of the Post Occupancy Evaluation, and is being used but not fully Level 2 BIM compliant
Operational level participants maturity level average		2.75	1.25	2.50	1.83	1.67	2.83	1.92	1.75	2.42	3.00	Consistency		2.03	

Table 8.25 indicates that participants at the operational level have given maturity scores that range from **Awareness** to **Consistency**. The sub metrics with an overall score of **Consistency** were **CDE** and **LoD (2.40)**. The descriptor for each sub metric at this level is given. The 11 remaining sub metrics were at the **Occasional** application level and no sub metric had an overall level of **Awareness.** Only two participants had individual scores for some sub metrics that did not contain scores at the **Awareness** level, whilst the remaining scores ranged across all three maturity levels. This shows that the sub metric participant scores that almost fell equally were across all three maturity levels. This indicates that participants' maturity at the operational level varied from one level to another. As a result, in terms of **Sharing**, participants showed that CDEs are fully applied and compliant with Level 2 BIM standards, and for **Capital Delivery**, LoDs are fully understood and the capabilities to use the models are in place. In general, the scores that are scored as either **Awareness** or **Occasional** need to be reviewed to enable participants to move to and maintain the **Consistency** level, which can be achieved through a series of actions (Section 7.4.5).

1. Descriptive: Frequencies and Relationships between BIM maturity and KPI metrics

Table 8.26 presents the results of the KPI metrics relationships with the BIM maturity metrics.

Table 8.26 KPIs strength of relationship frequency and average (Relationship)

The Evidence = Relationship of BIM and KPIs																							
Operational Level		KPIs strength of relationship responses based on 10 Operational level participant responses																					
Sub Metrics		Relationship with KPIs																					
level 2 BIM	ISO19650	Cost		Time		Quality		Satisfaction		Health and Safety		Performance		Profitability		Productivity		Sustainability		Collaborative Culture		KPIs (Total)	
		Frequency	Total	Frequency	Total	Frequency	Total	Frequency	Total	Frequency	Total	Frequency	Total	Frequency	Total	Frequency	Total	Frequency	Total	Frequency	Total	Frequency	Relationship
Information Requirements (EIR)	Exchange Information Requirement (EIR)	3	2.50	3	2.40	3	2.30	2 3	2.10	2	1.80	2	2.20	2 3	2.10	2	1.90	2	1.80	3	2.20	M S	2.13
Document management stage- Common Data Environment (CDE)	<CDE> State	3	2.30	3	2.40	2 3	2.10	2	2.00	2	1.70	3	2.30	2	1.80	2	2.20	3	1.90	3	2.30	Significant (Strong)	2.10
3D – 6D inputs		2	2.20	3	2.30	3	2.40	3	2.00	2	1.70	2	2.10	2	1.90	2	2.10	2	1.90	2	1.80	Moderate (Medium)	2.04
Level of Development (LoD)	Level of Information need	2	1.60	2	1.70	3	2.20	2 3	2.10	1 2	1.50	2	2.00	2	1.60	3	2.10	2	1.70	3	2.30	Moderate (Medium)	1.88
Project reviews		2 3	2.10	3	2.30	2 3	2.10	2	1.90	2	1.69	2	1.90	2	1.90	2 3	2.10	3	2.00	2 3	2.10	Moderate (Medium)	2.00
Lifecycle Analysis		2	2.20	2 3	2.10	2	2.10	2	1.90	2	1.80	2	2.10	2	2.00	2	2.20	2	2.00	2	2.00	Moderate (Medium)	2.04
As built model		3	2.20	3	2.10	3	2.30	2	2.20	3	2.00	2	2.20	2	2.00	3	2.20	3	2.00	3	2.20	Significant (Strong)	2.14
Project Information Model (PIM) exchanges		3	2.20	2 3	2.10	3	2.40	3	2.30	2	1.70	2	2.20	2	2.00	3	2.00	2	2.00	3	2.30	Moderate (Medium)	2.12
Information Delivery (AIM)		3	2.40	3	2.40	3	2.40	3	2.40	3	2.20	3	2.60	3	2.20	3	2.30	3	2.30	3	2.30	Significant (Strong) (3)	2.35
COBie data		2 3	1.70	2	1.70	3	1.90	2 3	1.60	0 1	1.20	2	1.70	2	1.70	2	1.70	2	1.70	2 3	2.00	Moderate (Medium)	1.69
Handover requirements (GSL)		2 3	2.00	2 3	1.70	3	1.90	2	2.00	1 2	1.50	3	1.80	2	1.60	3	1.90	2	1.60	2	1.70	Moderate (Medium)	1.77
Post Occupancy Evaluation (POE)		2	1.40	2	1.40	3	2.00	2	1.90	2	1.70	2	1.60	2	1.40	1 2	1.50	2	1.40	3	1.60	Moderate (Medium)	1.59
Operational level participants maturity level average		Moderate (Medium)	2.07	Significant (Strong)	2.05	Significant (Strong)	2.18	Moderate (Medium)	2.03	Moderate (Medium)	1.70	Moderate (Medium)	2.06	Moderate (Medium)	1.85	Moderate (Medium)	2.02	Moderate (Medium)	1.86	Significant (Strong)	2.07	Moderate (Medium)	1.99

Legend	Current KPI relationship legend
No Relationship (None) 0	No Relationship (None)= (0-0.75)
Not Significant (Weak) 1	Not Significant (Weak)= (0.75-1.5)
Moderate (Medium) 2	Moderate (Medium)= (1.5-2.25)
Significant (Strong) 3	Significant (Strong= (2.25-3)

Table 8.26 indicated that participants gave strength of relationship scores that ranged from **Not Significant (Weak), Moderate (Medium)**, and **Significant (Strong)**, while no scores were given for **No relationship**, which indicates that there is a relationship between BIM maturity and all of the KPIs. Across the KPI relationship averages with all of the BIM sub metrics, the following had only a frequency with no overall totals of **Significant: Time, Quality, and Collaborative culture**. This indicates that participants do not see **a significant relationship** with all KPIs across all of the BIM sub metrics. In comparison, the rest of the KPIs had a frequency and total of **Moderate**

(1.85-2.18), which shows that all participants see a **moderate relationship** with the remaining KPIs across all the BIM metrics. Moreover, Table 8.26 shows that KPIs with a significant relationship across all BIM metrics were:

- **Cost** with **EIR, CDE, As built model, PIM,** and **AIM,**
- **Time** with **EIR, CDE, 3D-6D inputs, Project reviews, As built model,** and **AIM,**
- **Quality** with **EIR, 3D-6D inputs, LoD, As built model, PIM, AIM, COBie data, GSL,** and **POE,**
- **Satisfaction** with **3D-6D inputs, PIM,** and **AIM,**
- **Health and Safety** with **As built model,** and **AIM,**
- **Performance** with **CDE** and **AIM,**
- **Profitability** with **AIM,**
- **Productivity** with **LoD, As built model, AIM, and GSL,**
- **Sustainability** with **CDE, Project reviews, As built model,** and **AIM,** and
- **Collaborative culture** with **EIR, CDE, LoD, As built model, PIM, AIM,** and **POE.**

This indicates that most of the KPIs had a strong relationship frequency with CDE and 'As built model', and both frequency and an overall average strong relationship with AIM **(2.35),** while the rest were moderate. **Cost, Time, Quality, and Collaborative Culture** had a strong relationship with most of the BIM sub metrics, and the remaining BIM and KPIs with a strong relationship indicates that those BIM and KPIs metrics are strongly related, which reflects on their maturity levels. No KPIs have a **Not significant** relationship across the BIM metrics, but the KPIs with a **Not Significant** relationship total across all BIM metrics were: **Cost** with **POE (1.40), Time** with **POE (1.40), Health and Safety** with **COBie data (1.20), Profitability** with **POE (1.40),** and **Sustainability with POE (1.40)**. This indicates that these KPIs will be reviewed to identify the existing issues that result in this relationship level. In addition, these KPIs would need to be highlighted to identify the actions that could be taken to upskill and move to another level, based on the proposed action plan (Section 7.4.5). The remaining BIM Maturity and KPI metrics had **a moderate relationship**, which indicates there is stability with both variables, that they are related at the same levels and could be reviewed to obtain a stronger relationship.

Organisations at this (operational) level would implement the proposed strong relationship and invest more in such relationships since these would help to enhance the organisational performance. Meanwhile, metrics in a medium relationship or less would need to be reviewed to determine what needs to be changed to allow the BIM Maturity and KPI metric relationships to move from this level to the next.

2. a) Inferential: Chi square test of relationship between BIM Maturity and KPI metrics

Table 8.27 demonstrates the results of the Chi square test across the implementation level. Those highlighted are the values which returned $p<0.05$ indicating that that there is no relationship between the BIM Maturity and KPI metrics.

Table 8.27 Chi Square tests results

KPI		Cost	Time	Quality	Satisfaction	Health and Safety	Performance	Profitability	Productivity	Sustainability	Collaborative Culture
Level 2 BIM	ISO19650	Asymp. Sig									
Information Requirements (EIR)	Exchange Information Requirement (EIR)	0.150	0.150	0.273	0.308	0.013	0.273	0.308	0.079	0.308	0.221
Document management stage- Common Data Environment (CDE)	<CDE> State	0.497	0.150	0.308	0.221	0.572	0.273	0.308	0.273	0.572	0.079
3D – 6D inputs		0.150	0.273	0.150	0.572	0.079	0.150	0.079	0.150	0.079	0.013
Level of Development (LoD)	Level of Information need	0.079	0.045	0.221	0.308	0.308	0.221	0.221	0.308	0.572	0.273
Project reviews		0.308	0.079	0.308	0.079	0.221	0.079	0.572	0.308	0.572	0.308
Lifecycle Analysis		0.273	0.308	0.150	0.007	0.308	0.150	0.045	0.273	0.221	0.045
As built model		0.221	0.308	0.273	0.273	0.572	0.273	0.221	0.221	0.572	0.221
Project Information Model (PIM) exchanges		0.221	0.308	0.150	0.273	0.572	0.273	0.045	0.221	0.221	0.273
Information Delivery (AIM)		0.150	0.150	0.150	0.150	0.221	0.007	0.221	0.079	0.079	0.079
COBie data		0.940	0.308	0.572	0.079	0.753	0.308	0.308	0.308	0.308	0.670
Handover requirements (GSL)		0.670	0.940	0.572	0.670	0.940	0.572	0.753	0.572	0.753	0.308
Post Occupancy Evaluation (POE)		0.572	0.572	0.572	0.572	0.308	0.753	0.572	0.940	0.572	0.221

Table 8.27 shows that only a few BIM maturity and KPI metric values returned values of $p<0.05$ indicating a statistical significance in the result. Therefore, the null hypothesis (H_o) that there is no relationship between BIM maturity and the KPIs is accepted, and the alternative hypothesis (H_1) that there is a relationship between BIM maturity and the KPIs is rejected. These were: Time with LoD (0.045), Satisfaction with Lifecycle analysis (0.007), Health and Safety with EIR (0.013), Performance with AIM (0.007), Profitability with Lifecycle analysis (0.045) and PIM (0.045), and Collaborative culture with 3D-6D inputs (0.013) and lifecycle analysis (0.045). Similar to the Strategic level results (Table 8.9), this indicates that the results given by participants at this organisational (operational) level determined an existing relationship between BIM maturity and the KPI metrics. The remaining values were $p>0.05$ indicating no statistical significance in the result. Therefore the null hypothesis (H_o) that there is no relationship between BIM maturity and the KPIs is rejected and the alternative hypothesis (H_1) that there is a relationship between BIM maturity and the KPIs is accepted, which answers the research question on whether if there is a relationship between BIM maturity and KPI metrics.

2. b) Kruskal Wallis test of independence between BIM maturity and KPI metrics

Table 8.28 demonstrates the results of the Kruskal Wallis test across the operational level; those highlighted are the values which returned p< 0.05 indicating that BIM Maturity and KPI metrics depend on each other.

Table 8.28 Kruskal Wallis test results

KPI		Cost	Time	Quality	Satisfaction	Health and Safety	Performance	Profitability	Productivity	Sustainability	Collaborative Culture
Level 2 BIM	**ISO19650**	**Asymp. Sig**									
Information Requirements (EIR)	Exchange Information Requirement (EIR)	0.678	0.935	0.939	0.415	0.166	0.509	0.394	0.107	0.443	0.366
Document management stage- Common Data Environment (CDE)	<CDE> State	0.675	0.606	0.293	0.449	0.162	0.651	0.790	0.835	0.320	0.346
3D – 6D inputs		0.905	0.419	0.189	0.228	0.288	0.339	0.408	0.905	0.345	0.095
Level of Development (LoD)	Level of Information need	0.534	0.528	0.938	0.856	1.000	0.446	0.899	0.485	0.799	0.508
Project reviews		0.831	0.871	0.765	0.439	0.351	0.439	0.200	0.831	0.138	0.831
Lifecycle Analysis		0.916	0.456	0.470	0.269	**0.026**	0.470	0.802	0.522	0.349	0.146
As built model		0.817	0.934	0.564	0.705	0.372	0.522	0.294	0.817	0.164	0.228
Project Information Model (PIM) exchanges		0.754	0.931	0.735	0.750	0.067	1.000	0.698	0.534	0.260	0.750
Information Delivery (AIM)		0.273	0.273	0.171	0.273	0.116	0.329	**0.019**	0.061	0.302	0.061
COBie data		0.342	0.398	0.459	0.240	0.564	0.749	0.398	0.398	0.749	0.475
Handover requirements (GSL)		0.646	0.200	0.494	0.646	**0.030**	0.230	**0.024**	0.245	0.067	0.056
Post Occupancy Evaluation (POE)		0.063	0.063	0.382	0.483	0.111	0.284	0.063	0.053	0.063	0.107

Table 8.28 shows that only a few BIM maturity and KPI metric values returned values of ρ<0.05 indicating a statistical significance in the result. Therefore, the alternative hypothesis (H_1) that there is independence between BIM maturity and the KPI metrics (KPI strength of relationship does not depend on BIM maturity level) is rejected or the null hypothesis (H_o) that there is no independence between BIM maturity and the KPI metrics (KPI strength of relationship depends on BIM maturity level) is accepted. These were: Health and Safety with Lifecycle analysis **(0.026)** and GSL **(0.030)**, Profitability with Uses **(0.019)** and GSL **(0.024)**. This may indicate that the results given by participants at this organisational level did not determine that the KPI strength of relationship would depend on the BIM maturity level across the non-highlighted values but rather that the KPI strength of relationship would depend on the BIM maturity level across those highlighted values. These will be examined further in the upcoming regression analysis to indicate if the KPI strength of relationship depends on the BIM maturity levels and to determine if they move in the same or different directions. The remaining values were p>0.05 indicating no statistical significance in the result and therefore, accepting the alternative hypothesis (H_1) that there is independence between BIM maturity and the KPI metrics, or rejecting the null hypothesis (H_o) that there is dependence between BIM maturity and the KPI metrics. This answers the research question on whether there is a relationship between BIM maturity and KPI metrics.

3. Spearman Correlation Coefficient analysis

Table 8.29 displays the results of the operational level correlations.

Table 8.29 Spearman Correlation Coefficient

Correlation between BIM maturity and KPI metrics			Cost	Time	Quality	Satisfaction	Health and Safety	Performance	Profitability	Productivity	Sustainability	Collaborative Culture
Spearman's rho	Level 2 BIM \ ISO19650 Information Requirements (EIR) \ Exchange Information Requirement (EIR)	Correlation Coefficient	0.230	-0.037	0.036	0.408	0.335	0.043	0.138	0.470	0.411	0.323
		Sig. (2-tailed)	0.522	0.919	0.922	0.241	0.344	0.906	0.703	0.171	0.238	0.363
		N	10	10	10	10	10	10	10	10	10	10
	Document management stage-Common Data Environment (CDE) \ <CDE> State	Correlation Coefficient	-0.076	0.165	0.486	0.377	0.439	0.007	0.144	0.156	0.411	0.485
		Sig. (2-tailed)	0.834	0.649	0.154	0.283	0.204	0.984	0.692	0.668	0.238	0.155
		N	10	10	10	10	10	10	10	10	10	10
	3D – 6D inputs	Correlation Coefficient	-0.040	0.269	0.438	0.402	0.354	0.319	-0.276	-0.040	0.315	0.557
		Sig. (2-tailed)	0.913	0.452	0.205	0.250	0.315	0.369	0.441	0.913	0.375	0.095
		N	10	10	10	10	10	10	10	10	10	10
	Level of Development (LoD) \ Level of Information need	Correlation Coefficient	0.327	0.136	-0.030	-0.147	0.000	0.328	0.149	0.384	0.217	0.335
		Sig. (2-tailed)	0.357	0.708	0.935	0.686	1.000	0.356	0.681	0.273	0.548	0.344
		N	10	10	10	10	10	10	10	10	10	10
	Project reviews	Correlation Coefficient	-0.031	0.163	-0.195	-0.229	-0.222	-0.229	-0.047	-0.031	0.104	-0.031
		Sig. (2-tailed)	0.933	0.652	0.589	0.525	0.537	0.525	0.897	0.933	0.774	0.933
		N	10	10	10	10	10	10	10	10	10	10
	Lifecycle Analysis	Correlation Coefficient	-0.075	0.288	-0.051	0.289	0.579	-0.051	-0.028	-0.298	0.146	0.222
		Sig. (2-tailed)	0.838	0.420	0.888	0.419	0.079	0.888	0.939	0.403	0.688	0.537
		N	10	10	10	10	10	10	10	10	10	10
	As built model	Correlation Coefficient	0.201	0.110	-0.078	0.149	0.343	0.341	0.313	0.201	0.562	0.563
		Sig. (2-tailed)	0.577	0.762	0.830	0.681	0.331	0.335	0.379	0.577	0.091	0.090
		N	10	10	10	10	10	10	10	10	10	10
	Project Information Model (PIM) exchanges	Correlation Coefficient	0.097	0.120	-0.231	0.224	0.448	0.000	0.250	0.340	0.389	0.224
		Sig. (2-tailed)	0.789	0.742	0.520	0.535	0.194	1.000	0.486	0.336	0.267	0.535
		N	10	10	10	10	10	10	10	10	10	10
	Information Delivery (AIM)	Correlation Coefficient	0.516	0.516	0.279	0.516	**.690***	0.470	**.890****	**.744***	0.458	**.744***
		Sig. (2-tailed)	0.127	0.127	0.436	0.127	**0.027**	0.171	**0.001**	**0.014**	0.184	**0.014**
		N	10	10	10	10	10	10	10	10	10	10
	COBie data	Correlation Coefficient	-0.242	-0.003	-0.273	0.142	-0.320	-0.172	-0.003	-0.003	-0.172	0.062
		Sig. (2-tailed)	0.501	0.992	0.446	0.696	0.367	0.634	0.992	0.992	0.634	0.865
		N	10	10	10	10	10	10	10	10	10	10
	Handover requirements (GSL)	Correlation Coefficient	0.250	0.582	0.286	0.250	**.884****	0.572	**.892****	0.510	**.771****	**.794****
		Sig. (2-tailed)	0.486	0.077	0.423	0.486	**0.001**	0.084	**0.001**	0.132	**0.009**	**0.006**
		N	10	10	10	10	10	10	10	10	10	10
	Post Occupancy Evaluation (POE)	Correlation Coefficient	0.517	0.517	0.021	-0.074	0.331	0.244	0.517	0.539	0.517	0.333
		Sig. (2-tailed)	0.126	0.126	0.954	0.839	0.350	0.496	0.126	0.108	0.126	0.346
		N	10	10	10	10	10	10	10	10	10	10

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

The results show that BIM Maturity and KPI metrics reported a number of Sig. values ranging from 0.008 to 0.045, and highlighted in black. Only a limited number of values were returned at significant ρ=**0.01 and ρ=*0.05, which are also highlighted (in black) in the table.

1. The KPIs that returned a ρ=**0.01 level and less than 0.01 that indicated very strong evidence to reject the null hypothesis were: Health and Safety with Handover Requirements (GSL) **(.884**; ρ=0.001)**, Profitability with Information Management (AIM) **(.890**; ρ=0.001)**, and GSL **(.892**; ρ=0.001)**, Sustainability with GSL **(.771**; ρ=0.009)**, and Collaborative Culture with GSL **(.794**; ρ=0.006)**.
2. The KPIs that returned a ρ=*0.05 level and between 0.05-0.01 that indicated strong evidence to reject the null hypothesis were: Health and Safety with AIM **(.690*; ρ=0.027)**, Productivity with AIM **(.744*; ρ=0.014)**, and Collaborative Culture with AIM **(.744*; ρ=0.014)**.
3. The KPIs that did not return significant values ρ=0.05 and ρ=0.01 (2-tailed) levels were: Cost, Time, Quality, Satisfaction, and Performance.
4. The results that did not return values of more than 0.1 (More than 10% chance), with a probability level = weak to no evidence to reject the null hypothesis, or between 0.1-0.05 (between 10%-5% chance) with a probability level = weak evidence to reject the null hypothesis.

Figure 8.23 and Table 8.30 demonstrate the results of the operational level strength of relationship.

Organisation Level		KPIs									
Operational		Cost	Time	Quality	Satisfaction	Health and Safety	Performance	Profitability	Productivity	Sustainability	Collaborative Culture
+		BIM sub metrics									
Significant (Strong) (0.7-1.0)	7					(GSL)		(AIM) (GSL)	(AIM)	(GSL)	(AIM) (GSL)
Moderate (Medium) (0.3-0.7)	45	(AIM) (POE) (LoD)	(GSL) (AIM) (POE)	3D – 6D inputs (CDE)	(AIM) (EIR) (CDE) 3D – 6D inputs	(AIM) Lifecycle Analysis (POE) (CDE) 3D – 6D inputs As built model (PIM) (EIR)	(GSL) (AIM) (LoD) 3D – 6D inputs As built model	(POE) As built model	(LoD) (POE) (GSL) (EIR) (PIM)	(POE) As built model 3D – 6D inputs (CDE) (EIR) (PIM) (AIM)	As built model (CDE) (LoD) (POE) (EIR) 3D – 6D inputs
Not significant (Weak) (0.1-0.3)	29	As built model (GSL) (EIR)	(LoD) 3D – 6D inputs As built model Project reviews (PIM) (CDE) Lifecycle Analysis	(AIM) (GSL)	(GSL) As built model COBie (PIM) Lifecycle Analysis		(POE)	(CDE) (LoD) (PIM) (EIR)	(CDE) As built model	(LoD) Project reviews Lifecycle Analysis	(PIM) Lifecycle Analysis
No Relationship (None) (0.0-0.1)	9	(PIM)		(LoD) (EIR) (POE)		(LoD)	(CDE) (PIM) (EIR)				COBie
−											
No Relationship (None) (-0.1 _ 0.0)	17	(CDE) Project reviews 3D – 6D inputs Lifecycle Analysis	COBie (EIR)	As built model Lifecycle Analysis	(POE)		Lifecycle Analysis	COBie Project reviews Lifecycle Analysis	3D – 6D inputs Project reviews COBie		Project reviews
Not significant (Weak) (-0.3_- 0.1)	12	COBie		COBie (PIM) Project reviews	(LoD) Project reviews	Project reviews	Project reviews COBie	3D – 6D inputs	Lifecycle Analysis	COBie	
Moderate (Medium) (-0.7 _ -0.3)	1					COBie					
Significant (Strong) (- 1.0_ - 0.7)											

Figure 8.23 Spearman Correlation Coefficient: Strength of relationship

Table 8.30 Spearman Correlation Coefficient: Strength of relationship

The Evidence = Examining the Relationship between BIM Maturity and KPI metrics based on 10 participants							Current BIM Maturity-KPI relationship total						
Sub Metrics		Maturity level	Operational Level	(Operating BIM across the organisation / project, and how the management of information being collected is achieved.)			Significant (Strong) = (-1.0 _ -0.7)				Significant (Strong) = (0.7 - 1.0)		
Secondary metrics associated with the main BIM metrics that is expected to be measured to achieve BIM		Awareness	Distributing the correlation between the BIM Maturity and KPI metrics				Moderate (Medium) = (-0.7 _ - 0.3)				Moderate (Medium) = (0.3 - 0.7)		
		Occasional Application					Not significant (Weak) = (-0.3 _ -0.1)				Not significant (Weak) = (0.1 - 0.3)		
		Consistency					No Relationship (None) = (-0.1 - 0)				No Relationship (None) = (0 - 0.1)		
Level 2 BIM	ISO19650	Maturity Level	Cost	Time	Quality	Satisfaction	Health and Safety	Performance	Profitability	Productivity	Sustainability	Collaborative Culture	Correlation
Information Requirements (EIR)	Exchange Information Requirement (EIR)	2.20	0.230	-0.037	0.036	0.408	0.335	0.043	0.138	0.470	0.411	0.323	0.236
Document management stage- Common Data Environment (CDE)	<CDE> State	2.40	-0.076	0.165	0.486	0.377	0.439	0.007	0.144	0.156	0.411	0.485	0.259
3D – 6D inputs		2.00	-0.040	0.269	0.438	0.402	0.354	0.319	-0.276	-0.040	0.315	0.557	0.230
Level of Development (LoD)	Level of Information need	2.40	0.327	0.136	-0.030	-0.147	0.000	0.328	0.149	0.384	0.217	0.335	0.170
Project reviews		1.90	-0.031	0.163	-0.195	-0.229	-0.222	-0.229	-0.047	-0.031	0.104	-0.031	-0.075
Lifecycle Analysis		2.00	-0.075	0.288	-0.051	0.289	0.579	-0.051	-0.028	-0.298	0.146	0.222	0.102
As built model		2.10	0.201	0.110	-0.078	0.149	0.343	0.341	0.313	0.201	0.562	0.563	0.271
Project Information Model (PIM) exchanges		2.00	0.097	0.120	-0.231	0.224	0.448	0.000	0.250	0.340	0.389	0.224	0.186
Information Delivery (AIM)		1.80	0.516	0.516	0.279	0.516	.690*	0.470	.890**	.744*	0.458	.744*	0.582
COBie data		1.90	-0.242	-0.003	-0.273	0.142	-0.320	-0.172	-0.003	-0.003	-0.172	0.062	-0.099
Handover requirements (GSL)		2.00	0.250	0.582	0.286	0.250	.884**	0.572	.892**	0.510	.771**	.794**	0.579
Post Occupancy Evaluation (POE)		1.60	0.517	0.517	0.021	-0.074	0.331	0.244	0.517	0.539	0.517	0.333	0.346
Current Maturity level (Total)		2.03	0.116	0.229	0.057	0.163	0.322	0.108	0.245	0.248	0.344	0.384	0.232
**. Correlation is significant at the 0.01 level (2-tailed).													
*. Correlation is significant at the 0.05 level (2-tailed).													

Figure 8.23 and Table 8.30 show that:

1) Unlike the KPIs at the strategic level which retuned significant correlation values, only **Health and Safety, Profitability, Productivity, Sustainability, and Collaborative Culture** returned significant correlation with BIM maturity metrics.
2) The returned significant values were all positive indicating that, as BIM maturity levels increase, the KPI strength of relationship with BIM maturity increases.
3) The returned positive significant values between BIM maturity and KPI metrics indicate a strong relationship between BIM maturity and KPI metrics and strong evidence that, as the BIM maturity levels increase, the KPI strength of relationship with BIM maturity increases. These are: **Health and Safety with GSL** (.884**; ρ=0.001), **Profitability with AIM** (.890**; ρ=0.001), **and GSL** (.892**; ρ=0.001), **Sustainability with GSL** (.771**; ρ=0.009), and **Collaborative Culture with GSL** (.794**; ρ=0.006). KPIs that returned ρ = 0.05 level are: **Health and Safety with AIM** (.690*; ρ=0.027), **Productivity with AIM** (.744*; ρ=0.014), and **Collaborative Culture with AIM** (.744*; ρ=0.014).
4) The returned positive significant value between BIM maturity and KPI metrics indicate a medium relationship between BIM maturity and KPI metrics and medium evidence that, as the BIM maturity levels increase, the KPI strength of relationship with BIM maturity increases. This is: **Health and Safety with AIM** (.690*; ρ=0.027).

5) Similar to the KPIs at the implementation level, which returned negative values across a number of KPIs, the results indicated that all KPIs returned either positive values indicating either as the maturity level increases/decreases the KPI relationships increase/decrease with strength of relationship and strength of evidence values ranging from **No relationship (0.000) to Strong (.890).** Alternatively, it returned negative values indicating an opposition which meant as the maturity level increases/decreases, the KPI relationships decrease/increase with strength of relationship and strength of evidence values ranging from **No relationship (-0.000) to Medium (-0.320)**.
6) Only GSL and AIM retuned significant correlation values.
7) The most 'strength of relationship and evidence values' returned was in the positive moderate category, and the least values returned was in the negative moderate category, indicating more of a moderate relationship and moderate evidence that, as the BIM maturity levels increase, the KPI strength of relationship with BIM maturity increases.

Having presented the findings of the Spearman Correlation Coefficient, the next section will discuss the findings of the regression analysis.

4. Regression analysis

Table 8.31 presents the complete list of results for the operational level while the scatter plot tables between BIM maturity and each KPI are available in Appendix G.

Table 8.31 Scatter plot diagram results

KPI	Regression formula	Scatterplot interpretation
Cost	$\hat{y}$ = 1.23+0.41X, R^2 Linear= 0.081	Weak Positive Linear
Time	$\hat{y}$ = 1.09+0.47X, R^2 Linear= 0.101	Weak Positive Linear
Quality	$\hat{y}$ = 1.91+0.13X, R^2 Linear= 0.027	Weak Positive Linear
Satisfaction	$\hat{y}$ = 1.76+0.14X, R^2 Linear= 0.023	Weak Positive Linear
Health and Safety	**$\hat{y}$ = 1.94+0.12X, R^2 Linear= 0.012**	**Weak Negative Linear**
Performance	$\hat{y}$ = 1.22+0.42X, R^2 Linear= 0.119	Weak Positive Linear
Profitability	$\hat{y}$ = 1.62+0.11X, R^2 Linear= 0.012	Weak Positive Linear
Productivity	$\hat{y}$ = 1.06+0.47X, R^2 Linear= 0.218	Weak Positive Linear
Sustainability	$\hat{y}$ = 1.68+0.09X, R^2 Linear= 0.008	Weak Positive Linear
Collaborative Culture	$\hat{y}$ = 0.78+0.64X, R^2 Linear= 0.342	Weak Positive Linear
OPERATIONAL LEVEL (BIM AND KPIs)	$\hat{y}$ = 1.43+0.28X, R^2 Linear= 0.086	Weak Positive Linear

Table 8.31 shows that the following KPIs returned a positive regression, indicating that as the BIM maturity levels increase the KPI strength of relationship increased: Weak = Cost, Time, Quality, Satisfaction, Performance, Profitability, Productivity, Sustainability, Collaborative Culture, and the total BIM maturity and KPIs across the Operational level. This shows that the aforementioned KPI strength of linearity would depend on the BIM maturity levels and would move in the same direction. Thus, as BIM maturity levels increase, the KPI strength of relationship increases. The following KPIs returned a negative regression indicating the opposite direction that, as the BIM maturity levels increase/decrease, the KPI strength of relationship

decreases/increases: Weak= Health and Safety. This shows that the aforementioned KPI strength of linearity would not depend on the BIM maturity levels and that it would move in a different direction (as BIM maturity levels increase/decrease, the KPI strength of relationship decreases/increases). Having presented the analysis and findings of the operational level, the next section will present the analysis and findings of all organisational levels combined.

8.4.2.5 Summary of the descriptive and inferential statistics across all organisational levels

This section presents the outcomes of the descriptive and inferential statistical analysis carried out across all organisational levels. Having conducted detailed analysis on the existing relationships between the BIM Maturity sub metrics and KPIs across all organisational levels, this section aims to summarise the outcomes of the relationships based on the participants' point of view. The participants were required to assess their BIM maturity levels for the presented BIM Maturity sub metrics across the three organisational levels (strategic, implementation, and operational) using three maturity levels (1= Awareness, 2= Occasional application, and 3= Consistency). They then identified the KPI strength of relationship through four relationship levels [0=No relationship (None), 1=Not Significant (Weak), 2=Moderate (Medium), 3=Significant (Strong)]. The results revealed the following outcomes for the BIM maturity levels and their relationship to the KPIs:

1. Across all three organisational levels, in terms of the maturity level scores (Tables 8.5, 8.16, 8.24), 21 participants in total scored themselves in the Occasional Application maturity level across all organisational levels.
2. Only two participants scored themselves in the Awareness level (5%), 21 participants in total scored themselves in the Occasional Application level (52.5%), and 17 participants in total scored themselves in the Consistency maturity level (42.5%). This indicates that the majority of participants see themselves as adopting and implementing BIM sub metrics across all organisational levels and believe they are either in the Occasional Application or the Consistency maturity level.

1. Descriptive: Frequencies and Relationships between BIM maturity and KPI metrics

Furthermore, the results (Tables 8.7, 8.18, 8.26) indicate a relationship across all the BIM maturity and KPIs metrics at all organisational levels. Most relationships were either at the **Occasional Application level and Moderate relationship or Consistency level and Significant relationship**, with a few at the **Awareness level and Weak relationship,** which aligns with the aim of this research, namely to identify the potential relationships between BIM maturity and KPI metrics. The KPIs that did not return a **Consistency-Significant relationship** across all organisational levels indicates that these KPIs do not have a **Consistency-Significant relationship** across the BIM metrics unlike the remaining KPIs, which shows that participants did not see a strong relationship across these KPIs that would reflect on the BIM maturity levels and the need to revisit them through proposed action plans to determine actions to take to enable them to move towards and maintain a **Consistency-Significant relationship**.

In addition, as Collaborative Culture is added as an additional KPI (based on the interview findings), the results showed that the relationships between Collaborative Culture and the majority of the BIM metrics across all three organisational levels were **Consistency-Significant relationship.** This confirms the importance of Collaborative Culture as a KPI and reinforces the decision to add this to the proposed list of KPI metrics for assessment. Having presented the outcomes of the BIM maturity and KPI metric relationships, the next section will present the outcomes on how BIM maturity and KPI metrics are associated.

2. a) Inferential: Organisational level Chi square test of relationship between BIM and Maturity KPI metrics

Across all three organisational levels, in the Chi square test of relationship results (Tables 8.9, 8.19, 8.27), most values were $p>0.05$ indicating no statistical significance in the result and therefore, accepting the alternative hypothesis (H_1) that there is a relationship between BIM maturity and the KPI metrics. This answers the research question 'is a relationship between BIM maturity and KPI metrics?' This was achieved at the strategic and operational level, thus participants recognised a relationship between BIM maturity and the KPI metrics. However, at the implementation level, the number of returned values was $\rho<0.05$ indicating a statistical significance in the result, and therefore rejecting the alternative hypothesis (H_1) that there is a relationship between BIM maturity and the KPIs. This may indicate that participants at this organisational level did not recognise a relationship between BIM maturity and KPI metrics. This was examined across the Spearman Correlation to determine the strength of relationship between BIM maturity and KPI metrics and the direction in which they are both moving (Same=positive and Different=negative). Having presented the Chi square test of relationships between the BIM maturity and KPI metrics, the next section will demonstrate the results of the Kruskal Wallis test of independence.

2. b) Kruskal Wallis test of independence between BIM maturity and KPI metrics

Furthermore, it can be seen that, in terms of the Kruskal Wallis test results across all organisational levels (Tables 8.11, 8.20, 8.28), only a limited number of BIM maturity and KPI metric values returned values of $\rho<0.05$. This indicates a statistical significance in the result, and therefore, rejecting the alternative hypothesis (H_1) that there is independence between BIM

maturity and the KPI metrics (KPI strength of relationship does not depend on BIM maturity level). The results suggest that participants across all organisational levels do not see an impact from the BIM maturity levels on the KPIs' strength of relationship to the BIM maturity metrics. This was examined across the linear regression analysis to determine if there is a linear relationship between BIM maturity and the KPI metrics, and an impact on the value change in the BIM maturity on the KPI metrics. Having presented the Kruskal Wallis test of independence between the BIM maturity and KPI metrics, the next section
will demonstrate the results of the Spearman Correlation coefficient analysis.

3. Spearman Correlation Coefficient analysis

Across the three organisational levels (Tables 8.12, 8.21, 8.29), the majority of the BIM Maturity sub metrics returned positive values with the KPIs indicating that, as the maturity level increases/decreases the KPI relationships increase/decrease and that both BIM Maturity and KPI metrics are related to each other. Only a limited number of BIM Maturity and KPI metrics values were signified as a statistical significance of ρ=0.05 and ρ=0.01 (2-tailed) levels. This indicates that the observed correlation is unlikely to be due to chance and there is a very high probability that the null hypothesis is wrong. Also, a number of KPIs returned ρ=**0.01 level and less than 0.01 indicating very strong evidence to reject the null hypothesis. KPIs returned ρ=*0.05 level and between 0.05-0.01 indicating that there is strong evidence to reject the null hypothesis. Moreover, values that did return values more than 0.05 meant they would accept the alternative hypothesis that there is a correlation between the BIM maturity and KPI data sets, and hence, the results were not statistically significant. Although the values indicated the strength of the relationships (Tables 8.12, 8.21, 8.29), they did not clearly distinguish the strength of relationships between BIM Maturity and KPI metrics, and thus needed further examination to determine the actual strength of relationships between BIM Maturity and KPI metrics. These were presented in the correlation interpretation coloured tables (Tables 8.14, 8.22, 8.30). Since there are three organisational levels with various numerical values, it was worth comparing those results in a more meaningful and simple way to visualise and see how the BIM Maturity and KPI metrics related. These were presented in Figures 8.19, 8.22, 8.23 which detailed the KPIs on the horizontal axis and their relationship with the BIM Maturity metrics on the vertical axis. These figures showed: which of the BIM Maturity metrics had positive values and their strength of relationship, and those with the negative values and their strength of relationship. Having presented the results of the Spearman Correlation analysis, the next section will demonstrate the strength of linearity between BIM Maturity and KPI metrics through the scatter plot interpretations and the impact of the value change in the BIM maturity metric levels on the KPIs strength of relationships.

4. Regression analysis

Across the three organisational levels (Tables 8.15, 8.23, 8.31), is a linear relationship between the BIM maturity and KPI metrics. The strength of the linear relationship returned either a weak positive or a moderate positive linear relationship across all organisational levels, as the scatter dots deviate from the line and indicate that, as BIM Maturity increased/decreased, the KPI relationships increased/decreased. Only a limited number of relationships returned a weak negative linear relationship across all organisational levels where the scatter dots deviate from the line and indicate that, as BIM Maturity increased, the KPI relationships decreased and vice versa. Since this was examined across the sample of 40 questionnaire respondents, it was necessary to examine this with different samples to see if the same results would be returned, which would indicate if the results could be generalised in terms of existing linear relationships. Results of all the scatter plots between the BIM Maturity metrics and all KPIs across the three organisational levels are included in Appendix G. Having presented a summarised finding of the BIM Maturity and KPI metrics relationships, the next section presents the additional proposed BIM Maturity and KPI metrics.

8.4.2.6 Additional BIM Sub Metrics-KPIs to be included

The last part of the BIM maturity and KPI relationship assessment was to seek more information on additional BIM Maturity metrics, or KPIs. Overall, 95% of the participants viewed that no additional information was required to the existing BIM Maturity and KPI metrics. However, there have been some minor recommendations as to assessment inclusions across the three organisational levels (Table 8.32).

Table 8.32 Additional BIM / KPIs / BIM-KPIs to be included

BIM Sub Metrics		**KPIs**
1) Supply chain management **2) More on behaviours, like innovation, communication, etc.** (Strategic)		**Understanding** (Strategic)
Level of Development (Implementation)		**Clash Detection** (Implementation)
Plain Language Questions (Operational)	**Project Information Requirements (PIR)**	**Depends on organisational goals** (Any Organisation level)

Digital KPI Area	**KPI Item**	**KPI Measure 1**
BIM	**Training**	Training hours promised
BIM	**Clash Detection**	Number of clashes detected/resolved in Pre-Construction
Quality	**QA Inspections**	Number of QA Inspections
Compliance	**Snags/defects**	Number of snags identified & closed in Construction
Safety	**Hazard Identification**	Number of hazards Identified & Mitigated in Pre-Construction
BIM	**Asset Data Compliance**	Number of assets identified in Pre-Construction

It can be assumed that the presented information would be applicable across all three organisational levels. Table 8.32 shows that for the:

1) Strategic level, there has been a suggestion to include Supply Chain Management, and behaviours; innovation and communication as additional BIM Maturity sub metrics and Understanding KPIs and how they would be measured as a new KPI metric.
2) Implementation level there has been suggestion to include the Level of Development. Although it exists at the operational level, it can be assumed that if the participant was to fill out the operational level, they would have not proposed this inclusion, or that the sub metric should also be included at the implementation level. Clash detection was also proposed for inclusion as a KPI, which was mentioned previously in the interview findings. This suggests it could work across all three organisational levels.
3) Operational level there has been a suggestion to include Plain Language Questions as a new BIM Maturity metric. If it is to be translated to the new BS EN ISO19650 standards, it would read as Project Information Requirement (PIR). For the KPIs, an indicator that would depend on organisational goals.

Finally, from a working group with the NWCH, the proposed combined BIM- KPIs were:

1) BIM as a digital KPI comprising four key areas: a) BIM, b) Quality, c) Compliance, and d) Safety.
2) KPIs would be: a) Training; Training hours promised, b) Clash detection; number of clashes detected, c) QA inspections; number of QA inspections, d) Snags/defects; number of snags identified, e) Hazard Identification; number of hazards identified, and f) Asset Data Compliance; number of hazards identified.

This concludes this section, and the last section will present findings from the assessment from the participants' points of view.

8.4.3 Section 3: Assessment feedback, expected benefits, recommendations and conclusion

Having conducted the BIM maturity assessment across the three organisational levels and having established a relationship between BIM maturity and KPI metrics, the third and final section of the questionnaire seeks to demonstrate feedback from the presented assessment, along with benefits expected, and recommendations to take this assessment forward. Nine questions and some sub questions were asked to collect this data. As mentioned earlier three participants dropped out from answering these questions, thus this section had responses from forty participants, which was the total number of completed responses returned.

This section presents the personal opinion of participants concerning the conducted assessment. The results showed that 24 participants were able to see that measuring the maturity level would determine the impact of BIM Maturity on the measured KPI outcome (60%), whereas only one disagreed when assessing the impact, and 15 selected maybe (37.5%). This shows that most participants are able to determine the impact of BIM Maturity on the measured outcomes, which supports the assessment in that BIM maturity and KPI metrics reflect on each other.

When asked about reasons behind this, Figure 8.24 presents a summary of the reasons. The reasons provided are based on responses from 37 participants (three did not give their reasons). The results show eight key topic areas to determine the impacts, and most participants perceived an existing relationship such that the impact would occur (nine indicated this representing 24% of the different reasons given). After this, reasons for both the baseline and benchmark, and the benefits of linking both were given by seven each (19%), while four indicated difficulties in measuring BIM with KPIs (11%), three (8%) indicated the following reasons: More information required, future improvements and better implementation, deficiencies with the assessment, and nothing additional to occur. Finally, one participant indicated the need for more knowledge/experience to determine the impact. The results show that 60% of participants recognised the existing relationship, that benefits would occur from this and that this could be provided as benchmark. However, 40% of the participants saw there could be difficulties in measuring both, which could result in deficiencies with the assessment, which would require more information, future improvement and more knowledge. This indicates a number of strengths and weaknesses associated with the assessment and future considerations that need to be addressed.

	Name	Description	Examples	Number of discussions
1)	Relationship exist	Acknowledgement of a relationship that exist and information supporting it	*"Because BIM Maturity and KPI are totally related"*	$\boxed{9}$
2) a)	Baseline and benchmark	Agreement to the link and information that sets starting points to benchmark this	*"Useful in benchmarking performance and identifying shortfalls in knowledge and process efficiency"*	7
b)	Benefits of linking both	Additional benefits expected to occur to link both	*"BIM is meant to increase efficiency and reduce waste and cost and the KPI measured outcomes are a means to benchmark and improve processes."*	7
3)	Difficult to measure BIM with KPIs	Discussions that revolves around the difficulty of linking BIM with KPIs	*"It is hard to measure BIM maturity with KPI's"*	4
4) a)	More information required	Information that is still required to support current findings	*"I feel there needs to be robust guidance and evidence on the links between BIM maturity and KPI's."*	3
b)	Future improvement and better implementation	Future steps required to take	*"it would help to better implement the process"*	3
c)	Deficiencies with the assessment and nothing additional to occur	Issues faced with the assessment and nothing new to add to organisation	*"More to it than that after all it would be a different person that would complete it than the person that analysis the KPI's"*	3
5)	More knowledge / experience	Provision of more knowledge and experience	*"The more knowledge/experience that you have about BIM the more likely you are to determine the impact of BIM and KPI's"*	1

Percentage

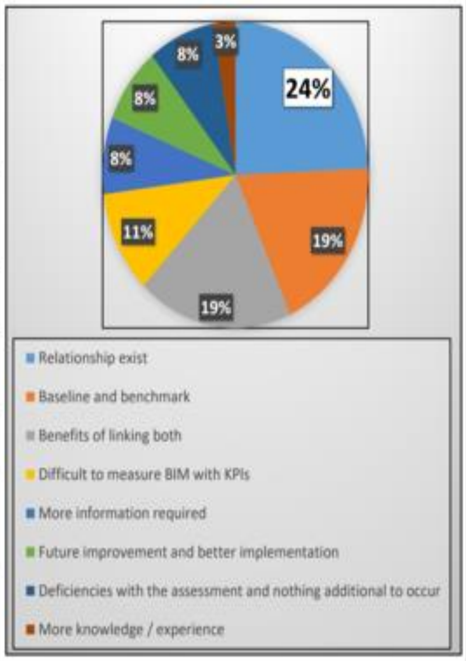


Figure 8.24 Determining the impact of BIM on KPI measured outcomes reasons

Furthermore, there is an expectation that the BIM maturity levels would impact on the KPI strength of relationships. The results showed that 30 participants were unable to see the impact of their level of maturity scores on the KPIs' strength of relationship scores (87.5%), and only five agreed on the impact (12.5%). This shows that most of the participants were not able to score the KPIs' strength of relationship based on BIM metrics' maturity level. Instead these were based on the metrics in general, which indicates that the assessment would be conducted separately based on BIM maturity level. After this the KPIs strength of relationship would be established based on BIM metrics outcome in general and not on its maturity level. The mechanism for BIM maturity and KPI metrics to work separately could represent a minor limitation in this research, which aims to demonstrate the KPI strength of relationships based on BIM maturity level. Instead, the participants recognise the KPI metrics relationship from the metrics in general and not from its maturity level. To those five participants who answered yes, they established that the impact would occur by reducing reworks and enhancing the level of coordination and programme on complex projects. Two specified that it helps to identify the BIM levels within the organisation and across the wider industry, as more productivity would occur, and the more mature the company is with BIM maturity, the higher the level of KPI scores generated by the company. When questioning the same participants about their BIM maturity level and its impact on the overall organisational/project performance, they all agreed that it would deliver the necessary impact. This suggests that there is a potential impact between both BIM maturity and KPI metrics which reflects on the overall organisational/project performance by improving current defects, and replacing them with drivers and performance enhancements. However, this would not be the case with the remaining participants, which represents a limitation for this research, but will not impact on the research findings on developing the proposed framework.

Figure 8.25 presents a summary of the level of agreement between the benefits expected to emerge from the combined BIM maturity and KPI metrics presented on the conceptual framework (Section 4.5.3). The results show that most participants agreed with the presented benefits as 12 responses were received for reduced lifecycle cost and 23 for improved certainty and reduction of uncertainty (37.5-57.5%). This was followed by strongly agreement with the benefits, while six responses were received for improved safety and 15 for reduced lifecycle cost (15-37.5%). A number of participants selected neutral, namely three responses were received for improved collaboration and improved certainty while 15 were received for improved safety. Most of the benefits received between nine and 13 neutral responses (22.5-32.5%). In addition, between one and three participants disagreed on the benefits to emerge, and one to two participants strongly disagreed on the benefits. The results shows that, across all the presented benefits more participants strongly agreed to reducing the lifecycle cost as a key benefit. Moreover, when averaging the percentages, almost 43% agreed to the benefits, followed by 27% who strongly agreed, then 23% who were neutral, while approximately 4% disagreed and around 3% strongly disagreed with the benefits. This shows that 70% either agreed or strongly agreed with the proposed benefits from combining BIM maturity and KPI metrics, which indicates there could be benefits to emerge from this linkage, and further supports the benefits addressed in the conceptual framework (Section 4.5.3).

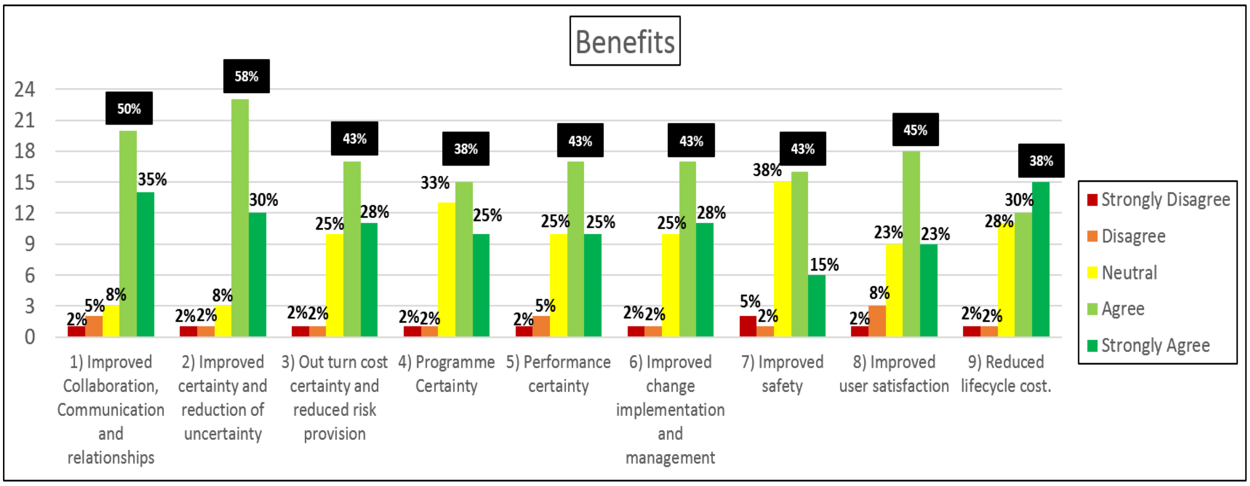


Figure 8.25 Level of agreement to the benefits of linking BIM maturity and KPIs together

Furthermore, 34 stated that there would not be benefits beyond those presented (85%), whereas six indicated that there could be benefits to emerge (15%). This indicates that the presented benefits would present a benchmark and baseline to benefits that would emerge from combining both and validates the previous findings concerning the benefits across the interviews. Amongst those who said yes to the emergence of further benefits, they also listed: Environment benefits, Collaboration, Client satisfaction, Better facilities management, efficient buildings, outcome benefits (Table 8.33). This indicates potential further benefits that could occur from combining BIM maturity and KPI metrics, which may inform future research on the expected benefits.

Table 8.33 Additional benefits

Benefits
Environmental benefits - considering programme, re-works etc.
Collaboration
Again client satisfaction when it comes to potentially winning more work with the same client.
Better Facilities Management
Better and more efficient buildings / assets
Outcome benefits, not just output benefits

In terms of organisations adopting the proposed BIM maturity assessment (Section 6.8), the results show that 25 participants agreed that organisations may adopt the proposed assessment (62.5%), whereas 15 disagreed on this (37.5%). This confirms one of the objectives of this research, namely to present a BIM maturity assessment to be used across organisations to assess BIM projects and organisational performance, which represents a major contribution to practice. Of those 25 who said yes, they were asked for their reasons and about the impacts that could result to help measure the organisational performance. Figure 8.26 presents a summary of the reasons. It shows that eight key topic areas in relation to adopting the assessment in organisations, which are as follows: Six indicated that highlighting training requirements would be a reason to adopt the assessment, five recognised the impact of future requirements, such as the application of KPI metrics across all projects and not just BIM. Four identified levels of improvement across organisations, and three were still unsure how it would be adopted. Furthermore, two each who believed it would assign a benchmark and standards across organisations and provide a focus to move forward, and finally, one each indicated that it would enhance communication and benefits such as “*improved overall product to client, improved quality and performance, and less rework*”. These views enhance the delivery of the assessment, indicate that it could contribute to organisations in various ways, and ensure that it enhances an organisation’s performance, whilst providing additional benefits and setting a benchmark to assess organisations to determine their current maturity levels.

	Name	Examples	Number of discussions	Percentage
1)	Training	*"A L2 assessment would highlight where processes need to be improved and highlight training requirements for staff."*	6	
2)	Future consideration	*"KPI's should happen on all projects, not just level 2 BIM projects"*	5	
3)	Improvement	*"Level of improvement across the board"*	4	
4)	Undecided	*"Depends on adoption"*	3	
5) a)	Benchmark and setting standards	*"It will provide us with the relevant benchmarks"*	2	
b)	Focus and move forward	*"Lessons learned & focus going forward"*	2	
6) a)	Enhanced communication	*"Consistent and common approach across projects enabling more effective communication between staff and clients"*	1	
b)	Benefits	*"Improved overall product to our client, improved quality, less rework, improved performance etc"*	1	

Figure 8.26 Reasons for adopting the proposed BIM assessment

Furthermore, the 15 who said no were asked for their reasons and Figure 8.27 presents a summary of these reasons. It shows that seven key topic areas in relation to not adopting the assessment in organisations, which are as follows: four indicated that they would be using their own in house assessments, and an example of this was "*bespoke assessments*", while three each indicated that either there were difficulties with the assessment when measuring BIM maturity and KPI metrics or they were unsure about how would they adopt the assessment. Two indicated that there was need for organisational change in order to implement the assessment and to raise awareness amongst practitioners in the industry. In addition, one each indicated the following reasons: "*BIM not being a requirement*", "*BIM not affecting KPIs*", and "*BIM level 2 to be replaced with the digital framework (ISO19650) and transferring the new terms to the future assessment*". This indicated some challenges with implementing the assessment across organisations since there are some issues with measuring BIM maturity and KPI metrics together, and a need to transfer to the new BS EN ISO19650 standard (UK BIM framework. 2019b). Moreover, existing assessments could be favoured over the present assessment, while organisations need to change, and some problems exist with the current assessment. This indicates that the assessment (Section 6.8) would need to be introduced to organisations that would need to be educated on how to use it.

	Name	Examples	Number of discussions	Percentage
1)	In house assessment	*"Currently run our own in-house assessment"*	4	
2) a)	Difficulties with Assessment	*"It is hard to measure BIM maturity with KPI's"*	3	
b)	Undecided	*"Not sure about that"*	3	
3)	Organisation change	"I think it would need to be an organisation change that could be implemented if a focus group were to raise awareness of issues to senior management."	2	
4) a)	Requirements	*"BIM is not a client driven requirement"*	1	
b)	Challenges affecting both	*"BIM is not the only factor affecting KPI's"*	1	
c)	Snapshot of time	*"Unfortunately, the timing of this survey is such that BIM Level 2 will soon be replaced by Digital Framework (July 2019), but the principle could be transferred to the future measurement process"*	1	

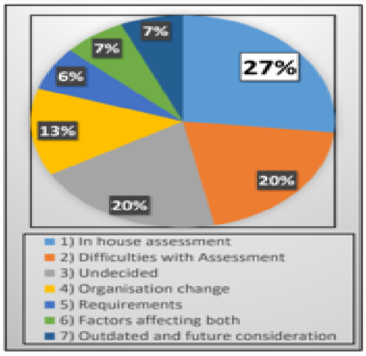


Figure 8.27 Reasons for not adopting the proposed BIM assessment

Figure 8.28 demonstrates a summary of the results on the potential ways that the proposed assessment could be introduced within organisations in order to measure their levels of maturity, link them with the KPI metrics and examine their organisational/project performance. Some participants gave more than one strategy to introduce the assessment. The results show seven key topic areas that would be considered to introduce the assessment, and most participants stated that they would consider applying education and training schemes within their organisations to introduce the assessment (23 stated this, representing 55% of the strategies). This was followed by other strategies, such as "top down" "Project Level" "Discovery day" (five stated this representing 12%). Four each (9% each) stated that they would use workshops and meetings such as a "*BIM kick off meeting*" to introduce the assessment, and use online resources, such as "Online Assessments", as a strategy to introduce the assessment. Finally, two each noted the following strategies: Consideration of external help- "*External BIM provider*" and Reports and annual reviews – "*Staff technical annual review*". However, two were not able to define a strategy or found it difficult to offer ideas on how they could introduce the assessment. This shows that a strategy that would be needed to introduce the assessment so that users fully understood it. These results suggest that the assessment could be easy to introduce across organisations through the presented seven key topic areas. This represents a key contribution of this research, namely that the assessment would work in organisations and various ways could be used to introduce it to enhance organisational/project performances.

	Name	Description	Examples	Number of discussions	Percentage
1)	Education and Training	Usage of various training and educational schemes	*"Educational and Training schemes"*	23	
2)	Others	Additional information related	*"From the top down", "At project Level", "Discovery day"*	5	
3)	Workshops and meetings	Informative workshops and meetings	*"As part of a BIM Kick off meeting or as part of our BIM review workshops"*	4	
b)	Online resources	Usage of various online tools	*"Online assessment"*	4	
4)	Unable to define strategy or difficult	No strategy in place	*"Not sure", "Pass"*	2	
b)	External help	Outsourcing externals	*"External BIM provider"*	2	
c)	Reports and annual reviews	Producing written reports and reviews	*"Make it part of the staff technical annual review process"*	2	

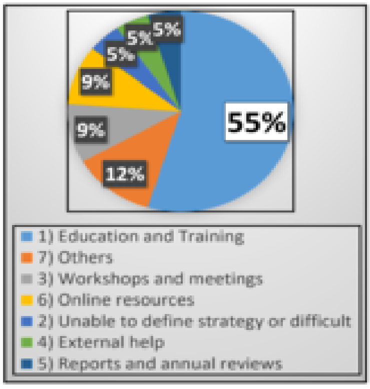
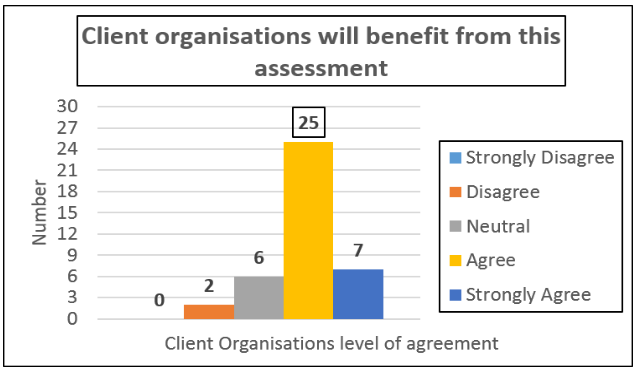


Figure 8.28 Strategies to introduce the assessment in organisations

In regards to clients benefitting from the assessment, if participants agree or strongly agree with this statement, the research successfully met the aim, delivered the suggested assessment, and clients could benefit from this (Figure 8.29). The results confirm that 25 agreed that clients would benefit from this assessment (62.5%), while seven strongly agreed (17.5%), 6 selected neutral (15%), two disagreed, and nobody strongly disagreed. This indicates that 85% of the participants either agreed or strongly agreed that clients would benefit from the assessment, which validates the findings and confirms the successful achievement of the main aim and objectives.

Although it was necessary to gather reasons from those who strongly disagreed or disagreed, participants provided reasons regardless of the response provided. Amongst those who responded with strongly agree or agree, four participants offered the following reasons: "*To raise awareness of the overall benefits of BIM against performance measurement*", "*We will only know once it is implemented and feedback is received*", "*Proof that they are paying for something that is adding value to their building/project*", and *"Client BIM knowledge is one of the most important KPI of a project. Ill-informed clients = bad KPI's".* These reasons indicate that it is vital that clients benefit from and understand the assessment, which would allow greater awareness, deliver overall benefits of BIM on performance, and result in the delivery of value-added outcomes to projects from the budget spent. For those selected Neutral, disagree, or strongly disagree, four participants provided reasons for their selection by stating that: "*Some of the biggest organisations are running successfully without this assessment*", "*How would a client use it? On reviewing their organisation? Or assessing their supply chain?*", "*It's more about the active project members*", and "*Most clients are not willing to pay for BIM services*". This shows that the assessment might not be of interest to some organisations since they operate well without it, and as clients might face difficulties in using it they might refrain from paying extra for the service.

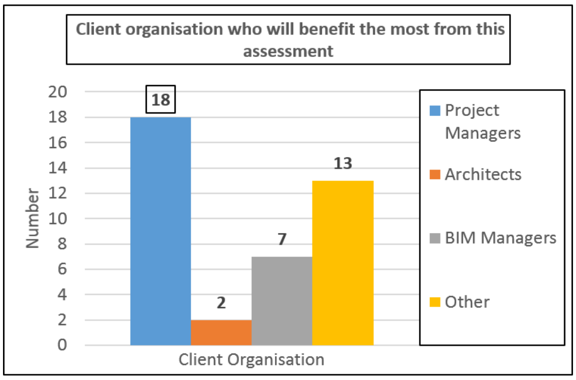


Client organisations will benefit from this assessment

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	2	5.0	5.0	5.0
	Neutral	6	15.0	15.0	20.0
	Agree	25	62.5	62.5	82.5
	Strongly Agree	7	17.5	17.5	100.0
	Total	40	100.0	100.0	

Figure 8.29 Client organisation benefitting from the assessment level of agreement

The results in Figure 8.30 outline who would benefit most from this assessment: 18 participants viewed that project managers would benefit most from this assessment (45%), while 13 selected others (32.5%). While seven indicated everyone, one each selected the following: Project sponsors, governmental bodies, project managers/BIM managers, operators, directors and project leads. Furthermore, seven indicated BIM managers (17.5%) and two selected architects. This indicates that project managers would mainly benefit from this assessment followed by BIM managers, which suggests that this assessment would be most often given to these individuals for completing as they were perceived to be the greatest beneficiaries in terms of outcome.



Who within the client organisation will benefit the most from this assessment and therefore, recommend the most to use the suggested assessment?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Project Managers	18	45.0	45.0	45.0
	BIM Managers	7	17.5	17.5	62.5
	Architects	2	5.0	5.0	67.5
	Other	13	32.5	32.5	100.0
	Total	40	100.0	100.0	

Figure 8.30 Client organisation to benefit from this assessment

Table 8.34 illustrates the 17 responses to the question how clients would benefit from this. With six responses each, both the need to demonstrate the benefits and not being able to demonstrate the benefits to the clients were most common reasons given. This was followed by better understanding and BIM management / BIM maturity with four responses each. After this, three responses each indicated: Better project performance and delivery, financial related and overall picture and setting standards. Moreover, two indicated enhanced communication / collaboration. Finally, a collection of reasons with one response each indicated: Responsibility for the delivery of BIM, decision making, quality control, change, more education, shared data, involvement in projects, lessons learned and training. This confirms that clients could benefit from this assessment in various ways and that it is vital to introduce the assessment (as noted within the objectives) so that they can maximise its usage.

Table 8.34 Selected client organisational benefits from this assessment

	Name	Examples	Number of discussions
1) a)	Unable to demonstrate benefits to clients	*"Still a lack of awareness of the advantages of BIM by Clients across all sectors. Any education or advice that can be provided to Clients (FOC) would be of benefit to enable them to understand the basic principles."*	6
b)	Demonstrating benefits	*"The client needs to assess where there organisation sits within the BIM Maturity Level to determine potential benefits and PM's need to advise clients more effectively on the above to avoid wasted effort"*	6
2) a)	Better understanding	*"Better understanding of the relationship between capability and performance"*	4
b)	BIM management / BIM maturity related	*"To demonstrate / manage BIM maturity across a portfolio of projects."*	4
3) a)	Better project performance and delivery	*"Project performance should be improved long term."*	3
b)	Overall picture and setting standards	*"Clear agreed metrics to measure against" "They should see the overall picture."*	3
c)	Financial related	*"Again proof that the funds being spent on implementing BIM are paying off on the project."*	3
4)	Enhanced communication / collaboration between teams	*"Co-ordination. It all depends what information is embedded within the model."*	2
5) a)	Responsible for delivery of BIM	*"He is the person dealing with BIM in the company"*	1
b)	Decision making	*"PMs are part of the decision making process and ultimately the simpler the BIM elements to the project can be made and causal links between capability and performance are transparent and easy to understand"*	1
c)	Quality control	*"Having certified stakeholders with ease the workload of BIM managers in terms of monitoring and quality control"*	1
d)	Change	*"They are closer to the Clients and better placed to implement thought change."*	1
e)	More educated	*"For education and self reflection. But if they are not BIM experts the answer may be ill informed and struggle to maximise the benefit."*	1
f)	Shared data	*"As with all KPI measurement it provides valuable data for shared learning and continuous improvement."*	1
g)	Involvement in projects	*"Because it affects everyone involved in projects"*	1
h)	Lessons learned	*"The BIM manager needs to know how well or poor his/her BIM project is performing. Any areas for improvement identified need to be addressed prior to the next project. Lessons learnt."*	1
i)	Training sessions	*"Workshops, training sessions, group discussions, demonstrations."*	1

In terms of other comments or suggestions, 28 participants did not provide with any further information (70%), whilst 12 provided more information (30%). Table 8.35 summarises the suggestions given by these 12 participants. Three participants noted that there would be difficulties with the use of the assessment as the language and terminology could mean it is difficult to engage the wider industry, and that clients need to understand the KPI metrics to make use of them. Two each indicated the importance of focusing on the benefits, such as what could be the benefits that clients could extract from BIM maturity, the importance of culture change since BIM maturity (aligned to BS EN ISO19650) is the future, and the assessment not addressing wider challenges to ensure the spread of a consistent message across the industry. Finally a single recommendation was given as follows: Sharing the work along the BIM Task Group, positive feedback in terms of interest in the linkage, examples of activities to drive KPI improvements, project lifecycle since KPI metrics would take time to embed in organisations, and improvements needed which this assessment could enable through assessing and measuring the impacts of BIM maturity methods and technologies used across the industry. The comments and recommendations stipulate that, although the assessment could work well with organisations and that clients could benefit, some clients could face difficulties in understanding it. Thus, it would be necessary to introduce the assessment to the industry, and there needs to be a focus on the benefits and impacts that the assessment could deliver. Finally, the assessment would need to be disseminated so that clients could utilise and benefit from it.

Table 8.35 Comments / Observations / Recommendations / Any other inputs to take this work forward

Name		Examples	Number of discussions
1)	Difficulties	*"Some of the language and terminology is potentially difficult for engaging with a wider audience" "Public sector clients need to understand the KPI metrics and how to make use of them in guiding their choices in procurement away from "lowest-cost"."*	3
2) a)	Focus on benefits	*"I would focus more on what benefits the client get from BIM", "Collaborative groups to meet/ demonstrate benefits to clients."*	2
b)	Culture change	*"Interesting points, but the assessment seems very clinical and I do not see this changing the wider challenges of spreading a consistent message across the industry." "BIM is the future"*	2
3) a)	Share amongst users	*"Share this work with the BIM task group."*	1
b)	Positive feedback	*"Well done I like the link between the processes"*	1
c)	Additional examples	*"Examples of activities that drive the most or more obvious KPI improvements would be useful."*	1
d)	Project Lifecycle	*"KPIs will take time to embed within any organisation."*	1
e)	Improvement	*"Majority of the time BIM methods and technologies are getting used without assessing or measuring its impact. Hence this should improve the way BIM is implemented."*	1

Having completed the online questionnaire findings, the next section will provide a summary of the chapter.

8.4.4 The 'How, Evidence and The Why' stage: Evolution of the framework

This section presents the evolution of the conceptual framework to the initial framework in terms of the 'How' stage. Figure 8.31 presents the development step of the 'How' stage, which demonstrates the evolution from the conceptual framework (Section 4.5) to the initial framework development. This section will demonstrate the findings of the online questionnaires which lead to the following:

1) Demonstrating the strength of relationships between the BIM maturity and KPI metrics.
2) Presenting scatter plot diagrams in determining the BIM maturity and KPI metrics directions.
3) Proposing a standardised list of benefits and determining levels of agreement.
4) Proposing an action plan to upskill from one maturity level to another.

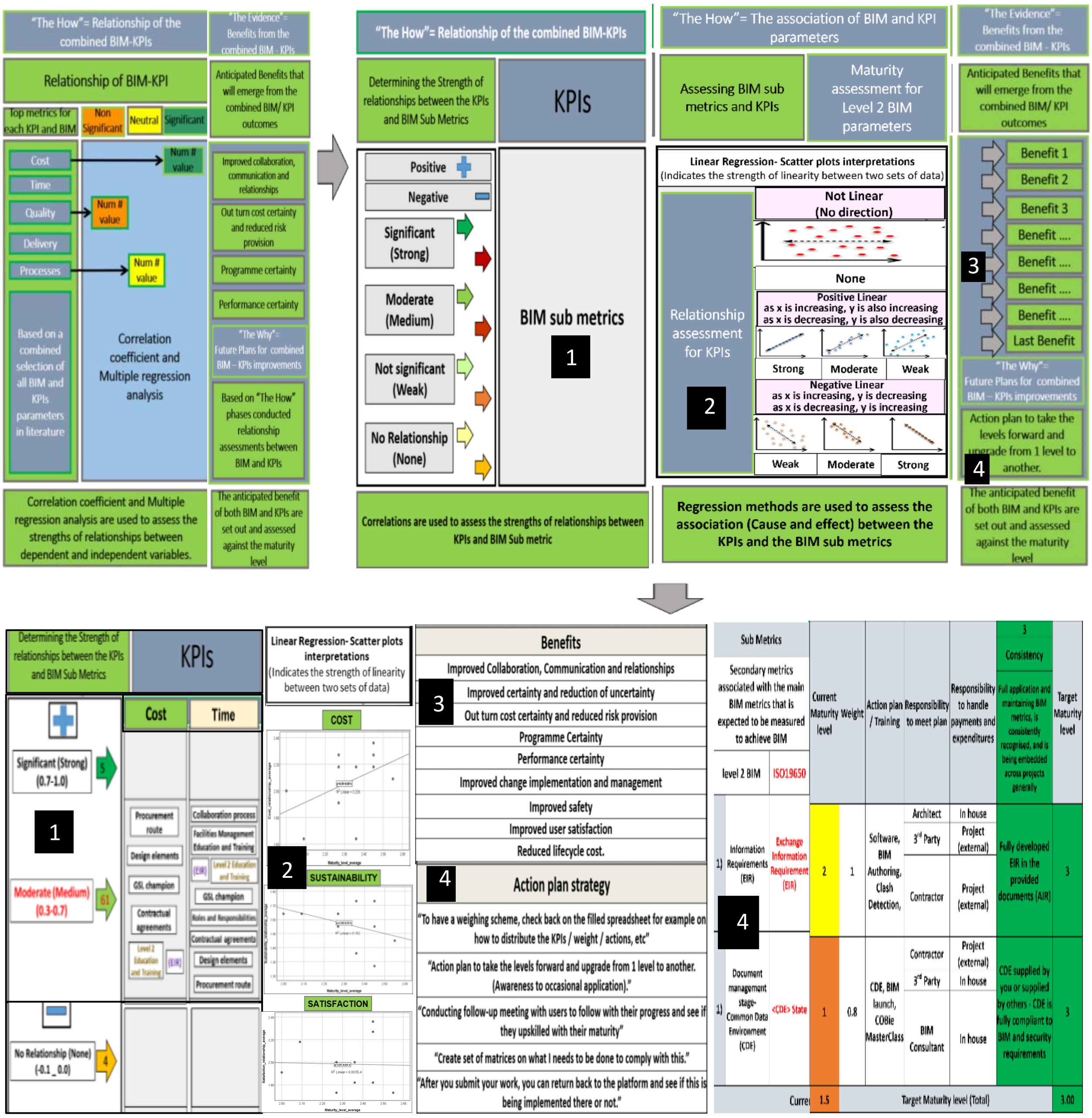


Figure 8.31 The evolution of the 'How, Evidence and The Why' stages from the conceptual to the initial framework

The 'How' stage is presented to identify the potential linkages between BIM maturity and KPI metrics for the framework and for the assessments proposed in this research. The linkage between maturity level scores and KPI strength of relationship (no relationship, weak, medium, strong) were identified, while the correlation analysis was presented in the findings (Section 8.4.2). The initial framework development presents the findings of the maturity levels and the KPI strength of relationship. In addition, with the correlation between the BIM maturity and KPI links was presented, and the regression results through scatter plot diagrams in determining if the BIM maturity and KPI metrics move in the same or a different direction.

The 'Evidence and The Why' stage identifies the BIM maturity and KPI metrics relevant for the framework and for the assessments proposed in this research. The conceptual framework proposes an outline of the expected benefits (Section 4.5.3) to emerge from link between BIM maturity and KPI metrics as proposed in the 'Evidence' stage. Moreover, an action plan that presents the movement from one level to another will be presented in the 'Why' stage, as explained in the previous section. The action plan will rely on the conducted assessment as explained in the 'How' stage, in terms of the maturity levels and KPI strength of relationship assessments. The initial framework development would present all benefits that were identified from linking BIM maturity and KPI metrics. In comparison, the action plan would demonstrate the steps required to upskill through the maturity levels, note the strength of relationship from one level to another, and demonstrate other actions required, as noted in the interview findings. The benefits (Figure 8.25) and action plan (Figure 7.11, Table 7.31) demonstrate the benefits from combining BIM maturity and KPI metrics and the action plan that would be required to upskill the users from one maturity level to another, which would better educate the UK client sector on how to improve their maturity levels and inform them of the benefits that are expected to emerge. This further supports the need to link BIM maturity and KPI metrics. Additional benefits (Tables 7.6, 7.30, 8.33) and actions (Tables 7.6, 7.10, 7.30) have emerged from the interview and questionnaire findings, which are eligible for the 'Evidence and The Why' stage.

Having presented the development of the framework, demonstrated how BIM maturity and KPI metrics would be linked together, and what are the expected and additional benefits to emerge and further actions to be taken, the next section will provide a summary of the chapter.

8.5 Summary

This chapter presented the findings of the survey with the UK client sector to collect additional information on how BIM maturity and KPI metrics could be linked, and to examine the potential relationships. Similar to the interview process, a number of questions were asked to collect information on how the BIM Maturity and KPI metrics would be examined to determine how they would impact on the overall performance of UK construction projects/organisations across the UK client sector. A mixture of open and close-ended questions were asked, followed by an assessment that determined the statistical relationships between the levels of BIM maturity and the strength of the KPI relationships to BIM Maturity. The questionnaire was distributed to a wide range of UK practitioners, but due to various reasons, a total of 40 individuals participated by completing the questionnaire in full. The participants determined their organisational level position, filled out the BIM maturity assessment and linked it to the KPI metrics. A series of descriptive and inferential analysis was conducted to determine the strength of relationships, which ranged from the assessment itself through descriptive statistics. In addition, the inferential statistics included the following tests: Chi square (to examine if there is a relationship between BIM maturity and KPI metrics), Kruskal Wallis (to examine if the BIM maturity and KPI metrics would depend on each other or not), Spearman correlation (to examine the potential relationships between BIM maturity and KPI metrics and see if they were moving in the same direction or not), and finally regression analysis (to determine if there was a linear relationship between both metrics, and to predict how BIM maturity related to the KPI metrics). A limited number of additional BIM Maturity and KPI metrics were proposed and a number of recommendations and suggestions were provided on how to take the relationship assessment forward to enable introduction within organisation. A number of benefits were agreed as a standardised list of benefits, which emphasised how the client sector would benefit from this assessment. An update to the conceptual framework has been presented, which discussed the findings related to “The How, and The Evidence and The Why” stage of the framework, and how it has developed from the proposed framework (Section 4.5) towards the initial framework development.

This chapter concludes the data collection phase, having statistically analysed and demonstrated a relationship between BIM Maturity and KPI metrics. The next chapter discusses the findings of the whole data collection phase, which includes discussions of the initial framework development (internal validation), and conducts an external validation that aims to generalise the research findings, and evaluates and presents the final BIM maturity-KPI assessment framework.

Chapter 9: Conceptual framework discussions, initial framework development and final framework evaluation and validation

9.1 Introduction

The main aim of this chapter is to discuss the findings from the data analysis across all data collection phases and to relate the findings to the literature. The validity of the research will be presented throughout the findings discussed in the previous chapters, and this will be linked to the proposed conceptual framework. A brief outcome of the findings from the literature review (Chapter 3), the conceptual framework (Chapter 4), the focus group workshops (Chapter 6), the semi structured interviews (Chapter 7), and the online questionnaire (Chapter 8) will be presented. These have all influenced the formation of the proposed conceptual framework. The initial framework development will be taken to an external validation stage following which the final framework will be delivered, and will validate the overall research. The main purpose of the external validation is to examine the applicability of the research findings to practice.

9.2 Framework rationale

This section will present the rationale for the development stages of the conceptual framework, which was initially based on a critical review of the literature. The subsequent primary data collection phases further informed the model's development. The rationale behind the initial framework development was as follows:

1) A critical review of key literature was conducted on existing BIM maturity assessment, KPI metrics, and combined BIM maturity and KPI assessments, as presented in Chapter 3. The findings identified a number of frameworks, and helped to link BIM and KPIs across a number of combined BIM maturity and KPI assessments in the UK and global construction industry (Section 3.10). Furthermore, a number of KPIs were identified from key literature (Section 3.7), which delivered a list of nine KPIs (cost, time, quality, safety, satisfaction, performance, profitability, productivity and sustainability). These formed the basis of the KPIs used to measure the performance of construction projects and organisations amongst UK clients. A number of BIM metrics were identified across the key literature and a number of BIM maturity assessments (Section 3.4), which included the transition from level 2 BIM to the new BS EN ISO 19650 standards (BIM Level 2. 2016; UK BIM framework. 2019b). Finally, the literature identified the most popular method for assessing BIM maturity through five maturity levels (i.e. initial, defined, managed, integrated, optimised) to determine the BIM maturity performances across organisations.
2) A proposed conceptual BIM maturity-KPI assessment framework was subsequently presented (Section 4.5) following the critical review and was presented in Chapter 4. The framework results from a number of frameworks within the literature (Sections 3.4, 3.7, 3.10) and

outlines a number of steps that link BIM maturity and KPIs. Furthermore, a range of strengths was noted that linked to the mechanisms used (i.e. scoring criteria) and these determine BIM maturity level. Five maturity levels are outlined, which link with the KPI metrics. Having reviewed the data a number of weaknesses emerged, such as the usage of KPI metrics as BIM elements or a list of questions, and the absence of a standardised linkage between an identified benchmark list of BIM maturity and KPI metrics.

The proposed conceptual framework consists of three stage elements:

a) The 'What': Demonstrating the BIM maturity top metrics and identifying the list of KPIs (Section 3.7). These emerge from a number of BIM maturity metrics that follow BIM maturity information across an information delivery cycle (UK BIM Framework. 2019a) and are assessed across three organisational levels (strategic, implementation, operational). These levels acknowledge the importance of the proposed users who would be responsible for understanding how each of the BIM maturity metrics would be conducted.
b) The 'How': Assessing the BIM maturity and KPI metrics from the previous stage. However, from critically reviewing previous BIM maturity assessments the levels were reduced from five to three (awareness, occasional application, and consistency), to provide the necessary distinction, as similarities could be seen existing amongst the five levels. The assessment also included an indication of how the BIM maturity and KPI metrics are linked based on a proposed relationship (Section 4.5.2) and having reviewed key literature (Section 3.10) (i.e. sustainability which is linked to collaboration and EIR).
c) The 'Evidence and the Why': Benefits are expected from combining BIM maturity and KPI metrics in the previous stage. These include: Improved collaboration, communication and relationships, improved certainty and a reduction of uncertainty, greater cost certainty and reduced risk provision, programme certainty, performance certainty, improved change implementation and management, improved safety, improved user satisfaction, and reduced lifecycle cost. Finally, it includes future plans that indicate actions to take in terms of the BIM maturity metrics in order to move from one level to another. It also considers how KPIs link with the BIM maturity metrics, and how to ensure the benefits are attained.

3) The findings of the focus group workshops, which covered the 'What" stage of the conceptual framework were presented in Chapter 6. The findings consisted of eight workshops that were held with focus group members to discuss the development of the 'What' stage and identify the BIM maturity and KPI metrics. A number of BIM maturity metrics were identified across the three organisational levels that reflect BIM maturity information across the information

delivery cycle, and accord with the transition from the Level 2 BIM standards to the new BS EN ISO19650 standards (UK BIM framework. 2019b).These were populated in the proposed framework, and resulted in the delivery of three BIM maturity assessments across all organisational levels (Section 6.8) and consist of top and sub metrics, the descriptors for each of the metrics, and a three-level BIM maturity level assessment (awareness, occasional application, and consistency). The proposed list of nine KPI metrics (Section 3.7) have been presented and agreed amongst the group members, and linked with the BIM maturity metrics.

4) The findings of the semi structured interviews covered the 'How' and 'Why' stage of the conceptual framework, as presented in Chapter 7. These gave results on the link between BIM maturity assessment, and the KPI metrics, and formed an action plan to identify how to improve from one maturity level to another. The findings from 15 UK client interviewees considered BIM maturity assessment across three organisational levels and visualised the current maturity levels under which the participants would fall. The KPI metrics were subsequently determined and linked with the BIM maturity metrics (i.e. sharing = cost). This achieved the objective for the 'How' stage. The interviewees proposed an additional KPI metric (collaborative culture), and the importance of positioning KPIs alongside the previous list to reflect organisational performance and the need to address cultural behaviours. The interviewees demonstrated how BIM maturity and KPIs are linked (Section 7.4.4), which presented the KPI metrics and how they were linked with the BIM maturity metrics across all organisational levels (i.e. profitability = collaboration and capital delivery) (Section 7.4.1-7.4.3). An action plan that addressed the objective for the 'Why' stage (Section 7.4.5) was proposed by interviewees as a step to improve a BIM maturity level and enable movement from one level to another (i.e. from occasional application to consistency). This was achieved by presenting potential methods to monitor the progress of construction organisations and how the KPI metrics are linked to enhance the performance of construction projects.

5) The findings from the online questionnaire covered the 'How' and 'Evidence' stage of the conceptual framework. This phase considered the combination of BIM maturity and KPI metrics, the assessment of the relationship, and the extent to which participants agreed on the presented list of benefits, as presented in Chapter 8. The findings consisted of 40 completed questionnaires, which were returned by participants who were UK clients and different to those who participated in the interviews. The findings explored the relationships between BIM maturity and KPI metrics across the three organisational levels. Similar to the interviewees and to achieve the objective of the 'How' stage, the participants were required

to conduct the BIM maturity assessment and identify their maturity level. From this, a relationship assessment was proposed (Appendix G) to see how the maturity level for the BIM maturity and KPI metrics could be linked. The relationship assessment offered a four-levels of strength for KPI relationships (no relationship, weak, medium, strong) across the three-levels of BIM maturity (i.e. collaboration process = occasional application, and cost = medium). This was achieved through correlation (strength of relationships) to determine how BIM maturity and KPI metrics are linked, and linear regression (as BIM maturity levels increased/decreased, then KPI relationships would increase/decrease directions). It thereby determined how BIM maturity metric levels impact on the KPI strength of relationships. To achieve the objective of the 'Evidence' stage, a number of benefits were proposed after combining BIM maturity and KPI metrics (Section 4.5.3); this delivered a standardised list of nine benefits and ascertained the extent to which participants agreed with these benefits.

Having presented the rationale for how the conceptual framework evolved into the initial framework development, the next section will present the internal validation stage that discusses each of the conceptual framework's three stage elements, namely the 'What', 'How' and the 'Evidence and the Why'. It described how a number of decisions were taken following the primary data collection, which helped to justify and formulate a rationale for the initial framework development. Moreover, the primary data was linked to the literature that informed the initial framework development.

9.3 Internal Validation

The internal validation (discussion) process was applied to consider the extent of any bias in the research. The approaches for assessing internal validity in construction management include comparisons with published literature (Ankrah, 2007; Manu, 2012; Proverbs, 1998; Xiao, 2002). Thus, the main aim of the internal validation is to compare the primary data collection findings with the key literature and relate these to each of the conceptual framework's three stages. This step demonstrates how the conceptual framework evolved from its initial stage and supports the decisions taken to develop it. Upon completion of the internal validation, key topic areas were explored through a cross case thematic analysis. This outlines the sub topics and their relationship with the key topic areas; moreover, it links them with the primary data from the focus group workshops, interviews, and questionnaire findings (i.e. data on the three organisational levels, such as the BIM maturity assessment results). These are subsequently compared with the literature to outline similarities and differences, and indicate the evolvement from the initial framework development. The initial framework is presented in Figure 9.1.

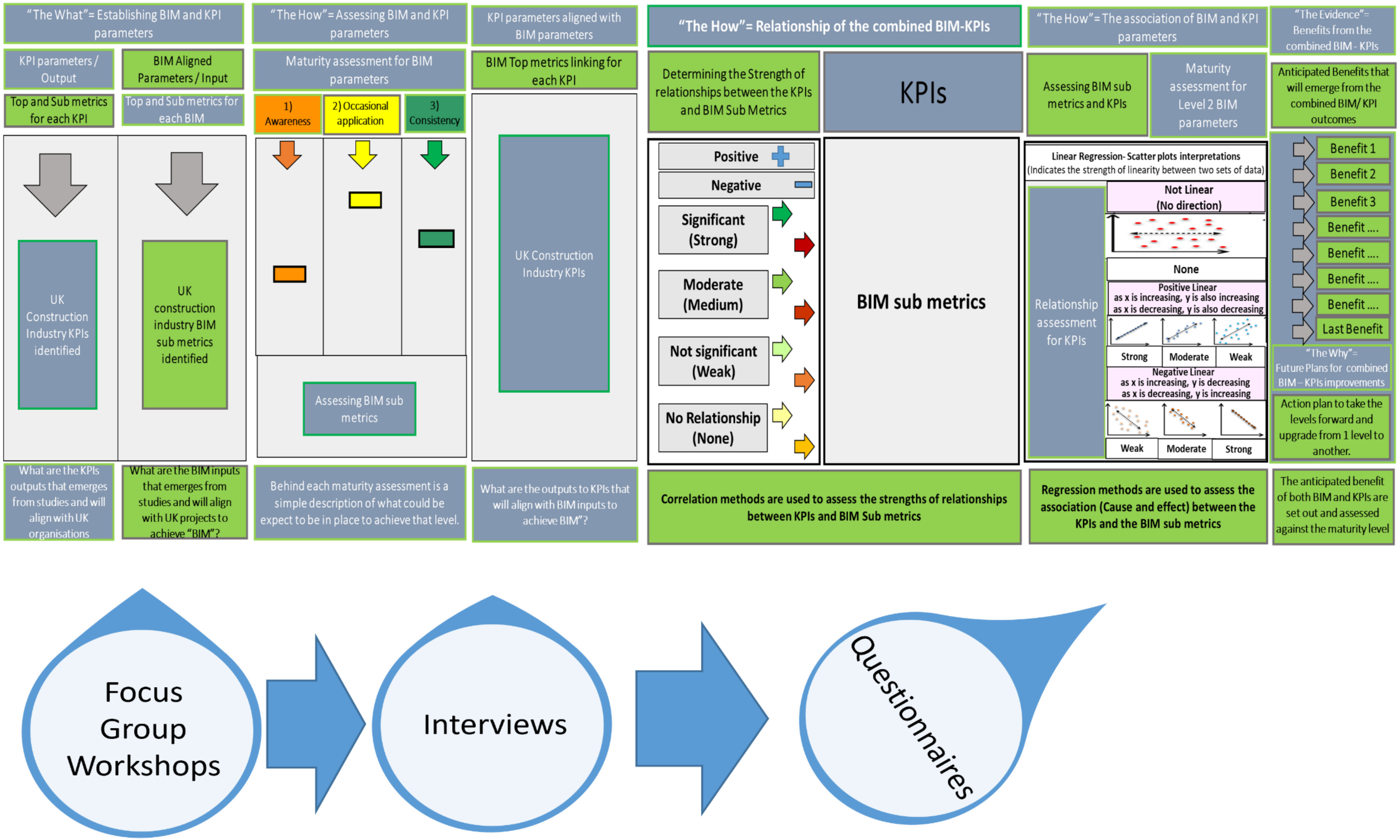


Figure 9.1 Initial Framework development

9.4 "The What" stage: Discussion on the identification of BIM maturity and KPI metrics

This section relates the primary data to the literature and links it with the BIM maturity metrics that were proposed across the focus group workshops and interviews. This demonstrates the evolvement of the 'What' stage concerning the BIM maturity and KPI metrics. The discussions related to: 1) The adoption and compliance with BIM, 2) The transition from Level 2 BIM to BS EN ISO 19650 standards, and 3) The usage of KPIs across organisations, will be presented.

1. BIM adoption and compliance

In terms of BIM adoption, the primary data revealed that 60 – 90% of the participants confirmed they are currently using BIM, which reflects the findings of several other studies that indicated BIM adoption at 60% or above (Alazmeh, Underwood, & Coates, 2018; Ashworth, Tucker, & Druhmann, 2019; Blay, Tulli, Mensah, 2019; Ganah, 2015; Georgiadou, 2019; Jallow et al., 2019; Kensek and Noble, 2014; Piroozfar et al., 2019). The NBS survey (2018) indicated that 70% of organisations are currently adopting BIM, whereas when repeated a year later (2019), the survey found that revealed that 51% of participants believed the UK government mandate to be unsuccessful, while 39% were unclear as to what has to been done to comply with the government mandate, and only 22% believed that the construction industry was delivering on the government mandate. This suggests that there is still a view that the UK construction industry is unclear about the requirements of BIM and what is required to achieve BIM Level 2. Nevertheless, this also raises a concern about organisations moving forward to Level 3 while many are still unclear about BIM and its operation at Level 1. This is believed to comply with the same survey (NBS. 2019), which indicates that 57% of participants agree that local governments are not enforcing the government BIM mandate.

Various studies have reported different adoption rates, both in the UK and across the globe. But it is worth mentioning that the UK has taken a step forward with adoption towards BIM Level 3, or the usage of the new BS EN ISO19650 standards. This research started around the same time as the government BIM mandate, and results indicate a high level of response. The focus group workshops and interviews were conducted prior to the release of the new BS EN ISO19650 standards. The standards became available to the public during the questionnaire survey period, and thus were not included as questions to participants. The next section will describe the transition from Level 2 BIM to the new BS EN ISO19650 standards, but it is worth noting that the findings across the data collection phases that include Level 2 BIM will remain relevant to the new BS EN ISO19650 standards.

2. The transition from Level 2 BIM to BS EN ISO19650 standards

Table 9.1 demonstrates the transition of BIM maturity metrics between Level 2 BIM and the new BS EN ISO19650 standards, according to the recent UK BIM vision (BSI. 2019).

Table 9.1 Transition guidance between Level 2 BIM and BS EN ISO19650 standards (BSI. 2019)

1192 term	19650 term	Comments
[New]	Risk register	The reference to the risk register is now explicit in BS EN ISO 19650-1
BIM execution plan	Information delivery plan (in BS EN ISO 19650-1) BIM execution plan (in BS EN ISO 19650-2)	BS EN ISO 19650-1 uses information delivery plan as the generic term for any plan in support of information delivery.
Capital/delivery phase	Delivery phase	Delivery phase is a simplification of capital/delivery phase without making any assumption about how the project funding is being treated in financial accounting
<CDE> area/section	<CDE> state	Area and section imply moving information from one place to another. This is not necessary in a CDE. It is the state of the information container that is important, not where it is stored.
CDE gate	Transition	Transition is used to denote change (in the state of the information container)
Container / file / document	Information container	ISO 19650 standardizes on the term Information container
Contract	Appointment	The more generic term appointment has been used in ISO 19650 instead of contract. This means one term can be used for both external contracts and internal work instructions
Employer	Appointing party / lead appointed party / appointed party	ISO 19650 term depends on where in the hierarchy the employer is located. Lead appointed party is not the same as design lead or construction lead in PAS 1192-2.
Employer's information requirements (EIR)	Exchange information requirements (EIR)	These are synonymous.
Graphical / non-graphical	Geometrical / non-geometrical	Geometrical is more appropriate to describe spatial positioning and relationships
Level of model definition / level of detail (LOD) / level of information (LOI)	Level of information need (no acronym)	Level of information need is a more generic term than any of the existing "Level of ..." terms used in 1192. It is not supposed to be shortened to an acronym.
Model / information model	Information model	ISO 19650 focuses specifically on the concept of the information model containing multiple types of information (geometrical and/or non-geometrical). This concept was in PAS 1192-2 but was not spelt out as consistently as it could have been.
Plain language questions (PLQ)	Project information requirements (PIR)	PLQ and PIR are both expressions of the high-level information needed by the client and/or their stakeholders to make key decisions concerning the project. The PIR, like the PLQ, are used to develop the detailed and contractual EIR. However, PIR can also include non-technical requirements and therefore can be broader than PLQ.
Project delivery team	Delivery team	In ISO 19650, delivery teams are the first-level breakdown of a project team and are led by a lead appointed party. Within a delivery team (both 1192 and 19650) there are one or more task teams who have their own appointments. In 19650 these are from the lead appointed party
Responsibility matrix	Responsibility matrix / Assignment matrix	In ISO 19650 there is a principle to develop responsibility matrices to cover information management activities and information delivery. The former is illustrated as the assignment matrix in BS EN ISO 19650-2:2019, Annex A.
Roles	Function	Information management roles are not included within BS EN ISO 19650-2. Instead, all activities within the information management process are to be undertaken by a single "information management function". BS EN ISO 19650-2:2019, Annex A provides a template for an information management function assignment matrix, which can be used by the appointing party to assign each activity (requirement) to themselves, to an appointed party or a third-party. Once an activity has been assigned, it is for the relevant party to identify the role that is responsible for the activity.
Standard method and procedure (SMP)	Combination of information standard and information production method and procedure	The 1192 term has been broken down into an information standard and an information production method and procedure. The content of the SMP is covered by these two separate elements
Suitability	Status	The terms are equivalent, as both define the permitted uses of information. BS 1192 also uses the term "status" to mean the combination of suitability and revision. There is no ISO 19650 equivalent for this BS 1192 use of "status"
Supplier	Lead appointed party (tier 1) / appointed party (tier 2 and below)	ISO 19650 term depends on where in the hierarchy the supplier is located.
Task team	Task team	There is no change in meaning, but compare with Project delivery team
Volume strategy	Federation strategy	The concept of volumes for sub-division of an information model is now described in terms of the reasons for which separate information models might need to be federated. This was an easier concept for non- UK countries to understand.

Table 9.1 shows a comparison between the Level 2 BIM metrics (according to PAS1192-2), and those of the BS EN ISO19650 standards - parts 1 and 2 (PD 19650-0. 2019). The seven metrics highlighted have been used across BIM maturity assessments over the three organisational levels (strategic, implementation, operational) according to the primary data findings (Section 6.8). Table 9.1 indicates that Level 2 BIM has been superseded by BS EN ISO19650 parts 1 and 2, but the essence of the description remains the same. According to recent publications on the new standards, the principles and requirements of the new BIM terms are recognised from the previous UK standards and BIM level 2 website (BSI. 2008, 2013, 2014; BIM Level 2. 2016; Kumar, 2015; NBS. 2020). This suggests that the transition between the previous and new standards deliver an enhanced understanding of the changes that will occur due to this replacement. For this research, and to follow the new guidance on BIM maturity, it was necessary to include the transition from Level 2 BIM to the new BS EN ISO19650 standards when developing the BIM maturity metrics within the maturity assessments (Section 6.8). However, the assessment

remains the same and nothing additional will be expected. The focus group workshops and semi structured interviews were conducted when there was no mention of the transition to new guidance. However, the BS EN ISO19650 standards (parts 1 and 2) were released during the questionnaire survey and during this data collection phase, there was some discussion on the BS EN ISO19650 standards. Although this research began in April 2016, during the UK government Level 2 BIM mandate (NBS. 2016), Table 9.1 demonstrates that BIM maturity assessments will still comply with the new BS EN ISO19650 standards parts 1 and 2 (UK BIM framework. 2019b) (i.e. in roles and responsibility to function) and the assessments remain valid according to the latest UK vision for BIM (NBS. 2020).

As a result, the organisational levels have been amended to include this transition (Section 6.8) where the metrics of both Level 2 BIM and ISO10650 are included. This will be added to the reasons for adopting the current assessment and address the absence of BIM maturity assessments that comply with the new BS EN ISO19650 standards. When asked about comments and actions to take forward, participants discussed the BS EN ISO19650 standards. This shows that the research would add to the literature by introducing new guidance to different organisational levels. This could result in a greater likelihood of assessment and BIM adoption amongst clients, according to a recent NBS survey (NBS. 2020). The survey has indicated 30% adoption of BS EN ISO19650- parts 1 and 2, thus the research may help to increase these levels.

3. KPIs used in organisations to evaluate the success/performance of an organisation/project

This research delivered a list of KPI metrics as a standardised list for use in KPI assessments. Findings relating to the proposed KPIs are displayed in Table 9.2.

Table 9.2 KPIs evolvement (Literature and Data collection)

Primary KPIs
Cost
Time
Quality
Secondary KPIs
Satisfaction
Health and Safety
Performance
Profitability
Productivity
Sustainability

Primary KPIs
Cost
Time
Quality
Secondary KPIs
Satisfaction
Health and Safety
Performance
Profitability
Productivity
Sustainability
**Collaborative Culture*

The KPIs detailed on the left hand side of Table 9.2 deliver a standardised list of metrics that emerged from the literature and have been used in construction projects and organisations in the UK and around the globe (Section 3.7). The focus group participants agreed that this could act as a standardised list when linking with BIM metrics (Section 6.11). When asked about core KPIs in use (and before presenting the list of KPIs), interviewees noted a sample of KPIs that were different to this list (Section 7.3.3).

Some interviewees indicated the use of Internal or in house-standard KPIs within their practices; which aligns with studies that mentioned internal KPIs (discussed in Chapter 3). Examples given included: Close-outs, internal QA procedures, digital engineering venues, KPI self-assessments, and KPI internal developed tools. Other KPIs focused on the outcomes for organisations and social aspects. Some of the aforementioned processes align with Kagioglou, Cooper, & Aouad (2001) in offering a framework for performance management, a means to benchmark and a focus on organisational strategy and goals. Moreover, Aboumoemen (2016) aligned the NWCH framework of KPIs with the anticipated benefits from the BIM-KPI assessment, while Lin and Shen (2007) offered a benchmark to develop a KPI framework, and Yeung et al., (2013) developed a benchmarking model for construction projects that included KPIs.

Some studies mentioned benchmarking for construction projects (Chan and Chan 2004; Costa et al. 2006; Cox et al. 2003; Lee et al. 2005). Another KPI parameter mentioned across the interviews but not considered for this research is predictability. It has been used as a sub parameter for two main KPIs (cost and time), and has been defined as: *"Actual Cost/Time against the Cost/Time predicted at tender"* (Swan and Kyng, 2014, p. 11). Predictability (cost and time) has been mentioned by some publications across the UK as part of their KPI review (Aboumoemen, 2016; Costa et al., 2006; Egan, 1998; Ofori-Kuragu et al., 2016; UK IPR. 2018). Two interviewees noted the use of predictability as a KPI: *"One of the other ones that have some thoughts around is **predictability**, and it could come under **risk and predictability**"* (Interviewee I04) and *"When we think back with predictability, is about if it's going to be delivered what we say it is to the cost and the quality"* (Interviewee I05). This indicates that predictability could be used as a sub-metric for KPIs under the top metrics of cost, time, risk, and so forth.

Ofori-Kuragu et al. (2016) conducted a survey to demonstrate the relevance of KPIs across Ghanian contractors, which includes a similar list of KPIs as this research but with the addition of predictability. The results showed that predictability was the least relevant of the KPIs with a negative score of (-14), which indicates a highly irrelevant KPI. Therefore, it has been omitted from the standard list of KPIs in this study. Some of the interviewees have mentioned the importance of human nature as part of the KPIs; one of the interviewees stated that *"I feel you need to draw in the human, collaborative and cultural KPIs into this a bit more as you cannot rely solely on technology and the process."* (Interviewee I05). Furthermore, *"social value"* (Interviewee I08) was noted, while Interviewee I12 noted, *"We have a range of KPIs across projects, but the big KPIs are around collaboration"*. The interviewees revealed the importance of human related KPIs that allow for organisational change and forward movement. Nevertheless, Beatham et al. (2004) and Costa et al. (2006) criticized KPIs in their current format, stating that that they do not offer the opportunity for organizational change. Therefore, human nature has been included as a KPI, named as “Collaborative Culture” as shown in Table 9.2 (right-hand side). This addition accords with some of the literature findings as construction industry reports have noted problems in the construction industry, calling for improved processes to address them. As a result, it is proposed that collaborative culture, which was suggested as a KPI, and accords with Egan (1998) Piroozfar et al., (2019) and Wolstenhome (2009), could improve the fragmented nature of the industry. Collaborative culture (working) was mentioned by some studies (Akintoye *et al.,* 2012; Balfour Betty, 2018; Constructing Excellence. 2019a, 2019b; Miles and Trott, 2011; Pala et al., 2013) and was defined as: *“Working together in a seamless team to common objectives that deliver benefit for all through mutually-beneficial (i.e. including commercial) alignment”* (Constructing Excellence, 2019b). Moreover, collaborative working and human and people aspects were mentioned by several studies as KPIs, as shown in Table 9.3.

Table 9.3 Alternative names for collaborative culture

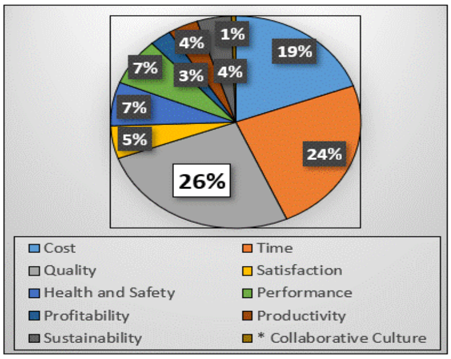
KPI	Collaborative Culture KPI alternative	References
Collaborative Culture	Educational, Social and professional aspects	(Chan et al., 2002; Latham, 1994; Lin and Shen, 2007; Maya, 2016; Ofori-Kuragu et al., 2016; Parfitt and Sanvido, 1993; Sousa et al., 2006; Takim and Akintoye, 2002; UK IPR. 2018; Westerveld, 2003; Yeung et al., 2013)
	Effectiveness of Communications	
	Employee learning	
	Human Factors	
	Human resource	
	People	
	Respect for People	

In addition, to help determine the most frequently used KPIs and deliver a list of KPIs for this research, interviewees were asked to demonstrate a link between the BIM metrics and KPIs to determine which KPIs would be used and which would appear to be the most used, (illustrated in Table 9.4). Also, the questionnaire asked participants to determine which of the KPIs were used to evaluate the performance of construction organisations/project on an individual basis, (Section 8.4.1).

Table 9.4 The most commonly appearing KPIs across the literature

	Determining relationships between Level 2 BIM and KPIs based on 15 Interviewees	Number of appearance
1	Cost	35
2	Time	43
3	Quality	47
4	Satisfaction	9
5	Health and Safety	12
6	Performance	13
7	Profitability	5
8	Productivity	7
9	Sustainability	8
10	*Collaborative Culture	3

Percentage distribution



The literature in Chapter 3 ranked the KPIs in the order of cost, time, and quality, and interview results indicated that the most commonly used KPIs linked with BIM metrics was quality, followed by time and cost. This aligned with one of the interviewee's responses that the order of appearance for the KPIs should be "*Quality, Time and Cost*" (Interviewee I08) but contradicts with another response that suggests: "*In reality everyone is looking to the cost, time and quality, but the order should be Time, Quality and Cost*" (Interviewee I02). Across the questionnaires the KPI most used to evaluate construction organisation/project performances was quality, and this correlated with Ofori-Kuragu et al., (2016) who conducted a survey amongst Ghanian Contractors to rank the relevance of KPIs. This was followed by time then cost according to the interview and questionnaire findings; however, the study by Ofori-Kuragu et al., (2016) found that cost was the third most important and time the fourth. This would not change the order of the KPIs, since they appeared in most studies and were considered as objective and primary measures; however, it was worth mentioning that amongst the three, quality was seen as the most relevant. For the secondary KPIs, one study placed health and safety as an objective measure (Chan et al., 2002); however, as this was not considered relevant by other studies, it was considered secondary and a subjective KPI measure.

Additional KPIs for consideration across the questionnaire phase, and a key part of the digital KPI area, measure the number of clash detections/resolutions at the pre-construction stage. Nevertheless, according to the literature, clash detection was mentioned: as part of the BIM process when scoping the client's requirements regarding FM and EIRs (Ashworth et al., 2018); as part of a BIM scorecard to assess the integration of clash detection, estimating and scheduling (Joblot et al., 2018; Mahamadu, 2017; Vico. 2011); as an element of BIM use for the Design-Construction stage (Dakhil, 2017); as an application of BIM for the project execution process, and considered a critical success factor for BIM projects (Badrinath et el., 2019). Furthermore, clash detection was also considered a BIM characteristic (Piroozfar et al., 2019; Thomsen et al., 2009), a benefit in meeting quality assurance (Blay et al., 2019), and as a parametric modelling process that allows for the association of more sophisticated properties to objects to generate warnings when other objects infringe on that space (Crotty, 2011; Gyarting, 2014).

It was addressed in the literature review for BIM and the UK, and for quantity surveying (Marsh, 2017) as a powerful tool for performing clash detection (Weygant, 2011). In addition, it was considered a key BIM benefit for cost consultants (Goucher and Thurairajah, 2012), for 5D software in offering the ability to check for clashes (Won et al., 2011) and as part of an early risk identification process (Haque and Mishra, 2007; Harrison & Thurnell, 2015; Sebastian, 2011;

Stanley and Thurnell, 2014). This indicates that clash detection is recommended as part of BIM-KPI metrics, and could be included in the standardised list of KPIs for future studies. The remaining KPIs from the primary data collection phase could be considered in future studies and would need to be reviewed to determine how they could be generalised and added to the existing list of KPIs.

9.5 The 'How' stage: Discussion on the linkage between BIM maturity and KPI metrics

This section discusses relating the primary data findings; it compares the literature and links it with the BIM maturity and KPI assessment results from the interviews and questionnaires in order to demonstrate the evolution of the 'How' stage. A number of discussions related to:

1) The awareness of BIM maturity assessments;

2) The existing BIM maturity assessments across organisations;

3) The methods used to measure KPIs to evaluate the success/performance of organisations;

4) How BIM maturity and KPI metrics could be linked;

5) The mechanism for linking BIM maturity and KPI metrics based on the data collection findings, and

6) The result of for linking BIM maturity and KPI metrics across the three organisational levels. These are based on the data collection findings, and the relationship between BIM maturity and KPI metrics. These are established by comparing the BIM maturity metrics and KPI (Cost) findings across all the organisational levels, which has been conducted through the following analysis: a) Frequency and total averages, b) Spearman correlation, and c) Linear regression.

1. Awareness of BIM maturity assessments/tools/models

Section 3.4 has delivered a condensed list of BIM maturity assessments that exist across the globe, with emphasis on existing BIM assessments in the UK. Thirty three assessments exist in the UK, including popular and/or additional assessments (Aboumoemen, 2016; ARUP. 2014; Badrinath et al., 2019; Bew and Richards, 2008; BIMIcon, 2021; BIMTASKFORCE, 2013; BRE. 2016; CDBB. 2021a, 2021b; CPI. 2011; Dakhil, 2017; DBE Careers, 2021a, 2021b, 2021c; Dakhil et al., 2019; DFT; 2016; HS2 BIM. 2016; Ifm. 2018; Jenaban et al., 2016; Jones; 2020; Khosrowashahi and Arayici, 2012; Kumar and Hayne, 2016; Mahamadu et al., 2019; Marsh, 2017; MoJ. 2016; Mott Macdonald. 2017; Munir et al., 2019; NBS. 2016; NFB. 2016; Scottish Future Trust. 2017; Supply Chain Sustainability School. 2017; Walters, 2021; Wates. 2019). When questioned on their awareness of BIM maturity assessments, the interviewees indicated they would recognise a significant low sample of the BIM maturity assessments. Specifically, some recognised the existence of the Capability Maturity Measure (NIBS. 2007), the Penn State Organisational

Assessment (CIC. 2013), the ARUP Maturity Measure (ARUP. 2014), the Compass and Upskilling Tool (Scottish future trust. 2017), BIM level 2 Certification (BRE. 2016) and the NBS Toolkit (NBS. 2016). Moreover, questionnaire participants were aware of the list of assessments presented (Section 8.4.1.2).

Interestingly, some interviewees stressed that BIM maturity assessments were well known within academic practice and not well recognised in UK working practices. In addition they emphasised that some reasons for lack of awareness of assessments amongst practice is due to restrictions on accessing assessments and organisational unwillingness to share data. This correlates with Badrinath et al. (2019) who provided a comprehensive list of 32 assessments, some of which were accessible, whilst others that were available were based on a recognisable few within the global market while some were less practical. This also aligns with Azzouz et al., (2016a) who signified that widespread challenges associated with BIM AMs were based on shortage of frameworks for use within the industry, and absence of an overarching research agenda. Both authors have stated that there are few case studies to support and validate assessments. This presents a challenge for BIM assessments in general and shows the importance of spreading awareness and allowing accessibility to assessments for use by construction organisations.

2. BIM maturity assessment(s)/tool(s)/model(s) used in organisations.

There is a growing number of BIM maturity evaluation models and the number of BIM performance measurement tools has gradually increased over the last decade (BRE. 2016; Chen et al., 2012; Giel and Issa, 2013a; Mom and Hsieh, 2012; Nepal et al., 2014; Succar, 2010a). A number of BIM maturity assessments exist within the AEC industry. These assessments are noted as six (Aboumoemen, 2016; Giel and Issa, 2013), nine (Bougroum, 2016; Wu et al., 2017), 11 (Dakhil et al., 2015; 2016; Månsson and Lindahl, 2016) 16 (Azzouz et al., 2016a, 2016b), 32 (Badrinath et al., 2019) and 45 assessments (Aboumoemen and Underwood, 2017).

The assessments have the following characteristics: 1) They consist of performance individual measures (Bougroum, 2016); 2) They are based on project and organisational assessments (Giel and Issa, 2013b); 3) Maturity models produce valuable benefits to BIM users (Giel and Issa, 2013b; Nepal et al., 2014; Succar, 2010a); 4) Models and frameworks measure BIM performance by assessing the capabilities and maturity of individuals, teams or organisations (Månsson and Lindahl, 2016; Månsson et al., 2017); 5) A growing number of assessments assess individuals, organisations, project teams (Badrinath et al., 2016; Badrinath et al., 2019); 6) They cover aspects of people, process, technology (Succar, 2009, 2010a), and 7) People, Process, Technology, Strategy (Dakhil, 2017; Dakhil et al., 2015, 2016, 2019). An extensive review of various BIM maturity assessments across the globe with different classifications were critically reviewed in Section 3.4 and **92 BIM maturity assessments** were identified under BIM maturity assessments, tools, models, and frameworks. Building on to this research, the assessments could all be categorised under seven main categories: **1) BIM competencies and capability assessment (self), 2) Assessment framework, 3) Assessment methods (other), 4) BIM functional model (tool), 5) Maturity models based on levels 1-5, 6) Scoring criteria percentages for projects; and 7) A scoring criteria percentage on a model with possible certification.** The assessments were identified under the following maturities: either project, organisational, or both project and organisational. As an additional category and requirement for this research, some of the assessments had embedded KPIs, and were categorised as; **8) Combined BIM/KPI (driven by other categories).** Based on these assessments, this research delivered a BIM maturity assessment to be conducted across three organisational levels **(strategic, implementation, and operational)**. Throughout the focus group workshops, the BIM metrics were discussed in more detail and allocated according to where they were believed to fit for each organisational level, based on experiences with the industry experts. Descriptions for each sub metric were given to provide a better understanding of what they represent and the essence behind them.

Finally, users who would best fit within each organisational level and hold responsibility for completing the assessment were recommended, namely: **1) Strategic: Senior Managers**, **2) Implementation: Information Managers, and 3) Operational: Project Managers**. This research critically reviewed assessments that consisted of a five maturity levels. These levels were mentioned across a number of publications although there have been some changes to the naming convention of the level. The concept of maturity levels emerged from a quality management grid, that had five stages including: **uncertainty, awakening, enlightenment, wisdom,** and **certainty** (Crosby, 1979). These were then applied to assess software and technological capabilities which addressed maturity levels based on the following: **Ad-hoc, defined, managed, integrated,** and **optimised** (Humphrey, 1988; SEI. 1993).

A list of maturity models unrelated to BIM was also noted; based on a review of the literature, it identified the need to follow the CMMI assessment, since this was more relevant to the background of BIM and construction. These levels were; **performed, managed, defined, quantitatively managed,** and **optimising** (Chrissis et al., 2003; Paulk et al., 1994). Some studies built on their assessments by using the concept of five level maturity in which there was a slight change to the naming convention; for example, **performed** was changed to **initial,** but the remaining levels remained the same (Succar, 2009; 2013; Succar et al., 2010a, 2010b, 2016). In relation to the UK context, capability maturity and its relationship with the UK BIM mandate were: **Accuracy, generalisation, interoperability, level of detail,** and **meta-data** (Godfrey, 2008; Humphrey, 1988; Nolan, 1973; Survey4BIM. 2015).

The most famous models identified in the literature delivered assessments based on the following maturity levels: **Non-existent, initial, managed, defined, measured** and **optimising** (ARUP. 2014; CIC. 2013). Building on to this research, some studies delivered five-level maturity assessments (ARUP. 2014; Change Agent AEC. 2013; CIC. 2013; Succar, 2009) that were based on that of the Software Engineering Institute (SEI. 1993). Aboumoemen (2016) and Aboumoemen & Underwood (2017, 2019) suggested reducing the maturity assessments from five to three levels to provide the necessary distinction since similarities could be seen between some levels. As a result, this research presented a three-level assessment as follows: **Awareness, occasional application,** and **consistency.**

An extract of the findings related to this research's BIM maturity assessment is shown in Table 9.5, and the complete results are available in Appendix G.

Table 9.5 BIM maturity assessment findings across all organisational levels

Strategic level
Interviews (Left) vs Questionnaire (Right)

Maturity level		Maturity level descriptor	Sub Metrics		Maturity level		Maturity level descriptor
Frequency	Total		Level 2 BIM	ISO19650	Frequency	Total	
3	2.45	Systems that are able to integrate the BIM models (CDE) that are compliant with Level 2 BIM standards into operations.	Collaboration process		3	2.45	Systems that are able to integrate the BIM models (CDE) that are compliant with Level 2 BIM standards into operations.
3	2.55	Understanding and fully implementing the UK BIM Level 2 standards. Fully understanding and application of the CAPEX and OPEX	Processes and Standards		2	2.09	Understanding and partially implementing the UK BIM Level 2 standards. Partial understanding of the CAPEX and OPEX
3	2.36	Partial understanding of roles defined in PAS 1192-2:2013 and have limited internal resources	Roles and Responsibilities	Function	2	2.18	Partial understanding of roles defined in PAS 1192-2:2013 and have limited internal resources
2	2.27	Good understanding of how form of contracts are and alignment of standards with Level 2 BIM projects (i.e. 1 to 2 project).	Contractual agreements		2	1.82	Good understanding of how form of contracts are and alignment of standards with Level 2 BIM projects (i.e. 1 to 2 project).
3	2.36	Awareness training required and producing a roadmap, and some staff training in the basics.	Level 2 Education and Training		3	2.36	Awareness training required and producing a roadmap, and some staff training in the basics.
2	2.27	Some confidence in a particular procurement route and how Level 2 BIM is being implemented from stage 1.	Procurement route		2	2.09	Some confidence in a particular procurement route and how Level 2 BIM is being implemented from stage 1.

Implementation level
Interviews (Left) vs Questionnaire (Right)

Maturity level		Maturity level descriptor	Sub Metrics		Maturity level		Maturity level descriptor
Frequency	Total		Level 2 BIM	ISO19650	Frequency	Total	
2	2.16	There is internal training undertaken (i.e. intermediate BIM training or system training) CDE, FM, software based training	Level 2 Education and Training		2	1.90	There is internal training undertaken (i.e. intermediate BIM training or system training) CDE, FM, software based training
2	2.16	Basic template and external procured EIR	Information Requirements (EIR)	Exchange Information Requirement (EIR)	2 3	2.33	Basic template and external procured EIR
2	2.47	BIM uses are outlined but not tailored for specific projects	Uses		2	2.20	BIM uses are outlined but not tailored for specific projects
3	2.37	BIM uses are outlined but not tailored for specific projects	Supplier assessment forms		2	1.89	BIM uses are outlined but not tailored for specific projects
3	2.47	Clients are able to review the BEP	Execution Plan (BEP)	Information Delivery Plan	3	2.40	Clients are able to review the BEP
2	2.21	Consultant reviews of MIDP and TIDP.	Master Information and Task Team Information (MIDP and (TIDP)		2	2.00	Consultant reviews of MIDP and TIDP.

Operational level
Interviews (Left) vs Questionnaire (Right)

Maturity level		Maturity level descriptor	Sub Metrics		Maturity level		Maturity level descriptor
Frequency	Total		Level 2 BIM	ISO19650	Frequency	Total	
2	2.00	Basic template and external procured EIR	Information Requirements (EIR)	Exchange Information Requirement (EIR)	2 3	2.20	Basic template and external procured EIR
2	2.33	CDE supplied by you or supplied by others - CDE implemented but not Level 2 BIM compliant / PAS1192-5 compliant	Document management stage- Common Data Environment (CDE)	<CDE> State	3	2.40	CDE supplied by you or supplied by others - CDE is fully compliant to Level 2 BIM and security requirements
1 2	1.50	Simply Identified 3D-6D elements, but not fully followed	3D – 6D inputs		1 3	2.00	Identified but not used in a certain degree over projects
2	2.00	Good understanding of the LoD and basic ability to check (Visual checks) the models	Level of Development (LoD)	Level of Information need	3	2.40	Full understanding of the LoD and capability to use the models (Visualise and check the information)
2	1.83	Good understanding of the roles and responsibility and acknowledging the clients on the gateway reviews to be applied	Project reviews		1	1.90	Good understanding of the roles and responsibility and acknowledging the clients on the gateway reviews to be applied
1 2	1.50	No capability to operate on the lifecycle.	Lifecycle Analysis		2	2.00	Basic Usage of the Lifecycle but not fully managed

The scoring averages were as follows: **(1) 1-1.6=Awareness (Aw), (2) 1.6-2.4=Occasional Application (OA), and (3) 2.4-3=Consistency (Co).** Across all organisational levels and based on the data collection findings, the overall maturity levels showed an average between **1.80 and 2.32** indicating an **OA** level. The individual sub metric scores are shown for awareness and consistency. This indicates that most participants see themselves within the occasional application levels.

This represents a contribution in the delivery of an assessment with the BS EN ISO19650 standards embedded, and includes three organisational and three maturity assessment levels. Across the literature, and as part of the BIM maturity assessments benefits, some demonstrated that: The quantification of evaluation is high (Du *et al.,* 2014; Gao; 2011; Kam *et al.,* 2013a; Wu *et al.,* 2017) and easy to implement (CIC. 2013; IU; 2009a; NIBS, 2007; Succar, 2009; Wu *et al.,* 2017). Guidance on what performance measures should be obtained has been provided and emphasized by Bougroum (2009) and Neely *et al.* (1997).

Due to the awareness of BIM maturity assessments, the primary data findings indicated the use of internal in house/own assessments, which were developed within their organisations to assess their BIM projects. Examples include: 1) Internal checklists, 2) PQ questionnaires, 3) Capability assessments, 4) Capability questionnaires, 5) BMA templates, 6) BSI, and 7) Bespoke measures. This research calls for the delivery of a standardised BIM maturity assessment for use within organisations to assess the BIM maturity of their projects and organisations and to be shared amongst users across the UK industry. This research identified a total of 92 existing BIM assessments across the globe, while 33 are applied across the UK.

This is not to say that BIM related assessments do not exist with the UK industry, but as a result of copyrights and restricted access from some organisations, the researcher was not able to access further assessments that are believed to exist within the UK. Thus, the list was based on the researcher's ability to collect as many of the existing BIM maturity assessments as possible. Further research could be conducted on additional existing assessments in the UK and, should there be access to wider assessments across UK organisations, then researchers may be able to identify some of the BIM related maturity assessments that extend beyond the list provided in Section 3.4 and from the primary data findings.

Following an overview of existing BIM maturity assessments in the literature, which is the first study to recognise an exhaustive list of assessments, and deliver a BIM maturity assessment that adds to the existing list of assessments, the next section will discuss KPI metrics and their importance within project/organisation performances.

3. Measuring KPIs to evaluate the success/performance of an organisation/project

In order to measure KPIs, it is necessary to have a database to record the KPIs, and checklists to monitor and record the usage of KPIs, which correlates with Parfitt and Sanvido (1993) who advise a checklist to record the critical success factors of projects, and systems to track the progress of KPIs. This aligns with Kagioglou et al. (2001) who developed a framework to measure, monitor and record KPIs; this also correlates with Constructing Excellence (2004b) and Kiew, Ismail, & Yusof (2012) in providing a process to calculate, report, and remeasure KPIs. Nevertheless, some interviewees indicated a lack of experience creates difficulties in measuring KPIs; moreover, further issues arise when excessive information is received from KPIs, when monitoring and dealing with this information, in being unable to benchmark them, and in not having formal KPIs for measurement.

This confirms the findings of Aboumoemen (2016), Eadie et al., (2013), Gyarting (2014), Marsh (2017), and Yeung et al., (2013) who state that some of the challenges that exist relate to a lack of experience and deficiencies in dealing with the presented information. When the list of KPIs was provided, as revealed from the interview findings, 60% agreed with this list while the remaining disagreed. Amongst those who agreed, supporting information on how each KPIs was being used was provided to enable a greater insight and in-depth exploration into how KPIs could be approached and delivered within practice. Amongst those who disagreed, the main reasons given were the absence of internal KPIs, being aware of some KPIs, and the KPI list not operating and aligning with working practice. Some studies across the literature presented KPIs as different methods (Parmenter, 2015), such as: **critical success factors** (Amuda-Yusuf, 2018; Badrinath et al., 2019; Joblot et al. 2019; Tsai et al., 2014; Westerveld, 2003); **performance success** (Yang et al., 2010; Westerveld, 2003); **performance measurements** (Bassioni et al., 2004; Gosselin, 2005; Hatzigeorgiou and Manoliadis, 2018; Hegazy, 2012; Kagioglou et al., 2001; Karim and Marosszeky, 1999; Lin and Shen, 2007; Maya, 2016; Neely, 1999; Robinson et al., 2005; Sousa et al., 2006); **project performance** (Gyarting, 2004, Smits et al., 2016; Wong et al., 2016); **measuring construction success** (Chan et al., 2002; Chan and Chan, 2004; Ofori-Kuragu et al., 2016; Parfitt and Sanvido, 1993; Takim and Akintoye, 2002; Westerveld, 2003), and **Fuzzy AHP process** (Khanzadi et al., 2019; Zhao et al., 2017).

4. How could BIM maturity and KPI metrics be linked?

Data was collected on the possibility of linking BIM maturity and KPI metrics to see what impacts could occur and whether they would operate together. The interviewees indicated that almost everyone agreed to a link. Examples given were: "*It comes down to* ***the way we deploy*** *on how* *we do it on projects"* (Interviewee I01); "There is a link, *if you're* ***not capable of delivering something (BIM)****, then it* ***will affect the cost of the delivery and maybe the time and might affect the overall quality (KPIs)"*** (Interviewee I02), and ***"The*** ***more mature you are*** *in the process, the* ***more you understand the process****, the* ***better you will perform"*** (Interviewee I03). In comparison, 55% of the questionnaire participants agreed with the linkage. When asked about the potential methods for this link, interviewees indicated that it could happen through: Training, monitoring capabilities, a methodology for measuring BIM, and internal project management systems. Questionnaire participants also indicated that it could happen through reviews and reports, the delivery of a tool, and both project and organisational performances.

The results across the collected data indicate that it is possible to link BIM maturity and KPI metrics and the above would be the supporting methods on how such linkage would occur. This accords with Smits et al., (2016) who states that it is possible to BIM and KPIs but such links are yet to be empirically tested. Moreover, Wong et al., (2016) states that limited studies exist to determine the potential linkage between BIM and project performance. A limited number of existing publications had noted the possible relationships between BIM maturity and KPIs across construction projects (Smits et al., 2016). Other studies viewed the influence of Critical Success Factors on either BIM elements or KPIs in terms of project performance (Ashworth, Tucker, & Druhmann 2018; Badrinath et al., 2019; Dakhil et al., 2019; Ozorhon and Karahan, 2016; Shin and Choi, 2016). This implies a failure to link BIM maturity and KPIs to realise potential benefits.

Following research into BIM-KPIs, this study has managed to outline **33** existing BIM/KPI assessments, which were classified into six categories: **1) BIM impact on construction projects (KPIs), 2) KPI impacts on BIM implementation, 3) Assessment frameworks, 4) Assessment methods, 5) BIM implementation within organisations, and 6) Assessment tools**. Furthermore, three previous assessments were found to have conducted a similar approach by analysing the links between BIM maturity and KPI metrics (Aboumoemen, 2016; Smits et al., 2016; Wong et al., 2016). They delivered: potential linkages through frameworks that identified how BIM maturity and KPI metrics could be linked (Aboumoemen, 2016); a statistical relationship of six BIM metrics across three KPIs, namely time, cost and quality (Smits et al., 2016), and the statistical and potential relationship of eleven BIM capabilities across two KPIs, namely time and cost (Wong et al., 2016). Other studies recommended the need to consider KPIs and their links with existing BIM assessments (Amuda-Yusuf, 2018; Dakhil, 2017; Joblot et al., 2019), while others have noted the need to reassess the relationship between BIM maturity and KPI metrics with alternative metrics than those previously applied (Smits et al., 2016).

5. The mechanism for linking BIM maturity and KPI metrics

A sample BIM maturity assessment and relationship assessment across the three organisational levels is presented in Figure 9.2, and the complete version for all organisational levels is available in Section 6.8 and Appendix G.

BIM maturity assessment (Transition from level 2 BIM to the new BS EN ISO19650 standards)

Organisation: No. #	Organisation: Level	Top Metrics: Main BIM metrics and their descriptions		Sub Metrics: Secondary metrics associated with the main BIM metrics that is expected to be measured to achieve BIM (level 2 BIM / ISO19650)			Essence of descriptors: Description of the secondary metrics to provide a clear definition of each metric	Maturity level: 1 = Awareness (General Knowledge and understanding of BIM metrics in Strategic level, but is sometimes not being recognised across the organisation)	2 = Occasional Application (Partial Application of BIM metrics and is somehow being recognised, but is not being embedded generally)	3 = Consistency (Full application and maintaining BIM metrics, is consistently recognised, and is being embedded across projects generally)	Currrent Maturity level
1)	STRATEGI	a)	Collaboration (Collaborative behaviour strategies expected to be present in a complete project to meet BIM)	1)	Collaboration process		Common Data Environment (CDE), Softwares required for the design team to use (BIM 360) and aligning softwares with the hardware (BS 1192:2007, PAS 1192-2:2013, PAS 1192-3:2014)	No awareness of systems to be used	Common Data Environment (CDE) identified that are compliant with Level 2 BIM standards and free viewer	Systems that are able to integrate the BIM models (CDE) that are compliant with Level 2 BIM standards into operations.	1
				2)	Processes and Standards		Level of BIM processes, procedures and standards expected to be achieved in a project. Some UK Level 2 BIM standards examples to follows are: (BS 1192:2007, PAS 1192-2:2013, PAS 1192-3:2014, PAS 1192-5:2015, BS 8541-1:2012) More information is available at: [https://www.bre.co.uk/page.jsp?id=3508]	Aware and understand what the UK BIM Level 2 standards are, but not embedded. Minimal understanding of the CAPEX and OPEX	Understanding and partially implementing the UK BIM Level 2 standards. Partial understanding of the CAPEX and OPEX	Understanding and fully implementing the UK BIM Level 2 standards. Fully understanding and application of the CAPEX and OPEX	
				3)	Roles and Responsibilities	Function	Key Team roles and responsibilities level of expectations to be achieved within a project	Minimal understanding of roles defined in PAS 1192-2:2013 and no internal resources	Partial understanding of roles defined in PAS 1192-2:2013 and have limited internal resources	Distribution of roles and responsibilities amongst team members that have been embedded across projects which are applied frequently in organisations.	
				4)	Contractual agreements		Level of Contractual agreement agreed by project team members	Minimal Understanding of how form of contracts are some awareness of alignment and no previous experience with Level 2 BIM.	Good understanding of how form of contracts are and alignment of standards with Level 2 BIM projects (i.e. 1 to 2 project).	Full understanding of how form of contracts are and alignment of standardised clauses to contract document (i.e 5+ projects).	
				5)	Education and Training		Level of education and training expected to be present within a team to achieve BIM	No internal or staff training on Level 2 BIM, and no awareness of roadmap required.	Awareness training required and producing a roadmap, and some staff training in the basics.	There is a full training strategy for the Level 2 BIM and a metrics of (minimum of 50-60% of relevant staff).	
				6)	Procurement route		Client fully understand how each procurement route will impact on the BIM deliverables	Not aware which route is the best for the client and the project based on the BIM deliverables.	Some confidence in a particular procurement route and how Level 2 BIM is being implemented from stage 1.	Full confidence in correct procurement routes for the client in particular projects and how Level 2 BIM will be used from stage 1.	

The Evidence = Relationship of BIM and KPIs

Strategic Level (The Strategic goals and gearing up of the delivery of BIM at the organisation / project Level, and Organisational and project levels that are being managed by the organisation team.)

Sub Metrics: Secondary metrics associated with the main BIM metrics that is expected to be measured to achieve BIM (level 2 BIM / ISO19650)		Maturity level and descriptor: Awareness / Occasional Application / Consistency	Relationship with KPIs: Cost	Time	Quality	Satisfaction	Health and Safety	Performance	Profitability	Productivity	Sustainability	Collaborative Culture	Current KPI relationship total
Collaboration process		No awareness of systems to be used	1										1.00
Processes and Standards													
Roles and Responsibilities	Function												
Contractual agreements													
Education and Training													
Procurement route													

Legend
No Relationship (None) 0
Not Significant (Weak) 1
Moderate (Medium) 2
Significant (Strong) 3

Figure 9.2 BIM maturity assessment and BIM maturity- KPI relationship assessment sample

Figure 9.2 shows that, following the assessment of BIM maturity levels, users would assess the KPI strength of relationship and connect it with the maturity level for each BIM maturity sub metric. The averages for the strength of relationship was identified as follows: **(0) 0-0.75= no relationship (none), (1) 0.75-1.5= not significant (weak), (2) 1.5-2.25= moderate (medium), and (3) 2.25-3= significant (strong)**. As mentioned in this study, a framework is needed to show the potential relationships between BIM maturity and KPI metrics in order to measure construction project success. Although BIM maturity has emerged as a method to measure project and organisational maturity through different levels, and KPI metrics measure construction project and organisational success, there needs to be an overall assessment that combines both in order to provide a holistic assessment method that meets the goals of both.

This research delivers an assessment that consists of BIM assessment across seven top metrics and 34 BIM sub metrics, as follows: 1) Strategic: 11 sub metrics, 2) Implementation: 11, and 3) Operational: 13. Some sub metrics overlap with others across the organisational levels (i.e. EIR across all organisational levels; CDE and COBie in implementation and operational levels, and Level 2 BIM education and training in strategic and implementation). After identifying the maturity levels, 10 KPI metrics are assigned as a standardised list for a KPI assessment, following which, users would either identify the potential relationships amongst the 10 KPI metrics across the seven top metrics. This was considered in the interview findings, which signified the difficulty in establishing: a relationship across the sub metrics, the strength of relationships amongst KPI based on existing maturity levels [**i.e. EIR= (1) Aw and cost= (2) moderate**] or on sub metrics as a general concept. This was also revealed in the questionnaire findings, namely that, in general, the BIM sub metric did not impact on the KPI levels. The data collection findings delivered a number of additional (and previously absent) BIM-KPI linkage metrics, which needed consideration in the previous assessment. A sample are shown in Table 9.6.

Data were collected from interviewees and questionnaire participants on their thoughts about the study's assessment that links BIM maturity and KPI metrics. Interviewees indicated that when linking the two there is an impact when assessing the supply chains, assessing documented papers, determining major effects on projects, identifying capacity and a team's experience, and on management process.

The questionnaire participants stated that the impact would occur through the provision of a baseline/benchmark, where the BIM maturity and KPI metric are related, and knowledge/experience is required to determine maturity. This concords with studies that showed the positive reflect of BIM capabilities on the KPIs (Wong et al., 2016) but however, contradicted to other studies that indicated the impact of BIM and KPIs may be limited (Khanzadi et al., 2019; Smits et al., 2016). This suggests the assessment could play a key role in delivering the expected linkages between BIM maturity and KPI metrics.

Table 9.6 Additional BIM Maturity and KPI metrics to be included

BIM Sub Metrics	KPIs related to BIM	
Collaboration	1) Clash detection – technical queries, 2) Potential for better outcomes, 3) Program, 4) Disputes	Collaborative Culture
Employers' requirements	1) Validation – Delivery 2) Quality of design and service, 3) Maintainability, 4) Program, 5) Incidents – number of incidents report, 6) Snapshot in time	
Processes	1) Validation – Delivery, 2) Predictability	
Delivery	1) Resources 2) Predictability	
Sharing	1) Compliance with CDE, 2) Co-ordination in sharing the information	
Capital Delivery	1) Predictability, 2) Quality of design and service, and service in terms of timescales	
Facilities Management	1) Asset information, 2) Predictability, 3) Capacity, 4) Soft landings Implementation plans	

BIM Sub Metrics	KPIs	Digital KPI Area	KPI Item	KPI Measure 1
1) Supply chain management 2) More on behaviours, like innovation, communication, etc. (Strategic)	Understanding (Strategic)	BIM	Training	Training hours promised
		BIM	Clash Detection	Number of clashes detected/resolved in Pre-Construction
Level of Development (Implementation)	Clash Detection (Implementation)	Quality	QA Inspections	Number of QA Inspections
		Compliance	Snags/defects	Number of snags identified & closed in Construction
Plain Language Questions (Operational) Project Information Requirements (PIR)	Depends on organisational goals (Any Organisation level)	Safety	Hazard Identification	Number of hazards Identified & Mitigated in Pre-Construction
		BIM	Asset Data Compliance	Number of assets identified in Pre-Construction

6. The primary data results on linking BIM maturity and KPI metrics

Different relationship methods between BIM maturity and KPI metrics were noted across the data collection phases. During the interviews, interviewees were asked to state which organisational level they would best fit within, and to conduct a BIM maturity assessment related to their organisational level. They were then asked to link the BIM maturity sub metrics to the KPI metrics. The findings revealed that the majority of interviewees found it difficult to link KPI metrics across sub metrics, and as a result indicated a link to the BIM maturity top metrics. Across all BIM/KPI publications, a relationship was noted between the primary KPIs **(cost, time, and quality)** and BIM elements therefore, the researcher incorporated this linkage (Figure 9.3 on the left-hand side).

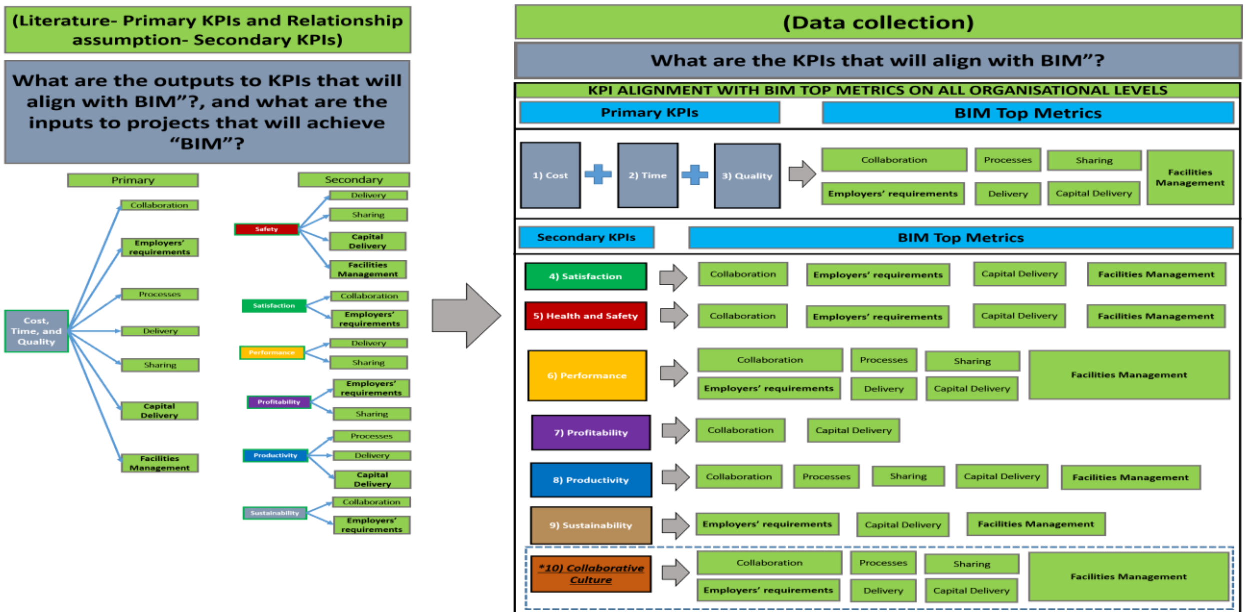


Figure 9.3 Organisational levels BIM-KPI linkage comparison (Literature vs Interviews)

Amongst the secondary KPI metrics **(satisfaction, health and safety, performance, profitability, productivity and sustainability)**, different relationships exist and there is no standard linkage between the BIM elements and secondary KPIs,; thus the researcher offered an assumption on this linkage, based on a critical review of the literature (Section 3.10). The assumption was formulated from checking the descriptions for the BIM maturity top metrics and KPI metrics and identifying those that would best align. This theoretical linkage between the BIM maturity top metrics and KPI metrics are presented in Figure 9.3, on the left-hand side. This diagram was presented to interviewees who struggled to demonstrate the potential linkage; they were thus assisted in the delivery and identification of a potential linkage. As a result, the interviewee findings showed that the primary KPIs would be linked to all BIM top and sub metrics in general across all organisational levels. This correlate with the literature findings that identified an existing relationship between key BIM metrics and KPIs, namely cost, time, and quality (Aboumoemen, 2016; Barlish and Sullivan, 2012; Eadie et al., 2013; Gyarting, 2014; Hassan, 2012; Khanzadi et al., 2019; Poirer et al., 2015; Smits et al., 2016; Suermann and Issa, 2007; Sun and Zhou, 2010; Won and Lee, 2014; Wong et al., 2016). Nevertheless, other publications have only demonstrated a link between BIM maturity and KPI metrics by presenting KPIs as either BIM components, treating KPIs as Critical Success Factors or as processes that would lead to such linkages with no mention of the actual KPIs presented in this research. Hence, this led to the secondary KPIs, whereby the findings have revealed different linkages across all organisational levels and were thus combined to enable comparisons between the research assumption and interview findings.

The findings revealed the following:

1) **Satisfaction**: a) Literature review: collaboration and employer requirements; b) Interviews: As before, along with capital delivery and facilities management. This indicates that satisfaction would have been reflected amongst the previous BIM maturity top and sub metrics, and would offer a potential linkage. This correlates with Aboumoemen (2016) in demonstrating a potential linkage between satisfaction and BIM maturity metrics across organisational levels.
2) **Health and Safety**: a) Literature review: Delivery, sharing, capital delivery, facilities management; b) Interviews: As before, while delivery and sharing are replaced with collaboration and employer requirements. This shows that Health and Safety would reflect on the previous BIM top and sub metrics, and deliver a potential linkage. This aligns with Aboumoemen (2016) by demonstrating a linkage between Health and Safety and BIM maturity metrics across organisational levels. It also coincides with the findings of Eadie et al.

(2013) through the BIM/KPI metric measurement of BIM; with Khanzadi et al., (2019) through conducting a Fuzzy AHP analysis on BIM applications to construction stage KPIs in building projects; with Suermann and Issa (2007) in the weighted factors of BIM effects on KPIs and the Pearson Chi-Square test of Association, and with Sun and Zhou (2010) through the adoption of BIM and the Iron Triangle diagram that includes safety and the statistical analysis of BIM application to KPIs.

3) **Performance**: a) Literature review: Delivery, sharing; b) Interviews: All BIM maturity top metrics, which indicates that performance would reflect on the previous BIM maturity top and sub metrics along alongside a potential linkage.
4) **Profitability**: a) Literature review: Delivery, sharing; b) Interviews: Collaboration and capital delivery, which suggests that profitability would reflect on the previous BIM maturity top and sub metrics, and would deliver a potential linkage.
5) **Productivity**: a) Literature review: Process, delivery, capital delivery; b) Interviews: As above, while delivery is replaced with collaboration, sharing, and facilities management, which indicates that productivity would reflect on the previous BIM maturity top and sub metrics, and would deliver a potential linkage. This finding agrees with Aboumoemen (2016) by demonstrating a potential linkage between productivity and BIM maturity metrics across organisational levels; with Khanzadi et al., (2019) by conducting a Fuzzy AHP analysis on BIM applications towards the building project KPI construction stage; with Poirer et al., (2015) by assessing the performance of BIM implementation through productivity, and with Suermann and Issa (2007) through the Pearson Chi-Square test of Association.
6) **Sustainability**: a) Literature review: Collaboration and employers' requirements; b) Interviews: As above, although collaboration is replaced with capital delivery and facilities management, which suggests that sustainability would reflect on the previous BIM top and sub metrics, and would deliver a potential linkage to determine how they would be related. This conforms with the findings of Khanzadi et al., (2019) in conducting a Fuzzy AHP analysis on BIM applications to the construction stage of building project KPIs, and with Sun and Zhou (2010) through the adoption of BIM and the Iron Triangle diagram that includes energy (sustainability) and statistical analysis of BIM application to KPIs.
7) **Collaborative culture**; Interviews: All BIM maturity top metrics. This shows that collaborative culture would reflect on the previous BIM top and sub metrics and would deliver a potential linkage. Since collaborative culture was not mentioned in any of the combined BIM-KPIs assessment, this confirms a contribution by this research.

The questionnaire on BIM maturity levels and the KPI strength of relationships was distributed online. When considering the KPI metrics against the BIM maturity sub metrics, **cost** is chosen as an example for comparison across all organisational levels (Figure 9.4). In terms of the assessment, the results indicate that most relationships were in the moderate level across all organisational levels, which indicates an overall moderate relationship with cost within the BIM maturity sub metrics. The relationships that did not fall under a moderate relationship were: 1) Strategic level: Strong for Contractual agreement, design elements, and EIR; 2) Implementation level: Strong for CDE, and information exchange; 3) Operational level: Weak for POE, and strong for EIR, CDE, and AIM. This confirms that cost has a strong relationship with the EIRs across the strategic and operational levels, and a strong relationship with CDEs across the implementation and operational levels. These findings indicate users believed cost has a strong relationship and could reduce additional costs across the previously mentioned BIM maturity sub metrics. However, they may need to spend more across the remaining BIM maturity sub metrics. This correlates with a number of findings that cost savings and spending the necessary amounts could lead to increased efficiency in the usage of BIM and increased productivity (Aboumoemen, 2016; Barlish and Sullivan, 2012; Dakhil, 2017; Eadie et al., 2013; Gyarting, 2014; Haron, 2013; Mahamadu, 2017; Marsh, 2017; NBS. 2020; Smits et al., 2016; Suermann and Issa, 2007; Wong et al., 2016).

COST

Strategic level

Sub Metrics		Frequency		Total
Collaboration process		2		2.18
Processes and Standards		2		2.09
Roles and Responsibilities	Function	1	2	1.64
Contractual agreements		2		2.27
Level 2 Education and Training		2		2.18
Procurement route		2		1.91
Design elements		2		2.27
Information Requirements (EIR)	Exchange Information Requirement (EIR)	3		2.36
Asset Information Requirement (AIR)		2		2.18
GSL champion engagement		2		1.64
Facilities Management Education and Training		2		2.00
BIM Maturity level Totals		Moderate (Medium)		2.07

Implementation level

Sub Metrics		Frequency		Total
Level 2 Education and Training		2		2.11
Information Requirements (EIR)	Exchange Information Requirement (EIR)	2		2.00
Uses		2		2.16
Supplier assessment forms		2		2.11
Execution Plan (BEP)	Information Delivery Plan	2	3	2.21
Master Information and Task Team Information (MIDP and (TIDP)		2	3	2.21
Model production Delivery Table (MPDT)		3		2.11
Responsibility Matrix (RM)	Assignment Matrix	3		2.05
Document management stage- Common Data Environment (CDE)	<CDE> State	2	3	2.42
Information Exchange		3		2.37
COBie data		3		2.21
BIM Maturity level Totals		M	S	2.18

Operational level

Sub Metrics		Frequency		Total
Information Requirements (EIR)	Exchange Information Requirement (EIR)	3		2.50
Document management stage- Common Data Environment (CDE)	<CDE> State	3		2.30
3D – 6D inputs		2		2.20
Level of Development (LoD)	Level of Information need	2		1.60
Project reviews		2	3	2.10
Lifecycle Analysis		2		2.20
As built model		3		2.20
Project Information Model (PIM) exchanges		3		2.20
Information Delivery (AIM)		3		2.40
COBie data		2	3	1.70
Handover requirements (GSL)		2	3	2.00
Post Occupancy Evaluation (POE)		2		1.40
BIM Maturity level Totals		Moderate (Medium)		2.07

Figure 9.4 Comparing KPI strength of relationship with the BIM maturity levels across the organisational levels (assessment)

Moreover, the results indicated a statistically significant correlation between cost and the BIM maturity sub metrics at ($p<0.05$) across Level 2 BIM Education and Training at the strategic level and CDE at the implementation level. The strength of relationships indicated that, for most of the BIM maturity sub metrics, there was a positive correlation between cost and the sub metrics indicating that as the level of maturity increased or decreased, the cost strength of relationship would follow the same direction (Figure 9.5). The metrics with a negative correlation indicate that, as the level of BIM maturity increased/decreased, the cost strength of relationship decreased/increased as follows: 1) strategic level = collaboration process (not significant); 2) implementation level = information exchange (no relationship), and 3) operational level = COBie (not significant) and CDE, 3D-6D inputs, project reviews, and lifecycle analysis (no relationship). Interestingly, some metrics existed at more than one organisational level, thus, on the one hand, CDE had a positive correlation and a moderate relationship at the implementation level, but a negative correlation and a no relationship at the operational level. On the other, COBie had a positive correlation and a weak relationship at the implementation level, but a negative correlation and a weak relationship at the operational level. This shows that the same sub metrics may differ in terms of correlation and strength of relationship from one organisational level to another; therefore, it is necessary to examine the causes behind this. EIRs existed at all organisational levels and had a positive correlation, but the strength of relationship differed from one level to another (1: Moderate relationship at the strategic and implementation levels, and 2: Weak relationship at the operational level). Similarly, Level 2 education and training had a positive correlation, but the strength of relationship differed from one level to another (1: Moderate relationship at the strategic level and 2: Weak relationship at the implementation level). This again shows that the sub metrics in terms of cost could be correlated, but the strength of relationship may differ from one organisational level to another. Finally, no sub metrics were found to have a significant relationship across all organisational levels whether positively or negatively correlated. Nevertheless, this contradicts the findings of Smits et al. (2016) who conducted a Pearson correlation and returned results with more significant, and all positively correlated across the BIM maturity and KPI metrics. This indicated that *"the impact of BIM maturity on project performance may be limited"* (Smits et al., 2016, p. 8), while Wong et al. (2016) conducted a Spearman Correlation but found that Time and Cost were significant and positively correlated across the 11 BIM capability metrics. However, Wong et al. (2016, p.7) suggest "*that project performance in the aspect of time and cost were improved when QSs adopted BIM capabilities in their practice*".

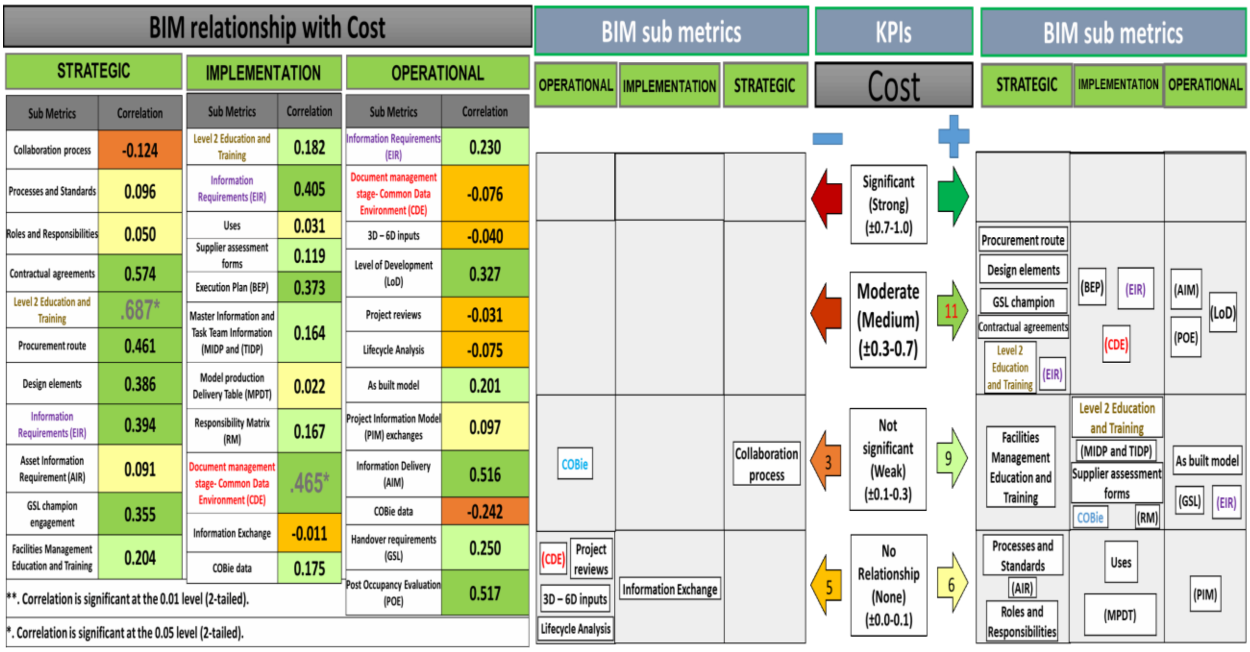


Figure 9.5 Comparing KPI strength of relationship and BIM maturity levels across organisational levels (correlation)

Finally, in terms of linear regression (Figure 9.6), the results illustrated a weak positive linear relationship between BIM maturity and cost at all organisational levels. The regression equation returning the following data: 1) Strategic level = ŷ=0.49+0.68X, and the R^2 Linear=0.208; 2) implementation level = ŷ=1.53+0.28X, and the R^2 Linear = 0.285, and 3) operational level = ŷ=1.09+0.47X, and the R^2 Linear = 0.101. This shows that, in regard to cost, as the BIM maturity levels increased or decreased, the cost strength of relationship followed the same direction. A logistic regression analysis was conducted across time and cost and all 11 BIM capabilities (Wong et al., 2016) and the results showed that both time and cost were significant predictors across four BIM capabilities.

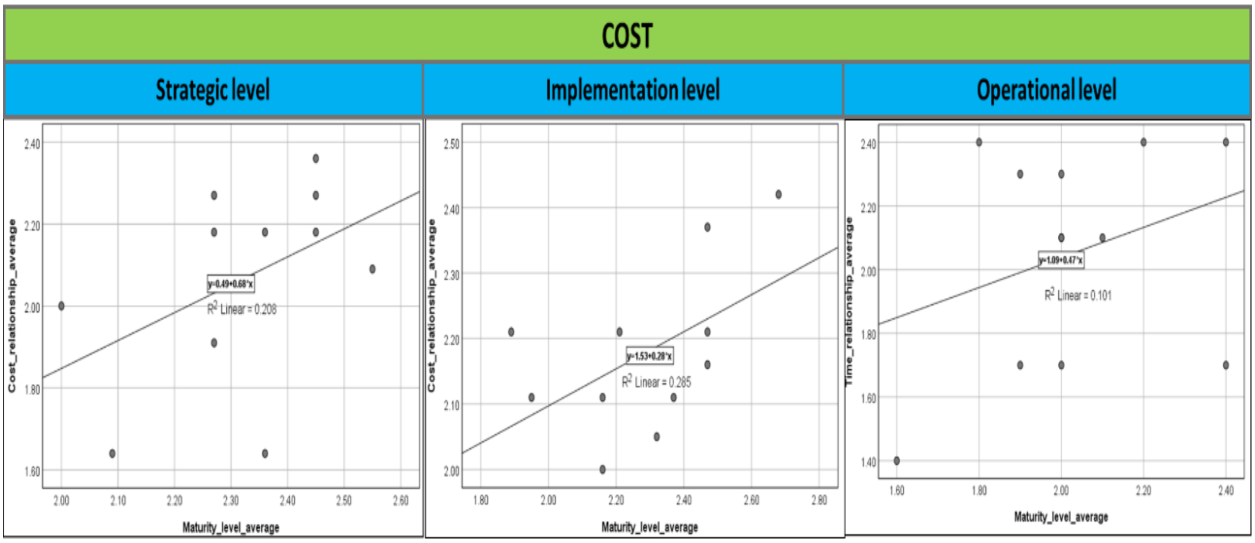


Figure 9.6 Comparing KPI strength of relationship with BIM maturity levels across organisational levels (regression)

9.6 The 'Evidence and The Why' stage: Discussion on the benefits to emerge and actions to take

This section compares the primary data findings with the literature and link them to the BIM maturity and KPI assessment results that were conducted across the interviews and the questionnaires to demonstrate the evolution of 'the 'Evidence and The Why' stage. This demonstrates how BIM maturity and KPI metrics are linked between the conceptual framework (as a result of the critical review of key literature) and the initial framework through the decisions taken. A number of discussions related to: 1) The benefits and drivers of BIM to the client sector; 2) The anticipated benefits that would emerge from the proposed BIM maturity-KPI assessment framework; 3) The barriers and challenges of BIM to the client sector, and 4) The actions that are relevant for linking BIM maturity and KPI metrics and for demonstrating how the performance levels could improve from one level to another.

1. **Clients and BIM Drivers and Benefits**

A number of benefits have emerged from the use of BIM with clients. A summary of the key BIM drivers from the client's perspective are noted in the interviews (Section 7.3.5) and questionnaires (Section 8.4.1.2). Key benefits that emerged were based on an increase in knowledge of BIM, early engagement from the FM team, adoption, differing levels of success due to an understanding and willingness to embrace change, and the client's requirements concerning the BIM delivery. This shows the potential benefits of BIM, as encapsulated for clients and how they can move forward with the adoption of BIM. Some of the presented benefits align with a number of studies, such as the NBS survey (2020, 2021), which shows that one of the benefits of BIM would clients insisting its usage (indicated by 66% of participants). Furthermore, Yan and Damian (2008) reported improved sustainability and creativity as BIM user benefits. Other benefits that emerged from the data collection findings were: Early collaboration, reduced time, improved quality through quality assurance, and clarity in communication. These correlate with a number of studies that identified challenges related to BIM skills amongst users (Azhar, 2011; Barlish and Sullivan, 2012; Blay, Tulli, Mensah, 2019; BSI, 2010, Bryde et al., 2013; Farnsworth et al., 2015; Ghaffarianhoseini et al., 2017; Hardin and McCool, 2015; Marsh, 2017; McGraw Hill construction. 2013; Yan and Damian, 2008). Additional benefits that emerged from the primary data findings and correlate with other studies (Dakhil, 2017; Eastman et al., 2011; Mahamadu, 2017; Marsh, 2017; NBS. 2018). These benefits include: More and faster decision making, higher quality delivery, and improved visualisation. After presenting some of the benefits from the application of BIM amongst users, it is necessary to identify the potential barriers/challenges that exist when applying BIM.

2. Benefits expected to emerge from combining BIM maturity and KPI metrics

An assessment to link BIM maturity and KPI metrics aims to recognise and specify the benefits of this combination. This research delivered a list of benefits that were expected to emerge from the linkage (Section 8.4.3), which aligns with a previous study (Aboumoemen, 2016). The results from the primary data indicated agreement with the list of proposed benefits and the additional benefits expected to emerge (Sections 7.4.5 and 8.4.3). Further to the proposed benefits noted in this research, studies have shown that a relationship enabled through a framework would enhance the level of understanding amongst QS (Wong et al., 2016). Moreover, leveraging the overall quality of a project and its combination with BIM capabilities could minimise errors and omissions, enhance efficiency and precision, and upgrade design evaluation and communication (Khanzadi et al., 2019). Nevertheless, Smits et al. (2016) argues that with the limited impact of BIM on project performance, the large investments in BIM mean that use is instrumental in enabling the impact on project performance. Following a discussion on the assessment, it is then necessary to compare the results of the KPIs across all organisational levels, which will be discussed in the next section. This represents a contribution by delivering the first combined BIM-KPI assessment that aligns with the BS EN ISO19650 standards at three organisational levels, and three maturity assessment levels, and with a standardised list of 10 KPI metrics.

3. Clients and BIM Barriers and Challenges

In terms of the barriers, Sections 7.3.5 and 8.4.1.2 revealed a number of challenges. Key challenges related to the client's lack of understanding of the presented data, a lack of client demand, and a lack of collaboration (engagement). These confirm the NBS report findings on the list of challenges, while other studies have stated similar reasons (Azhar, 2011; Azhar et al., 2015; Blay et al., 2019; BSI. 2010, Dakhil, 2017; Eadie et al., 2013; Eastman, et al., 2011; Gu and London, Gyarting, 2014; Khosrowshahi and Arayici, 2012; Mahamadu, 2107; McGraw Hill construction. 2013; Navendren et al., 2014; NBS. 2019, 2020). The NBS survey (2020) confirmed the following barriers: 64% indicated no client demand, 48% noted a lack of training, and 28% stated the lack of collaboration. Moreover, 66% agreed that private clients do not understand the benefits of BIM, which also represents a barrier.

Other examples of challenges that existed across the data collection findings were: The lack of BIM skills across team members; access to information (industry as siloed); deficiencies with

COBie and excessive time spent on it, and the absence of information. This aligns with a number of studies that stated similar challenges relating to BIM skills amongst users (Alwan et al., 2017; Anderson et al., 2012; Arayici et al., 2011; Azhar et al., 2015; Bataw et al., 2014; Blay et al., 2019; BSI, 2010, Eadie et al., 2013; Gledson et al., 2016; Hardin and McCool, 2015; Khosrowshahi and Arayici, 2012; Succar, 2009).

Having identified the transition from Level 2 BIM to the BS EN ISO19650 standards, BIM adoption, and the various benefits and challenges, the next section will discuss the application of these elements to the BIM maturity assessment.

4. Actions for linking BIM and KPIs

A list of actions was drafted to scope the linkage between BIM maturity and KPI metrics (Section 7.4.5). Some of the actions provided by interviewees included:

1. Providing an action plan, and
2. Measuring BIM maturity and creating KPIs (which means noting where the problems are, improving them, and re-measuring, which accords with Kiew et al., (2012) on the proposed process steps to monitor KPIs).

3) Ascertaining the maturity amongst participants' skills
4) Establishing a management process throughout a project,
5) Assuring programme certainty.

Some actions from the questionnaire participants included: Training, setting benchmark standards, applying fact based analytics to allow fact-based findings, and conducting annual reviews with BIM/KPI result. Some of these actions align with studies that state the importance of BIM adoption to improve project performance (Wong et al., 2016) BIM has the potential to improve the construction quality management process (Khanzadi et al., 2019); nevertheless, Smits et al., (2016) argues that this represents a challenge amongst practitioners and researchers when determining the potential of BIM to improve project performance.

Having presented the initial framework development and compared it with the conceptual framework to demonstrate the main differences (Chapter 3), which lead to the conceptual framework (Chapter 4), and the achievements across the data collection findings (Chapters 6-8) that lead to the initial framework development, the next section will present the validation process for the initial framework.

9.7 External Validation

External validation relies on generalising research findings within the context in which the research is conducted (Fellows and Liu, 2015). The most widely adopted validation approach amongst construction management research is convergence analysis (Ankrah, 2007; Anvuur, 2008; Bashir, 2013; Manu, 2012). Thus, convergence analysis was adopted as the main external validation approach for this research. It involves the use of different research methodologies to test for a level of agreement in the findings (Denzin, 2009). The use of research participant opinion is also regarded as an important validation approach in convergence analysis (Creswell, 2009; Silverman, 2006). In this research, expert respondent feedback was gathered from focus group workshops. This was achieved the invitation to members by NWCH (who were established contacts) to participate in the workshops. This helped to finalise the research findings and validate the framework. As a result, a total of five BIM practitioners from UK clients participated in the validation workshops, which was deemed sufficient, as they possessed the necessary expertise (Anvuur, 2008). The following steps were undertaken for the external validation:

1) Present the initial framework development to the validation group members, elicit feedback on the framework, and establish if further adjustments and enhancements are required.
2) Present the final BIM maturity and KPI assessment framework having revisited feedback on the initial framework development that delivered a number of steps to better enhance the framework and make it clearer to UK clients.

The next section will outline the external validation focus group members and the process undertaken to validate and finalise the proposed assessment framework.

9.8 NWCH Digital Construction working group: Focus group member selection criteria

This section will discuss the selection criteria for the validation focus group members. Similar to the focus group workshops conducted earlier in this research, the validation stage for this research was conducted with a NWCH Digital construction working group that consisted of a homogenous group of five members, all sharing a common background in that they were all built environment professionals with expertise in the fields of architecture and construction. Their roles and coding in the text are: Procurement Framework (V1), Senior Digital Engineer (V2), BIM Consultant (V3), BIM Project Information Manager (V4), and Quantity Surveyor (V5). Table 9.7 presents a detailed description of the participants, their relative backgrounds, and the selection criteria used to identify and invite their participation. A number of questions were posed to enable this description and identify their organisational level (strategic, implementation, and operational). This ensured that participants possessed expertise relevant to the 3 organisational levels, which was necessary for the validation process and finalisation of the framework.

Table 9.7 Background and Criteria for selecting participants for Focus group validation workshops

General information		V1	V2	V3	V4	V5
Background: (i.e. Civil engineer)		Procurement framework / Product design management	Architectural Technology and Construction Management	BIM consultant	Architect / BIM	Quantity Surveyor
Area of expertise: (i.e. Facility Management)		Construction framework management / Lean construction	BIM	BIM	Contractor	Commercial management of construction projects
Level of experience with BIM: (i.e. Number of years)		2	5	5	3	7
General Knowledge on BIM (i.e. Low, Medium, High)		Medium- Good Understanding of principles, benefits. Some technical knowledge	High	High	Medium +	Low- Medium
Number and types of Projects that you have been involved with that includes BIM (i.e. 5 Residential projects)		None delivered projects	0	+ 15	5 Infrastructure Highways	None
Your personal experience with BIM (i.e. enhances delivery of projects, meets projects objectives)		Big opportunity to add value	Personal opinion: Deliver of projects is more efficient	Enhanced transparency	Delivery of information between design to contractor to client	Enhanced FM of projects. Increase certainty of delivery
Your current Organisational level(s): **[Strategic**= Senior Managers, responsible for setting up the strategic goals and gearing up the department to deliver BIM, are expected to complete the assessment at this level. **Implementation**= Information Managers, responsible for ensuring that the strategic goals set out in regards to implementing BIM are delivered, and systems (i.e. people, processes, technologies) are in place to facilitate this, would be expected to complete the assessment at this level. **Operational**= Project Managers, responsible for the day-to-day users operating within a BIM environment, would be expected to complete the assessment at this level.**]**	**Strategic**			✓		✓
	Implementation	✓	✓	✓	✓	
	Operational		✓	✓	✓	

Based on Table 9.7, all participants are involved with architecture and construction, while the level of BIM experience varied from two to seven years, which indicates a mix of experiences. The general knowledge on BIM varied from Low-Medium to high, which again shows that the range of current BIM knowledge varied from one participant to another. Two of the participants were local authority clients that were directly involved with BIM projects; V3 with +15 projects and V4 with 5 projects. They were mainly involved with infrastructure, education or residential, which suggests that BIM is mostly applied within the infrastructure, education and residential sectors. Moreover, participant expertise ensured they could offer relevant inputs to the validation process of the initial framework development. Each participant had personal views on their experience of BIM based on opportunities to add value, greater efficiency with project delivery, enhanced transparency, greater information delivery amongst disciplines and enhanced FM within projects, which could all be seen as benefits driven from the usage of BIM amongst various projects, and better support the validation. Finally, in terms of the organisational levels, all three organisational levels were covered by the participant group, with V1 expertise at the implementation level, V2 and V4 at the implementation and operational level, V5 at the strategic level, and V3 at all organisational levels. This ensured coverage of all organisational levels. The validation workshops process is explained in the next section.

9.9 Research framework: Validation workshop process

During the workshops, the primary data findings were presented along with the initial framework development. The process followed for the external validation included a respondent feedback survey, which included a feedback sheet with a set of close-ended questions covering a mix of percentages, open-ended discussion, and Likert scale responses. Discussions were also held with participants to collate subjective, qualitative data and to help understand their responses. The Likert-scale questions required participants to rate their agreement with the components of the initial framework, particularly in terms of the findings for the 'What', 'How', 'Evidence' and 'Why' stages and the overall picture of the framework. Therefore, a number of statements were available to be questioned on the clarity of the proposed framework. Moreover, a validation of the quality management framework through quality factors was conducted to evaluate and improve its quality (Moody and Shanks, 2003). A combination of qualitative and quantitative methods was applied to empirically validate the framework, while six main quality factors used (Table 9.8).

Table 9.8 Level of Agreement research validation steps (Moody and Shanks, 2003)

Factor	Description	Reference
Correctness	Evaluated in terms of the number of errors in the use of the entity relationship technique	(Kim and March, 1995)
Completeness	Evaluated in terms of number of requirements missing from the model. This was expressed as a percentage of the total user requirements.	(Kim and March, 1995)
Simplicity	Evaluated in terms of the number of entities and relationships in the model	(Moody and Shanks, 1994)
Flexibility	Likert scale (Subjective rating)	(Moody and Shanks, 2003)
Understandability		
Overall quality		

Table 9.8 presents the six quality factors used to validate the quality management framework in Moody and Shanks' (2003) research. The process to finalise the framework was discussed for this study (Section 5.13) namely the external validity step to evaluate the initial framework development and present the final framework. This involved triangulation, which incorporated different sources of information (literature, fieldwork, external validity). The same factors were used to validate the framework in the level of agreement questions, as follows:

1) **Correctness**: Evaluated in terms of the framework structure.
2) **Completeness**: Evaluated in terms of the complete framework, whether it covers the requirements for a BIM maturity and KPI metric relationship, and if it is sufficient.
3) **Simplicity**: Evaluated in terms of the simplicity of the framework for presentation to clients. The set of questions were based on a five-level percentage to indicate the level of agreement (0-25%, 5-50%, 50-70%, 70-90%, 90-100%); these were also included in the to open discussion.

The remaining factors were considered on a five-point Likert scale (strongly disagree to strongly agree)

4) **Flexibility:** Framework to operate within multiple client sectors.
5) **Understandability:** Level of understanding of the framework and demonstration of the necessary relationship between BIM maturity and KPI metrics
6) **Overall quality:** Framework to meet the client sector's requirement for a BIM maturity and KPI assessment framework, namely the main aim of this research.

In addition to these factors, three questions related to:

1) Overall feedback, which aimed to evaluate whether the framework met the expectations of expert focus group members, whether they thought that organisations would benefit from the framework, and if the performance levels within organisations would be reflected in the framework.
2) Finally, an evaluation form was provided to participants to complete and to outline any further comments/recommendations.

Table 9.9 presents a summary of the feedback survey form.

Table 9.9 Level of agreement questions: Feedback survey form

Category	Statements (Please tick where necessary)	0 – 25%	25-50%	50-70%	70-90%	90-100%
Correctness	How much do you think the 3 part division of the framework (What, how and evidence) presents a complete structure for the framework formulation?					
Completeness	How much do you think that the framework covers the essential requirements of a relationship between BIM and KPIs?					
Simplicity	How much do you think the existing relationship is sufficient in terms of its simplicity when presented to the client sector					
	Statements (Please tick where necessary)	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Flexibility	The framework should fit well within any of the UK client sectors and not in the designated sector in specific					
Understandability	The presented framework was easy to understand and it demonstrated the relationship between BIM and the KPIs					
Overall Quality	The presented framework shall meet the client sector's vision for a combined BIM / KPI approach					
Overall feedback	The framework meets your expectations in a combined BIM / KPI approach					
	Client organisations will benefit from this framework					
	The performance levels within the client organisation could be enhanced and reflected positively by introducing the framework to them?					
Further comments	Do you have any further comments to add?	Yes		No		
	If yes then what are they?					

Having presented the questions during the validation sessions, the next section presents the outcomes from the discussions on the initial framework development.

9.9.1 Research framework: Focus group workshop discussions

This section will outline the findings from the proposed initial framework development that enabled the delivery of the final BIM maturity-KPI assessment framework. A validation workshop was conducted to present the initial framework development to the group members, determine the extent to which participants agreed with the framework, amend the framework based on the feedback received, and finalise the framework. Table 9.10 presents a summary of the structure and process of discussion held across the workshop. The next section discusses the workshop in more detail.

Table 9.10 Focus group workshops discussions

Workshop label	Workshop discussion	Workshop findings
Workshop process	a) Presenting the initial framework development b) Collecting feedback on the framework through the level of agreement feedback form c) Amending the initial framework and presenting the final framework	a) Initial framework development feedback b) Final BIM maturity- KPI assessment framework
Validation Workshop	a) Feedback presented from the focus group workshop members on the following: I. Findings that are associated to "The What" stage, including the design of the stage on the framework and what has been delivered across the stage II. Findings that are associated to "The How" stage, including the design of the stage on the framework and what has been delivered across the stage III. Findings that are associated to "The Evidence and The Why" stage, including the design of the stage on the framework and what has been delivered across the stage b) Filling out the level of agreement form to determine to how extent do the members agree to the initial framework development c) Presenting the final BIM maturity-KPI assessment	a) Initial framework development across all of its stages "The What, The How, The Evidence and The Why" b) Level of feedback form completed and discussions around the initial framework development towards amending it to the final framework c) Final BIM maturity- KPI assessment framework presented

The workshop has been structured to provide meaningful steps towards the presentation of the final BIM maturity-KPI assessment framework to UK clients. According to the structure of the workshop (Table 9.10), the data collected were discussed as follows:

a) **Validation Workshop:** Presented findings from the initial framework development in terms of the complete structure (Figure 9.1). Moreover, the findings were associated to each of the three stage elements, namely the What, How, and Evidence and Why (Sections 9.4-9.6) to explain the research objectives and present the achievements against each objective. In the level of agreement feedback form (Table 9.10), group members completed and provided feedback on the initial framework development and discussed additional amendments.

Having presented the process of the validation workshop, the next section will present the findings from the focus group workshop.

9.9.2 Analysis and findings on the initial framework development

Previous data collection findings were presented, along with the initial framework development within this stage. Discussions were also held with participants in order to understand their responses to the level of agreement feedback form (Table 9.10). They considered the six quality factors presented in the previous section and overall feedback and further comments on the initial framework development. The research findings were presented, which included a presentation of the following:

1) The initial framework development (Figure 9.1)
2) Findings related to the framework's three stage elements (What, How, and Evidence and Why) as discussed in Sections 9.4-9.6.

For each phase, the findings that emerged from each data collection stage were shown. The initial framework development stages were presented which included the following findings:

1) The 'What' (Section 6.12):
   a) The What - Findings on the KPI metrics (Section 6.12).
   b) The What - Presenting the BIM maturity assessment across the three organisational levels (strategic, implementation, operational) which were considered in the focus group workshops (Section 6.8), and incorporated the new BS EN ISO19650 standards in accordance with the questionnaire findings (Table 9.1).
2) The 'How' (Section 7.5 and Section 8.4.4):
   a) The How - Maturity assessment results based on the data collection findings (Section 8.4.2).
   b) The How - Findings on the link between BIM maturity and KPI metrics as gathered from the interviews (Section 7.4.4) and the relationship with KPI metrics from the questionnaires (Section 8.4.2).
   c) Determining the strength of relationship between the BIM maturity and KPI metrics based on four different methods from the questionnaire findings. These were presented in the following sequence (Section 8.4.2): 1) BIM maturity and KPI metric averages, 2) Spearman Correlation, and 3) Linear Regression.

A sample of the relationship assessment across the three organisational levels is presented in Figure 9.2, and the complete version of all organisational levels is available in Appendix G.

3) "The Evidence and The Why" (Section 8.4.4):
   a) Benefits from the combined BIM maturity and KPI metrics (Section 8.4.3).
   b) Proposition of an action plan to upskill from one maturity level to another (Section 7.4.5).

The feedback sheet was given to participants to complete to gather their opinions on the findings and framework. Table 9.11 presents the findings from the workshop and survey form.

Table 9.11 Level of agreement findings on initial framework development

Level of agreement to the following statements											
Category	**Statements (Please tick where necessary)**	**0 – 25%**	**25-50%**	**50-70%**	**70-90%**	**90-100%**	**V1**	**V2**	**V3**	**V4**	**V5**
Correctness	How much do you think the 3 part division of the framework (What, how and evidence) presents a complete structure for the framework formulation?	✓			✓✓	✓✓					
Completeness	How much do you think that the framework covers the essential requirements of a relationship between BIM and KPIs?		✓	✓✓	✓	✓					
Simplicity	How much do you think the existing relationship is sufficient in terms of its simplicity when presented to the client sector			✓✓✓	✓✓						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree					
Flexibility	The framework should fit well within any of the UK client sectors and not in the designated sector in specific				✓✓✓	✓✓					
Understandability	The presented framework was easy to understand and it demonstrated the relationship between BIM and the KPIs		✓✓	✓	✓✓						
Overall Quality	The presented framework shall meet the client sector's vision for a combined BIM / KPI approach		✓		✓✓	✓✓					
Overall feedback	The framework meets your expectations in a combined BIM / KPI approach		✓		✓✓	✓✓					
	Client organisations will benefit from this framework				✓	✓ ✓✓✓					
	The performance levels within the client organisation could be enhanced and reflected positively by introducing the framework to them?				✓✓✓	✓✓					
Further comments	Do you have any further comments to add?	Yes	✓✓✓✓	No		✓	**No**	**Yes**	**Yes**	**Yes**	**Yes**
If yes then what are they?	**V2** • **Correctness:** It covers more than the necessary to evaluate BIM maturity. • **Completeness:** Unnecessary Part 3 **"The Evidence".** • **Simplicity:** I don't think organisations should rate the relationship themes **(+ / -)** at all. • I believe the Sub metrics represent Level 2 BIM KPIs, you should make it clear the others are organisational KPIs. • **"The what"** and **"The how"** assessment is sufficient to establish the Level 2 BIM maturity of an organisation. **"The Evidence"** is just a bonus good to know information on how doing better in BIM can improve their organisational performance. • I think Organisations should score themselves against BIM KPIs. You should give them **"The Evidence"** sheet completed based on your research. **V3** • Make it Human Digestible **V4** • **Overall Quality:** To be revised • Start with their strongest point **V5** • The framework should provide guidance on how to improve maturity (i.e. based on current maturity what are steps to be taken to achieve the next level • Would be ideal to have a dashboard summary for each organisational level										

Table 9.11 shows various levels of agreement to the questions asked, and most offered comments to further support the initial framework development (except V1 who did not have any further comments to add to the framework since the inputs given on the feedback were felt to be sufficient). In terms of the six quality factors and how they could improve the quality of the framework, the findings demonstrated:

1) **Correctness:** In terms of the initial framework development structure across each of the framework's three stage elements: the What, How, and Evidence and Why (Figure 9.1), V4 indicated that only 0-25% would experience difficulties in understanding the presented framework. While V3 and V5 indicated the framework was 70-90% correct. Moreover, V2 suggested that the framework covered more than the necessary information to evaluate BIM maturity and recommendations to reduce the findings related to the 'How' stage stipulating only the BIM maturity and KPI metric averages, and the Spearman correlation; this last finding was agreed amongst all focus group members.

This indicates that the overall results were positive in terms of the framework being correct (rated at 70-100%), whereas some minor adjustments were required on the framework's three stage elements in order to comply with the group members' feedback. As a result, in order to meet the correctness factor, it is necessary to revisit the findings for each of the framework's elements, to determine which are relevant and to amend each element based on the comments received from the group members. The development of each element is presented in Figures 9.7-9.10 to show the amendments that occurred from the initial framework to the final framework.

a) <u>The 'What' stage</u> (Figure 9.7):

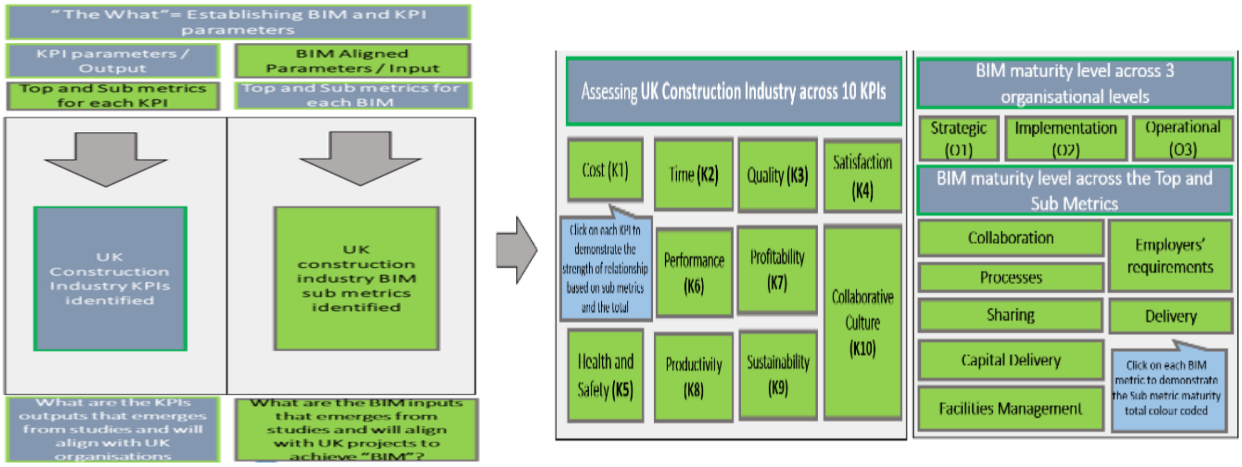


Figure 9.7 The 'What' stage evolvement from the initial framework development (left) to the final framework (right)

The 'What' stage identifies the required BIM maturity and KPI metrics for the framework and assessments (Section 3.4). Since the final framework evolved from the initial framework (Figure 9.1) due to feedback from group members (Table 9.11), it was necessary to provide an explanation as to the development process and identify the main differences between this stage, the initial framework development and the final framework. The 'What' stage of the initial framework development (Figure 9.7, left side) presented the BIM maturity and KPI metrics that were based on the data collection findings (Figure 9.2). As a result of the level of agreement in the findings that indicated 70-100% correctness no changes were required. Thus, the 'What' development stage of the proposed final framework (Figure 9.7 on the right side) remained the same as the initial framework development.

b) The ‘How’ stage (Figure 9.8):

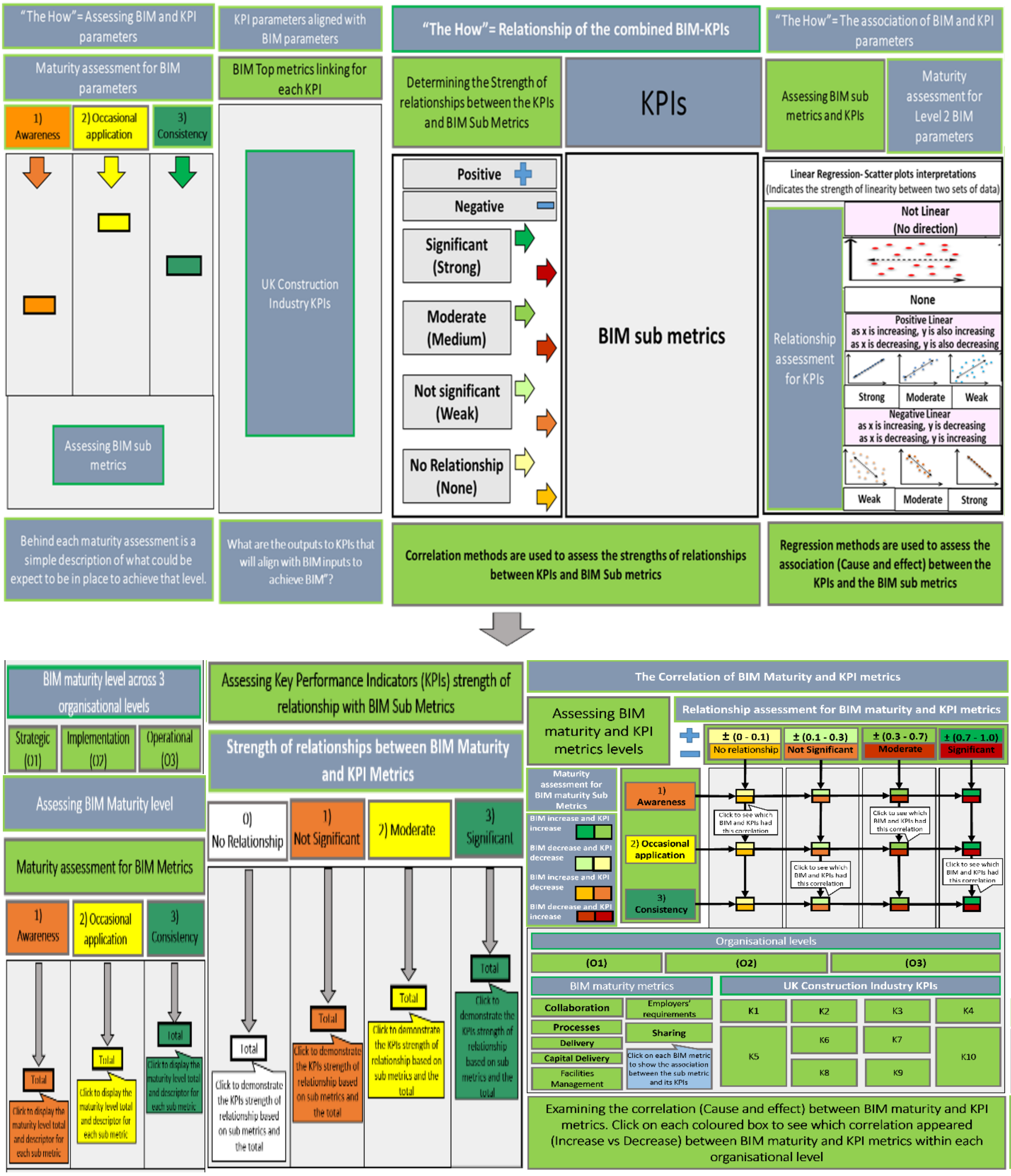


Figure 9.8 The ‘What’ stage evolvement from the initial framework development (above) to the final framework (below)

The ‘How’ Stage identifies the potential linkages between BIM maturity and KPI metrics for the framework and for the assessments proposed for this research. Since the final framework evolved from the initial framework development (Figure 9.1) as a result of the level of agreement in the feedback from group members (Table 9.11), it was necessary to provide an explanation of the development process and identify the main differences with the ‘How’ stage. The ‘How’ stage of the initial framework development (Figure 9.8) presented the results by linking BIM maturity and KPI metrics based on the data collection findings (Figures 9.9-9.10 and Section 8.4.2). Nevertheless, the level of agreement indicated 0-25% correctness and difficulties in understanding the initial framework development (according to V4), specifically with the 'How' stage since a number of findings contained the following: **1) BIM maturity and KPI metric averages, 2) Spearman Correlation and 3) Linear Regression**. In addition, V2 proposed to *"Reduce the presentation of the findings in this stage to only the BIM maturity and KPI metric averages and the Spearman correlation since those would be better understood within the client sector and it demonstrates how are BIM maturity and KPI metrics being linked without the need to include the results of the linear regression to avoid further confusion with the BIM maturity and KPI linkages"*. This indicated that it was necessary to revisit the 'How' stage of the initial framework development and remove the results of the linear regression since these results seemed to create confusion amongst group members. Instead, the results of the BIM maturity and KPI metric averages and the spearman correlation were better understood amongst group members. Therefore, the level of agreement in the findings indicated 0-25% correctness and difficulties in understanding the initial framework development at this stage. As such, the 'How' development stage of the final framework (Figure 9.8) remained the same as the initial framework in terms of the results for **1) BIM maturity and KPI metric averages and 2) Spearman Correlation**. However, the results associated with the **3) Linear Regression** were removed, which was the main change across this stage and aimed to enable better understanding of the relationship between BIM maturity and KPI metrics. Figures 9.9-9.10 presents the results of the BIM maturity and KPI metric relationship averages and the Spearman correlations across all the organisational levels (strategic, implementation, operational).

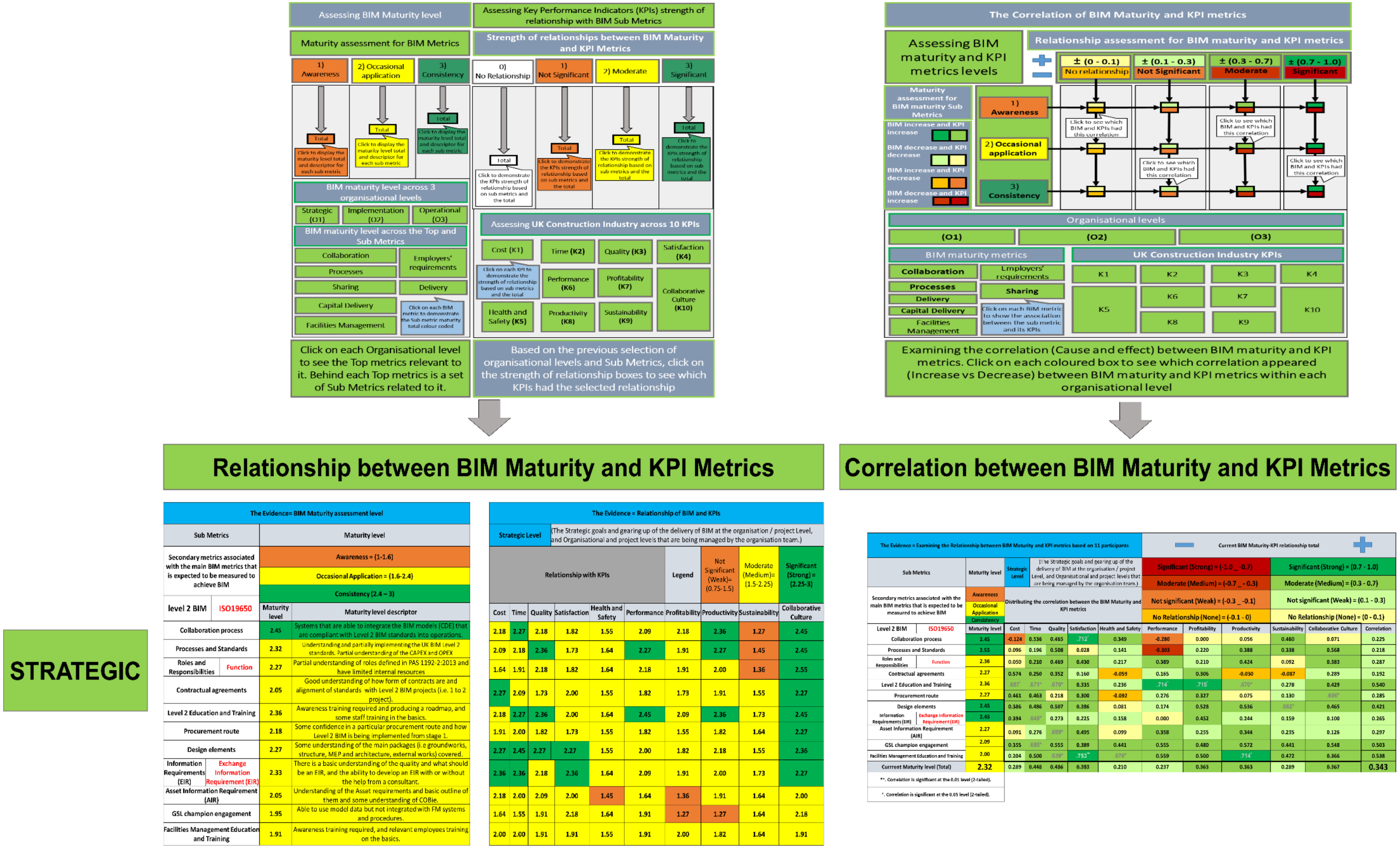


Figure 9.9 Research findings related to the 'How' framework stage (Relationship and Correlation)

IMPLEMENTATION

The Evidence= BIM Maturity assessment level			
Sub Metrics		Maturity level	
Secondary metrics associated with the main BIM metrics that is expected to be measured to achieve BIM		Awareness = (1-1.6)	
		Occasional Application = (1.6-2.4)	
		Consistency (2.4 – 3)	
level 2 BIM	ISO19650	Maturity level	Maturity level descriptor
Level 2 Education and Training		2.07	There is internal training undertaken (i.e. intermediate BIM training or system training) CDE, FM, software based training
Information Requirements (EIR)	Exchange Information Requirement (EIR)	2.21	Basic template and external procured EIR
Uses		2.38	BIM uses are outlined but not tailored for specific projects
Supplier assessment forms		2.21	BIM uses are outlined but not tailored for specific projects
Execution Plan (BEP)	Information Delivery Plan	2.45	Clients are able to review the BEP
Master Information and Task Team Information (MIDP and (TIDP)		2.14	Consultant reviews of MIDP and TIDP.
Model production Delivery Table (MPDT)		1.96	Basic MPDT Template
Responsibility Matrix (RM)	Assignment Matrix	2.24	Basic RM template developed but not completed.
Document management stage-Common Data Environment (CDE)	<CDE> State	2.64	CDE supplied by you or supplied by others - CDE is fully compliant to BIM Level 2 and security requirements
Information Exchange		2.38	Information exchange is defined with basic requirements.
COBie data		1.93	Understanding the use of COBie but not incorporated on the FM.

The Evidence = Relationship of BIM and KPIs									
Implementation Level	(Implementing BIM across the organisation / project level, in line with the organisation / project strategic goals in relation to BIM implementation.)								
Relationship with KPIs						Legend	Not Significant (Weak)= (0.75-1.5)	Moderate (Medium)= (1.5-2.25)	Significant (Strong) = (2.25-3)
Cost	Time	Quality	Satisfaction	Health and Safety	Performance	Profitability	Productivity	Sustainability	Collaborative Culture
2.11	2.21	2.47	2.32	2.16	2.26	2.00	2.21	1.47	2.53
2.00	2.00	2.37	2.32	1.79	2.00	1.89	2.11	1.53	2.42
2.16	2.26	2.26	2.21	2.11	2.16	1.89	2.53	1.84	2.42
2.11	2.21	2.37	2.21	2.05	2.21	1.84	2.32	1.89	2.42
2.21	2.42	2.53	2.42	1.95	2.26	2.00	2.26	1.84	2.58
2.21	2.42	2.32	2.21	2.05	2.42	1.79	2.26	1.74	2.47
2.11	2.32	2.32	2.26	1.68	1.95	1.63	2.32	1.53	2.26
2.05	2.16	2.42	2.26	2.00	2.47	2.16	2.47	1.68	2.53
2.42	2.37	2.47	2.63	1.95	2.47	1.95	2.63	1.74	2.68
2.37	2.58	2.47	2.53	1.74	2.42	2.00	2.32	1.63	2.53
2.21	2.11	2.26	2.21	1.68	2.21	1.95	2.11	1.84	2.26

The Evidence = Examining the Relationship between BIM Maturity and KPI metrics based on 19 participants

Current BIM Maturity-KPI relationship total

Sub Metrics		Maturity level	Implementation Level	(Implementing BIM across the organisation / project level, in line with the organisation / project strategic goals in relation to BIM implementation.)	Significant (Strong) = (-1.0 _ -0.7)	Significant (Strong) = (0.7 - 1.0)
Secondary metrics associated with the main BIM metrics that is expected to be measured to achieve BIM		Awareness	Distributing the correlation between the BIM Maturity and KPI metrics		Moderate (Medium) = (-0.7 _ - 0.3)	Moderate (Medium) = (0.3 - 0.7)
		Occasional Application			Not significant (Weak) = (-0.3 _ -0.1)	Not significant (Weak) = (0.1 - 0.3)
		Consistency			No Relationship (None) = (-0.1 - 0)	No Relationship (None) = (0 - 0.1)

Level 2 BIM	ISO19650	Maturity level	Cost	Time	Quality	Satisfaction	Health and Safety	Performance	Profitability	Productivity	Sustainability	Collaborative Culture	Correlation
Level 2 Education and Training		2.16	0.182	0.197	0.117	0.160	.558*	.590**	0.351	-0.101	-0.071	-0.223	0.176
Information Requirements (EIR)	Exchange Information Requirement (EIR)	2.16	0.405	0.265	.544*	0.424	0.237	0.241	0.354	0.197	.498*	0.308	0.347
Uses		2.47	0.031	0.147	-0.102	-0.054	0.270	0.213	.485*	0.267	0.299	0.258	0.181
Supplier assessment forms		2.37	0.119	-0.087	-0.204	-0.205	-0.145	-0.194	-0.230	-0.399	-0.101	-0.368	-0.181
Execution Plan (BEP)	Information Delivery Plan	2.47	0.373	0.375	0.227	0.227	0.232	0.182	0.387	0.177	.588**	0.297	0.306
Master Information and Task Team Information (MIDP and (TIDP)		2.21	0.164	-0.150	-0.065	0.087	0.367	-0.136	0.043	-0.061	0.131	0.097	0.048
Model production Delivery Table (MPDT)		1.95	0.022	0.123	0.245	0.233	0.270	0.234	0.226	0.257	.500*	0.119	0.223
Responsibility Matrix (RM)	Assignment Matrix	2.32	0.167	0.115	0.019	0.102	0.139	-0.147	0.094	0.011	0.303	-0.059	0.074
Document management stage-Common Data Environment (CDE)	<CDE> State	2.68	.465*	0.281	-0.036	0.185	-0.011	0.000	0.173	-0.284	0.401	-0.218	0.096
Information Exchange		2.47	-0.011	0.023	0.156	-0.367	0.010	0.000	0.166	-0.223	0.284	0.000	0.004
COBie data		1.89	0.175	0.140	-0.205	-0.227	0.152	-0.056	-0.145	-0.280	-0.043	-0.114	-0.060
Current Maturity level (Total)		2.29	0.163	0.130	0.063	0.052	0.189	0.084	0.173	-0.040	0.254	0.009	0.110

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

OPERATIONAL

The Evidence= BIM Maturity assessment level			
Sub Metrics		Maturity level	
Secondary metrics associated with the main BIM metrics that is expected to be measured to achieve BIM		Awareness = (1-1.6)	
		Occasional Application = (1.6-2.4)	
		Consistency = (2.4-3)	
level 2 BIM	ISO19650	Maturity level	Maturity level descriptor
Information Requirements (EIR)	Exchange Information Requirement (EIR)	2.13	Basic template and external procured EIR
Document management stage-Common Data Environment (CDE)	<CDE> State	2.38	CDE supplied by you or supplied by others - CDE implemented but not Level 2 BIM compliant / PAS1192-5 compliant
3D – 6D inputs		1.81	Identified but not used in a certain degree over projects
Level of Development (LoD)	Level of Information need	2.25	Good understanding of the LoD and basic ability to check (Visual checks) the models
Project reviews		1.88	Good understanding of the roles and responsibility and acknowledging the clients on the gateway reviews to be applied
Lifecycle Analysis		1.81	Basic Usage of the Lifecycle but not fully managed
As built model		2.07	As built model is acknowledged by project team members in line with BIM level 2, and ready to be used.
Project Information Model (PIM) exchanges		2.00	Information model is acknowledged by project team members in line with BIM level 2, and ready to be used.
Information Delivery (AIM)		1.75	Good Understanding of AIM and using it in the basic level but is not fully level 2 BIM compliant
COBie data		1.88	Good Understanding and using it in the basic level but not fully integrated in the system
Handover requirements (GSL)		1.81	Good understanding of the Hand-overs required for the GSL, and is being used but not fully Level 2 BIM compliant
Post Occupancy Evaluation (POE)		1.56	Basic understanding of Post Occupancy Evaluation, but is not presented

The Evidence = Relationship of BIM and KPIs									
Operational Level	(Operating BIM across the organisation / project, and how the management of information being collected is achieved.)								
Relationship with KPIs						Legend	Not Significant (Weak)= (0.75-1.5)	Moderate (Medium)= (1.5-2.25)	Significant (Strong) = (2.25-3)
Cost	Time	Quality	Satisfaction	Health and Safety	Performance	Profitability	Productivity	Sustainability	Collaborative Culture
2.50	2.40	2.30	2.10	1.80	2.20	2.10	1.90	1.80	2.20
2.30	2.40	2.10	2.00	1.70	2.30	1.80	2.20	1.90	2.30
2.20	2.30	2.40	2.00	1.70	2.10	1.90	2.10	1.90	1.80
1.60	1.70	2.20	2.10	1.50	2.00	1.60	2.10	1.70	2.30
2.10	2.30	2.10	1.90	1.69	1.90	1.90	2.10	2.00	2.10
2.20	2.10	2.10	1.90	1.80	2.10	2.00	2.20	2.00	2.00
2.20	2.10	2.30	2.20	2.00	2.20	2.00	2.20	2.00	2.20
2.20	2.10	2.40	2.30	1.70	2.20	2.00	2.00	2.00	2.30
2.40	2.40	2.40	2.40	2.20	2.60	2.20	2.30	2.30	2.30
1.70	1.70	1.90	1.60	1.20	1.70	1.70	1.70	1.70	2.00
2.00	1.70	1.90	2.00	1.50	1.80	1.60	1.90	1.60	1.70
1.40	1.40	2.00	1.90	1.70	1.60	1.40	1.50	1.40	1.60

The Evidence = Examining the Relationship between BIM Maturity and KPI metrics based on 10 participants

Current BIM Maturity-KPI relationship total

Sub Metrics		Maturity level	Operational Level	(Operating BIM across the organisation / project, and how the management of information being collected is achieved.)	Significant (Strong) = (-1.0 _ -0.7)	Significant (Strong) = (0.7 - 1.0)
Secondary metrics associated with the main BIM metrics that is expected to be measured to achieve BIM		Awareness	Distributing the correlation between the BIM Maturity and KPI metrics		Moderate (Medium) = (-0.7 _ - 0.3)	Moderate (Medium) = (0.3 - 0.7)
		Occasional Application			Not significant (Weak) = (-0.3 _ -0.1)	Not significant (Weak) = (0.1 - 0.3)
		Consistency			No Relationship (None) = (-0.1 - 0)	No Relationship (None) = (0 - 0.1)

Level 2 BIM	ISO19650	Maturity Level	Cost	Time	Quality	Satisfaction	Health and Safety	Performance	Profitability	Productivity	Sustainability	Collaborative Culture	Correlation
Information Requirements (EIR)	Exchange Information Requirement (EIR)	2.20	0.230	-0.037	0.036	0.408	0.335	0.043	0.138	0.470	0.411	0.323	0.236
Document management stage-Common Data Environment (CDE)	<CDE> State	2.40	-0.076	0.165	0.486	0.377	0.439	0.007	0.144	0.156	0.411	0.485	0.259
3D – 6D inputs		2.00	-0.040	0.269	0.438	0.402	0.354	0.319	-0.276	-0.040	0.315	0.557	0.230
Level of Development (LoD)	Level of Information need	2.40	0.327	0.136	-0.030	-0.147	0.000	0.328	0.149	0.384	0.217	0.335	0.170
Project reviews		1.90	-0.031	0.163	-0.195	-0.229	-0.222	-0.229	-0.047	-0.031	0.104	-0.031	-0.075
Lifecycle Analysis		2.00	-0.075	0.288	-0.051	0.289	0.579	-0.051	-0.028	-0.298	0.146	0.222	0.102
As built model		2.10	0.201	0.110	-0.078	0.149	0.343	0.341	0.313	0.201	0.562	0.563	0.271
Project Information Model (PIM) exchanges		2.00	0.097	0.120	-0.231	0.224	0.448	0.000	0.250	0.340	0.389	0.224	0.186
Information Delivery (AIM)		1.80	0.516	0.516	0.279	0.516	.690*	0.470	.890**	.744*	0.458	.744*	0.582
COBie data		1.90	-0.242	-0.003	-0.273	0.142	-0.320	-0.172	-0.003	-0.003	-0.172	0.062	-0.099
Handover requirements (GSL)		2.00	0.250	0.582	0.286	0.250	.884**	0.572	.892**	0.510	.771**	.794**	0.579
Post Occupancy Evaluation (POE)		1.60	0.517	0.517	0.021	-0.074	0.331	0.244	0.517	0.539	0.517	0.333	0.346
Current Maturity level (Total)		2.03	0.116	0.229	0.057	0.163	0.322	0.108	0.245	0.248	0.344	0.384	0.232

**. Correlation is significant at the 0.01 level (2-tailed).

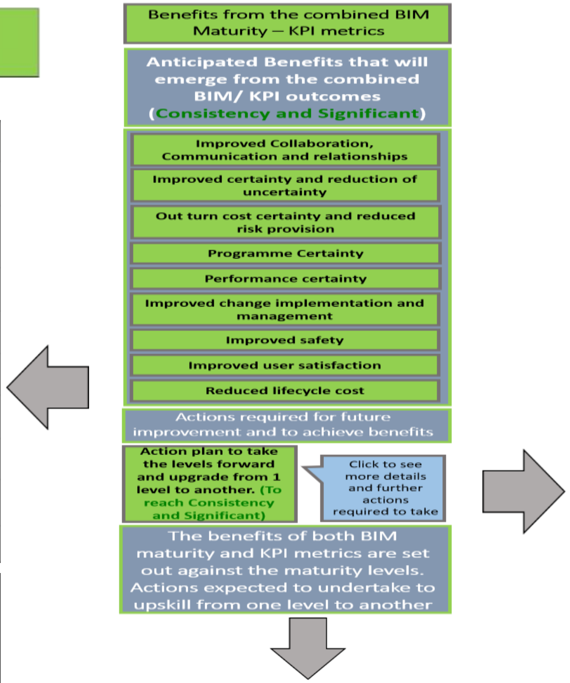
*. Correlation is significant at the 0.05 level (2-tailed).

Figure 9.10 Research findings related to the ‘How’ framework stage (Relationship and Correlation) continued

Benefits that is expected to emerge (Green)

Benefits
Improved Collaboration, Communication and relationships
Improved certainty and reduction of uncertainty
Out turn cost certainty and reduced risk provision
Programme Certainty
Performance certainty
Improved change implementation and management
Improved safety
Improved user satisfaction
Reduced lifecycle cost.

Additional benefits
Benefits
Achieving maturity 3 (consistency) all the time.
Improve overall project delivery, add value to the client, spreading more knowledge across the project team, spreading more BIM related stuff and they will be more aware."
*Visualisation to support decision making and *improved clash detection.*
Working collaboratively, there will be openness, projects will work on a smoother pace"
Safety and change management and things like that definitely comes in the construction period, along with the KPIs.
"Assess time savings or cost saving benefits of BIM and reflect this in more competitive quotes to clients to extra business."
"As long as the procurement routes are set up to integrate lifecycle analysis, that could be massive"
Environmental benefits - considering programme, re-works etc.
Collaboration
Again client satisfaction when it comes to potentially winning more work with the same client.
Better Facilities Management
better and more efficient buildings / assets
Outcome benefits, not just output benefits



Action plan strategy	Further Actions
"To have a weighing scheme, check back on the filled spreadsheet for example on how to distribute the KPIs / weight / actions, etc"	*"To make a positive change, you need to measure maturity"*
"Action plan to take the levels forward and upgrade from 1 level to another. (Awareness to occasional application)."	*"If the benefits could be tied to the KPIs, then that could improve the KPIs. if you can link them all together, then it can make it easier to put a business case for it"*
"Conducting follow-up meeting with users to follow with their progress and see if they upskilled with their maturity"	*"The process will be measure your BIM maturity, create your KPIs, and find out where the problems are, improve it, and then re-measure it."*
"Create set of matrices on what I needs to be done to comply with this."	*"Greater integration of Services & design with the whole supply chain should generate more efficiencies & savings."*
	"Yes it does. By bringing in Culture and Safety into it"
	"The action plans could then be linked to training plans, where you have a regular 1 to 1 sessions. You did this project and scored 1 so what could be done to improve this."

BIM maturity assessment (The What) (Transition from level 2 BIM to the new BS EN ISO19650 standards)						BIM maturity measurement (The How) (Transition from level 2 BIM to the new BS EN ISO19650 standards)									
						Maturity level 1	2	3						3	
Top Metrics		Sub Metrics			Essence of descriptors	Awareness	Occasional Application	Consistency	Current Maturity level	Weight	Action plan / Training	Responsibility to meet plan	Responsibility to handle payments and expenditures	Consistency	Target Maturity level
	Main BIM metrics and their descriptions		Secondary metrics associated with the main BIM metrics that is expected to be measured to achieve BIM		Description of the secondary metrics to provide a clear definition of each metric	General Knowledge and understanding of BIM metrics in operational level, but is sometimes not being recognised across the organisation	Partial Application of BIM metrics and is somehow being recognised, but is not being embedded generally	Full application and maintaining BIM metrics, is consistently recognised, and is being embedded across projects generally						Full application and maintaining BIM metrics, is consistently recognised, and is being embedded across projects generally	
			level 2 BIM	ISO19650											
a)	Employers' requirements (Defining stakeholder needs for projects to be able to achieve BIM)	1)	Information Requirements (EIR)	Exchange Information Requirement (EIR)	Presence of Employers Information Requirements and level of requirements expected for Employers	No EIRs presented	Basic template and external procured EIR	Fully developed EIR in the provided documents (AIR)	2	1	Software, BIM Authoring, Clash Detection,	Architect 3rd Party Contractor	In house Project (external) Project (external)	Fully developed EIR in the provided documents (AIR)	3
b)	Sharing (Distribution of information amongst stakeholders that is shared effectively amongst them)	1)	Document management stage- Common Data Environment (CDE)	<CDE> State	Achievements of File systems, workflows, library, and accessibility in projects' pre-contract and post-contract stage and a post-completion asset management stage for a Common Data Environment	CDE supplied by you or others - Not aware and CDE required	CDE supplied by you or supplied by others - CDE implemented but not Level 2 BIM compliant / PAS1192-5 compliant	CDE supplied by you or supplied by others - CDE is fully compliant to Level 2 BIM and security requirements	1	0.8	CDE, BIM launch, COBie MasterClass	Contractor 3rd Party BIM Consultant	Project (external) In house In house	CDE supplied by you or supplied by others - CDE is fully compliant to BIM and security requirements	3
Current Maturity level (Total)									1.5	Target Maturity level (Total)					3.00

Figure 9.11 Research findings related to the 'Evidence' and the 'Why' stage (Benefits and Action plan)

c) <u>The 'Evidence' and the 'Why' (Figure 9.11):</u>

The 'Evidence' and the 'Why' stage was presented to identify the BIM maturity and KPI metrics relevant for the framework and for the assessments proposed in this research. Since the final framework evolved from the initial framework development (Figure 9.1) as a result of the level of agreement on feedback results from the group members (Table 9.11), it was necessary to provide an explanation of the development process and identify the main differences between the 'Evidence' and the 'Why' stage, the initial framework development and the final framework. As a result, the level of agreement in the findings indicated 70-100% correctness. From this, the 'Evidence' and the 'Why' development stage of the final framework (Figure 9.11) remained the same as the initial framework development and no further changes were made.

2) **Completeness:** The initial framework development covered the essential relationship between BIM maturity and KPI metrics (Figure 9.2); V1 and V4 indicated 50-70% completion, V5= 70-90% and V3= 90-100%. Moreover, V2 indicated that it was only 25-50% complete and stated that *"It is unnecessary to have Part three the 'Evidence' and the 'Why' since it is only relevant to demonstrate how BIM maturity and KPI metrics would be linked together, without the need to demonstrate what are the expected benefits to emerge from this linkage or to demonstrate what are the relevant actions to take to move from one maturity level to another"*. Thus, V2 proposed to keep all stages of the framework except the 'Evidence' and the 'Why' stage since they believe it is unnecessary to demonstrate the benefits and actions to take. However, a number of discussions were held with group members to understand how framework could be complete by covering the required relationships between BIM maturity and KPI metrics. The discussions revealed the importance of the benefits and actions associated with BIM maturity and KPI metrics linkages, since it is vital for UK clients to understand how this linkage would help to enhance the performance of construction projects within the sector, and how the number of actions required would help to improve the maturity levels and ensure improvements in that the overall performance of the sector. Also, the discussions indicated that it would be vital to determine how the relationship assessment would reflect on organisations, in terms of the current scores given, and if there were improvements across the organisations as a result of combining BIM maturity and KPI metrics in the future. As a result, it was agreed to keep all of framework findings as they were, as presented in Figures 9.9-9.11.

In addition, V2 stated that it would not be necessary to break down the framework to three stages, which was further agreed by the group members. Instead, they recommended including the results of the BIM maturity and KPI metrics along with the benefits and action plans. V5 stated that, for this to happen, the framework could be presented as a dashboard summary displaying these results (Figures 9.9-9.11). As a result, the findings of the framework (Figures 9.9-9.11) were be presented in the final framework and the naming convention of the What, How, and Evidence and Why stages were all removed.

This shows that the overall results were mid-way between positive and negative, as some minor adjustments were required to the framework according to focus group member feedback. Hence, in order to meet the completeness factor, it was necessary to revisit the breakdown of the framework into three stage elements, to amend the elements and only present the results without mentioning the three stage elements. This required the collation of the findings (Figures 9.9-9.11) to demonstrate how the end result of the framework would work. As a result, the final BIM maturity- KPI assessment framework as a dashboard summary is presented in Figure 9.12.

3) **Simplicity:** All participants agreed that it was difficult to understand the framework and therefore it was not simple enough for the client sector. As a result, V1, V3 and V5 selected 50-70% and V2 and V4 selected 70-90%. Moreover, V2 stated that *"I do not think organisations should rate the relationship themes (+ and -) at all, since the organisations are more interested to see if there is a relationship that exist between the BIM maturity and KPI metrics and the strength of this relationship, but not necessary the direction of the relationship",* and V4 sharing similar views with V2. V3 added that *"The results of the linear regression analysis are still relevant to your research to determine if the KPIs would depend on the BIM maturity levels, but the organisations are more interested to see what the current BIM maturity levels are and how are the KPIs being linked to it",* and V5 sharing similar views with V3. The results indicated that the regression analysis of the research findings (Section 8.4.2) was still relevant for presentation and exploration in this research, but that it is not required in the final framework, as explained in the correctness factor. Thus, the results for the linear regression were excluded from the final framework.

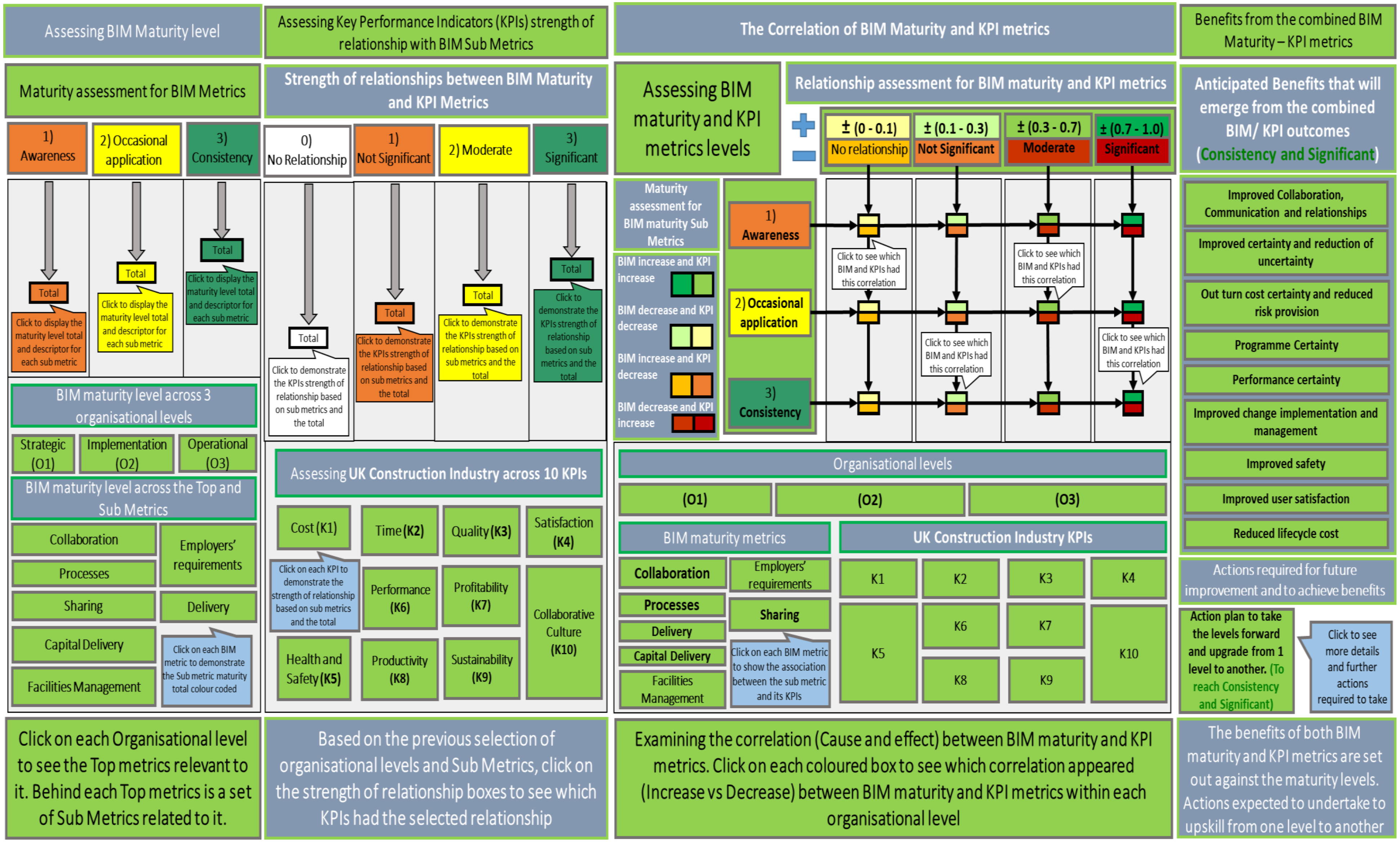


Figure 9.12 Final BIM Maturity-KPI Assessment Framework (Dashboard Summary)

This shows that the overall results for simplicity were halfway between positive and negative. Thus, it was necessary to simplify the framework as much as possible and remove any additional, unnecessary information to comply with the group members' feedback. A set of discussions were held to agree on the findings to present to the client sector and ensure a clear and better understanding of the BIM maturity and KPI linkages. The group members agreed to the following findings: 1) Combining the BIM assessment overall averages from the data collection findings; 2) To include the averages and the spearman correlation results for the BIM maturity and KPIs relationship assessment, and 3) To include the benefits from the combined BIM maturity and KPI metrics, and the actions required for future improvements, which were explained in the correctness factor (Figures 9.9-9.11).

4) **Flexibility:** All participants either agreed or strongly agreed that the framework should work and fit within other UK client sectors and not just the client sector selected in this research, as V2, V3, and V5 selected agree while V1 and V4 selected strongly agree. This indicates that the overall results for flexibility were positive since the participants agreed or strongly agreed that the framework should fit within any UK client sector. Thus, the changes made to both frameworks (Initial and final) were sufficient and the final framework could be used across a range of UK client sectors.
5) **Understandability:** All participants stated that it was difficult to understand the framework and that the relationship between BIM maturity and KPI metrics was not clear. Thus, it would require some changes to enable greater clarity, as V2 and V3 selected disagree, V4 selected neutral, and V1 and V5 selected agree. This shows that, similar to completeness, the overall results for understandability lay between positive and negative, whereas the majority of comments tended towards disagree. Thus, this was the only factor that had serious negative feedback to address. As a result, a series of adjustments were made to the initial framework to deliver the best fit and representation for the linkages in the final framework. This final development demonstrates the BIM maturity and KPI metrics, how they are they linked, the benefits that could emerge from linking them, and relevant actions to improve the maturity levels and their relationship with KPI metrics in order to enable movement from one level to another. As a result, this has been addressed within the final framework (Figure 9.12) alongside the findings associated with the understandability factor (Figures 9.9-9.11).
6) **The Overall Quality:** Only V4 disagreed that the framework would meet the client sector's vision and noted that the framework would need to be revised; the remaining participants either agreed or strongly agreed. This shows that the results for the overall quality was

positive, and, having discussed the relevant changes required to the framework in the previous five factors, the final framework (Figure 9.12) would meet the overall quality factor in terms of the client vision for combining BIM maturity and KPI metrics.

These findings were conducted to evaluate the six quality factors on the initial framework development in order to improve the overall quality of the framework, and to address the relevant actions to revisit and amend the initial framework development in order to produce the final framework (Figure 9.12). Having completed the analysis of the initial framework development, the next list of questions relates to:

1) **The overall feedback:** Three questions were asked based on the overall feedback on the framework.
   a) In terms of whether the initial framework meets the focus group members' expectations for combined BIM maturity and KPI metrics. Again, V4 selected disagree and explained that, after revising the framework, it might be clearer to them; the remaining participants either agreed or strongly agreed.
   b) In terms of client organisations benefiting from the framework, all group members either agreed or strongly agreed to benefiting, while V3's response was halfway between both agreement levels.
   c) In terms of enhancing the performance levels within the client organisation, three participants selected agree while two selected strongly agree.

   This shows that the overall feedback received was positive as client organisations were felt to benefit from the initial framework and performance levels enhanced across organisations. To meet the focus group member expectations, amendments to the initial framework development were necessary, as explained across the six quality factors, which improved the overall quality of the framework. The overall feedback was achieved through the delivery of the final framework, having gathered feedback from the focus group members.
2) **The overall comments:** Whilst VI did not have any additional comments, other group members offered the following views:

a) V2= Sub metrics represent BIM KPIs, and thus it should be made clear that the KPIs presented separately are organisational.
b) V3= Make the framework and presentation 'human digestible'.
c) V4= Start with the strongest points.

d) V5= The framework should provide guidance on how to improve maturity (i.e. based on current maturity, the steps to be taken to achieve the next level, and provide a dashboard summary for each organisational level).

This shows that both positive and negative comments were received, which demonstrates how BIM maturity and KPI metrics could be linked, the benefits that could be extracted, and the actions that could be taken to upskill the users from one maturity level to another. Moreover, comments were also offered on the impact on the KPI metrics (positive) and the framework was adjusted for presentation to the UK client sector (negative). Following consideration of the focus group members' comments, a final group workshop was arranged to present the final framework to group members. This enabled the researcher to explain the mechanism by which it worked, and to collect any additional feedback on the final framework. This will be explained further in the next section.

9.9.3 Final development of the framework

This section will outline the findings on the final BIM maturity-KPI assessment framework and the mechanism by which the framework operated having revisited the feedback and comments from the validation workshop and made amendments. The next section will demonstrate the overall results of the final framework and how it will operate.

The final framework (Figure 9.12) and the mechanism by which it would operate (Figure 9.13) was presented as a result of the changes requested by the focus group members and to further explain how the final framework would operate.

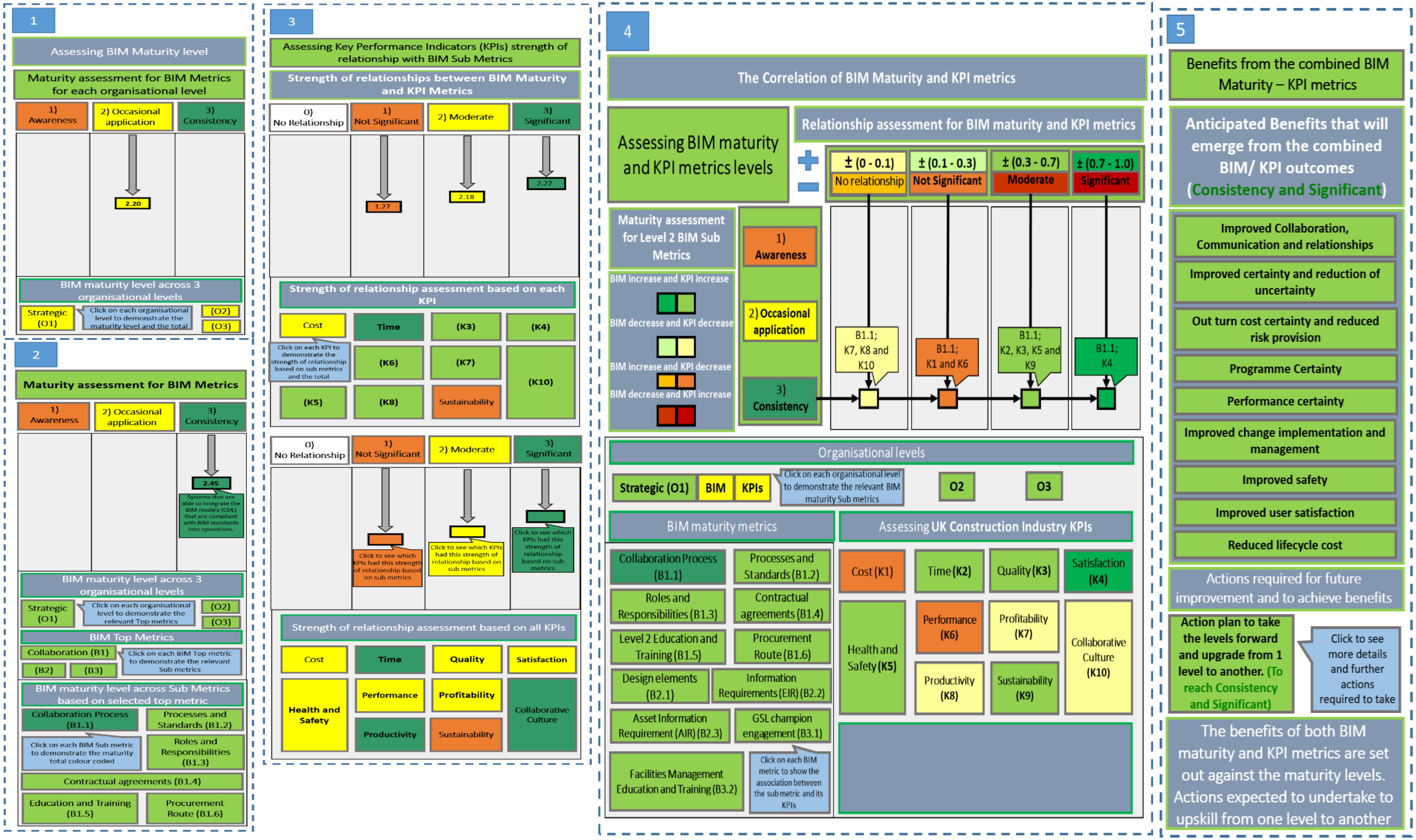


Figure 9.13 Final framework (Dashboard summary steps explained)

As presented in Figure 9.12, the final framework was presented as a dashboard summary for each organisational level and showed the: BIM maturity and KPI metrics relationship, the correlation between both, the benefits expected from combing them, and the actions necessary to upskill from one level to another. The process and mechanism on how the framework shall operate (Figure 9.13) was explained to focus group members to give a better understanding of how the framework would operate amongst UK clients. The mechanism by which the framework would operate is explained as follows (Steps 1-4: Figures 9.9-9.10 and Step 5: Figure 9.11):

Step 1: Present the overall results of the BIM maturity assessment by clicking on the organisational level boxes to demonstrate the final maturity level of each organisational level.

Step 2: Demonstrate the individual results of the BIM metrics, by starting with the top metrics of each organisational level, then after selecting the relevant top metric, select the desired sub metric that falls under the top metric. Then select the overall maturity level for that sub metric to appear along with its descriptor [i.e. Strategic-Collaboration: Collaboration process= 2.45 (descriptor)]. To make the process faster, the sub metrics can be shown after selecting the organisational level without needing to show the top metrics. From this, the previous step can be repeated to show the maturity level and descriptor [i.e. Strategic-Collaboration process= 2.45 (descriptor)].

Step 3: Based on the BIM maturity selection, this step will then present the KPI strength of relationships with the selected BIM metric and can be presented by either selecting each KPI individually to determine the overall strength of relationship score based on the selected BIM metric [i.e. Collaboration process and Cost= 2.18 (Moderate)], or by clicking on the strength of relationship coloured boxes to show the overall KPIs and the selected relationship [i.e. collaboration process and weak= sustainability (1.27)].

Step 4: Click on the organisational level boxes to demonstrate the BIM maturity level and KPI metric strength of relationship total [Strategic level: BIM maturity level total= Occasional application and KPI strength of relationship total= Moderate)], Select each organisational level, select the BIM Sub metric, and again either select each KPI individually to see the correlation based on the selected BIM metric [i.e. Collaboration process (Consistency) and Time (Moderate positive)= Medium evidence that, as collaboration process increase, then time increases], or click on the strength of relationship coloured boxes to show the overall BIM - KPI relationship, where it would show the correlations between the metrics [i.e. collaboration process (consistency) and (Significant positive) box= Satisfaction= Strong evidence that, as Collaboration process increase, then Satisfaction increases].

Step 5: Finally, after all the previous steps are complete, the final step shows the benefits from the assessment, by clicking again on the anticipated benefits to show the additional benefits that will occur. After this, future improvements can be selected by clicking on the action plan box to present the actions required.

Presenting the framework and the mechanism by how it operates in this manner will help organisations to see the current status for BIM maturity and KPI metrics, and decide on what they would need to reflect on concerning those that fall under awareness-no/weak and occasional application-medium relationship levels, the benefits that could be achieved from this and the decision to implement and maintain those that fall under the consistency-strong relationship levels. Testing the dashboard as an online tool is proposed as a recommendation for future studies to see how the final framework would operate (Figure 9.13). This concluded the external validation stage of this research. The next section will provide a summary of the chapter.

9.10 Summary

This chapter presented the findings of the final framework development and its validation through the research findings. The evolution from the conceptual framework (Section 4.5) and the initial framework development (Figure 9.1) was outlined to deliver the necessary progress and to offer distinction between the conceptual framework and the initial framework development in preparation to validate the final framework (Figure 9.12). The initial framework that emerged from the data collection findings was completely changed, and this emphasised the importance of an external validation stage to present the findings and collect ideas from experts on how to formulate and finalise the proposed framework. An explanation of how the final framework would operate (Figure 9.13) was presented to provide a clear indication of how it would be adopted and to presented to the UK client sector. This also added to the current list of BIM maturity and KPI metrics identified in Chapter 3; with the introduction of the new BS EN ISO19650 standards (Table 9.1), a new developed assessment framework was proposed to fill the gap by linking BIM maturity and KPI metrics.

A comparison of the results across all organisational levels was presented alongside the literature and degree to which the findings were related. This demonstrated how the findings would link to the research aim, objectives, and research problem. The next chapter will present a set of conclusions to this research, and provide a number of limitations and recommendations from this study. Furthermore, it will identify future research steps to extend these findings in the future.

Chapter 10: Research Contributions, Limitations, Recommendations and Conclusions

10.1 Introduction

Having presented the final framework, this chapter provides a list of the overall recommendations, limitations, and conclusions from the research. The achievement of each objective is outlined alongside a set of contributions. The chapter also highlights a number of limitations and offers several recommendations concerning the adoption such a framework by industry. Indeed, there consensus amongst the scientific community that limitations exist within any research (Saunders et al., 2019). Finally, the conclusions are given at the end of the chapter, which represent a point of closure for this research.

10.2 Summary of the research findings

The research provided a comprehensive conceptual framework based on a critical review of the literature concerning BIM maturity assessments, KPI metrics, and both combined. The framework is the result of existing problems that were identified and critically reviewed in the associated literature. This review addressed the following issues: the lack of client demand; an in depth understanding of BIM and how it is implemented across the UK client sector, and the absence of rigorous understanding of BIM maturity and KPI metrics. This has resulted in the proposition of a number of BIM maturity metrics that have not been fully defined, are unreliable and do not follow a BIM maturity scoring criterion (i.e. maturity levels). Furthermore, KPI metrics are treated either as BIM metrics or as a set of questions that aim to meet BIM objectives, which lacks the consensus concerning the existing KPIs (i.e. cost, time, quality). Moreover, there is a lack of understanding of how the KPI metrics could be measured or used across organisations, and an absence of standardised BIM maturity and KPI metrics. The field lacked an assessment that could be used to assess the overall performance of construction projects across the UK. In offering a response to the above issues, this framework could be adopted and used as a guide for future research that might investigate how a standardised list of BIM maturity and KPI metrics could be compiled through an assessment to measure the overall performance of the UK construction and public sector local authority clients specifically.

The literature in Chapters 2 and 3 critically reviewed current problems associated with UK clients by considering problems such as the lack of client demand, the absence of understanding of BIM and how it is being implemented across the UK, the absence of a clear definition for Level 2 BIM, and how the new BS EN ISO19650 standards supersede Level 2 BIM. An in-depth exploration and critical review of existing BIM maturity metrics and their assessments, KPI metrics and their assessments, and a limited number of combined BIM maturity and KPI metric assessments were conducted. This helped to compile a standardised list of BIM maturity and KPI metrics including how they could be assessed and measured (i.e. five maturity levels, which was then reduced to three levels for BIM, and percentage scoring criteria for KPIs). This enabled the development of a conceptual framework with a standardised list of BIM maturity and KPI metrics, which considered how they are being assessed together and the benefits of combining them (discussed in Chapter 4). Taken from the literature review findings, the framework consisted of a number of BIM maturity metrics, which follow the transition from Level 2 BIM to the new BS EN ISO19650 standards. These are assessed across a three-level BIM maturity assessment (awareness, occasional application, consistency) for three organisational levels (strategic, implementation, operational). Along with this, a standardised list of nine KPI metrics was proposed (cost, time, quality, satisfaction, health and safety, performance, profitability, productivity, sustainability). The links between each of the KPI metrics and the BIM maturity metrics were demonstrated to enable an understanding of the similarities and how are assessed together. In addition, the benefits expected from linking BIM maturity and KPI metrics were proposed from the literature review findings from those that emerged from existing assessments of BIM maturity, KPI, and both combined.

The research conducted workshops within a case study to develop a BIM maturity assessment across each organisation level. This considered a number of BIM maturity top and sub metrics, the description of each metric's mean, and the description of each metric across the three BIM maturity levels [i.e. implementation level= sharing (top metric): information exchange (sub metric): information exchanged achieved and validated (metric descriptor), and awareness (maturity level): no defined information exchange (maturity level descriptor)].

This was followed interviews to: investigate the levels of BIM maturity and KPI metric adoption across the UK client sector; complete the BIM maturity assessment; establish potential relationships with KPI metrics, and propose any further KPI metrics for consideration. The result of linking BIM maturity and KPI metrics resulted in an additional KPI metric (collaborative culture) as the importance of addressing the cultural and human behaviour was emphasised by participants as a KPI metric. These areas were further examined through a questionnaire survey that statistically examined the relationships between BIM maturity and KPI metrics. The relationship was assessed through a four-level relationship (No relationship, Weak, Medium, Strong) and the findings indicate a relationship between the BIM maturity and KPI metrics. Moreover, they demonstrate that BIM maturity levels impact on KPI metrics so that, as BIM maturity levels increase, the KPI strength of relationships increases, and vice versa.

Having completed the data collected phases, the proposed framework was further developed through an internal validation stage that discussed the data collection findings and compared them with the literature review findings, which supported the evolvement of the conceptual to the initial framework. In addition, the initial framework was taken to an external validation stage that involved focus group validation workshops that finalised the framework and ensured it met the overall UK public sector local authority client vision. Hence, the research proposed a final BIM Maturity-KPI assessment framework for the UK client sector. Finally, the research provided UK clients with an overview of existing BIM Maturity and KPI metrics, and how they can be linked. Having presented the overall research findings, the next section will outline the achievement of the research aim and objectives.

10.3 Achievement of the Research Aim and Objectives

The main aim of this research was "*to develop a BIM Maturity-KPI assessment framework for the UK public sector local authority client to assess BIM adoption in line with the UK construction strategy.*" The research objectives (outlined in Section 1.5) explained how the aim of this research would be achieved, and the objectives were as follows:

1. To determine the Building Information Modelling (BIM) approach, its relevance to the client sector, and its level of adoption across the construction industry, both globally and within the UK specifically.
2. To establish key principles of BIM maturity and evaluate existing BIM assessment frameworks, models, and tools to understand the principles of existing industry key performance metrics and indicators.
3. To evaluate existing combined BIM-KPI assessment methods, models and tools, and establish the main drivers, barriers and challenges of BIM maturity and KPIs for the UK construction strategy.
4. To develop a BIM maturity-KPI assessment framework for UK public sector local authority construction industry clients.
5. To examine the relationships between the proposed BIM maturity and the KPIs.
6. To evaluate and propose a final BIM maturity-KPI assessment framework for UK public sector local authority construction industry clients.

Six objectives were identified to achieve the aim, and the process for how this was achieved is presented (Section 5.3 and 9.3). Moreover, Figure 10.1 provides the research phases, the findings related to each phase and each objective, and the alignment of the objectives to the research questions. The next section will discuss how each of the objectives were achieved in more detail.

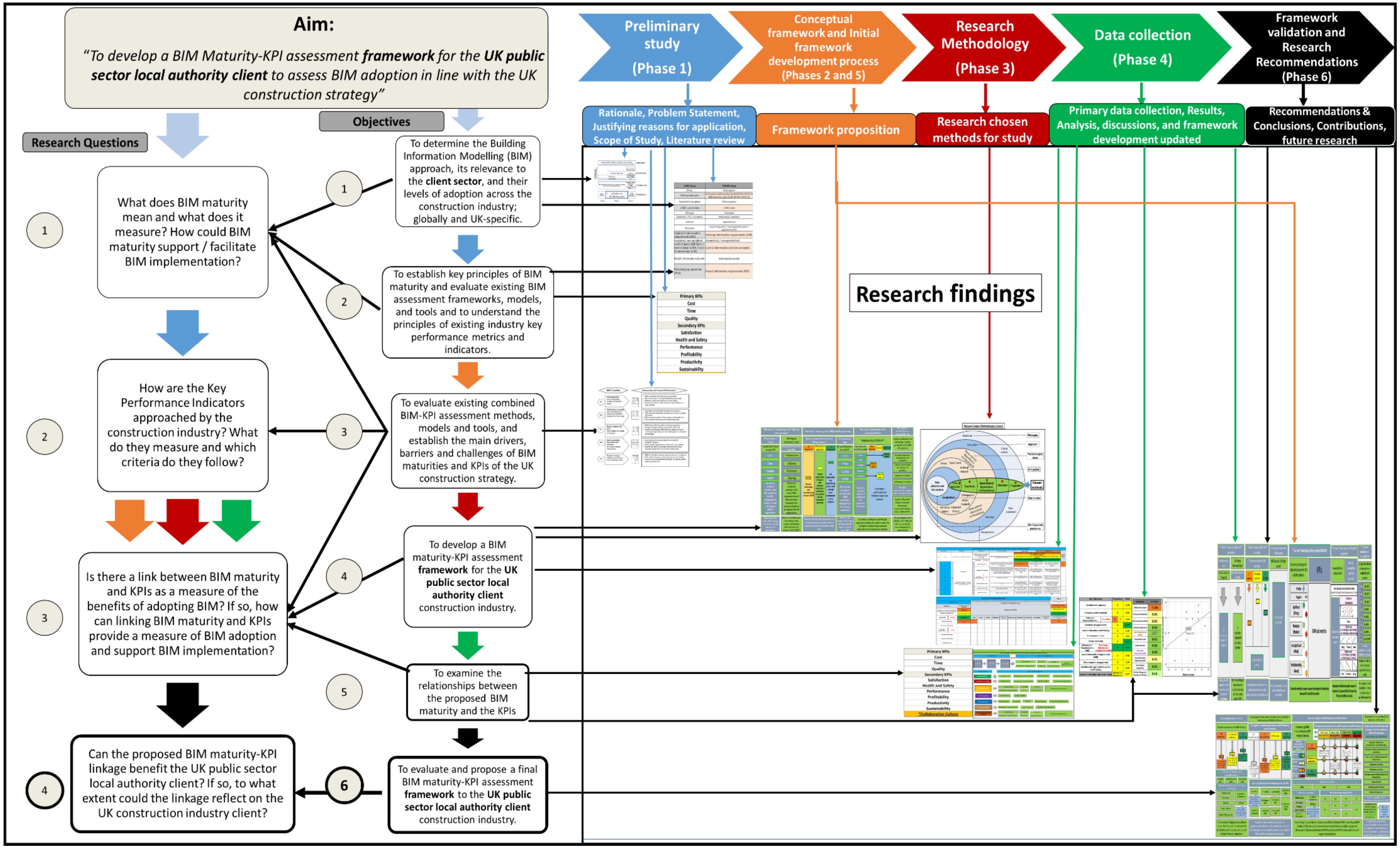


Figure 10.1 Completed research phases

10.3.1 Review and Synthesis on the Research Aims and Objectives

This section identifies the deliverables and outcomes of each objective, which encapsulates the overall findings of the research. Table 10.1 summarises the relationships between the objectives, chosen methods, and chapters. A discussion on how the objectives were achieved will be presented in more detail.

Table 10.1 Research Aim and Objectives: Alignment with methods and chapters for each objective

<table>
<tr><th colspan="4">Aim</th></tr>
<tr><td colspan="4">"To develop a BIM Maturity-KPI assessment framework for the UK public sector local authority client to assess BIM adoption in line with the UK construction strategy"</td></tr>
<tr><th colspan="2">Objectives</th><th>Methods achieved</th><th>Chapters related to methods achieved</th></tr>
<tr><td>1</td><td>To determine the Building Information Modelling (BIM) approach, its relevance to the client sector, and their levels of adoption across the construction industry; globally and UK-specific.</td><td>a. Introduction
b. Literature review
c. Discussions and framework validation</td><td>a. Chapter 1
b. Chapter 2
c. Chapter 9</td></tr>
<tr><td>2</td><td>To establish key principles of BIM maturity and evaluate existing BIM assessment frameworks, models, and tools and to understand the principles of existing industry key performance metrics and indicators.</td><td>a. Literature review
b. Conceptual framework
c. Experts Opinion, and Focus group workshops (5 members)
d. Interviews
e. Discussions and framework validation</td><td>a. Chapter 3
b. Chapter 4
c. Chapter 6
d. Chapter 7
e. Chapter 9</td></tr>
<tr><td>3</td><td>To evaluate existing combined BIM-KPI assessment methods, models and tools, and establish the main drivers, barriers and challenges of BIM maturities and KPIs of the UK construction strategy.</td><td>a. Literature review
b. Conceptual framework
c. Interviews (15 interviewees)
d. Questionnaires (40 participants)
e. Discussions and framework validation</td><td>a. Chapter 3
b. Chapter 4
c. Chapter 7
d. Chapter 8
e. Chapter 9</td></tr>
<tr><td>4</td><td>To develop a BIM maturity-KPI assessment framework for the UK public sector local authority client construction industry.</td><td>a. Literature review
b. Conceptual framework
c. Research Methodology
d. Experts Opinion and Focus group workshops
e. Interviews
f. Questionnaires
g. Discussions and framework validation</td><td>a. Chapter 3
b. Chapter 4
c. Chapter 5
d. Chapter 6
e. Chapter 7
f. Chapter 8
g. Chapter 9</td></tr>
<tr><td>5</td><td>To examine the relationships between the proposed BIM maturity and the KPIs.</td><td>a. Literature review
b. Conceptual framework
c. Interviews
d. Questionnaires
e. Discussions and framework validation</td><td>a. Chapter 3
b. Chapter 4
c. Chapter 7
d. Chapter 8
e. Chapter 9</td></tr>
<tr><td>6</td><td>To evaluate and propose a final BIM maturity-KPI assessment framework to the UK public sector local authority client construction industry.</td><td>a. Literature review
b. Conceptual framework
c. Discussions, and framework validation (5 members)
d. Research contributions</td><td>a. Chapter 3
b. Chapter 4
c. Chapter 9
d. Chapter 10</td></tr>
</table>

Objective 1: "To determine the Building Information Modelling (BIM) approach, its relevance to the client sector, and its level of adoption across the construction industry, both globally and within the UK specifically".

Objective 1 was achieved in Chapters 1 and 2 by outlining the current research aim and objectives and providing a brief background on the current state of the UK construction industry. Emphasis was placed on existing problems within the UK and the main reasons for conducting and tackling such problems were given. This was achieved by conducting a critical review of the key literature, and by examining the situation for the UK and its current position in terms of BIM. The UK construction industry was studied to extract the key problems that currently exist, and the targets that could be implemented to tackle such problems. A brief outline of the different types of clients was given to understand the needs of the target for this research. A quick review of the history and definitions of BIM were provided to deliver a better understanding of what it is, and a set of benefits/opportunities were identified. Moreover, the challenges/obstacles were presented to tackle and/or avoid them in the future. The approach to BIM within the UK was illustrated to understand the current levels of adoption and emphasis was placed on Level 2 BIM including the transition to the new BS EN ISO19650 standards (HM government. 2020c, UK BIM framework. 2019a). This signified the different governmental approaches to BIM in recent years. Reflections on the UK's current BIM uptake amongst clients were given to identify the impact on clients and their understanding with BIM. Furthermore, a comparison between the UK's level of BIM adoption with that across the EU and globe was illustrated to understand the UK's position. Following the data collection process discussed in Chapter 5, key areas were explored in relation to the levels of BIM adoption across the UK, Level 2 BIM and the new BS EN ISO19650 standards. These were further investigated, and cross analysis were conducted on data collected on these areas. The data collection techniques used, and the associated literature were presented in Chapter 2.

It has been suggested and signified that Level 2 BIM would act as a maturity process whereas the new BS EN ISO19650 standards would act as an information management process, which includes the transition of the levels of maturity from Levels 0-3 to stages 1-3. However, there is no major difference between Level 2 BIM and the new BS EN ISO19650 standards, which was justified by the presentation of a transition of terms. Furthermore, this research remains relevant to the rapidly changing and varied approaches to BIM in the UK. The results revealed that UK clients were compliant to Level 2 BIM and could transition of the new BS EN ISO19650 standards.

Objective 2: ***"To establish key principles of BIM maturity and evaluate existing BIM assessment frameworks, models, and tools and to understand the principles of existing industry key performance metrics and indicators."***

This objective was achieved in Chapter 3 by conducting an extensive systematic literature review on existing BIM maturity assessments in the UK and across the globe. This enabled emphasis on the main categories, including the strengths and weaknesses amongst the assessments, which enabled linkages to the proposed assessment in this research. The differences between Capability, Maturity, and Competences were outlined to justify the reasons for selecting BIM maturity as the main approach for the assessment. This also outlined how maturity first emerged (Chrissis et al., 2003; Crosby, 1979; Paulk et al., 1994; SEI. 1993), and explained its linkages with BIM (Succar, 2010a). Moreover, the chapter explained how this impacted the UK government mandate (Bew and Richards; 2008; BIM level 2. 2016; Gleeson and Penney, 2016; Humphrey, 1988; Kumar, 2015; Survey4BIM. 2015). Section 3.4 presented 92 existing BIM maturity assessments and classified them into eight categories, which represents a contribution to knowledge by this research.

Some facts and figures that summarises the assessments that existed were outlined, whilst the expected BIM maturity outcomes were illustrated to visualise how BIM maturity previously existed, and how this shaped the development of BIM maturity requirements. The main approaches were outlined and justified, whilst the main strengths and weaknesses were captured to extract the key areas amongst the assessment, and to note and address any defects and challenges in this research.

The same process was repeated with the Key Performance Indicators, which only included a selection of the most popular KPI assessments; thus, nine main KPIs were selected and explained, namely cost, time, quality, satisfaction, health and safety, performance, profitability, productivity, sustainability (Section 3.7). Since a significant variety of KPIs were identified and critically reviewed in the literature, it was vital to justify why the selection of these nine as a standardised set for this research. It was also important to outline differences between the Critical Success Factors, Key Result indicators, Performance Measurements, and KPIs and to justify the main reasons for selecting KPIs for this research. A conceptual framework was proposed in Chapter 4, whilst the development of the BIM maturity assessment was described in Chapter 6 (conducted through focus group workshops), and a set of KPIs was offered in Chapter 7 (developed through the semi structured interviews).

A detailed discussion of the findings and links to the literature are presented in Sections 9.4-9.6 for BIM maturity and the KPI metrics.

Objective 3: ***"To evaluate existing combined BIM-KPI assessment methods, models and tools, and establish the main drivers, barriers and challenges of BIM maturities and KPIs of the UK construction strategy."***

This objective was also accomplished in Chapter 3 through the systematic literature review on existing combined BIM maturity and KPI metrics assessments - both in the UK and across the globe – for which a limited number of publications were found to outline such linkages. Section 3.10 lists 33 such assessments, in which 17 of these assessments proposed to link BIM capabilities and at least three primary KPIs (cost, time, and quality). The remaining assessments (16) addressed KPIs as CSF, BIM elements, or other approaches but did not address KPI metrics within them. These were presented and classified within six categories, and thus represents a contribution to knowledge. The same assessment analysis process was conducted for the BIM maturity and the KPI assessments. After presenting the findings, a set of similarities and differences between BIM maturity and KPI metrics were presented that considered the conceptual framework development (Section 3.10).

At this point, the absence of a rigorous relationship between BIM maturity and a list of KPI metrics for the UK client sector were emphasised. This was subsequently addressed in the proposed conceptual framework and addressed in Chapter 4. The issue was examined more closely in the data collection phase in Chapters 7-8, and discussed in more detail within the validation stage in Chapter 9 (Section 9.4). Based on previous research that reviewed the combined BIM-KPI frameworks (Aboumoemen, 2016; Badrinath et al., 2019; Mom & Hsieh, 2012; Shin et al., 2015; Wong et al., 2016) this research developed an initial framework development that evolved from the proposed conceptual framework towards presenting a final framework to explain how a combined BIM maturity and KPI metrics assessment would reflect on UK clients; this adds to the body of literature and is discussed in Chapter 9.

Objective 4: ***"To develop a BIM maturity-KPI assessment framework for the UK public sector local authority client construction industry."***

Following the critical review of the key literature on existing assessments and frameworks for BIM, KPIs, and combined BIM-KPIs, and having outlined the main outcomes, this objective outlined the framework development and the expected requirements of the framework for this research, also outlining the distinction between this and previous frameworks (Aboumoemen, 2016; Badrinath et al., 2019; Mom & Hsieh, 2012; Shin et al., 2015; Wong et al., 2016). The findings from Chapters 2 and 3 were considered in the development of the proposed conceptual framework. This was further clarified in Chapter 5, in terms of the methods adopted to develop the framework and collect the necessary data from the UK sample.

A summary of the selected methods is discussed in Section 5.3, including the process used to collect and analyse the data, and approaching the required sample for the research, and how participants would be selected were discussed in more detail in Sections 5.4-5.8. An initial framework development evolved from the conceptual framework (Chapter 4) through the outcomes of the specified data collection phases (focus group workshops, semi-structured interviews, and questionnaire surveys) in Chapters 6-8. A detailed discussion of the framework was presented in Sections 9.4-9.6.

The presentation and comparison between the previous combined BIM maturity and KPI metrics frameworks (Section 4.4), the conceptual framework for this research (Section 4.5), and the initial framework development (Section 9.3) that evolved from the conceptual framework was proposed following the data collection phases (Sections 6.12, 7.5, 8.4.4). The conceptual framework was broken down into three stage elements: "The What", "The How" and "The Evidence and the Why". Each stage was discussed in more detail in Sections 4.5.1-4.5.3 and was revisited in Chapters 6-8 following the collection of data from the UK sample. The conceptual framework was iteratively developed, and a set of refinements and adjustments to the framework was conducted. This development phase ensured the framework was populated with the necessary combined BIM maturity and KPI metrics relationships. The inner components were examined and are discussed in the next section.

Objective 5: ***"To examine the relationships between the proposed BIM maturity and the KPIs."***

This objective represented a critical point in meeting the research aim set for this research, as it presented the findings concerning the relationships between BIM maturity and KPI metrics to participants involved in the research, as discussed in Section 3.10, and presented in Figure 4.9. This process started with presenting the findings to experts, as explained in Section 4.6; greater emphasis was placed on the redevelopment and repopulation of the BIM maturity assessment proposed from a number of studies (Aboumoemen, 2016; Smits et al., 2016; Wong et al., 2016) with the selected members of the focus group workshops. In these workshops, three organisational levels were proposed through the conceptual framework as: (a. Strategic, b. Implementation, and c. Operational) and the maturity assessment was conducted as follows: 1=Awareness, 2=Occasional Application, 3=Consistency.

The next phase involved the conduct of semi-structured interviews. These consulted a number of UK practitioners to collect in depth information on the BIM maturity assessments and KPI metrics. The findings of the BIM maturity assessment were discussed in Section 7.4 for which interviewees were required to identify their organisational levels and complete the assessment assigned to each and demonstrate the potential linkage between the assessment and predefined KPIs. The findings revealed that an additional KPI should be included in the predefined list of KPIs (Collaborative Culture), the importance of the human factor was also emphasised. This KPI was noted across a number of studies under different names and considered alternatives to collaborative culture by representing social and cultural influences (Section 9.4). This is considered a contribution to knowledge.

Having presented a complete list of ten standardised KPIs and linked them with the top metrics, the research process subsequently examined the relationships between the BIM sub metrics and the KPIs. The KPI metrics relationship with BIM maturity were assessed through a 4-level relationship (0=No relationship, 1=Weak, 2=Medium, 3=Strong).

This research presented different ways to demonstrate and examine the relationship between the BIM maturity and KPI metrics, which represent a contribution to the research. This was the final step to update the framework based on the findings and to discuss the findings with a specific research sample to enable external validation stage (discussed below under Objective 6). A sample of the strategic level BIM maturity-KPI assessment is available in Section 9.5, and the same structure was adopted for the implementation and operational levels.

Objective 6: ***"To evaluate and propose a final BIM maturity-KPI assessment framework to the UK public sector local authority client construction industry."***

Having undertaken all research steps (Proposing a BIM maturity assessment, developing a standardised set of KPI metrics, delivering a combined BIM maturity-KPI assessment, and proposing the relationships between BIM maturity and KPI metrics) the final objective focused on the evaluation of the final framework to determine whether it was appropriate to the sample for this research. The previous findings (Chapters 3-4, and 6-8) showed the development of and evolvement between a conceptual framework (Section 4.5) and an initial framework development (Section 9.3), whilst the final stage concerned the validation by experts to evaluate and present the final framework and the mechanism on how it shall operate (Sections 9.9.1-9.9.3). The final proposed framework and the brake-down of the stages is available (Sections 9.9.2-9.9.3). The external validation stage (required to achieve the aim of this research) was discussed, which presented the revised framework based on the data collection stages. The validation workshop followed a sequence concerning the level of agreement (Moody and Shanks, 2003), which comprised six quality factors: correctness, completeness, simplicity, flexibility, understandability, and overall quality on the initial framework development. The questions and scoring criteria used for the validation stage was presented (Section 9.9). The findings of the research were presented to group members to explain and gather feedback on the framework.
Having outlined the findings under each objective, the next section reviews the research questions raised to address this research area.

10.3.2 Review and Synthesis of the Research Questions

The following questions were designed to enable appropriate outcomes for the aim and objectives:

Question 1: "*What does BIM maturity mean and what does it measure? How could BIM maturity support / facilitate BIM implementation?*"

The main purpose of BIM maturity is to measure the effectiveness of BIM capabilities and competencies across the construction industry, which was reflected by the UK mandate and examines BIM projects success across the UK. The BIM maturity assessment formally measures the level of BIM capability and adoption. It was designed to help derive benefit and value through the development of organisational maturity in relation BIM implementation. Adopting maturity models can enable valuable benefits to BIM users, including client organisations, by managing any changes required. This can be simplified into levels to achieve the desired BIM benefits (Giel and Issa, 2013b; Nepal et al., 2014; Succar, 2010a). The benefits are avoiding risk, reworks, delay, extra costs and clashes (Godfrey, 2008; Humphrey, 1988; Nolan, 1973; Survey4BIM. 2015). Capability Maturity Model Integration (CMMI) should be adapted for other such models to follow, since most BIM maturity models in the literature have adopted the CMMI approach (Chrissis et al., 2003; Paulk et al., 1994). BIM maturity in this research is used to cover all relevant BIM concepts, namely: assessments, models, capability, competencies, and maturity. However, in the context of this research, "the extent of that ability" was acknowledged when developing a BIM assessment, since it was not only important to assess "the minimum ability and a set of abilities" when implementing BIM across individuals and organisations, but vital to recognise the extent of that ability and how it could determine the implementation of BIM across an assessment. As a result, the concept that best fit this research was BIM maturity due to its representation of a set of BIM activities and processes, which measure progression from one point to another. Thus, maturity delivers the required measure and a set of descriptions from one level to another.

Question 2: ***"How are the Key Performance Indicators approached by the construction industry? What do they measure, and which criteria do they follow?"***

Key performance indicators are numbers designed to succinctly convey as much information as possible. A KPI is the measure of a process that is critical to the success of an organisation. KPIs are compilations of data measures that are used to assess the performance of a construction operation. They are the management methods used to evaluate employee performances on a particular task. Furthermore, KPIs could benchmark purposes that act as key components, thereby enabling organisations to achieve best practice (Enshassi, Mohamed, and Abushaban, 2009). According to Dissanayaka and Kumaraswamy (1999), various value representations based on cost and time performances were used for evaluations. The following are included as main representations: project characteristics, the procurement system, the project team performance, client representation characteristics, contractor characteristics, design team characteristics, and external conditions (Navon, 2005). Ten main KPIs were identified and presented as a benchmark for the Construction Industry, namely: Cost, time, quality, satisfaction, health and safety, performance, profitability, productivity, sustainability, and collaborative culture. To measure KPIs, a database to record them, and checklists to monitor and record their use were recommended. KPIs were presented in the literature as different methods, such as: Critical Success Factors, performance success, performance measurements, project performance, measuring construction, and the Fuzzy AHP process.

Question 3: ***"Is there a link between BIM maturity and KPIs as a measure of the benefits of adopting BIM? If so, how can linking BIM maturity and KPIs provide a measure of BIM adoption and support BIM implementation?"***

Although other studies have previously linked BIM maturity and KPI metrics, few studies have addressed the possible links between BIM implementation on primary KPIs for construction projects. This can be attributed to the lack of rigorous understanding of BIM maturity and KPI metrics. A number of BIM maturity metrics have not been properly defined, while KPI metrics lack the consensus of a KPI (i.e. cost, time, quality). Moreover, there is a lack of understanding on how KPI metrics could be measured or used across organisations, and the absence of standardised BIM maturity and KPI metrics, or an assessment to assess the overall performance of construction projects across the UK. The main purpose of BIM maturity is to measure the effectiveness of BIM capability and adoption across construction industries, which may reflect on the UK governmental mandate and require the examination of successful BIM projects across the UK. KPIs are measures that are critical to the success of an organisation, and a number of performance measures define the success of a project or organisation. There is a conspicuous lack of studies that focus on the identification of potential areas of BIM utilization in construction and the association with construction KPIs. BIM maturity emerged as a method to measure the development of projects through maturity levels. This aims to assess levels of BIM maturity across projects and organisations, and KPIs act as a method to measure construction project and organisational success; thus, there needs to be an overall assessment to combine both concepts. Linking BIM maturity and KPI metrics together was conducted previously across thirty three assessments, whilst thirty four BIM maturity sub metrics were demonstrated through three organisational level assessments: Strategic (Eleven sub metrics), Implementation (Eleven sub metrics), and Operational (Twelve sub metrics) and links were conducted across ten KPIs.

The link between both metrics showed that the primary KPIs were strongly and effectively linked across all BIM maturity metrics, with varying strengths in relationship. In comparison, the links differed from one organisational level to another in terms of the secondary KPI metrics, which returned weaker linkages. The anticipated benefits from such links were: Improved collaboration, communication and relationships; improved certainty and reduction of uncertainty; cost certainty and reduced risk provision; programme certainty; performance certainty; improved change implementation and management; improved safety; improved user satisfaction, and reduced lifecycle cost. However, the focus of this research was not to explore potential ways to measure such benefits, but on the relationships between the BIM maturity and KPI metrics.

Question 4: "Can the proposed BIM maturity-KPI linkage benefit the UK public sector local authority client? If so, to what extent could the linkage reflect on the UK construction industry client?"

The BIM maturity-KPI assessment framework proposes nine benefits that could emerge from combining BIM maturity and KPI metrics, as discussed in the previous section. The interview and questionnaire findings revealed a number of benefits from the proposed framework, such as: Improved overall project delivery; added value to clients; better facilities management, and collaborative working. It is believed that should the framework, BIM maturity assessments, and BIM-KPI relationship assessments be adopted within organisations and across a number of projects, this would offer benefits allowing users to identify their current BIM maturity levels and identify the actions required to improve from one maturity level to another (i.e. from occasional application to consistency), which would also allow the KPIs/BIM maturity levels relationship to improve from one level to another (i.e. from medium to strong). Thus, the KPI metric relationships would depend on the BIM maturity levels and whether they move in the same direction. Therefore, as the maturity levels and KPI relationship levels increase, this would impact on the overall performance of construction projects within organisations and would enable overall improvement to the organisational performance. Moreover, as the BIM maturity levels increase, the overall project delivery would improve, clients would achieve a better understanding of the BIM maturity metrics and how they could improve from one level to another. This would enable collaborative working amongst teams and better education on the actions required to upskill from one level to another.

The proposed framework would benefit the UK public sector local authority clients who would have an understanding of the current status of organisations in terms of overall BIM maturity and KPI relationship levels. Furthermore, it would identify the relevant actions required to enhance the overall performance of clients, and allow them to revisit the framework in the future to determine improvements across the sector. Together, this would allow the client sector to lead the adoption of BIM maturity (aligned to the BS EN ISO19650 standards), maximise the proposed benefits, and measure themselves to gauge whether their overall performance is improving.

Having reviewed and answered the research questions, the next step outlines a number of essential recommendations to UK public sector local authority clients.

10.4 Research Recommendations

A number of recommendations are offered to the UK public sector local authority client. These recommendations will enable an understanding of how clients could move from the adoption of Level 2 BIM to the new BS EN ISO19650 standards, gain a better understanding of the new standards, and link BIM maturity and KPI metrics to enhance the overall performance of the UK construction industry. Thus, the following are recommendations offered for this purpose:

1) **Experience, Training, and Knowledge**

   There has been a lack of client demand and an absence of understanding of BIM maturity and KPI metrics, Level 2 BIM, and the similarities/difference between Level 2 BIM and the new BS EN ISO19650 standards. There needs to be effective training programs and strategies to educate clients on the meaning of BIM maturity and KPI metrics, and more educational programs on the new BS EN ISO19650 standards to enable a better understanding of how the standards work in order to enhance understanding and tackle the industry's issues with information management.

   The provision of such training and educational programs will deliver a better understanding of BIM maturity and the new standards, which will allow users within the client sector to adopt to new standards and access benefits, such as improved overall project and organisational performance. Hence, this could encourage better information management and faster adoption of the new standards. Moreover, it could enhance the knowledge of the client sector and enable greater experience of BIM adoption. With the enhanced knowledge, greater experience, and the provision of training and educational programs, this would tackle existing challenges in understanding BIM since clients would have the tools (i.e. knowledge, experience, training) to offer and better educate BIM users, while the application of such tools would allow for a more rapid adoption of BIM (aligned to the BS EN ISO19650 standards).

2) **Collaboration**

   Studies have revealed a lack of collaborative strategies between project teams. The data collection findings also stressed the importance of including collaboration (i.e. collaborative culture for the KPI metrics, and the collaboration process for the BIM maturity metrics) as aspects that address human and cultural, behaviours. This ensured the study did not rely solely on the technological aspects. Thus, it is vital to review the current status of collaboration amongst organisations, and explore how project teams coordinate and communicate in order to enable more effective and greater collaborative working amongst such teams. As collaborative working relates to user knowledge and experience, there is a greater potential for the better understanding of project and organisational needs, which would allow users to work collaboratively, and thus ensure that collaboration is maintained and sustained across the sector.

3) **Research**

The release of the new BS EN ISO19650 standards in the UK has prompted a transit from Level 2 BIM. However, a number of reports have addressed issues with understanding Level 2 BIM, which has led to confusion on what it is, while further uncertainty has emerged following the release of the new standards. Thus, in order to adapt to the government mandates and the rapid movement of BIM, it is essential to apply research across practice and within the educational sector. Research is with knowledge, training, and experience, and closely connected to collaboration, since the provision of potential research projects within the educational sector, and research teams within the practice allows for an in-depth exploration and understanding of the new standards and BIM maturity. This could occur through the provision of Knowledge Transfer Partnership programs that could link the education with practice. Thus, research projects could be offered to better understand and gain more knowledge on the new standards and increase the levels of experience amongst potential BIM users. This would allow for collaborative working amongst project teams and promote common goals based on improving project and organisational performance levels. The new standards could then be linked to research teams within practice, which would offer a link between the academic sector and practice. This link would offer an enriched understanding and in-depth knowledge on the new standards and BIM maturity from which users could gain more experience and develop greater skills through adopting BIM. This could allow for collaboration between education and practice, enabling a rapid and greater understanding of the standards.

Having outlined a number of recommendations, the next step will summarise the contributions of this research to knowledge and practice.

10.5 Research Contributions

The novelty of this research is the development of *"A BIM Maturity-KPI assessment framework for the UK public sector local authority client to assess BIM adoption in line with the UK construction strategy"*. The literature review highlighted the absence of a clearly defined relationship between BIM maturity and KPI metrics; therefore, this research explored and investigated the delivery of such a relationship. The literature review noted previous links between BIM maturity and KPI metrics being conducted; however, both BIM maturity and KPI metrics undertook different approaches that did not allow such associations. The KPI metrics used to link with BIM maturity were mainly the primary KPIs, whereas the BIM maturity approaches considered either technological, capability, or organisational approaches. As a result, this research aimed to deliver a framework that would effectively examine the relationships between BIM maturity and KPI metrics and to deliver an assessment to determine how they could work together (Contribution to knowledge) to improve the performance of the UK construction industry client sector and offer organisational benefits as a result of adopting the framework (Contribution to practice). Nine benefits emerged from conducting this assessment and, ultimately, a number of contributions to knowledge and practice were made by this research.

10.5.1 Contributions to knowledge

A number of contributions result from this research, which are outlined as follows:

1) **Exploring a complete set of BIM maturity assessments**

   Although a wide range of BIM maturity assessments exist, this research delivered an extensive review of the existing BIM maturity assessments and resulted in the delivery of a table of 92 BIM maturity assessments (Section 3.4) that were classified into eight categories. The highest number of assessments that were previously reviewed totalled 32 (Badrinath et al., 2019). The research has managed to address the majority of existing BIM maturity assessments across the literature and organisations, and based on the critical review of the literature, deliver a standardised list of BIM maturity metrics that were applied across three organisational levels and through a three level BIM maturity assessment.

2) **Identifying existing combined BIM maturity and KPI metrics relationship assessments**

   Although previous attempts were conducted to link BIM maturity and KPI metrics together, this research has addressed the most existing assessments that conducted such links, which has resulted in the presentation of a table of 33 BIM maturity and KPI metrics assessments (Section 3.10) that were classified into six categories. This helped to propose a standardised assessment that links BIM maturity and KPI metrics together.

3) **Proposing a combined BIM maturity-KPI assessment framework**

The study has delivered a practical combined BIM Maturity-KPI assessment framework to the UK client local authority public sector. The standardised BIM maturity approach was introduced along with a generalised list of KPIs for consideration within the UK. Few studies have delivered an applicable assessment framework that includes the components of BIM maturity and KPI metrics separately, or linking both BIM maturity and KPI metrics together, or a validated result that is examined across various industries generally and the UK and clients specifically. A proposed conceptual framework was developed, and a new combined BIM Maturity-KPI assessment was produced that was validated by experts from the UK construction industry and by clients. The proposed BIM maturity-KPI assessment framework would aim to solve existing problems relating to:

a) A lack of consideration for client needs, which result in difficulties deciding whether to implement BIM maturity and KPI metrics or not;
b) A poor level of understanding on what BIM maturity and KPI metrics are;
c) How are such assessments operate in organisations generally;
d) The absence of a rigorous relationship between the new BS EN ISO19650 standards, BIM maturity and KPI metrics for UK clients; and
e) A failed attempt to link them to realise benefits that could have an impact on the overall performance of the UK industry.

4) **Techniques to determine the BIM maturity and KPI metrics strength of relationship**

Various ways to link BIM maturity and KPI metrics have previously been identified, and similar approaches were adopted in this research, such as conducting a Spearman correlation to examine the statistical relationship between both variables, and conducting a linear regression analysis to determine the cause and effect for both. However, this research delivered alternatives to determine links between BIM maturity and KPI metrics. This achieved within the interviews, which first determined how both BIM maturity and KPI metrics could be linked to determine whether a potential linkage already existed. This helped to determine whether the KPI metrics could be linked with the BIM maturity metrics, which could then be used for further examination. Various interpretations of correlations exist, which was not mentioned in many studies. This research condensed and reviewed different interpretations and selected the most relevant for the combined BIM-KPI assessment.

5) **A first BIM assessment and combined BIM maturity and KPI metrics assessment with BS EN ISO19650 recognition**

   This research began in April 2016, at which point the government mandate concerning BIM Level 2 was announced. At this stage, the focus group workshops and interviews were conducted on the proposed BIM maturity assessments and exploring the relationship between BIM maturity and KPI metrics being relevant to Level 2 BIM and the questionnaire survey was being prepared during the mention of Level 2 BIM only. However, when the questionnaire survey was released, the new BS EN ISO19650 standards were released, which aimed to internationally recognise the BIM metrics and transition between Level 2 BIM and the BS EN ISO19650 standards. Thus, the BIM assessment in this research incorporated this transition, which means it will be the first BIM assessment to include BS EN ISO19650 metrics. This means it follows an up to date UK approach to BIM concerning its continuous development, and fills the gap concerning the absence of BS EN ISO19650 standards, and in accordance to the government guidance with digitisation (HM government. 2020c).

10.5.2 Contributions to Practice

There are a number of contributions to practice to emerge from this research as follows:

1) **The first BIM maturity and combined BIM maturity and KPI metrics assessment for public sector clients with BS EN ISO19650 to be recognised and examined across UK practices**

   The new BS EN ISO19650 standards aim to internationally recognise the BIM maturity metrics and transition guidance between Level 2 BIM and BS EN ISO19650. The BIM maturity assessment in this research incorporated this transition, meaning that it is the first BIM assessment to incorporate BS EN ISO19650 metrics (at the time of writing the thesis). This means it has adopted an up to date approach to BIM within the UK concerning its continuous development. This would be the first BIM maturity and combined BIM-KPI assessment to be given to UK clients and construction organisations to assess their BIM maturity. Previous assessments have been developed that follow the Level 2 BIM approach concerning the governmental mandate. These assessments, however, did not include the transition from Level 2 BIM to the new BS EN ISO19650 standards. Thus, this assessment could help organisations and UK clients to determine how this transition could be made by enabling a better understanding of BIM development, to realise the benefits from combining BIM maturity and KPI metrics together and how they can help enhance the overall performance of the UK practices and benefit them, and by offering an assessment to decide whether they are compliant to the BS EN ISO19650 standards.

2) **The BIM maturity-KPI assessment framework**

   The external validation stage delivered a dashboard that demonstrates the results of the combined BIM-KPI assessment (Section 9.9.2). The findings of this research would enable UK clients to determine the relationship between BIM maturity and KPI metrics, the areas which require improvement in order to progress to the next level, and to implement and invest in strong areas and ensure that they continuously achieve Consistency-strong levels in the future. The dashboard and assessment would be an online tool developed for UK clients.

3) **New method of assessing BIM maturity and KPI metrics to the client sector**

   The combined BIM-KPI framework will be introduced to UK construction industry clients as a new, verified tool that is ready for application across the UK. This tool will be subject to continuous validation and a record of its performance and measurement of anticipated improvements across projects and organisations. The proposed BIM maturity and KPI metrics linkages will bridge the gap that exists in both metrics, which means it is a new framework for the UK construction industry. The BIM Maturity-KPI assessment framework aims to help users arrive at solutions on how to deliver combined BIM maturity and KPI metrics by considering a standardised list of ten KPI metrics that are linked with BIM maturity sub metrics to extract benefits that could impact on the overall performance of the industry. It is expected that the framework will be embedded amongst UK clients through its application across NWCH, who will propose this to local authorities and deliver it to the list of contracting companies with which they have partnerships.

10.6 Research Limitations

Throughout this research, a number of measures were taken to increase reliability, validity and rigour of the research. The data collection phases started with focus group workshops to develop the proposed BIM maturity assessment, which was followed by interviews to examine the assessment and to outline a list of KPI metrics to be examined and used. A mechanism to link BIM maturity and KPI metrics was proposed to see if new KPI metrics would emerge from which ten were proposed. This was then examined and statistically tested in the questionnaire to determine the strength of correlation, the strength and level of relationships, and the level of independence between the BIM maturity sub metrics and the KPIs. This was followed by a focus group validation workshop to finalise and validate the findings. According to Gray (2014), challenges that may occur when conducting case studies and focus group workshops involve accessing organisations, changes to participants, and generalisability. As a result, a longer time may be required to conduct the research, which therefore may result in a failure to produce the solutions expected. As such, a number of data collection procedures were conducted in this research to refine the framework and collect information on links between BIM maturity and KPI metrics amongst various users. However, some limitations were encountered when completing this research, which are:

1) **Time constraints**

   Although the researcher identified a larger sample population, only forty completed responses were returned to the questionnaire survey. Thus, a larger response rate may have strengthened the findings for this phase of the research. The proposed relationship tests were based on these forty responses, thus, the limited timescale of a Ph.D thesis also represents a limitation to this study. Should more time have been available and a greater number of responses was received, the results may have differed, thereby changing the findings concerning the established relationships between BIM maturity and KPI metrics.

2) **BS EN ISO19650 standards existing information**

   Throughout the research journey, different UK approaches to BIM have arisen. This started with governmental mandate to Level 2 BIM and, up to this point, the new BS EN ISO19650 standards have been demonstrated along with a transition guidance from Level 2 BIM to the internationally recognised BS EN ISO19650. As a result, this research could only rely on existing, information concerning the BS EN ISO19650 standards as it emerged and developed, and its transition guidance, which could also be updated with time.

3) **Measuring the benefits of combined BIM maturity and KPI metrics**

   Nine benefits were proposed as occurring from the combined BIM maturity and KPI metrics. However, these benefits were not statistically examined nor measured to see how these reflect on UK clients. Therefore, this research has not measured the benefits proposed to determine how they would impact UK clients and reflect on the construction industry.

4) **UK client's understanding of the combined assessment**

   Enabling understanding of the BIM maturity-KPI assessment amongst clients was another challenge encountered within this research. This was a significant problem since the framework expected UK clients to understand BIM maturity and KPI metrics although no previous assessments exist for clients. Since there has not existed a previous assessment to client, then it was worth visualising how shall this reflect on the UK client sector.

5) **Access to relevant users and construction organisations**

A critical limitation was accessing the most suitable users and construction organisations with a background of Level 2 BIM and the new BS EN ISO19650 standards. This issue arose as some organisations were not operating under Level 2 BIM since results have shown that there is no standardised definition to Level 2 BIM leading to a confusion on how to adopt Level 2 BIM (Winfield, 2018). Thus, the process of selecting a relevant sample with whom to share the framework needed careful consideration in order to meet the vision of UK clients concerning the combination of BIM maturity and KPI metrics and to validate the proposed findings. Some of the selected sample for the interviews and online questionnaire were found to have different levels of understanding of BIM, results have also shown that there are still issued related to people's understanding and industry's issues revolving around Information Management using BIM (Kemp, 2020; UK BIM Alliance. 2020; Winfield, 2020), and some were not aware of industry KPIs.

10.7 Future Research

Having outlined the research contributions, limitations, and recommendations for the UK public sector local authority client, the research has addressed the importance of linking BIM maturity and KPI metrics in order to extract the benefits for the construction industry that reflect on the UK client sector. Nevertheless, the UK is fast progressing through the levels of BIM adoption, whilst there is ongoing transition from Level 2 BIM to the new BS EN ISO19650 standards. As the levels of adoption increase, this should deliver benefits, such as improving organisation performance, increased productivity, more collaboration, and greater efficiencies, to thereby address the aforementioned problems of fragmentation and lower productivity, as mentioned in the construction industry reports (Egan, Latham, Wolstenholme). This will meet the recent drive by reports to respond to modern working and prevent potential threats to the industry (Farmer, 2016). Hence, this research proposes incorporating the fast approach of BS EN ISO19650 standards, to link BIM maturity and KPI metrics, and to embed collaborative strategies to meet these objectives. As a result, the research directions that could achieve this are as follows:

1) **Approaching different client sector(s) and more UK practitioners**

As this research had a limited timeframe and approached a comparatively small number of participants and organisations, further studies could approach a wider selection of clients and different types of clients, and to reach out to more UK practitioners with high levels of BIM experiences. This would enable the collection of more in-depth data about BIM maturity and

KPI metrics relationships and the results would potentially be more generalisable than those for this research.

2) **Greater emphasis on BS EN ISO19650 standards as BIM moves forward**

   There has been some confusion between Level 2 BIM and the new BS EN ISO19650 standards, which meant that participants either did not participate in the questionnaire survey or fully understand the BIM implementation process. Although there is little major difference between Level 2 BIM and BS EN ISO19650, more emphasis and focus could be placed on the new BS EN ISO19650 standards to meet the UK's BIM approach over the upcoming years. The more focus on the new standards, the better the adoption of BIM will be.

3) **Revisit the organisations to see if levels of maturity have changed**

   Organisations and individuals conducted the BIM maturity assessment(s) proposed in this research. Since the results reflected the current state of organisational operations and existing maturity levels, the same individuals and organisations could be revisited at a later stage to identify whether similar levels of maturity exist or have changed. If they have changed, further research could determine whether the levels of maturity were higher or lower.

4) **Measuring the benefits of combined BIM maturity and KPI metrics**

   The benefits of combined BIM maturity and KPI metrics could be measured by future studies to determine the extent to which they could be achieved. This would require a revision of the methodology reports and methods undertaken for this research (Section 2.5.2) to determine how to measure the benefits.

5) **Determining the level of readiness to transition from Level 2 BIM to ISO19650, along with collaborative behaviours and strategies**

   The latest government and NBS reports have identified the level of readiness for Level 2 BIM and addressed the transition to the new BS EN ISO19650 standards. The level of readiness to transition from Level 2 BIM to the BS EN ISO19650 standards should be identified to explore if organisations are ready for this transition and if there is an enhanced understanding to the new standards. The level of readiness with collaborative behaviour should also be explored, since collaborative culture was noted as a KPI and collaboration process as a BIM maturity metrics, and to see if organisations are ready to implement collaborative strategies or not.

6) **Reassess the relationships between BIM maturity and KPI metrics**

   Having reviewed the current state of relationships between BIM maturity and KPI metrics, and having understood the new BS EN ISO19650 standards, BIM maturity and KPI metrics could be revisited to see if BIM maturity levels impact on the KPI relationships such that if the levels of relationships of BIM maturity increase then the KPI relationships with BIM maturity would increase. Revisiting the relationships would allow to see if there have been overall performance improvements within organisations as a result of the change occurring between the relationships of BIM maturity and the KPI metrics.

7) **To extract the benefits of combined BIM and KPIs and provide steps to measure them**
   Having delivered a standardised list of benefits from combined BIM maturity and KPI metrics, the additional benefits that were proposed could be reviewed to identify key benefits that could be included within the existing list of benefits, and to provide steps on how these benefits could be measured. A review of the benefits methodology report (PwC. 2018) would be necessary to visualise how they could be measured.
8) **To examine the correlation between each KPI and further investigate collaborative culture**
   This research has conducted a correlation analysis between BIM maturity and KPI metrics. The same analysis is required to be conducted amongst the KPI metrics to determine the strength of relationships between them. As collaborative culture was introduced as a new KPI, further investigation could be undertaken to identify its key features and how it reflects on the UK.

10.8 Conclusions

Having recommended further research directions prompted by this research, the following conclusions can be drawn from this research:

- The scatter plots table revealed either a weak or moderate positive linear regression between BIM maturity and KPI metrics, indicating that the KPI metrics would depend on the BIM maturity levels and it would move towards the same direction, such that as BIM maturity levels increase, then the KPI strength of relationship increases.
- There needs to be a better understanding of the transition from Level 2 BIM to the new BS EN ISO19650 standards, in order to tackle the existing confusion between both and better educate the client sector with the new standards.
- There is more emphasis on collaboration through greater collaborative behaviour and supportive strategies with UK practices, thus, it is vital to address collaboration within the UK practices to maintain collaborative working amongst project teams within the practice, in order to enhance the overall performance within the UK client sector.
- There are anticipated benefits from linking BIM maturity and KPI metrics; however, they would need to be measured to visualise if the benefits would reflect back on the overall project and organisational performance and see if those benefits would be maintained.

- The findings revealed that, for the most part, as BIM maturity increases the strength of relationship with KPI metrics either decreased or did not relate to BIM maturity. This suggests that there is no relationship between them.
- Although there is an increase in the level of BIM adoption and a drive for greater (international) recognition of BIM in the BS EN ISO19650 standards, there still lacks a consensus definition for BIM. Moreover, BIM maturity assessments could be perceived as an obligation with no clear review of its metrics or whether this would reflect on projects and organisations.
- It is vital to provide education and training strategies to better educate teams with Level 2 BIM, the BS EN ISO19650 standards, the BIM maturity assessment, and ways on establish a relationship between BIM maturity and KPI metrics.

The research highlighted the importance of combining BIM maturity and KPI metrics to identify the strength of relationships between them, and the benefits that could be achieved, which would help to tackle existing problems within the UK construction sector. It is believed that the research findings would support the current implementation of BIM maturity in the UK, enhance and improve cultural behaviours within organisations, and deliver a positive impact on the UK construction industry’s overall performance. Having presented the research conclusions, the next section will deliver the summary of this chapter.

10.9 Summary

This chapter delivered a review of the aim and objectives of this research and how they, along with research questions, were achieved. The expected contributions to knowledge and practice were outlined to demonstrate how these reflect on knowledge, namely by filling existing gaps, explaining problems, and justifying the reasons for selecting the research. Moreover, the study offers an understanding of how this could impact on practice through the application of the proposed framework amongst UK clients in construction, and its impact on the overall performance of the industry. The limitations were highlighted and justified in line with the introduction, literature review, framework development, research methodology, data collection findings, and the validation of findings. A number of research recommendations and future research steps were delivered to identify the actions necessary in terms of the current research findings and those proposed for future research. Finally, a list of conclusions was provided following the completion of this research and key research areas and were noted.

References

Abbasianjahromi, H., Ahangar, M., & Ghahremani, F. (2019). A maturity assessment framework for applying BIM in consultant companies. *Iranian Journal of Science and Technology, Transactions of Civil Engineering, 43*(1), 637-649.

Abbasnejad, B. (2018). *Building information modelling adoption and implementation in construction firms: A multi-stage model* (Doctoral dissertation, Queensland University of Technology).

Abbasnejad, B., & Moud, H. I. (2013). BIM and basic challenges associated with its definitions, interpretations and expectations. International Journal of Engineering Research and Applications (IJERA) ISSN, 2248-9622.

Abbasnejad, B., Nepal, M. P., Ahankoob, A., Nasirian, A., & Drogemuller, R. (2020). Building Information Modelling (BIM) adoption and implementation enablers in AEC firms: a systematic literature review. *Architectural Engineering and Design Management*, 1-23.

Abdirad, H. (2017). Metric-based BIM implementation assessment: a review of research and practice. *Architectural Engineering and Design Management, 13(1)*, 52-78. doi: 10.1080/17452007.2016.1183474

Abdirad, H., Sc, M., Pishdad-bozorgi, P., & Ph, D. (2014). Trends of Assessing BIM Implementation in Construction Research. *Computing in Civil and Building Engineering*, (2011), 496–503. doi: 10.1061/9780784413616.062

Aboumoemen, A. & Underwood, J. (2017) A Level 2 BIM Maturity-KPI Assessment: Literature Review. 13th International Postgraduate Research Conference (IPGRC 2017), 14-15 September 2017, Salford, UK.

Aboumoemen, A. & Underwood, J. (2019) A Level 2 BIM Maturity-KPI Relationship Assessment. 14th International Postgraduate Research Conference (IPGRC 2019), 16-17 December 2019, Salford, UK.

Aboumoemen, A. (2016). A BIM Maturity / KPI assessment framework in support of the UK BIM level 2 construction strategy adoption: A case for a city council supply-chain-procurement platform, MSc BIM and Integrated Design dissertation. Salford: The University of Salford, School of the Built Environment.

Abu Awwad, K. (2020). *The implementation of Building Information Modelling (BIM) Level 2 in the UK construction industry: the case of small and medium enterprises* (Doctoral dissertation, Coventry University).

AbuEbeid, M., & Nielsen, Y. (2020). BIM Standards Around The World A Review of BIM Standards in the Global AEC Industry and BIM Roles of Project Stakeholders. *GSTF Journal of Engineering Technology (JET)*, *5*(1). DOI: 10.5176/ 2251-3701_5.1.107

Acampa, G., Forte, F., & De Paola, P. (2020). B.I.M. models and evaluations. *In Green Energy and Technology*. https://doi.org/10.1007/978-3-030-23786-8_20

Adedotun, O., & Pye, C. J. (2020). BIM implementation practices of construction organizations in the UK AEC industry (paper). *PM World Journal, 9(*10).

Adejumo, A. O., & Adetunji, A. A. (2013). Application of ordinal logistic regression in the study of students' performance. *Mathematical Theory and Modeling*, *3*(11), 10-19.

Adhiprasangga, A., Sari, A. P., Putra, T. W., & Java, W. (2003). Develop Balanced Scorecard From Kpi in Construction.

Adom, D., Hussein, E. K., & Agyem, J. A. (2018). Theoretical and conceptual framework: Mandatory ingredients of a quality research. *International journal of scientific research, 7*(1), 438-441.

Adonis (2017) Data for the Public good. Retrieved 21 April, 2021, from: [https://nic.org.uk/app/uploads/Data-for-the-Public-Good-NIC-Report.pdf]

Agresti, A. (2013). *Categorical data analysis* (3rd ed.). Hoboken, NJ: Wiley.

Ahadzie, D. K., Proverbs, D. G., & Olomolaiye, P. O. (2008). Critical success criteria for mass house building projects in developing countries. *International Journal of Project Management*, *26*(6), 675-687. doi: 10.1016/j.ijproman.2007.09.006

Ahankoob, A., Manley, K., Hon, C., & Drogemuller, R. (2018). The impact of building information modelling (BIM) maturity and experience on contractor absorptive capacity. *Architectural Engineering and Design Management*, *14*(5), 363-380. doi: 10.1080/17452007.2018.1467828

Ahern, D. M., Clouse, A., & Turner, R. (2004). CMMI distilled: a practical introduction to integrated process improvement: Addison-Wesley Professional.

AIA. (2007), Integrated Project Delivery: A Guide. American Institute of Architects. National and AIA California Council, Washington, DC.

Aibinu, A. A., & Papadonikolaki, E. (2020). Conceptualizing and operationalizing team task interdependences: BIM implementation assessment using effort distribution analytics. *Construction management and economics, 38*(5), 420-446.

Aitbayeva, D., & Hossain, M. A. (2020). Building Information Model (BIM) Implementation in Perspective of Kazakhstan: Opportunities and Barriers. *Journal of Engineering Research and Reports*, 13-24.

Akdag, S. G., & Maqsood, U. (2019). A roadmap for BIM adoption and implementation in developing countries: the

Pakistan case. *Archnet-IJAR: International Journal of Architectural Research*. Doi: 10.1108/ARCH-04-2019-0081

Akintoye, A., Goulding, J., & Zawdie, G. (Eds.). (2012). *Construction innovation and process improvement*. John Wiley & Sons.

Akoglu, H. (2018). User's guide to correlation coefficients. *Turkish journal of emergency medicine*, *18*(3), 91-93. doi: 10.1016/j.tjem.2018.08.001

Al Ahbabi, M., & Alshawi, M. (2015). BIM for client organisations: a continuous improvement approach. Construction Innovation, 15(4), 402-408. doi: 10.1108/CI-04-2015-0023

Alaghbandrad, A., April, A., Forgues, D., & Leonard, M. (2015). BIM maturity assessment and certification in construction project team selection. *5th International/11th Construction Specialty Conference (ICSC'15)*, 10p. University of British Columbia, Vancouver, Canada. doi: 10.14288/1.0076339

Alazmeh, N., Underwood, J., & Coates, P. (2018). Implementing a BIM collaborative workflow in the UK construction market. *International Journal of Sustainable Development and Planning, 13(1)*, 24-35. doi: 10.2495/SDP-V13-N1-24-35

Al-Harthi, A., Soetanto, R., & Edum-Fotwe, F. T. (2014). Revisiting client roles and capabilities in construction procurement.

Ali, H. A. E. M., Al-Sulaihi, I. A., & Al-Gahtani, K. S. (2013). Indicators for measuring performance of building construction companies in Kingdom of Saudi Arabia. *Journal of King Saud University - Engineering Sciences*, *25*(2), 125–134. doi: 10.1016/j.jksues.2012.03.002

Alkilani, S., Jupp, J., Kamardeen, I., and Sawhney, A. (2015). KEY PERFORMANCE INDICATORS FOR CONSTRUCTION CONTRACTORS IN DEVELOPING COUNTRIES: A CASE STUDY OF JORDAN. Retrieved 13th November, 2016, from: [http://www.rics.org/Global/Key%20Performance%20Indicators%20for%20Construction%20Contractors%20in%20Developing%20Countries%20-%20A%20Case%20Study%20of%20Jordan.pdf]

Alliance for Construction Excellence (ACE). (2008). BIM deliverable matrix, ACE Building Information Modelling: An Introduction and Best Methods Approach. Retrieved 13th November, 2016, from: [https://www.ace4aec.com/pdf/Introduction%20&%20Best%20Methods%20Manual%202008.pdf]

Almarabeh, T., & AbuAli, A. (2010). A general framework for e-government: definition maturity challenges, opportunities, and success. European Journal of Scientific Research, 39(1), 29-42.

Al-Meshekeh, H., & Langford, D. (1999). Conflict Management and Construction Project Effectiveness. *Journal of Construction Procurement*, *5*, 58-75.

Alnaggar, A., & Pitt, M. (2019). Towards a conceptual framework to manage BIM/COBie asset data using a standard project management methodology. *Journal of Facilities Management, 17(2)*, 175-187. doi: 10.1108/JFM-03-2018-0015

Alshawi, M. (2007). Rethinking IT in construction and engineering: Organisational readiness. Routledge.

Altman, D. G. (1991). *Practical statistics for medical research*. Boca Raton, FL: CRC Press.

Alwan, Z., Jones, P., & Holgate, P. (2017). Strategic sustainable development in the UK construction industry, through the framework for strategic sustainable development, using Building Information Modelling. *Journal of Cleaner Production*, *140*, 349-358. doi: 10.1016/j.jclepro.2015.12.085

Al-Zahrani, J.I. (2013) *The Impact of Contractors' Attributes on Construction Project Success*. PhD Thesis, University of Manchester. UK.

Amaratunga, D., Baldry, D., Sarshar, M., & Newton, R. (2002). Quantitative and qualitative research in the built environment: application of "mixed" research approach. *Work Study, 51*(1), 17–31. doi: 10.1108/00438020210415488

among perspectives: IAP.

Amuda-Yusuf, G. (2018). Critical success factors for building information modelling implementation. *Construction Economics and Building*, *18*(3), 55. doi: 10.5130/AJCEB.v18i3.6000

Andersen, E. S., & Jessen, S. A. (2003). Project maturity in organisations. *International Journal of Project Management*, *21*(6), 457–461. doi: 10.1016/S0263-7863(02)00088-1

Anderson, A., Marsters, A., Dossick, C. S., & Neff, G. (2012). Construction to operations exchange: Challenges of implementing COBie and BIM in a large owner organization. In *Construction Research Congress 2012: Construction Challenges in a Flat World* (pp. 688-697). doi: 10.1061/9780784412329.070

Ankrah, N. A. (2007). *An investigation into the impact of culture on construction project performance* (Doctoral dissertation, University of Wolverhampton).

Anvuur, A.M. (2008) *Cooperation in Construction Projects: Concept, Antecedents and Strategies*. PhD Thesis, Department of Civil Engineering, University of Hong Kong. Hong Kong.

Aouad, G. (2011). *How to succeed in your doctoral studies : personal experiences*. InSPARC 11 conference, 8-9 June.

Appleby, T., Cabanis-Brewin, J., Crawford, J. K., Cruz, F., Pennypacker, J. S., West, J. L., & White, K. R. J. (2007). Advancing Organizational Project Management Maturity. *USA: CBP–Center for Business Practices*.

Arayici, Y., Coates, P., Koskela, L., Kagioglou, M., Usher, C., & O'Reilly, K. (2011). BIM adoption and implementation for architectural practices. *Structural Survey*, *29*(1), 7–25. doi: 10.1108/02630801111118377

Arayici, Y., Egbu, C., & Coates, P. (2012). Building information modelling (BIM) implementation and remote construction projects: issues, challenges, and critiques. *Journal of Information Technology in Construction, 17*, 75-92.

Arayici, Y., Kiviniemi, A., Koskela, L. J., & Kagioglou, M. (2011). BIM implementation and adoption process for an architectural practice BIM implementation and Adoption Process for an Architectural Practice. *FIATECH Conference*, (January 2011).

ARUP. (2014). BIM Maturity Measure. Retrieved 13th November, 2016, from: [http://www.arup.com/news/2015_03_march/10_march_bim_maturity_measure_model_launch]

Asare, K. A., Issa, R. R., Liu, R., & Anumba, C. (2021). BIM for Facilities Management: Potential Legal Issues and Opportunities. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, 13*(4), 04521034.

Ashworth, S. J. (2021). *The evolution of facility management (FM) in the building information modelling (BIM) process: An opportunity to use critical success factors (CSF) for optimising built assets*. Liverpool John Moores University (United Kingdom).

Ashworth, S., & Tucker, M. (2017). FM Awareness of Building Information Modelling (BIM). *British Institute of Facilities Management.*

Ashworth, S., Tucker, M., & Druhmann, C. K. (2019). Critical success factors for facility management employer's information requirements (EIR) for BIM. *Facilities, 37(1/2)*, 103-118. doi: 10.1108/F-02-2018-0027

Ashworth, S., Tucker, M., Druhmann, C., & Kassem, M. (2016). Integration of FM expertise and end user needs in the BIM process using the Employer's Information Requirements (EIR). *Proceedings of CIB World Building Congress Vol 5, 2016,* (Vol 5).

Association of General Contractors (AGC). (2006). The Contractors' Guide to BIM. Retrieved 29th July, 2016, from [http://www.engr.psu.edu/ae/thesis/portfolios/2008/tjs288/Research/AGC_GuideToBIM.pdf]

Atkin, B., Flanagan, R., Marsh, A., & Agapiou, A. (1995). Improving value for money in construction: Guidance for chartered surveyors and their clients: Royal Institution of Chartered Surveyors London.

Attrill, R., & Mickovski, S. B. (2020). Issues to be addressed with current BIM adoption, prior to the implementation of BIM level 3. In 36th ARCOM Conference, *Association of Researchers in Construction Management, Glasgow, UK, September* (pp. 7-8).

Awwad, K. A., Shibani, A., & Ghostin, M. (2020). Exploring the critical success factors influencing BIM level 2 implementation in the UK construction industry: the case of SMEs. *International journal of construction management, 1-8.*

Azen, R. and Budescu, D. V. (2003) The Dominance Analysis Approach for Comparing Predictors in Multiple Regression. Psychological Methods, 8 (2), pp.129-148. doi: 10.1037/1082-989X.8.2.129

Azhar, S. (2011). Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry. *Leadership and management in engineering, 11*(3), 241-252. doi: 10.1061/(ASCE)LM.1943-5630.0000127

Azhar, S., Ahmad, I., & Sein, M. K. (2010). Action Research as a Proactive Research Method for Construction Engineering and Management. *Journal of Construction Engineering and Management, 136*(1), 87–98. doi: 10.1061/ASCECO.1943-7862.0000081

Azhar, S., Khalfan, M., & Maqsood, T. (2015). Building information modelling (BIM): now and beyond. *Construction Economics and Building*, *12*(4), 15–28. doi: 10.5130/ajceb.v12i4.3032

Azhar, S., Nadeem, A., Mok, J. Y., & Leung, B. H. (2008). Building Information Modeling (BIM): A new paradigm for visual interactive modeling and simulation for construction projects. *In Proc., First International Conference on Construction in Developing Countries. 25(1)*, 435-446. doi: 10.1080/01446190601114134

Aziz, M.N. and Salleh, H. (2011) A Readiness Model for IT Investment in the Construction Industry. African Journal of Business Management, 5 (7), pp.2524-2530. doi: 10.5897/AJBM10.1025

Azzouz, A., Copping, A., Shepherd, P., & Duncan, A. (2016a). Using the Arup Bim Maturity Measure To Demonstrate Bim Implementation in Practice Literature Review : Bim-Ams. *Proceedings of the 32nd Annual ARCOM Conference*, *1*(September), 25–34. doi: 10.13140/RG.2.2.33188.27527

Azzouz, A., Shepherd, P., & Copping, A. (2016b). THE EMERGENCE OF BUILDING INFORMATION MODELLING ASSESSMENT METHODS (BIM-AMs). *Integrated Design Conference at University of Bath*, (July).

Babatunde, S. O., Ekundayo, D. O., & Adekunle, A. O. (201). Analysis of BIM maturity level among AEC firms in developing countries: a case of Nigeria. In *Proceedings of the 35th Annual ARCOM Conference* (pp. 225-234). Association of Researchers in Construction Management.

Babatunde, S. O., Ekundayo, D., Adekunle, A. O., & Bello, W. (2020). Comparative analysis of drivers to BIM adoption among AEC firms in developing countries. *Journal of Engineering, Design and Technology*. Doi: 10.1108/JEDT-08-2019-0217

Badrinath, A. C., Chang, Y., & Hsieh, S. (2016). An Overview of Global Research Trend in BIM from Analysis of BIM Publications. *16th International Conference on Computing in Civil and Building Engineering*, (September).

Badrinath, A. C., Hsieh, S. H., & Kumar, N. (2016). BIM PERFORMANCE ASSESSMENTS AND ITS APPLICATION IN INDIAN AECO INDUSTRY–A CASE STUDY. In *Proceedings of the 16th International Conference on Construction Applications of Virtual Reality* (Vol. 11, p. 13).

Badrinath, A., & Hsieh, S. H. (2019). Empirical Approach to Identify Operational Critical Success Factors for BIM Projects. *Journal of Construction Engineering and Management*, *145*(3), doi: 04018140. 10.1061/(ASCE)CO.1943-7862.0001607

Balfour Betty (2018) Collaborative construction. Retrieved 13th November, 2019, from: [https://www.balfourbeatty.com › redirects › collaborative-construction]

Banwell, H. (1964). The Placing and Management of Contracts for Building and Civil Engineering work. In *A report of the Committee under the chairmanship of Sir Harold Banwell*, London: HMSO.

Barlish, K. (2011). How To Measure the Benefits of BIM: A Case Study Approach. (Doctoral dissertation, ARIZONA STATE UNIVERSITY) Retrieved 13th November, 2016, from: [https://repository.asu.edu/attachments/57013/content/Barlish_asu_0010N_10983.pdf]

Barlish, K., & Sullivan, K. (2012). How to measure the benefits of BIM - A case study approach. *Automation in Construction*, *24*, 149–159. doi: 10.1016/j.autcon.2012.02.008

Bashir, A.M., (2013) *A Framework for Utilising Lean Construction Strategies to Promote Safety On Construction Sites,* PhD Thesis, School of Technology, University of Wolverhampton.

Bassioni, H. A., Price, A. D. F., & Hassan, T. M. (2004). Performance Measurement in Construction. *Journal of Management in Engineering*, *20*(2), 42–50. doi: 10.1061/(ASCE)0742-597X(2004)20:2(42)

Bassioni, H. A., Price, A. D. F., & Hassan, T. M. (2005). Building a conceptual framework for measuring business performance in construction: an empirical evaluation. *Construction Management and Economics*, *23*(5), 495–507. doi: 10.1080/0144619042000301401

Bataw, A., Burrows, M., & Kirkham, R. (2014). *The challenges of adopting Building Information Modelling (BIM) principles within Small to Medium sized Enterprises (SMEs)*. Proceedings of the 14th International Conference on Construction Applications of Virtual Reality (CONVR2014), 16-18 November 2014, Sharjah, UAE, 318-324.

Baxter, P. (2012). BIM Adoption and Developments. Autodesk, Retrieved November, 13, 2016, from: [http://www.nti.dk/media/1289410/nti-april2013-final.pdf]

Bayraksan, H. (2009). A Report on The Capability Maturity Model, (November).

Beatham, S., Anumba, C., Thorpe, T., & Hedges, I. (2004). KPIs: a critical appraisal of their use in construction. *Benchmarking: An International Journal*, *11*(1), 93–117. doi: 10.1108/14635770410520320

Becerik-Gerber, AM ASCE, B., Ku, K., & Jazizadeh, F. (2012). BIM-enabled virtual and collaborative construction engineering and management. Journal of Professional Issues in Engineering Education and Practice, 138(3), 234-245. doi: 10.1061/(ASCE)EI.1943-5541.0000098

Becerik-Gerber, B., & Kensek, K. (2009). Building information modeling in architecture, engineering, and construction: Emerging research directions and trends. Journal of professional issues in engineering education and practice, 136(3), 139-147. doi: 10.1061/(ASCE)EI.1943-5541.0000023

Becerik-Gerber, B., & Rice, S. (2009). The Value of Building Information Modeling: Can We Measure the ROI of BIM? *AECbytes Viewpoint #47*, *47*, 1–6. Retrieved November 13, 2016, http://www.aecbytes.com/viewpoint/2009/issue_47.html

Begić, H., & Galić, M. (2021). A Systematic Review of Construction 4.0 in the Context of the BIM 4.0 Premise. *Buildings, 11*(8), 337.

Belay, S., Goedert, J., Woldesenbet, A., & Rokooei, S. (2021). Comparison of BIM Adoption Models between Public and Private Sectors through Empirical Investigation. *Advances in Civil Engineering*, *2021*.

Bell, J. (2014). *Doing Your Research Project: A guide for first-time researchers*. *McGraw-Hill Education*.

Bell, J., & Waters, S. (2018). *EBOOK: DOING YOUR RESEARCH PROJECT: A GUIDE FOR FIRST-TIME RESEARCHERS.* McGraw-Hill Education (UK).
Bello, M. J. S. (2003). A case study approach to the supplier selection process. Master of engineering. Management Systems Engineering, University of Puerto rico mayaguez campus.
Benson, P. L., Donahue, M. J., & Erickson, J. A. (1993). The faith maturity scale: Conceptualization, measurement, and empirical validation. Research in the social scientific study of religion, 5(1), 1-26.
Berlo, L. V., Dijkmans, T., Hendriks, H., Spekkink, D., & Pel, W. (2012). BIM QuickScan: benchmark of BIM performance in the Netherlands. Proceedings of the 29th International Conference. Beirut, Lebanon: CIB.
Bernhold, T., & Wiesweg, N. (2021). The use of key Key Performance Indicators in Real Estate Management A stocktaking along the CREM maturity level. In *The 20th EuroFM Research Symposium* (p. 63).
Bernstein, H. M., Jones, S. A., & Gudgel, J. E. (2010). The business value of BIM in Europe: Getting building information modeling to the bottom line in the United Kingdom, France and Germany. Bedford: McGraw-Hill Construction.
Bertram, D. (2007). Likert Scales. Cpsc 681, 2, 2013. doi: 10.1002/9780470479216.corpsy0508
Bew, M. and Underwood J. (2010). Delivering BIM to the UK Market. Handbook of research on building information modelling and construction informatics: Concepts and technologies (2010): 30-64.
Bew, M., and Richards, M. (2008). BIM maturity model, Royal Institute of British Architects (RIBA) Publishing, London.
BIM Industry Working Group. (2011). A report for the Government Construction Client Group - March 2011. *Communications*, (March), 107. Retrieved November 13, 2016, [http://www.bimtaskgroup.org/wp-content/uploads/2012/03/BIS-BIM-strategy-Report.pdf]
BIM Level 2. (2016) About BIM level 2. Partnered with the BSI website, Retrieved 13th October, 2016 from [http://bim-level2.org/en/]
BIM Task Group. (2013). Frequently asked questions, what is Building Information Modelling (BIM)? Retrieved 13th November, 2016, from: [http://www.bimtaskgroup.org/bim-faqs/]
BIMexcellence. (2016). BIMe Excellence Individual Discovery. Retrieved 13th November, 2016, from: [http://bimexcellence.com/assess/campaign/default/]
BIMIcon (2021) Practical BIM level assessment. Retrieved 18th Apr, 2022, from: [https://www.bimicon.com/practical-bim-level-assessment/]
BIM-profiler (2020) *BIM connect competency assessment*. Retrieved 18th Apr, 2022, from: [https://planbim.cl/home-mibim/?lang=en]
bimSCORE. (2013). Strategic Building Innovation •bimSCORE, Retrieved 13th November, 2016, from: [https://www.sbi.international/index.php/welcome]
BIMTalk. (2010). Levels of BIM maturity. Retrieved 13th October, 2016 from [http://bimtalk.co.uk/bim_glossary:level_of_maturity]
BIMTASKFORCE. (2013). Welcome to your BIM Capability Compass and Upskilling toolkit. Retrieved 13th November, 2016, from: [http://bim.knowledgesmart.net/BIM/Default.aspx]
Binesmael, M., Li, H., & Lark, R. (2018, September). Meta-standard for collaborative BIM standards: an analysis of UK BIM level 2 standards. In *Working Conference on Virtual Enterprises* (pp. 661-668). Springer, Cham.
BIS. (2011) Government Construction Strategy. London, UK: Department of Business and Innovation.
BIS. (2013) Industrial Strategy: Government and Industry in Partnership: Construction 2025. Report number: URN BIS/13/955.London, UK: Department for Business, Innovation and Skills.
Blackwell, D. B. (2012). Building Information Modelling-Industrial strategy: government and industry in partnership. London: HM Government. Retrieved November 13, 2016, from: [https://www.gov.uk/government/publications/building-information-modelling]
Blaikie, N. (2003) *Analyzing Quantitative Data*, *From Description to Explaination*.London: SAGE Publications.
Blay, K. B., Tuuli, M. M., & France-Mensah, J. (2019). Managing change in BIM-Level 2 projects: benefits, challenges, and opportunities. *Built Environment Project and Asset Management.* doi: 10.1108/bepam-09-2018-0114
Böes, J. S., Barros, J. D. P., & Lima, M. M. X. D. (2021). BIM maturity model for higher education institutions. *Ambiente Construído*, 21, 131-150.
Bolton, A., Butler, L., Dabson, I., Enzer, M., Evans, M., Fenemore, T., ... & Makri, C. (2018). *Gemini principles.* Retrieved 15th Nov, 2021, from: [https://www.cdbb.cam.ac.uk/DFTG/GeminiPrinciples]
Bonett, D. G., & Wright, T. A. (2000). Sample size requirements for estimating Pearson, Kendall and Spearman correlations. *Psychometrika*, *65*(1), 23-28.
Borgatti, S. (1999). Elements of Research: Theoretical Framework.
Borrmann, A., König, M., Koch, C., & Beetz, J. (2018). Building Information Modeling: Why? What? How?. In *Building Information Modeling* (pp. 1-24). Springer, Cham.
Bougroum, Y. (2016). AN ANALYSIS OF THE CURRENT BUILDING INFORMATION MODELLING ASSESSMENT METHODS. (Doctoral dissertation, University of Bath).

Boyd, D., & Chinyio, E. (2008). Understanding the construction client: John Wiley & Sons.
Boyd, D., & Chinyio, E. (2008). *Understanding the construction client*. John Wiley & Sons.
Boyd, D., & Wild, A. (2003). Tavistock studies into the building industry: communications in the building industry (1965) and interdependence and uncertainty (1966). *Construction Reports 1944-98*, 69-85. Tavistock Publications.
Brace, N., Kemp, R. and Snelgar, R. (2003) SPSS for Psychologists. A Guide to Data Analysis Using SPSS for Windows. Palgrave Macmillan.
Bradley, G. (2010). *Benefit Realisation Management : A Practical Guide to Achieving Benefits Through Change. Ed.: 2nd ed. Farnham, Surrey, England : Gower. 2010*. doi: 10.1017/CBO9781107415324.004
Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. doi: 10.1191/1478088706qp063oa
Braun, V., Clarke, V. & Weate, P. (2016). Using thematic analysis in sport and exercise research. In B. Smith & A. C. Sparkes (Eds.), Routledge handbook of qualitative research in sport and exercise (pp. 191-205). London: Routledge.
BRE. (2015). BIM Level 2 Business Systems Certification. Retrieved 13th November, 2016, from: [http://www.bre.co.uk/page.jsp?id=3389]
BRE. (2016). Key performance indicators (KPI's) for the construction industry. Retrieved 13th November, 2016, from: [https://www.bre.co.uk/page.jsp?id=1478]
Brinberg, D. and McGrath, J.E. (1985) *Validity and the Research Process.* California: Sage.
Broquetas, M. (2011) Using BIM as a Project Management Tool: How can BIM improve the delivery of complex construction projects, HFT Stuttgart. Retrieved 13th November, 2016, from: http://www.cadaddict.com/2011/02/summary-using-bim-asproject-management.html
Brown, A., & Adams, J. (2000). Measuring the effect of project management on construction outputs: a new approach. *International Journal of project management, 18*(5), 327-335. doi: 10.1016/S0263-7863(99)00026-5
Bryde, D. and Broquetas, M. and Volm, J.M. (2013) The Project Benefits of Building Information Modelling (BIM). *International Journal of Project Management, 31b* (7), pp.971–980. doi: 10.1016/j.ijproman.2012.12.001
Bryde, D. J., Unterhitzenberger, C., & Joby, R. (2019). Resolving agency issues in client–contractor relationships to deliver project success. *Production Planning & Control, 1-15.* doi: 10.1080/09537287.2018.1557757
Brydon-Miller, M., Greenwood, D., & Maguire, P. (2003). Why action research?. Action research, 1(1), 9-28. doi: 10.1177/14767503030011002.
Bryman, A. (2016). Social research methods. Oxford university press.
Bryman, A. (2019). *Social research methods*. Oxford university press.
BSI. (2008). Collaborative production of architecture, engineering and construction information- Code of practice. BS 1192:2007. British Standard Institute. UK.
BSI. (2010) Constructing the Business Case. Building Information Modelling. London and Surrey.
BSI. (2013). Specification for information management for the capital/delivery phase of construction projects using building information modelling. PAS 1192-2:2013. British Standard Institute. UK.
BSI. (2014) Specification for information management for the operational phase of assets using building information modelling. PAS1192-3:2014. British Standard Institute. UK.
BSI. (2018a) BS EN ISO 19650:2018: Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM). Information management using building information modelling BSI London, UK
BSI. (2018b) BS EN ISO 19650-2:2018: Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM). Information management using building information modelling. Delivery phase of the assets BSI London, UK
BSI. (2018c) BS EN ISO 19650-1:2018: Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM). Information management using building information modelling. Concepts and principles BSI London, UK
BSI. (2019) PD 19650‐0:2019 Transition guidance to BS EN ISO 19650. *The British Standard Institution*
Bubshait, A. A., & Almohawis, S. A. (1994). Evaluating the general conditions of a construction contract. *International Journal of Project Management*, *12*(3), 133-136. doi: 10.1016/0263-7863(94)90027-2
Building Smart Alliance (2011). About NBIMS-US: Building Smart Alliance (BSA).
Burgess, J. (1996). Focusing on fear: The use of focus groups in a project for the Community Forest Unit, Countryside Commission. *Area*, *28*(2), 130–135.
Bynum, P., Issa, R. R. A., & Olbina, S. (2013). Building information modeling in support of sustainable design and construction. *American Society of Civil Engineers*, *139*(1), 24–34. doi: 10.1061/(ASCE)CO.1943-7862.0000560.

Cabinet Office (2011). Government Construction Strategy May 2011. Retrieved 13th October, 2016 from [https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/61152/Government-Construction-Strategy_0.pdf]

Callcutt, J., & Britain, G. (2007). *The Callcutt Review of housebuilding delivery*. Communities and Local Government Publications.

Cameron, S., & Price, D. (2009). *Business research methods: a practical approach.* Kogan Page Publishers.

Carmines, E. G., & Zeller, R. A. (1979). *Reliability and validity assessment* (Vol. 17): Sage publications.

Carneiro, T. M., Lins, D. M. D. O., & Neto, J. D. P. B. (2012). Spread of BIM: A comparative analysis of scientific production in Brazil and abroad. *IGLC 2012 - 20th Conference of the International Group for Lean Construction*. Retrieved 13th October, 2016, from: [http://www.scopus.com/inward/record.url?eid=2-s2.0-84874454789&partnerID=tZOtx3y1]

CBPP. (2002). Key Performance Indicators.

CDBB (2021a) *Self assessment*. Retrieved 18th Apr, 2022, from: [https://www.cdbb.cam.ac.uk/file/selfassessment-cdbbxlsx]

CDBB (2021b) *International BIM Toolkit*. Retrieved 18th Apr, 2022, from: [https://www.cdbb.cam.ac.uk/AboutDBB/Promoting-digital-construction-Internationally/international-bim-toolkit

CDBB (2021c) *The Pathway towards an Information Management Framework.* Retrieved 18th Apr, 2022, from: [https://www.cdbb.cam.ac.uk/news/pathway-towards-IMF]

CDBB (2021d) *The Approach to Develop the Foundation Data Model for the Information Management Framework.* Retrieved 18th Apr, 2022, from: [https://www.cdbb.cam.ac.uk/files/250221_the_choice_of_start_point_for_the_foundation_data_model_for_the_information_management_framework_1.pdf]

CDBB (2021e) *An Integrated approach to Information Management.* Retrieved 18th Apr, 2022, from: [https://www.cdbb.cam.ac.uk/news/publication-integrated-approach-information-management-identifying-decisions-and-information]

CDBB (2021e) *National Digital Twin.* Retrieved 18th Apr, 2022, from: [https://www.cdbb.cam.ac.uk/news/publication-national-digital-twin-integration-architecture-pattern-and-principles]

CDBB (2021f) *A framework for composition.* Retrieved 18th Apr, 2022, from: [https://www.cdbb.cam.ac.uk/news/publication-framework-composition-step-towards-foundation-assembly]

CDBB (2021g) *Digital Twin Toolkit.* Retrieved 18th Apr, 2022, from: [https://digitaltwinhub.co.uk/files/file/62-digital-twin-toolkit/]

Cerovsek, T. (2011). A review and outlook for a "Building Information Model" (BIM): A multi-standpoint framework for technological development. *Advanced Engineering Informatics*, *25*(2), 224–244. doi: 10.1016/j.aei.2010.06.003

Cha, H. S., & Kim, C. K. (2011). Quantitative approach for project performance measurement on building construction in South Korea. *KSCE Journal of Civil Engineering*, *15*(8), 1319–1328. doi:10.1007/s12205-011-1323-5

Challender, J., & Whitaker, R. (2019). *The Client Role in Successful Construction Projects*. Routledge.

Challender, J., Farrell, P., & McDermott, P. (2019). *Building Collaborative Trust in Construction Procurement Strategies*. John Wiley & Sons, Incorporated.

Chan, A. P. (1996). *Determinants of project success in the construction industry of Hong Kong* (Doctoral dissertation).

Chan, A. P. C., & Chan, A. P. L. (2004). Key performance indicators for measuring construction success. *Benchmarking: An International Journal*, *11*(2), 203–221. doi: 10.1108/14635770410532624

Chan, A. P., Scott, D., & Lam, E. W. (2002). Framework of success criteria for design/build projects. *Journal of management in engineering*, *18*(3), 120-128. doi: 10.1061/(ASCE)0742-597X(2002)18:3(120)

Chan, D. W., Olawumi, T. O., & Ho, A. M. (2019). Critical success factors for building information modelling (BIM) implementation in Hong Kong. *Engineering, construction and architectural management.*

Chan, Y. H. (2003). Biostatistics 104: correlational analysis. *Singapore Med J*, *44*(12), 614-9.

Change Agents AEC (2013). BIM Excellence Performance Measurement Coporate Services. Retrieved 13th November, 2016, from: [http://changeagents.blogs.com/Public_Sharing/BIMe%20Excellence%20%20Corporate%20Services%20brochure%20v30918.pdf]

Chen, K. (2015). *A strategic decision making framework for organisational BIM implementation* (Doctoral

dissertation, Cardiff University).
Chen, K. (2015). A strategic decision making framework for organisational BIM implementation (Doctoral dissertation, Cardiff University).
Chen, K., & Li, H. (2016). AHP based weighting system for BIM implementation & assessment framework. *IEEE International Conference on Industrial Engineering and Engineering Management*, *2016–January*, 1727–1731. doi: 10.1109/IEEM.2015.7385943
Chen, L., Xie, X., Lu, Q., Parlikad, A. K., Pitt, M., & Yang, J. (2021). Gemini Principles-Based Digital Twin Maturity Model for Asset Management. *Sustainability, 13*(15), 8224.
Chen, Y., Dib, H., & Cox, R. F. (2012). A framework for measuring building information modeling maturity in construction projects. In 29th International Conference on Applications of IT in the AEC Industry.
Chen, Y., Dib, H., & F. Cox, R. (2014). A measurement model of building information modelling maturity. *Construction Innovation*, *14*(2), 186–209. doi: 10.1108/CI-11-2012-0060
Chen, Y., Dib, H., Cox, R. F., Shaurette, M., & Vorvoreanu, M. (2016). Structural Equation Model of Building Information Modeling Maturity. *Journal of Construction Engineering and Management*, *142*(3). doi: 10.1061/(ASCE)CO.1943-7862.0001147.
Chen, Y., Dib, H., Cox, R. F., Shaurette, M., Vorvoreanu, M., Manoosingh, C., & Maghiar, M. (2016). Global Stakeholders' Perception of Key BIM Maturity Indicators.
Chen, Y., John, D., & Cox, R. F. (2018). Qualitatively exploring the impact of BIM on construction performance. In ICCREM 2018: *Innovative Technology and Intelligent Construction* (pp. 60-71). Reston, VA: American Society of Civil Engineers.
Cheng, J. C. P., & Lu, Q. (2015). A review of the efforts and roles of the public sector for BIM adoption worldwide. *Journal of Information Technology in Construction*, *20*(October), 442–478.
Cheong, S. P., Anumba, C. J., Hill, R., & Bouchlaghem, D. (2003). Improving construction client satisfaction through functional briefing. In Construction Research Congress: Wind of Change: Integration and Innovation (pp. 1-10) doi:10.1061/40671
Cheung, S. O., Suen, H. C. H., & Cheung, K. K. W. (2004). PPMS: A Web-based construction Project Performance Monitoring System. *Automation in Construction*, *13*(3), 361–376. doi: 10.1016/j.autcon.2003.12.001
Choi, J., Leite, F., & de Oliveira, D. P. (2020). BIM-based benchmarking for healthcare construction projects. *Automation in Construction, 119*, 103347.
Chrissis, M. B., Konrad, M., & Shrum, S. (2003). CMMI guidlines for process integration and product improvement: Addison-Wesley Longman Publishing Co., Inc.
CIC. (2013) BIM Planning Guide for Facility Owners. Version 2.0. Retrieved 13th November, 2016, from: [http://bim.psu.edu/resources/owner/bim_planning_guide_for_facility_owners-version_2.0.pdf]
Clandinin, D. J., & Connelly, F. M. (2000). Narrative Inquiry: Experience and Story in Qualitative Research. *Narrative Inquiry*, *2*, 211
Clements-Croome, D. (Ed.). (2013). *Intelligent buildings: an introduction*. Routledge.
Coates, P., Arayici, Y., Koskela, K., Kagioglou, M., Usher, C., & O'Reilly, K. (2010). The key performance indicators of the BIM implementation process. *University of Salford*, (September 2016), 6. Retrieved 13th November, 2016, from: [http://usir.salford.ac.uk/9551/6/ID_15_camera_ready.doc]
Coates, S. P. (2013). BIM implementation strategy framework for small architectural practices (Doctoral thesis, University of Salford).
Codinhoto, R., Kiviniemi, A., Kemmer, S., & da Rocha, C. G. (2011). *BIM Implementation: Manchester Town Hall Complex*. University of Salford.
Codinhoto, R., Kiviniemi, A., Kemmer, S., Essiet, U. M., Donato, V., & Tonso, L. G. (2013). Research Report 2-BIM-FM-Manchester Town Hall Complex. Manchester City Council.
Cohen J. (1988). Statistical Power Analysis for the Behavioural Science (2nd Edition). *In Statistical Power Anaylsis for the Behavioural Science (2nd Edition).*
Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education*. *Professional Development in Education* (Vol. 38). doi: 10.1080/19415257.2011.643130
Collins, H. (2010). *Creative research: the theory and practice of research for the creative industries.* Bloomsbury Publishing.
Collis, J., & Hussey, R. (2014). *Business research: a practical guide for undergraduate and postgraduate students. Palgrave Macmillan UK* (Vol. 4th)
Connaughton, J. and Mbugua, L. (2003) 'Faster Building for Industry: NEDO (1983)'. In *Construction Reports 1944-98*. Ed. by Murray, M. and Langford, D. Oxford: Blackwell Science, 114-129
Conover, W. J. (1999). *Practical nonparametric statistics* (3rd ed.). Hoboken, NJ: Wiley & Sons.

Constructing Excellence (2011) Collaborative working: the principles Retrieved 13th November, 2019, from: [http://constructingexcellence.org.uk/category/collaborative-working-2/]

Constructing Excellence. (2012) Constructing excellence and BIM. Constructing Excellence, London, United Kingdom. Retrieved 3rd March, 2016, from: [http://constructingexcellence.org.uk/resources/constructing-excellence-and-bim/]

Constructing Excellence. (2014) UK Industry Performance Report Based on the UK Construction Industry Key Performance Indicators. Constructing Excellence, London, United Kingdom.

Cooke, D., & Clarke, G. M. (1989). *A basic course in statistics*. Arnold.

Cooke-Davies, T. (2004). Project Management Maturity Models. *The Wiley Guide to Managing Projects*, 1234–1255. doi: 10.1002/9780470172391

Cooper, D. R., & Schindler, P. S. (2014). *Business Research Methods*. *Business Research Methods.*

Costa, D. B., Formoso, C. T., Kagioglou, M., & Alarcon, L. F. (2004). Performance Measurement Systems for Benchmarking in the Construction Industry. *12th Annual Conference of the International Group for Lean Construction*, *44*(0), 1–13. 13th November, 2016, from: [http://www.iglc.net/papers/details/292]

Costa, D. B., Formoso, C. T., Kagioglou, M., Alarcón, L. F., & Caldas, C. H. (2006). Benchmarking initiatives in the construction industry: lessons learned and improvement opportunities. *Journal of Management in Engineering*, *22*(4), 158-167. doi: 10.1061/(ASCE)0742-597X(2006)22:4(158)

Cousins and Knutt (2017) BIM : What Clients Really Think, 21. BIM whitepaper, CIOB, BIM+, Retrieved 15th November 2017, from: [http://www.constructionmanagermagazine.com/bim-whitepaper/]

Cox, R. F., Issa, R. R. a., & Ahrens, D. (2003). Management's Perception of Key Performance Indicators for Construction. *Journal of Construction Engineering and Management*, *129*(2), 142–151. doi: 10.1061/(ASCE)0733-9364(2003)129:2(142)

CPA (2019) Three-year economic forecast for construction. Retrieved 13th November, 2019, from: [https://www.ggf.org.uk/cpa-release-three-year-economic-forecast-for-construction/]

CPI. (2011). CPIx-BIM Assessment Form. Retrieved 13th November, 2016, from: [http://www.cpic.org.uk/wp-content/uploads/2013/06/cpix_-_bim_assessment_form_ver_1.0.pdf]

CQE academy. (2019) *The Scatter Plot & Linear Regression.* Retrieved 13th November, 2019, from: [http://www.cqeacademy.com/cqe-body-of-knowledge/continuous-improvement/quality-control-tools/the-scatter-plot-linear-regression/]

Crawford, L. (2006). Developing organizational project management capability: theory and practice. *Project Management Journal*, *37*(3), 74-86.

Crawford, L. M. (2019). Conceptual and theoretical frameworks in research. *Research design and methods: An applied guide for the scholar-practitioner. Sage Publishing*.

Creswell, J. W. (2014). Research design: qualitative, quantitative, and mixed methods approaches (4th edn). London: SAGE Publications.

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.

Creswell, J., & Clark, V. (2011). *Designing and conducting mixed-methods research*. *The Sage handbook of qualitative research.*

Crosby, P. B. (1980). Quality is free: The art of making quality certain. Signet.

Cross, K. F., & Lynch, R. L. (1988). The "SMART" way to define and sustain success. *National Productivity Review*, *8*(1), 23–33. doi: 10.1002/npr.4040080105

Crotty, M. (1998). *The Foundations of Social Research: Meaning and Perspective in the Research Process*. *Book.*

Crotty, R. (2013). The impact of building information modelling: Transforming construction. Routledge.

Curtis, B., Hefley, B., & Miller, S. (2009). People Capability Maturity Model®(P-CMM®) Version 2.0, Second Edition. U.S: Software Engineering Institute. Carnegie Mellon University.

Dadashi Haji, M., Taghaddos, H., Sebt, M. H., Chokan, F., & Zavari, M. (2021). The Effects of BIM Maturity Level on the 4D Simulation Performance: An Empirical Study. *International Journal of Engineering, 34*(3), 606-614.

Dadmehr, N. & Coates, S. P. (2019) "*AN APPROACH TO "NATIONAL ANNEX TO ISO 19650-2"*. 14th International Postgraduate Research Conference (IPGRC 2019), 16-17 December 2019, Salford, UK.

Dado, F. E. (2011). Building information modeling: benefits, obstacles, adoption: Saarbrücken: LAP LAMBERT Academic

Dainty, A. R. J., Cheng, M.-I., & Moore, D. R. (2005). Competency-Based Model for Predicting Construction Project Managers' Performance. *Journal of Management in Engineering*, *21*(1), 2–9. doi: 10.1061/(ASCE)0742-597X(2005)21:1(2)

Dakhil, A. (2017) Building Information Modelling (BIM) maturity-benefits assessment relationship framework for UK construction clients. PhD thesis.

Dakhil, A. J., Underwood, J., & Alshawi, M. (2019). Critical success competencies for the BIM implementation process: UK construction clients. *Journal of Information Technology in Construction (ITcon)*, *24*, 80-94.

Dakhil, A., & Alshawi, M. (2014). Building Information Modelling Benefits-Maturity Relationship from Client Perspective. *Information and Knowledge Management*, *4*(9), 8–16.

Dakhil, A., Alshawi, M., & Underwood, J. (2015). BIM Client Maturity: Literature Review, (June), 229–238.

Dakhil, A., Underwood, J., & Al Shawi, M. (2016). BIM benefits-maturity relationship awareness among UK construction clients. *Proceedings of the First International Conference of the BIM Academic Forum*, (October).

Dancey, C. P., & Reidy, J. (2004). Statistics without maths for psychology. *Harlow: Pearson education limited*, *19*, 20.

Daniel, J., Kanwar, A., & Uvalić-Trumbić, S. (2009). Breaking Higher Education's Iron Triangle: Access, Cost, and Quality. *Change: The Magazine of Higher Learning*, *41*(2), 30–35. doi: 10.3200/chng.41.2.30-35

David, M., & Sutton, C. D. (2011). *Social research: An introduction*. SAGE Publications Ltd: London.

Davies, R. and Harty, C. (2013) Measurement and Exploration of Individual Beliefs about the Consequences of Building Information Modelling Use. Construction Management and Economics, 31 (11), pp.1110-1127. doi: 10.1080/01446193.2013.848994

Dawood, I., & Underwood, J. (2010). Research Methodology Explained. *Methodology*, (May), 177–186.

DBE. (2021a) *BIM competency assessment tool*. Retrieved 18th Apr, 2022, from: [https://www.dbe.careers/bim-competency-table/]

DBE. (2021b) *BIM competency framework*. Retrieved 18th Apr, 2022, from: [https://www.dbe.careers/wp-content/uploads/2020/03/Research-and-key-principles.pdf]

DBE. (2021c) *BIM competency self assessment*. Retrieved 18th Apr, 2022, from: [https://www.dbe.careers/bim-competency-assessments/the-bim-competency-self-assessment/]

De Bruin, T., Freeze, R., Kaulkarni, U., & Rosemann, M. (2005). Understanding the Main Phases of Developing a Maturity Assessment Model. *Australasian Conference on Information Systems (ACIS)*, 8–19. doi: 10.1108/14637151211225225

De Vaus, D. (2002) *Surveys in Social Research*, 5th ed. London: Routledge.

DEFRA. (2006). Environmental Key Performance Indicators: Reporting Guidelines for UK Buisness. *Department for Environment Food and Rural Affairs*, 74.

Denscombe, M. (2010). The Good Research Guide For Small Scale Research Projects. *Open University Press.* doi: 10.1371/journal.pone.0017540

Denzin, N.K. (2009) *The Research Act: A Theoretical Introduction to Sociological Methods.* Piscataway, New Jersey: Transaction Publishers.

Design Buildings Wiki (2019) *Construction industry reports*. Retrieved 13th November, 2019, from: [https://www.designingbuildings.co.uk/wiki/Construction_industry_reports]

Dissanayaka, S. M., & Kumaraswamy, M. M. (1999). Comparing contributors to time and cost performance in building projects. *Building and Environment, 34(1)*, 31-42. doi:10.1016/S0360-1323(97)00068-1

Doloi, H. (2009). Analysis of pre-qualification criteria in contractor selection and their impacts on project success. *Construction Management and Economics*, *27*(12), 1245–1263. doi: 10.1080/01446190903394541

Dowsett, R. (2016). *Assessing the success of BIM implementation* (Doctoral dissertation, University of Reading).

Drew, D., Skitmore, M., & Lo, H. P. (2001). The effect of client and type and size of construction work on a contractor's bidding strategy. *Building and Environment*, *36*(3), 393–406. doi: 10.1016/S0360-1323(00)00009-3

Du, J., Liu, R., & Issa, R. R. (2014). BIM cloud score: benchmarking BIM performance. *Journal of Construction Engineering and Management*, *140*(11), 4014054. doi:10.1061/(asce)co.1943-7862.0000891

Dulaimi, M. F., Ling, F. Y., & Bajracharya, A. (2003). Organizational motivation and inter-organizational interaction in construction innovation in Singapore. *Construction Management and economics*, *21*(3), 307-318. doi: 10.1080/0144619032000056144

Duncan, A., & Aldwinckle, G. (2014). BM6460 - How to Measure the Impact of Building Information Modelling on Your Business. *Autodesk University*.

Dunn, O. J. (1964). Multiple comparisons using rank sums. *Technometrics*, *6*, 241-252.

Dwairi, S., Mahdjoubi, L., Odeh, M., Kossmann, M., Arayici, Y., Ahmed, V., … Zave, P. (2016). Development of OntEIR Framework to Support BIM Clients in Construction. *International Journal of 3-D Information Modeling*, *5*(1),

45–66. https://doi.org/10.4018/IJ3DIM.2016010104
Eadie, R., Browne, M., Odeyinka, H., McKeown, C., & McNiff, S. (2013). BIM implementation throughout the UK construction project lifecycle: An analysis. *Automation in Construction*, *36*, 145–151. doi: 10.1016/j.autcon.2013.09.001
Eadie, R., Odeyinka, H., Browne, M., McKeown, C., & Yohanis, M. (2014). Building Information Modelling Adoption: An Analysis of the Barriers to Implementation. Journal of Engineering and Architecture, 2(1), 77-101.
Eadie, R., Perera, S., & Heaney, G. (2011). Key process area mapping in the production of an e-capability maturity model for UK construction organisations. Journal of Financial Management of Property and Construction, 16(3), 197-210. doi: 10.1108/13664381111179198
Eastman, C. M., Teicholz, P., & Sacks, R. (2011). BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors. John Wiley & Sons (2nd edn).
Eastman, C. M., Teicholz, P., & Sacks, R. (2018). BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors. John Wiley & Sons (3rd edn).
Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2008). BIM Case Studies. In *BIM Handbook* (pp. 319–465). doi: 10.1002/9780470261309.ch9
ECLLP, H. (2013). Supply Chain Analysis into the Construction Industry-A Report for the Construction Industrial Strategy. *BIS Research Paper*, *145*.
Edge Hill University. (2014). Code of Practice for the Conduct of Research., (1), 1–24.
Edirisinghe, R., Pablo, Z., Anumba, C., & Tereno, S. (2021). An Actor–Network Approach to Developing a Life Cycle BIM Maturity Model (LCBMM). *Sustainability*, *13*(23), 13273.
EFQM. (2012). An overview of the EFQM Excellence Model. Retrieved 13th November, 2016, from: [http://www.efqm.org/sites/default/files/overview_efqm_2013_v1.pdf]
Egan, J. (1998). Rethinking Construction: The Report of the Construction Task Force, DETR, H.M.S.O., London
Egan, J. (2004). Skills for Sustainable Communities. *The Egan Review*, *2*, 1–21, 103–104. Retrieved 13th November, 2016, from: [http://dera.ioe.ac.uk/11854/1/Egan_Review.pdf]
Egan, S. J. (2002). Accelerating Change A report by the Strategic Forum for Construction, London.
Egbu, C., & Coates, P. (2012). Building Information Modelling (Bim) Implementation and Remote Construction Projects : Issues , Challenges , and Critiques, *17*(May), 75–92.
Eisenhardt, M. (1991). Conceptual frameworks for research circa 1991: Ideas from a cultural anthropologist; implications for mathematics education rese.
Eisenhardt, K. M. (1991). Better stories and better constructs: The case for rigor and comparative logic. *Academy of Management review, 16*(3), 620-627.
Ekundayo, D., Shelbourn, M., & Babatunde, S. O. (2021). Collaborative multidisciplinary learning: Quantity surveying students' perspectives. *Industry and Higher Education, 35*(3), 211-222.
Elder, G. H., Pavalko, E. K., & Clipp, E. C. (1993). *Working with archival data: Studying lives* (Vol. 88). SAGE Publications Ltd: London.
El-Mashaleh, M. S., Edward Minchin Jr, R., & O'Brien, W. J. (2007). Management of construction firm performance using benchmarking. *Journal of Management in Engineering*, *23*(1), 10-17.
Emmerson, H. (1962). Survey of Problems Before the Construction Industries. In *A report prepared for the Ministry of Works by Sir Harold Emmerson*, London: HMSO.
Enegbuma, W., Aliagha, U., & Ali, K. (2014). Preliminary building information modelling adoption model in Malaysia. *Construction Innovation, 14(4)*, 408–432. doi: 10.1108/ci-01-2014-0012
Engineering, C. (2011). Federal University of Rio Grande do Sul A conceptual framework for defining customisation strategies in the house- building sector A CONCEPTUAL FRAMEWORK FOR DEFINING CUSTOMISATION STRATEGIES IN THE HOUSE-BUILDING SECTOR.
Enshassi, A., Mohamed, S., & Abushaban, S. (2009). Factors affecting the performance of construction projects in the Gaza strip. *Journal of Civil engineering and Management, 15(3)*, 269-280. doi: 10.3846/1392-3730.2009.15.269-280
EU_BIM Task Group, (2018) *Handbook for the introduction of Building Information Modelling by the European Public Sector, Strategic action for construction sector performance: driving value, innovation and growth*. Retrieved 13th November, 2019, from: [http://www.eubim.eu/handbook-selection/]
Eynon, J. (2016). *Construction manager's BIM handbook*. John Wiley & Sons.
Farmer, M. (2016). The Farmer Review of the UK Construction Labour Model: Modernise or Die. *Construction Leadership Council*.
Farnsworth, C. B., Beveridge, S., Miller, K. R., & Christofferson, J. P. (2015). Application, advantages, and methods

associated with using BIM in commercial construction. *International Journal of Construction Education and Research*, *11*(3), 218-236. doi: 10.1080/15578771.2013.865683

Fellows, R. and Lui, A. (2008) Research Methods for Construction, 3rd ed, Oxford: Blackwell Publishing.

Fellows, R. and Lui, A. (2015) *Research Methods for Construction*, (4th edn), Oxford: Blackwell Publishing.

Fenby-Taylor, H., Thompson, N., Maclaren, A., Bartley, T., Rossiter, D., Tennyson, R., & Philp, D. (2016). Scotland Global BIM Study. *Scotland Global BIM Study. dotBuiltEnvironment*, (July 2016). doi: 10.13140/RG.2.1.5108.8889

Ferraz, C., Loures, E. R., & Deschamps, F. (2020). BIM Maturity Models Evaluated by Design Principles. In Transdisciplinary Engineering for *Complex Socio-technical Systems–Real-life Applications* (pp. 504-513). IOS Press.

Fewings, P., & Henjewele, C. (2019). Construction project management: an integrated approach. Routledge.

Field, A. (2017) *Discovering Statistics Using SPSS*. 5th ed. London: SAGE Publications Ltd: London.

Field, A., Miles, J., & Field, Z. (2013). *Discovering Statistics Using SPSS*. SAGE Publications Ltd: London.

Fincher, A. & Levin, G. (1997) Project management maturity model. Proceedings of the Project Management Institute 28th Annual Seminar Symposium. Chicago, Project Management Institute

Fink, A., & Litwin, M. S. (1995). *How to measure survey reliability and validity* (Vol. 7). Sage.

Fisher, D. M. (2004). The business process maturity model: a practical approach for identifying opportunities for optimization. *Business Process Trends*, *9*(4), 11–15. Retrieved 13th November, 2016, from: [http://www.bpmg.orgwww.bptrends.com/publicationfiles/10-04ARTBPMaturityModel-Fisher.pdf]

Flick, U. (2015). *Introducing Research Methodology: A Beginner's Guide to Doing a Research Project*. *SAGE*.

Flyvbjerg, B. (2006). Five misunderstandings about case study research. *Qualitative Inquiry*, *12*(2), 219–245. doi: 10.1177/1077800405284363

Foster, J., & Sheppard, J. (2016). *British Archives: A Guide to archive resources in the UK*. Springer.

Fraser, P., Moultrie, J., & Gregory, M. (n.d.). The use of maturity models/grids as a tool in assessing product development capability. *IEEE International Engineering Management Conference*, *1*, 244–249. doi:10.1109/IEMC.2002.1038431

Fu, X. (2012). The Influences of Budgetary System in a Selection of Large Chinese companies in the Industry of Electronic Household Appliances (Doctoral dissertation, Durham University).

Fullerton, J., & West, M. A. (1996). Consultant and client-working together? *Journal of Managerial Psychology*, *11*(6), 40–49. doi: 10.1108/02683949610129749

Fumerton, R. (2008). Knowledge by Acquaintance vs. Description. *Stanford Encyclopedia of Philosophy.*

Furneaux, C., Hampson, K., Scuderi, P., & Kajewski, S. (2010). Australian Construction Industry KPIs. *CIB World Congress Proceedings - Building a Better World*, 1–12. Retrieved 13th November, 2016, [http://eprints.qut.edu.au/38809/]

Ganah, A. A., & John, G. A. (2014). Achieving Level 2 BIM by 2016 in the UK. In *Computing in Civil and Building Engineering (2014)* (pp. 143-150). doi: 10.1061/9780784413616.019

Ganah, A., & John, G. A. (2015). An overview of the feasibility of achieving level 2 building information modeling by 2016 in the UK. *Journal of Civil Engineering and Architecture*, *9*(8), 885-894. doi: 10.17265/1934-7359/2015.08.001

Gann, D. M., & Salter, A. J. (2000). Innovation in project-based, service-enhanced firms: the construction of complex products & systems. Research policy, 29(7), 955-972. doi: 10.1016/S0048-7333(00)00114-1

Gao, J. (2011). A Characterization Framework to Document and Compare BIM Implementations on Construction Projects *BIM-Maturity*, (December). (Doctoral dissertation, Stanford University).

Garrigos, A. G., Brebbia, C. A., Mahdjoubi, L., & Laing, R. (Eds.). (2018). *Building information systems in the construction industry*. WIT Press.

Georgiadou, M. C. (2016). Building Information Modelling in UK construction projects: a state of the art review. *RICS COBRA 2016.*

Georgiadou, M. C. (2019). An overview of benefits and challenges of building information modelling (BIM) adoption in UK residential projects. *Construction Innovation.* doi: 10.1108/CI-04-2017-0030

GeoSpatial World (2018). *BIM adoption around the world: how good are we?*. Retrieved 13th November, 2019, from: [https://www.geospatialworld.net/article/bim-adoption-around-the-world-how-good-are-we/]

Ghaffarianhoseini, A., Doan, D. T., Zhang, T., Ghaffarianhoseini, A., Naismith, N., & Tookey, J. (2016). A BIM readiness & implementation strategy for SME construction companies in the UK. In *Proceedings of the 33rd CIB W78 Conference.*

Ghaffarianhoseini, A., Tookey, J., Ghaffarianhoseini, A., Naismith, N., Azhar, S., Efimova, O., & Raahemifar, K. (2017). Building Information Modelling (BIM) uptake: Clear benefits, understanding its implementation, risks

and challenges. *Renewable and Sustainable Energy Reviews*, *75*, 1046-1053. doi: 10.1016/j.rser.2016.11.083
Gibbs, A. (1997). Focus groups. Social research update, 19(8), 1-8.
Giddens, A. (1984). *The constitution of society: Outline of the theory of structuration* (Vol. 349). Univ of California Press.
Giel, B. (2009). Return on investment analysis of building information modeling in construction. *Building Construction*, 1–107. University of Florida.
Giel, B., & Issa, R. (2013a). Quality and Maturity of BIM Implementation in the AECO Industry. In Applied Mechanics and Materials (Vol. 438, pp. 1621-1627). Trans Tech Publications. doi: 10.4028/www.scientific.net/AMM.438-439.1621
Giel, B., & Issa, R. (2013b). Synthesis of existing BIM maturity toolsets to evaluate building owners. *Computing in Civil Engineering*, 451–458. doi: 10.1061/9780784413029.057
Giel, B., & Issa, R. (2014) Framework for Evaluating the BIM Competencies of Building Owners. *Computing in Civil and Building Engineering*, (Cmm), 552–559. doi: 10.1061/9780784413616.069
Giel, B., & Issa, R. (2015) Framework for Evaluating the BIM Competencies of Facility Owners. Journal of Management in Engineering, ASCE, pp.1-15. doi: 10.1061/(ASCE)ME.1943-5479.0000378
Glaser, B. (2017). *Discovery of grounded theory: Strategies for qualitative research*. Routledge.
Glaser, B. G., & Strauss, A. L. (1967). *The Discovery of Grounded Theory: Strategies for Qualitative Research*. *Observations* (Vol. 1).
Gledson, B., Greenwood, D., Routledge, P., Watson, R., & Woddy, P. (2016). Preparing to work in level 2 BIM: an innovative approach to a training and educational need.
Gleeson, B., & Penney, M. (2016). What are you prepared to do? Land Journal, 14.
Gliem, J. A., & Gliem, R. R. (2003). Calculating, interpreting, and reporting Cronbach's alpha reliability coefficient for Likert-type scales. *Midwest Research-to-Practice Conference in Adult, Continuing, and Community Education.* doi: 10.1109/PROC.1975.9792
Gobar Adviseurs (2010), An International Scope of BIM – A systematic review of BIM guideline documents, Gobar Adviseurs, Netherlands.
Godfrey, S. (2008) What is CMMI?. NASA presentation. Retrieved 13th November, 2017, from: [https://ses.gsfc.nasa.gov/ses_data_2004/040601_Godfrey.ppt]
Goss, J. D., & Leinbach, T. R. (1996). Focus Groups as Alternative Research Practice: Experience with Transmigrants in Indonesia. *Area*, *28*(2), 115–123. doi: 10.2307/20003647
Gosselin, M. (2005). An empirical study of performance measurement in manufacturing firms. *International journal of productivity and performance management*, *54*(5/6), 419-437. doi: 10.1108/17410400510604566
Goucher, D., & Thurairajah, N. (2012). Usability and impact of BIM on early estimation practices: Cost consultant's perspective. *Irbnet.De*.
Gray, C., & Malins, J. (2004). *Visualizing research: a guide to the research process in art and design*. *Art and Design*. Retrieved 13th November, 2017, from: [http://books.google.com/books?id=f8fjnLbkY6YC&pgis=1]
Gray, D. (2014). *Doing Research in the Real World*. SAGE Publications Ltd: London.
Greaves, N. (2008). UK Commission for Employment and Skills - Employability Skills Project Review of Evidence on Best Practice in Teaching and Assessing Employability Skills Policy Research Institute. *UK Commission for Employment and Skills- Employbility Skills Project*, (June).
Green, S. (2003) 'Technology Foresight Report: Progress through Partnership (1995)'. *In Construction Reports 1944-98*. Ed. by Murray, M. and Langford, D. Oxford: Blackwell Science, 161-177
Greene, J. C., Caracelli, V. J., & Graham, W. F. (1989). Toward a conceptual framework for mixed-method evaluation designs. *Educational evaluation and policy analysis*, *11*(3), 255-274.
Group, B. T. (2013). Government Support. Retrieved 13th October, 2016 from [http://www.bimtaskgroup.org/]
Gruneberg, S. (2018). *A Strategic Approach to the UK Construction Industry*. Routledge.
Gu, N., & London, K. (2010). Understanding and facilitating BIM adoption in the AEC industry. Automation in Construction, 19(8), 988-999. doi: 10.1016/j.autcon.2010.09.002
Guilford, J. P. (1950). *Fundamental statistics in psychology and education (2nd ed.)*. New York, NY, US: McGraw-Hill.
Guilford, J.P. (1956). *Fundamental Statistics in Psychology and Education.* New York: McGraw Hill.
Guion, L., Diehl, D., & McDonald, D. (2011). Triangulation: Establishing the validity of qualitative studies. University of Florida IFAS Extension. *Online Document*.
Gyarting, K. A. (2014). *AN EVALUATION OF THE IMPACT OF BUILDING INFORMATION MODELLING (BIM) ON PROJECT PERFORMANCE IN THE UK CONSTRUCTION INDUSTRY*. Doctoral thesis. Coventry univervisty
Hackitt, J. (2018), *Building a safer future: independent review of building regulations and fire safety:*

final report. Retrieved 18th April, 2022, from: [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/707785/Building_a_Safer_Future_-_web.pdf]

Haidar, A. (2019). *Rethinking innovation in computational design: a theoretical framework for innovative strategies to enhance the efficiency of the 'digital'in architectural design* (Doctoral dissertation, University of Salford).

Hair, J.F., Black, W.C., Babin, B.J., Anderson, R.E. and Tatham, R.L. (2010) *Multivariate Data Analysis with Readings*, (7th edn). New Jersey: Prentice Hall.

Hakes, C. (2007). The EFQM Excellence Model. Zaltbommel: Van Haren Publishing.

Hannes Lindblad & Tina Karrbom Gustavsson (2021) Public clients ability to drive industry change: the case of implementing BIM, Construction Management and Economics, 39:1, 21-35, DOI: 10.1080/01446193.2020.1807032

Haque, M. E., & Mishra, R. (2007). 5D virtual constructions: Designer/constructor's perspective. In *2007 10th international conference on computer and information technology* (pp. 1-4). IEEE. doi: 10.1109/ICCITECHN.2007.4579377

Hardin, B., & McCool, D. (2015). *BIM and construction management: proven tools, methods, and workflows*. John Wiley & Sons.

Hardin, B., & McCool, D. (2015). BIM and construction management: proven tools, methods, and workflows. John Wiley & Sons.

Hardy, M. A. (1993). *Regression with dummy variables.* Newbury Park, CA: Sage.

Haron, A. T. (2013). Organisational readiness to implement building information modelling: A framework for design consultants in Malysia. University of Salford.

Harrison, C., & Thurnell, D. (2015). BIM implementation in a New Zealand consulting quantity surveying practice. *International journal of construction supply chain management, 5(1), 1-15.* doi: 10.14424/ijcscm501015-01-15

Harty, C. (2005). Innovation in construction: a sociology of technology approach. Building Research & Information, 33(6), 512-522. doi: 10.1080/09613210500288605

Harty, J., & Laing, R. (2010). Removing Barriers to BIM Adoption: Clients and Code Checking to Drive Changes. *Handbook of Research on Building Informaton Modeling and Construction Informatics: Concepts and Technologies*, 546–560. doi: 10.4018/978-1-60566-928-1.ch024

Harty, J., Kouider, T., & Paterson, G. (2015). *Getting to grips with BIM: a guide for small and medium-sized architecture, engineering and construction firms*. Routledge.

Hassan, M. A., (2012). Implementation of Building Information Modelling (Bim): Practices and Barriers in Construction Industry in GCC. (Doctoral dissertation, School of the Built Environment, Heriot-watt University).

Hatzigeorgiou, A., & Manoliadis, O. (2017). Assessment of performance measurement frameworks supporting the implementation of lean construction. In *Proceedings of the 25th Annual Conference of the International Group for Lean Construction, Heraklion, Greece* (pp. 9-12).

Hatzigeorgiou, A., & Manoliadis, O. (2018). Key Performance Indicators: Advances in Construction Projects Performance Measurement. In *Proceedings of the 10th International Conference on Construction in the 21st Century (CITC-10)*. *Colombo, Sri-Lanka* (pp. 9-12).

Havenvid, M. I., Hulthén, K., Linné, Å., & Sundquist, V. (2016). Renewal in construction projects: tracing effects of client requirements. Construction Management and Economics, 1-18. doi: 10.1080/01446193.2016.1208364

Hegazy, M. A. (2012). The development of key financial performance indicators for UK construction companies. *Hegazy, Mohamed and Hegazy, Sherif. The development of key financial performance indicators for UK construction companies. Accounting, Accountability & Performance*, *17*, 49-77.

Hergunsel, M. F. (2011). Benefits of Building Information Modeling. *Design*, (May), 1136–1145. doi: 10.1016/j.ijproman.2012.12.001

Heron, J., & Reason, P. (1997). A Participatory Inquiry Paradigm. *Qualitative Inquiry, 3*(3), 274–294. doi: 10.1177/107780049700300302

High Speed Two (HS2) BIM (2016) WHAT DOES BIM MEAN FOR HS2? Presentation by Sonia Zahiroddiny, Retrieved 13th October, 2017, from: [http://www.rsgbestpractice.org/wp-content/uploads/2016/08/what-does-bim-mean-for-hs2.pdf].

Hinkle, D. E., Wiersma, W., & Jurs, S. G. (2003). *Applied statistics for the behavioral sciences* (Vol. 663). Houghton Mifflin College Division.

HM Government (2020a) *Government transformation strategy 2017-2020*. Retrieved 21 April, 2021, from: [https://www.gov.uk/government/publications/government-transformation-strategy-2017-to-2020]

HM Government (2020b), *National infrastructure strategy – fairer, faster, greener – November 2020*.

Retrieved 28 April, 2020, from: [https://www.gov.uk/government/publications/national-infrastructure-strategy]
HM Government (2020c) *The construction playbook: government guidance on sourcing and contracting public works projects and programmes*.
HM Government (2021a) *The National Infrastructure and Construction Pipeline*. Retrieved 18th April, 2022, from: [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1016759/Analysis_of_the_National_Infrastructure_and_Construction_Pipeline_2021.pdf]
HM Government (2021b) *Golden thread report*. Retrieved 18th April, 2022, from: [https://www.gov.uk/government/publications/building-regulations-advisory-committee-golden-thread-report/building-regulations-advisory-committee-golden-thread-report]
HM Government. (2012). Building Information Modelling. *Industrial Strategy: Governement and Idustry in Partnership*, *Vol.1*, 1–22. doi: 10.1016/j.aei.2007.03.001
HM Government. (2013). Construction 2025, Industrial Strategy: Government and industry in partnership. *UK Government*, (July), 78. doi: HM Government
HM treasury (2014) *Improving Infrastructure Delivery.* Retrieved 18th Apr, 2022, from: [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/359853/Alliancing_Best_Practice.pdf]
Holt, G. D. (2014). Asking questions, analysing answers: relative importance revisited. *Construction Innovation*, *14*(1), 2–16. doi: 10.1108/ci-06-2012-0035
Holzer, D. (2011). BIM's seven deadly sins. *International Journal of Architectural Computing*, *9*(4), 463–480. doi: 10.1260/1478-0771.9.4.463
Holzer, D. (2016). *The BIM manager's handbook: guidance for professionals in architecture, engineering, and construction*. John Wiley & Sons.
Holzer, D. (2016). *The BIM manager's handbook: guidance for professionals in architecture, engineering, and construction*. John Wiley & Sons.
Hong Kong CIC. (2014). CIC Building Information Modelling Standards, 0–103.
Hong, R. (2014). *Practitioners' evaluations of theraplay as an effective tool in serving foster and adopted children and their families*. Dissertation Abstracts International Section A: Humanities and Social Sciences.
Hong, Y., Sepasgozar, S. M. E., Ahmadian, A. F. F., & Akbarnezhad, A. (2016). Factors influencing BIM Adoption in Small and Medium Sized Construction Organizations. *33rd International Symposium on Automation and Robotics in Construction (ISARC 2016)*, (Isarc), 2016.
Hooper, M. (2015). *BIM Anatomy II: Standardization needs & support systems*. Lund University (Media-Tryck). Retrieved 13th October, 2017, from: [http://lup.lub.lu.se/record/5275508]
Hore, A., McAuley, B., West, R., Kassem, M., & Kuang, S. (2017). Ireland's BIM Macro Adoption Study: Establishing Ireland's BIM Maturity. *School of Surveying and Construction Management*. *CITA BIM Gathering 2017*, November 23rd – 24th, p32-40.
Hosmer, D. W., Lemeshow, S., & Sturdivant, R. X. (2013). *Applied logistic regression* (3rd ed.). Hoboken, NJ: John Wiley & Sons.
Howell, D. C. (1997) Statistical Methods for Psychology. 4th ed. Belmont, CA: Wadsworth.
Huang, C.-H., & Hsieh, S.-H. (2015). A Case Study on Assessing the Productivity of a BIM team in a Construction Company. *The 6th International Conference on Construction Engineering and Project Management (ICCEPM 2015)*, (October). doi: 10.13140/RG.2.1.3821.6403
Humphrey, W. S. (1988). CHARACTERIZING THE SOFTWARE PROCESS: A MATURITY FRAMEWORK. *IEEE Software*, *5*(2), 73–79. doi: 10.1109/52.2014
Hyde, K. F. (2000). Qualitative Market Research: An International Journal Recognising deductive processes in qualitative research Recognising deductive processes in qualitative research. *Qualitative Market Research: An International Journal Iss Qualitative Market Research An International Journal Iss An International Journal*, *3*(4), 82–90. doi: 10.1108/13522751211257051
IFM. (2018). *BIM maturity assessment*. Retrieved 13th November, 2019, from: [https://www.ifm.eng.cam.ac.uk/research/asset-management/research-projects/bim-maturity-assessment/]
Ikediashi, D. I., Mendie, A., Achuenu, E., & Oladokun, M. G. (2012). Key performance indicators of design and build projects in Nigeria. *Journal of human ecology*, *37*(1), 37-46. doi: 10.1080/09709274.2012.11906447
Imenda, S. (2014). Is there a conceptual difference between theoretical and conceptual frameworks? *Journal of Social Science, 38*(2), 185–195. doi: 10.1111/j.1471-0528.2006.00853.x
Indiana University. (2009a). BIM Design & Construction Requirements. Indiana University, US. Retrieved 13th November, 2016, from:

[http://www.indiana.edu/~uao/docs/standards/IU%20BIM%20Rollout%20Presentation%209-10-2009.pdf]
Indiana University. (2009b). IU BIM Proficiency Matrix (Microsoft Excel), US. Retrieved 13th November, 2016, from: [http://www.iu.edu/~vpcpf/consultant-contractor/standards/bim-standards.shtml]
Infrastructure and Projects Authority. (2016). Government construction strategy 2016-2020.
Ingram, J. (2020). *Understanding BIM: The Past, Present and Future*. Routledge.
IPA (2017) *Transforming Infrastructure Performance*. Retrieved 18th Apr, 2022, from: [https://www.gov.uk/government/publications/transforming-infrastructure-performance-roadmap-to-2030]
Ippolito, A., & Cigola, M. (Eds.). (2016). *Handbook of research on emerging technologies for digital preservation and information modeling*. IGI Global.
Irizarry, J. (2020). *Construction 4.0: An innovation platform for the built environment*. Routledge.
Isikdag, U., & Underwood, J. (2010). A synopsis of the handbook of research on building information modeling. *Proceedings of CIB 2010 World Building*, (December 2009), 84–96. Retrieved 13th November, 2016, from: [https://www.researchgate.net/profile/Umit_Isikdag/publication/235759628_A_Synopsis_of_the_Handbook_of_Research_on_Building_Information_Modelling/links/09e4151338477b9fd2000000.pdf]
Isikdag, U., Underwood, J., & Kuruoglu, M. (2012). Building information modelling. Construction innovation and process improvement, 385.
Ismail, S., & Yusof, A. (2009). Benchmarking the performance of Malaysia's construction industry. *Management Research and Practice*, *1*(1), 1–13.
Issa, R. R., & Suermann, P. (2009). Evaluating industry perceptions of building information modeling (BIM) impact on construction. Journal of Information in Technology and Construction, 14, 574-594.
Jabareen, Y. (2009). Building a conceptual framework: philosophy, definitions, and procedure. *International journal of qualitative methods*, *8*(4), 49-62.
Jallow, H., Renukappa, S., Suresh, S., & Alneyadi, A. (2019). Implementing a BIM Collaborative Workflow In The UK Infrastructure Sector. *In Proceedings of the 2019 3rd International Conference on Information System and Data Mining* (pp. 103-108). ACM. doi: 10.1145/3325917.3325957
Jamieson, S. (2004). Likert scales: how to (ab) use them. *Medical Education*, *38*(12), 1217–1218. doi: 10.1111/j.1365-2929.2004.02012.
Jayasena, H. S., & Weddikkara, C. (2013). Assessing the BIM maturity in a BIM infant industry. In Proceedings of the Second World Construction Symposium 2013: Socio-Economic Sustainability in Construction (pp. 14-15).
Jenaban, M., Dawood, D., Craggs, D. And Kassem, M. (2016). A tool for the assessment of project compliance with Level 2 BIM, *13th International Conference on Construction Applications of Virtual Reality,* December 12-13, 2016 , Hong Kong.
Jernigan, F. E. (2008). *Big BIM, little bim: the practical approach to building information modeling: integrated practice done the right way!*
Jiang, R., Wu, C., Lei, X., Shemery, A., Hampson, K. D., & Wu, P. (2021). Government efforts and roadmaps for building information modeling implementation: lessons from Singapore, the UK and the US. *Engineering, Construction and Architectural Management*.
Jin, R., Zou, P. X., Li, B., Piroozfar, P., & Painting, N. (2019). Comparisons of students' perceptions on BIM practice among Australia, China and UK. *Engineering, Construction and Architectural Management.* doi: 10.1108/ECAM-07-2018-0275
Jin, X. H., & Zhang, G. (2011). Modelling optimal risk allocation in PPP projects using artificial neural networks. *International journal of project management*, *29*(5), 591-603. doi: 10.1016/j.ijproman.2010.07.011
Joblot, L., Paviot, T., Deneux, D., & Lamouri, S. (2019). Building Information Maturity Model specific to the renovation sector. *Automation in Construction*, *101*, 140-159. doi: 10.1016/j.autcon.2019.01.019
Johannesson, P., & Perjons, E. (2014). *An Introduction to Design Science*. *Springer International Publishing Switzerland*. doi: 10.1007/978-3-319-10632-8
John, D D. (2018). *Building Information Modeling (BIM) Impact on Construction Performance.* Master's thesis, Georgia Southern University, Statesboro, Georgia.
John, G. a, & Ganah, a a. (2014). Achieving Level 2 BIM by 2016 in the UK. *Computing in Civil and Building Engineering (2014)*, (2014), 143–150. doi: 10.1061/9780784413616.019
Jones, B. I. (2020). A study of Building Information Modeling (BIM) uptake and proposed evaluation framework. *J. Inf. Technol. Constr., 25*, 452-468.
Jones, E. A., & Voorhees, R. A. (2002). Defining and Assessing Learning: Exploring Competency-Based Initiatives.

Report of the National Postsecondary Education Cooperative Working Group on Competency-Based Initiatives in Postsecondary Education. Brochure [and] Report.

Jorgensen, D. L. (1989). *Participant observation*. John Wiley & Sons, Inc.

Jugdev, K., & Thomas, J. (2002). Project management maturity models: The silver bullets of competitive advantage. Project Management Institute, *Project Management Journal*, *33*(4), 4–14.

Jung, W., & Lee, G. (2015). The status of BIM adoption on six continents. *International Journal of Civil, Structural, Construction and Architectural Engineering*, *9*(5), 406–410.

Jung, Y., & Joo, M. (2011). Building information modelling (BIM) framework for practical implementation. *Automation in Construction*, *20*(2), 126–133. doi: 10.1016/j.autcon.2010.09.010

Junior, G. M., da Cunha Ribeiro, N., Pellanda, P. C., & de Miranda Reis, M. (2020). Implementation Framework for BIM Adoption and Project Management in Public Organizations. *Journal of Civil Engineering and Architecture*, *14*, 109-119.

Jus, A. (2017). *Usage, potentials and challenges of building information modelling (BIM) in Slovenia, Austria, Germany and Switzerland* (Doctoral dissertation, Wien).

Kagioglou, M. (1998). Generic design and construction process protocol: final report: University of Salford, Department of Radiology.

Kagioglou, M., Cooper, R., & Aouad, G. (2001). Performance management in construction: a conceptual framework. *Construction management and economics*, *19*(1), 85-95, doi: 10.1080/01446190010003425

Kagioglou, M., Cooper, R., Aouad, G., & Sexton, M. (2000). Generic design and construction process protocol. *Engineering, Construction and Architectural Management, 7*(2), 141–153.

Kam, C. (2014) Managing BIM Projects, Organizations, and Policies: Turning Aspirations into Quantitative Measures of Success. Building Information Modeling: BIM in Current and Future Practice, 267-280.

Kam, C., Ph, D., Song, M. H., & Senaratna, D. (2007). VDC Scorecard : Formulation , Application , and Validation, (Vdc), 1–9. doi: 10.1061/(ASCE)CO.1943-7862.0001233

Kam, C., Senaratna, D., Mckinney, B., & Xiao, Y. (2014). The VDC Scorecard: Formulation and Validation. *CIFE Working Paper*, *WP 135*(January), 40.

Kam, C., Senaratna, D., Xiao, Y. & McKinney, B. (2013a). The VDC Scorecard: Evaluation of AEC. Projects and Industry Trends.

Kam, C., Senaratna, D., Xiao, Y. & McKinney, B. (2013b). The VDC Scorecard: Formulation, and Validation. Stanford University.

Kam, C., Song, M. H., & Senaratna, D. (2016). VDC Scorecard: Formulation, Application, and Validation. Journal of Construction Engineering and Management, 0401600, doi: 10.1061/(ASCE)CO.1943-7862.0001233

Kamara, J., Anumba, C., & Evbuomwan, N. (1999). Client requirements processing in construction: a new approach using QFD. Journal of architectural engineering, 5(1), 8-15. doi: 10.1061/(ASCE)1076-0431

Kamara, J., Anumba, C., & Evbuomwan, N. (2000). Establishing and processing client requirements—a key aspect of concurrent engineering in construction. Engineering Construction and Architectural Management, 7(1), 15-28. doi: 10.1046/j.1365-232x.2000.00129.x

Kang, T. W., Won, J., & Lee, G. (2013). A study on the development direction of a BIM performance assessment tool. *Journal of Korea Spatial Information Society*, *21*(1), 53–62. doi: 10.12672/ksis.2013.21.1.053

Kaplan, R. S., & Norton, D. P. (2005). The balanced scorecard: measures that drive performance. Harvard business review, 83(7), 172.

Kapogiannis, G., & Sherratt, F. (2018). Impact of integrated collaborative technologies to form a collaborative culture in construction projects. *Built Environment Project and Asset Management.*

Karim, K., & Marosszeky, M. (1999). Process monitoring for process re-engineering-using key performance indicators. *In International conference on construction process reengineering*, CPR (Vol. 99).

Kassem, M., & Li, J., (2020) *Building Information Modelling: Evaluating Tools for Maturity and Benefits Measurement.* Centre for Digital Built Britain (CDBB) in partnership with the UK BIM Alliance, commissioned the University of Northumbria at Newcastle, UK.

Kassem, M., & Succar, B. (2017). Macro BIM adoption: Comparative market analysis. *Automation in Construction*, *81*(May), 286–299. doi: 10.1016/j.autcon.2017.04.005

Kassem, M., Succar, B., & Dawood, N. (2013). A Proposed Approach To Comparing the BIM Maturity of Countries. *Proceedings of the CIB W78 2013: 30th International Conference, Beijing, China*, (Succar), 9–12. doi: 10.13140/2.1.2308.5766

Kassim, Y., Underwood, J., & Raphael, B. (2010). Evaluating IT as Source of Competitive Advantage in Engineering and Construction Organisations. PM-05–Advancing Project Management for the 21st Century “Concepts, Tools & Techniques for Managing Successful Procets, 29-31.

Kemp, A. (2020). The BIM implementation journey: lessons learned for developing and disseminating City Information Modelling (CIM). *Built Environment*, *46*(4), 528-546.

Kendall, M. (1938) A New Measure of Rank Correlation. Biometrika 30:81–89

Kennedy, P., Milligan, J., Cattanach, L., & McCluskey, E. (2010). The development of Statutory Adjudication in the UK and its relationship with construction workload. In *RICS COBRA 2010 conference, Dauphine-Paris University, 2nd-3rd September*.

Kensek, K. M. (2015). Building Information Modeling. doi:10.1007/978-3-658-05606-3

Kensek, K., & Noble, D. (2014). *Building information modeling: BIM in current and future practice.* John Wiley & Sons.

Kerzner, H. (2017). *Project management metrics, KPIs, and dashboards: a guide to measuring and monitoring project performance*. John Wiley & Sons.

Ketokivi, M., & Mantere, S. (2010). Two strategies for inductive reasoning in organizational research. Academy of Management Review, 35(2), 315-333.

Khalfan, M. M., Anumba, C. J., & Carrillo, P. M. (2001). Development of a readiness assessment model for concurrent engineering in construction. Benchmarking: An International Journal, 8(3), 223-239. doi:10.1108/14635770110396638

Khalfan, M., & Raja, N. (2012). Improving Construction Process through Integration and Concurrent Engineering. *The Australian Journal of Construction Economics and Building*, *5*(1), 58–66.

Khalil, A. A. (2018). *Developing a strategy for the implementation of sustainable construction practices in Libya* (Doctoral dissertation, University of Salford).

Khanzadi, M., Sheikhkhoshkar, M., & Banihashemi, S. (2019). BIM applications toward key performance indicators of construction projects in Iran. *International Journal of Construction Management*, 1-16. 10.1080/15623599.2018.1484852

Khoshgoftar, M., & Osman, O. (2009). Comparison of Maturity Models School of Housing , Building and Planning ,. *Computer Science and Information Technology, 2009. ICCSIT 2009. 2nd IEEE International Conference*, 297–301. doi:10.1109/ICCSIT.2009.5234402

Khosrowshahi, F., & Arayici, Y. (2012). Roadmap for implementation of BIM in the UK construction industry. *Engineering, Construction and Architectural Management*, *19*(6), 610–635. doi: 10.1108/09699981211277531

Kiew, P., Ismail, S., & Yusof, A. (2012). Key Performance Indicators in Construction Quality Management System. Retrieved 15th November 2017, from [https://www.academia.edu/5714243/Key_Performance_Indicators_in_Construction_Quality_Management_System]

Kim, Y. G., & March, S. T. (1995). Comparing data modeling formalisms. *Communications of the ACM*, *38*(6), 103-115. doi: 10.1145/203241.203265

Kippenberger, T. (1996). The performance pyramid. The Antidote, 1(1), 10-11. doi: 10.1108/1368304011038514

Kitzinger, J. (1994). The methodology of Focus Groups: the importance of interaction between research participants. *Sociology of Health & Illness*, *16*(1), 103–121. https://doi.org/10.1111/1467-9566.ep11347023

Kitzinger, J. (1995). Qualitative Research: Introducing focus groups. *BMJ*, *311*(7000), 299–302. doi: 10.1136/bmj.311.7000.293

Kiviniemi, A., Tarandi, V., Karlshøj, J., Bell, H., Karud, O.J. (2008), Review of the Development and Implementation of IFC Compatible BIM, Erabuild.

Klaschka, R. (Ed.). (2019). *BIM in Small Practices: illustrated case studies*. Routledge.

Kleinbaum, D. G., & Klein, M. (2010). *Logistic regression* (3rd ed.). New York: Springer.

Knight, A. and Ruddock, L. (2008) Advanced Research Methods in the Built Environment. 1st ed. Oxford: Wiley-Blackwell.

Knutt (2016) LOW CONFIDENCE ON LEVEL 2 BIM RESTS ON WEAK UPTAKE OF '8 PILLARS': BIM + SURVEY. BIM whitepaper, CIOB, BIM+, Retrieved 15th November 2017, from: [http://www.bimplus.co.uk/news/bim-survey-low-confid3enc4e-limi1ted-experience/]

Koch, G. (1982) Intraclass Correlation Coefficient. In: Kotz, S. and Johnson, N.L. (Eds) Encyclopedia of Statistical Sciences 4. Ney York: John Wiley and Sons. pp. 213-217.

Kometa, S. T., Olomolaiye, P. O., & Harris, F. C. (1994). Attributes of UK construction clients influencing project consultants??? performance. *Construction Management and Economics*, *12*(5), 433–443. doi: 10.1080/01446199400000053

Kothari, C. R. (2004). Research methodology: Methods and techniques: New Age International.

Kouider, T., Paterson, G., & Harty, J. (2016). Architectural Technology and the BIM Acronym 3: Getting to Grips with BIM.

KPI Working Group. (2000) KPI Report for the Minister for Construction.
Kreider, R., & Messner, J. (2015). A Model Use Ontology 1 Introduction : The Need for a Model Use Ontology.
Kreider, R., Messner, J., & Dubler, C. (2010). Determining the frequency and impact of applying BIM for different purposes on building projects. *Proceedings of the 6th International Conference on Innovation in Architecture, Engineering and Construction (AEC)*, 1–10.
Krejcie, R. V, & Morgan, D. W. (1970). Determining Sample Size for Research Activities. *Education and Psychological Measurement*, *30*, 607–610. doi: 10.1177/001316447003000308
Krejcie, R. V., & Morgan, D. W. (1970). Determining sample size for research activities. *Educational and psychological measurement*, *30*(3), 607-610. doi: 10.1177/001316447003000308
Krueger, R. A., & Casey, M. A. (2014). Focus groups: A practical guide for applied research. SAGE Publications Ltd: London.
Kruskal, W. H., & Wallis, W. A. (1952). Use of ranks in one-criterion variance analysis. *Journal of the American Statistical Association*, *47*(260), 583-621.
Kuitert, L., Volker, L., & Hermans, M. H. (2019). Taking on a wider view: public value interests of construction clients in a changing construction industry. *Construction Management and Economics, 37(5)*, 257-277. doi: 10.1080/01446193.2018.1515496
Kumar, B. (2015). A practical guide to adopting BIM in construction projects. London, United Kingdom: Whittles Publishing.
Kumar, B., & Hayne, G. (2016). A Framework for Developing a BIM Strategy. *CIB W78 IT in Construction*.
Kumar, R. (2011). *Research Methodology: a step by step guide for beginners.* SAGE Publications Ltd: London.
Kumar, S., & Phrommathed, P. (2005). Research Methodology. *New Product Development,* 43–50. doi: 10.1007/0-387-23273-7_3
Kumar, S., & Phrommathed, P. (2005). Research methodology: Springer.
Kumaraswamy, M. and Matthews, J. (2000) Improved Subcontractor Selection Employing Partnering Principles. *Journal of Management in Engineering, 16 (3)*, pp.47-57. doi: 10.1061/(ASCE)0742-597X(2000)16:3(47)
Kumaraswamy, M. M., & Thorpe, A. (1996). Systematizing construction project evaluations. *Journal of Management in Engineering*, *12*(1), 34-39. doi: 10.1108/JHOM-09-2016-0165
Kwak, S. G., & Kim, J. H. (2017). Central limit theorem: the cornerstone of modern statistics. *Korean journal of anesthesiology*, *70*(2), 144. doi: 10.4097/kjae.2017.70.2.144
Kwak, Y. H., & Ibbs, C. W. (1996). Financial and Organizational Impacts of Project Management. *In Proceedings of the 28th Annual PMI Seminars & Symposium* (pp. 108-112).
Kwak, Y. H., & Ibbs, C. W. (2002). Project management process maturity (PM)2 model. *Journal of Management in Engineering, 18(3)*, 150–155. doi: 10.1061/(asce)0742-597x
Kymmel. W. (2008). Building Information Modelling: Planning and Managing Construction. New York: McGraw-Hill Companies, Inc.
Lacey, A., & Luff, D. (2007). Qualitative data analysis. *Trowbridge, Wiltshire: The Cromwell …*, 1–46. doi: 10.7903/cmr.14043
Laerd Statistics (2015a). Kruskal-Wallis H test using SPSS Statistics. *Statistical tutorials and software guides*. Retrieved 13th November, 2019, from: [https://statistics.laerd.com/premium/spss/kwht/kruskal-wallis-test-in-spss.php]
Laerd Statistics (2015b). Ordinal logistic regression using SPSS Statistics. *Statistical tutorials and software guides*. Retrieved 13th November, 2019, from: [https://statistics.laerd.com/premium/spss/olr/ordinal-logistic-regression-in-spss.php]
Laerd Statistics (2015c). Wilcoxon signed-rank test using SPSS Statistics. *Statistical tutorials and software guides*. Retrieved 13th November, 2019, from: [https://statistics.laerd.com/premium/spss/wsrt/wilcoxon-signed-rank-test-in-spss.php]
Laerd Statistics (2015d). Independent-samples t-test using SPSS Statistics. *Statistical tutorials and software guides*. Retrieved 13th November, 2019, from: [https://statistics.laerd.com/premium/spss/istt/independent-t-test-in-spss.php]
Laerd Statistics (2016a). Chi-square test for association using SPSS Statistics. *Statistical tutorials and software guides*. Retrieved 13th November, 2019, from: [https://statistics.laerd.com/premium/spss/gof/goodness-of-fit-in-spss.php]
Laerd Statistics (2018). Spearman's correlation using SPSS Statistics. *Statistical tutorials and software guides*. Retrieved 13th November, 2019, from: [https://statistics.laerd.com/premium/spss/sroc/spearmans-rank-

order-correlation-in-spss.php]
Laerd Statistics. (2016b) Prediction and mode fit. *Statistical tutorials and software guides*. Retrieved 13th November, 2019, from: [https://statistics.laerd.com/premium/spss/olr/ordinal-logistic-regression-in-spss-23.php]
Laine, T., & Karola, A. (2007). Benefits of Building Information Models in Energy Analysis. *Energy*, 8. Retrieved 13th November, 2016, from: [http://www.irbnet.de/daten/iconda/CIB8170.pdf]
Langston, C. (2012). Comparing international construction performance.
Langston, C. (2013). Development of generic key performance indicators for PMBOK® using a 3D project integration model. *Construction Economics and Building*, *13*(4), 78-91. doi: 10.5130/ajceb.v13i4.3658
Lasarte, N., Elguezabal, P., Sagarna, M., Leon, I., & Otaduy, J. P. (2021). Challenges for Digitalisation in Building Renovation to Enhance the Efficiency of the Process: A Spanish Case Study. *Sustainability, 13*(21), 12139.
Latham, M. (1994). Constucting the team: joint review of procurement and contractual arrangements in the United Kingdom construction industry. *Hmso*, *53*(9), 1689–1699. doi: 10.1017/CBO9781107415324.004
Latham, M. (2005). Improving public services through better construction. *National Audit Office, London*.
Leclezio, L., Jansen, A., Whittemore, V. H., & de Vries, P. J. (2015). Pilot validation of the tuberous sclerosis-associated neuropsychiatric disorders (TAND) checklist. *Pediatric neurology*, *52*(1), 16-24.
LeCompte, M. D., & Schensul, J. J. (2010). Designing and Conducting Ethnographic Research. Ethnographers Toolkit.
Lee, J. H. (2009). Development of BIM capability evaluation model for design organization. Iwha University.
Lee, J., & Yi, J. S. (2011). A study on BIM capability evaluation for design organization. *Journal of the Architectural Institute of Korea Planning & Design*, *27*(6), 257–266
Lee, S. H., Thomas, S. R., & Tucker, R. L. (2005). Web-based benchmarking system for the construction industry. *Journal of Construction Engineering and Management*, *131*(7), 790-798. doi: 10.1061/(ASCE)0733-9364(2005)131:7(772)
Lee, S., Yu, J., & Jeong, D. (2015). BIM acceptance model in construction organizations. *Journal of Management in Engineering*, *31*(3). doi: 10.1061/(ASCE)ME.1943-5479.0000252, 04014048
Lehmann, E. L. (2006). *Nonparametrics: Statistical methods based on ranks*. Upper Saddle River, NJ: Springer.
Leite, F. L. (2019). *BIM for design coordination: a virtual design and construction guide for designers, general contractors, and MEP subcontractors.* John Wiley & Sons.
Lester, F. K. (2005). On the theoretical, conceptual, and philosophical foundations for research in mathematics education. *Zdm*, *37*(6), 457-467.
Li, H. (2010). Building up a performance indicator system of international projects, based on the balanced scorecard. *Management Science and Engineering*, *4*(2), 82.
Liang, C., Lu, W., Rowlinson, S., & Zhang, X. (2016). Development of a Multifunctional BIM Maturity Model. *Journal of Construction Engineering and Management*, *142*(11), 6016003. doi: 10.1061/(ASCE)CO.1943-7862.0001186
Liao, L., & Ai Lin Teo, E. (2018). Organizational change perspective on people management in BIM implementation in building projects. *Journal of management in engineering, 34*(3), 04018008.
Liao, L., Lin, E. T. A., & Low, S. P. (2019). Assessing building information modeling implementation readiness in building projects in Singapore: A fuzzy synthetic evaluation approach. *Engineering, construction and architectural management.*
Liao, T. F. (1994). *Interpreting probability models: Logit, probit, and other generalized linear models.* Thousand Oaks, CA: Sage.
Lim, C. S., & Mohamed, M. Z. (1999). Criteria of project success: An exploratory re-examination. *International Journal of Project Management*, *17*(4), 243–248. doi: 10.1016/s0263-7863(98)00040-4
Lima, E. S., McMahon, P., & Costa, A. P. C. S. (2021). Establishing the relationship between asset management and business performance. *International Journal of Production Economics, 232*, 107937.
Lin, G., & Shen, Q. (2007). Measuring the performance of value management studies in construction: critical review. *Journal of Management in Engineering*, *23*(1), 2-9. doi: 10.1061/(ASCE)0742-597X(2007)23:1(2)
Lindblad, H. (2019). Black boxing BIM: the public client’s strategy in BIM implementation. *Construction management and economics, 37*(1), 1-12.
Lindblad, H., & Guerrero, J. R. (2020). Client’s role in promoting BIM implementation and innovation in construction. *Construction Management and Economics*, 1-15. Doi: 10.1080/01446193.2020.1716989
Lindblad, H., & Guerrero, J. R. (2020). Client’s role in promoting BIM implementation and innovation in construction. *Construction management and economics, 38*(5), 468-482.
Lindblad, H., & Karrbom Gustavsson, T. (2021). Public clients ability to drive industry change: the case of implementing BIM. *Construction Management and Economics, 39(1)*, 21-35.

Lindblad, H., & Vass, S. (2015). BIM Implementation and Organisational Change: A Case Study of a Large Swedish Public Client. *Procedia Economics and Finance*, *21*(15), 178–184. doi: 10.1016/S2212-5671(15)00165-3

Ling, F. Y. Y. (2003). Managing the implementation of construction innovations. *Construction management and economics*, *21*(6), 635-649. 10.1080/0144619032000123725

Ling, F. Y., Low, S. P., Wang, S., & Egbelakin, T. (2008). Models for predicting project performance in China using project management practices adopted by foreign AEC firms. *Journal of Construction Engineering and Management*, *134*(12), 983-990. 10.1061/(ASCE)0733-9364(2008)134:12(983)

Liu, A. M., & Walker, A. (1998). Evaluation of project outcomes. *Construction Management & Economics*, *16*(2), 209-219. doi: 10.1080/014461998372493

Liu, H., Song, J., & Wang, G. (2020). Development of a tool for measuring building information modeling (BIM) user satisfaction–method selection, scale development and case study. *Engineering, Construction and Architectural Management.*

Liu, Z., Lu, Y., Nath, T., Wang, Q., Tiong, R. L. K., & Peh, L. L. C. (2021). Critical success factors for BIM adoption during construction phase: a Singapore case study. *Engineering, Construction and Architectural Management.*

Lockamy III, A., & McCormack, K. (2004). The development of a supply chain management process maturity model using the concepts of business process orientation. *Supply Chain Management: An International Journal*, *9*(4), 272–278. doi: 10.1108/13598540410550019

Long, J. S. (1997). *Regression models for categorical and limited dependent variables.* Thousand Oaks, CA: Sage.

Long, N. D., Ogunlana, S., Quang, T., & Lam, K. C. (2004). Large construction projects in developing countries: A case study from Vietnam. *International Journal of Project Management*, *22*(7), 553–561. doi: 10.1016/j.ijproman.2004.03.004

Looney, S. W. (2018). Practical issues in sample size determination for correlation coefficient inference. *SM Journal of Biometrics and Biostatistics*, *3*, 1027.

Lorime, J. (2011). Why do we need BIM?. NBS. Retrieved 15th November, 2017, from: [http://www.thenbs.com/topics/bim/articles/whyDoWeNeedBIM.asp]

Love, P. E. D., Simpson, I., Hill, A., & Standing, C. (2013). Automation in Construction From justi fi cation to evaluation : Building information modeling for asset owners. *Automation in Construction*, *35*, 208–216. doi: 10.1016/j.autcon.2013.05.008

Love, P. E., Tse, R. Y., & Edwards, D. J. (2005). Time–cost relationships in Australian building construction projects. Journal of Construction Engineering and Management, 131(2), 187-194. doi: 10.1061/(ASCE)0733-9364

Love, P.E.D., and Holt, G.D (2000). Construction business performance measurement: the SPM alternative. Business Project Management Journal, 6 (5) pp 408-416. doi.org/10.1108/14637150010352417

Lund research (2012) Principles of research ethics. Retrieved 12th June, 2016, from [http://dissertation.laerd.com/principles-of-research-ethics.php]

Lund Research Ltd. (2013). Descriptive and inferential statistics. Laerd Statistics. Retrieved November 13, 2016, from [https://statistics.laerd.com/statistical-guides/descriptive-inferential-statistics.php]

Luu, T. V., Kim, S. Y., Cao, H. L., & Park, Y. M. (2008). Performance measurement of construction firms in developing countries. *Construction Management and Economics*, *26*(4), 373–386. doi: 10.1080/01446190801918706

Luu, V. T., Kim, S. Y., & Huynh, T. A. (2008). Improving project management performance of large contractors using benchmarking approach. *International Journal of Project Management*. doi: 10.1016/j.ijproman.2007.10.002

M&D Task force (2014) Key performance indicators creation process overview. Enterprise KPI development process, Retrieved 13th November, 2016, from: [https://www.slideshare.net/quangngoc186/enterprise-kpi-development-process-36007617]

Ma, X., Chan, A. P., Li, Y., Zhang, B., & Xiong, F. (2020). Critical Strategies for Enhancing BIM Implementation in AEC Projects: Perspectives from Chinese Practitioners. *Journal of Construction Engineering and Management*, *146*(2), 05019019. Doi: 10.1061/(ASCE)CO.1943-7862.0001748

MacIntosh, J. A. (1993). Focus groups in distance nursing education. *Journal of Advanced Nursing*, *18*(12), 1981–1985. doi: 10.1046/j.1365-2648.1993.18121981.

MacLeamy, P. (2004). MacLeamy curve. *Collaboration, Integrated Information, and the Project Lifecycle in Building Design and Construction and Operation (WP-1202)*.

Mahamadu, A. M. (2017). Development of a decision support framework to aid selection of construction supply chain organisations for BIM-enabled projects (Doctoral dissertation, University of the West of England).

Mahamadu, A. M., Mahdjoubi, L., Booth, C., Manu, P., & Manu, E. (2019). Building information modelling (BIM) capability and delivery success on construction projects. *Construction Innovation*, *19*(2), 170-192. doi: 10.1108/CI-03-2018-0016

Mahamadu, A. M., Manu, P., Mahdjoubi, L., Booth, C., Aigbavboa, C., & Abanda, F. H. (2019). The importance of BIM capability assessment: An evaluation of post-selection performance of organisations on construction projects. *Engineering, Construction and Architectural Management.*

Male, S. (2003) 'Faster Building for Commerce: NEDO (1988)'. in *Construction Reports 1944-98*. Ed. by Murray, M. and Langford, D. Oxford: Blackwell Science, 130-144

Malik, Q., Nasir, A. R., Muhammad, R., Thaheem, M. J., Ullah, F., Khan, K. I. A., & Hassan, M. U. (2021). BIMp-Chart—A Global Decision Support System for Measuring BIM Implementation Level in Construction Organizations. *Sustainability, 13*(16), 9270.

Mansson, D. W., Hampson, K.D., & Lindahl, G.A. (2017) Assessing BIM performance in building management organisations. In *Proceedings of 9th Nordic Conference on Construction Economics and Organisation*, 13-14 June 2017, Gothenburg Sweden.

Månsson, D. W., Sanchez, A. X., & Hampson Sbenrc, K. D. (2016). Assessing BIM performance through self-assessed benchmarking. In *Proceedings of the CIB World Building Congress 2016.*

Månsson, D., & Lindahl, G. (2016). 3 BIM performance and capability. Delivering Value with BIM: A Whole-of-life Approach, 46.

Manu, E. (2014) *Supply Chain Management Practices in Construction and Inter-organizational Trust Dynamics.* PhD Thesis, School of Technology, University of Wolverhampton. UK.

Manu, P. A. (2012) *An Investigation into the Accident Causal influence of Construction Project Features,* PhD Thesis, School of Technology, University of Wolverhampton. UK.

Manzione, L. (2013). Proposition for a Collaborative Design Process Management Conceptual Structure using BIM (Doctoral dissertation, PhD Thesis, Universidade de São Paulo).

Manzione, L., & Melhado, S. B. (2015). Design Process Maturity Level: the Four Interfaces. *Proc. of the 32nd CIB W78 Conference 2015, 27th-29th 2015, Eindhoven, The Netherlands*, 27–29.

Manzione, L., Wyse, M., Sacks, R., Van Berlo, L., & Melhado, S. B. (2011). Key performance indicators to analyze and improve management of information flow in the BIM design process. *Proceedings of the CIB W78-W102 2011: International Conference –Sophia Antipolis, France*

Marefat, A., Toosi, H., & Hasankhanlo, R. M. (2018). A BIM approach for construction safety: applications, barriers and solutions. *Engineering, Construction and Architectural Management.*

Marr, B. (2012). *Key Performance Indicators (KPI): The 75 measures every manager needs to know*. Pearson UK.

Marsh, D. (2017). *Building Information Modelling (BIM) and the UK Quantity Surveying Organisation: A Framework for Value Creation* (Doctoral dissertation, Liverpool John Moores University).

Masterman, J. (2003*). An introduction to building procurement systems:* Routledge.

Matos, R. V., Rodrigues, F. S., Rodrigues, H. F., & Costa, A. G. (2020, September). Strategies to Support Facility Management Resourcing Building Information Modelling. In *XV International Conference on Durability of Building Materials and Components (DBMC 2020)*.

Matos, R. V., Rodrigues, F. S., Rodrigues, H. F., & Costa, A. G. (2020). Strategies to Support Facility Management Resourcing Building Information Modelling. In *XV International Conference on Durability of Building Materials and Components (DBMC 2020).*

Maya, R. A. (2016). Performance management for Syrian construction projects. *Int J Constr Eng Manag*, *5*(3), 65-78. doi: 10.5923/j.ijcem.20160503.01

Mbugua, L. M., Harris, P., Holt, G. D., & Olomolaiye, P. O. (1999). A Framework for Determining Critical Success Factors Influencing Construction Business Performance. *Proceedings of the 15th Annual ARCOM Conference*, *1*(OCTOBER 1999), 255–264.

Mbugua, L. M., Harris, P., Holt, G. D., & Olomolaiye, P. O. (1999). A framework for determining critical success factors influencing construction business performance. In *Proceedings of the Association of Researchers in Construction Management 15th Annual Conference* (Vol. 1, pp. 255-64).

McAdam, B. (2010) Building Information Modelling: the UK Legal Context. International Journal of Law in the Built Environment, 2 (3), pp.246-259. doi: 10.1108/17561451011087337

McAuley, B., Hore, A. and West R. (2017) BICP Global BIM Study – Lessons for Ireland's BIM Programme Published by Construction IT Alliance (CitA) Limited, 2017. doi:10.21427/D7M049

Mcauley, B., Hore, A. V, & West, R. (2013). Establishing Key Performance Indicators to Measure the Benefit of Introducing the Facilities Manager at an early Stage in the Building Information Modelling Process. *International Journal of 3-D Information Modeling*, *2*(4), 38–51.

Mcauley, B., Hore, A., West, R. P., & Horan, T. (2015). The development of key performance indicators to monitor early facilities management performance through the use of BIM technologies in public sector projects.

Proceedings of the 2nd Proceedings International Conference on Civil and Building Engineering Informatics, 23-25th April, 1–8.
McAuley, B., Hore, A., West, R., & Horan, T. (2015). The development of key performance indicators to monitor early facilities management performance through the use of BIM technologies in public sector projects. *In Proceedings of the 2nd Proceedings International Conference on Civil and Building Engineering Informatics (pp. 1-8).*
MCC (2019). *Annual Workforce Profile Report*. Retrieved 13th November, 2019, from: [www.manchester.gov.uk › annual_workforce_profile_report_2018-19]
MCC (2019). *Manchester City Council About*. Retrieved 13th November, 2019, from: [https://www.linkedin.com/company/manchester-city-council/about/]
McCormack, K. P., & Johnson, B. (2001). Business process orientation, supply chain management and the e-corporation. *IIE Solutions*, (October), 33–37. Retrieved 13th November, 2016, [http://elibrary.ru/item.asp?id=6037083]
McCormack, K., Bronzo Ladeira, M., & Paulo Valadares de Oliveira, M. (2008). Supply chain maturity and performance in Brazil. Supply Chain Management: An International Journal, 13(4), 272-282. doi: 10.1108/13598540810882161
Mccuen, T. L. (2008). Building Information Modeling and the Interactive Capability Maturity Model. *Associated Schools of Construction International Proceedings of the 44th Annual Conference*.
McCuen, T. L., Suermann, P. C., & Krogulecki, M. J. (2011). Evaluating award-winning BIM projects using the national building information model standard capability maturity model. *Journal of Management in Engineering, 28(2), 224-230*. doi: 10.1061/(ASCE)ME.1943-5479.0000062
McGraw Hill (2009). The business value of BIM-getting building information modeling to the bottom line. Bedford, MA: McGraw-Hill Construction, 51.
McGraw Hill. (2008). SmartMarket Report: BIM - Transforming Design and Construction to Achieve Greater Industry Productivity, New York: McGraw Hill Construction.
McGraw-Hill (2010) The Business Value of BIM in Europe. Getting Building Information Modelling to the Bottom Line in the United Kingdom. France and Germany.
McGraw-Hill (2012). The business value of bim for infrastructure. The Business Value of BIM for Infrastructure Addressing Americas Infrastructure Challenges with Collaboration and Technology. Bedford, MA: McGraw-Hill Construction Research & Analytics.
McGraw-Hill (2013). SmartMarket Report: The Business Value of BIM for construction in Major Global Markets. UK
Mckinsey (2020) The next normal in construction. Retrieved 28 April, 2020, from: [https://www.mckinsey.com/~/media/mckinsey/industries/capital%20projects%20and%20infrastructure/our%20insights/the%20next%20normal%20in%20construction/executive-summary_the-next-normal-in-construction.pdf]
McKinsey Global Institute. (2017). Reinventing Construction. A Route to Higher Productivity. Viitattu 3.11. 2017.
McKinsey Global Institute. (2018). Solving the productivity puzzle: The role of demand and the promise of digitization. *International Productivity Monitor*, (35), 28-51.
McPartland and Mordue, (2015) The periodic table of BIM. NBS, RIBA enterprises London, United Kingdom. Retrieved 13th November, 2016, from [https://www.thenbs.com/knowledge/periodic-table-of-bim]
Medapalli (2016) Multiple regression Analysis. Education, Retrieved 13th November, 2016, from: [https://www.slideshare.net/NaveenKumarMedapalli/multiple-regression-analysis-mra]
Mehran, D. (2016). Exploring the Adoption of BIM in the UAE Construction Industry for AEC Firms. *Procedia Engineering*, *145*, 1110–1118. doi: 10.1016/j.proeng.2016.04.144
Melorose, J., Perroy, R., & Careas, S. (2015). BIM Maturity Matrix. *Bim Excellence*, *1*, 7. doi:10.1017/CBO9781107415324.004
Meng, X. (2012). The effect of relationship management on project performance in construction. *International journal of project management, 30(2), 188-198.* doi:10.1016/j.ijproman.2011.04.002
Meng, X., Sun, M., & Jones, M. (2011). Maturity Model for Supply Chain Relationships in Construction. *Journal of Management*, *27*(April), 97–105. doi: 10.1061/(ASCE)ME.1943-5479.0000035.
Mesároš, P., Behúnová, A., Mandičák, T., Behún, M., & Krajníková, K. (2021). Impact of enterprise information systems on selected key performance indicators in construction project management: An empirical study. *Wireless Networks, 27*(3), 1641-1648.
Messner, J., and Kreider, R. (2013). BIM planning guide for facility owners. Pennsylvania State Univ, University Park, PA.
Meyer, M., Helfert, M., & O'Brien, C. (2011). An analysis of enterprise architecture maturity frameworks.

In International Conference on Business Informatics Research. *Lecture Notes in Business Information Processing*, *90 LNBIP*, 167–177. doi: 10.1007/978-3-642-24511-4_13
Migilinskas, D., Popov, V., Juocevicius, V., & Ustinovichius, L. (2013). The benefits, obstacles and problems of practical bim implementation. *Procedia Engineering*, *57*, 767–774. doi: 10.1016/j.proeng.2013.04.097
Miles and Trott (2011) Collaborative working. Inside Out. Institute for government. Retrieved 13th November, 2019, from: [https://www.instituteforgovernment.org.uk › default › files › publications]
Miles, M. B., & Huberman, A. M. (1994). *Qualitative Data Analysis-An Expanded Sourcebook*. SAGE Publications Ltd: London.
Miles, M. B., Huberman, A. M., & Saldana, J. (2013). *Qualitative Data Analysis: A Methods Sourcebook 1–10*. SAGE Publications Ltd: London.
Miller, R. (2009). 10 Clients as innovation drivers in large engineering projects. Clients driving innovation, 88.
Mincks, W. R., & Johnston, H. (2003). Construction Jobsite Management (Vol. 2): Cengage Learning.
Mingers, J. (2001). Combining IS Research Methods: Towards a Pluralist Methodology. *Information Systems Research*, *12*(3), 240–259. doi: 10.1287/isre.12.3.240.9709
Mishra, S., & Mishra, A. K. (2014). Benefits and Barriers of Building Information Modelling, (2). Retrieved 13th November, 2016, from: [http://eisct.in/Adminfiles/(201405)BenefitsandBarriersofBuildingInformationModelling.pdf]
MoJ. (2016) BIM maturity KPI system. Retrieved 13th November, 2016, from: [https://n3g.4projects.com/document/publicfiles.aspx?DocumentID=e01e5cc7-bf8e-4673-9003-367509058169&VC=true]
Mom, M., & Hsieh, S. (2012). Toward performance assessment of BIM technology implementation. *14th International Conference on Computing in Civil and Building Engineering, 27-29 June*, 8.
Mom, M., Tsai, M. and Hsieh, S. (2014) Developing critical success factors for the assessment of BIM technology adoption: Part II. Analysis and results. *Journal of the Chinese Institute of Engineers*, *37*(7), 859–868. doi: 10.1080/02533839.2014.888798
Mom, M., Tsai, M. H., & Hsieh, S. H. (2011). On decision-making and technology-implementing factors for BIM adoption. *International Conference on Construction Applications of Virtual Reality, 217-229.*
Moody, D. L., & Shanks, G. G. (2003). Improving the quality of data models: empirical validation of a quality management framework. *Information systems*, *28*(6), 619-650. doi: 10.1016/S0306-4379(02)00043-1
Mordue, S., Swaddle, P., & Philp, D. (2015). *Building information modeling for dummies*. John Wiley & Sons.
Moreira, A. G. D. B. L. (2017). *BIM as a strategic tool for supply chain in main projects in the United Kingdom* (Doctoral dissertation).
Morgan L., D. (2007). Paradigms Lost and Pragmatism Regained: Methodological Implications of Combining Qualitative and Quantitative Methods. *Journal of Mixed Methods Research*, *1*(1), 48–76. doi: 10.1177/2345678906292462
Morgan, D. L. (1993). Successful Focus Groups: Advancing the State of the Art. *The Design and Analysis of Focus Group Studies in Social Science Research*, 35–50. doi: 0803948743, 9780803948747
Morgan, D. L. (1997). Focus Groups as Qualitative Research. *Sage Publications*, 32–46. doi: 10.4135/9781412984287
Morgan, D. L., & Krueger, R. A. (1993). When to use focus groups and why. In *Successful Focus Groups: Advancing the State of the Art* (pp. 35–50). doi: 0803948743, 9780803948747
Morgan, D. L., & Spanish, M. T. (1984). Focus groups: A new tool for qualitative research. *Qualitative Sociology*, *7*(3), 253–270. doi: 10.1007/BF00987314
Morrison, C. (2010). BIM 2010: The benefits and barriers for construction contractors in Auckland
Mosey, D. (2019). *Collaborative construction procurement and improved value*. Hoboken, NJ, USA: Wiley-Blackwell.
Mott Macdonald (2017) Ripe for transformation, ready for change? Project 13 Digital Transformation Workstream: Infrastructure industry benchmarking report. IGC, Institute of Civil Engineers (ICE). Retrieved 13th November, 2019, from: [https://project13.mottmac.com/]
Mukaka, M. M. (2012). A guide to appropriate use of correlation coefficient in medical research. *Malawi Medical Journal*, *24*(3), 69-71.
Munir, M. Y., Kiviniemi, A., Jones, S. W., Finnegan, S., & Mêda, P. (2019). Development of a BIMAsset maturity model. In *Advances in ICT in Design, Construction and Management in Architecture, Engineering, Construction and Operations (AECO): Proceedings of the 36th CIB W78 2019 Conference* (pp. 360-368). University of Northumbria.
Munir, M., Kiviniemi, A., Jones, S. W., & Finnegan, S. (2020). The business value of BIM for asset owners: a cross-case analysis. *Journal of Facilities Management.*

Munir, M., Kiviniemi, A., Jones, S., & Finnegan, S. (2020). BIM business value for asset owners: key issues and challenges. *International Journal of Building Pathology and Adaptation.*
Munir, M., Kiviniemi, A., Jones, S., & Finnegan, S. (2020). BIM-based operational information requirements for asset owners. *Architectural Engineering and Design Management, 16*(2), 100-114.
Murguia, D. (2021). *A model of systemic BIM adoption* (Doctoral dissertation, Loughborough University).
Murguia, D., Demian, P., & Soetanto, R. (2021). Systemic BIM Adoption: A Multilevel Perspective. *Journal of Construction Engineering and Management, 147*(4), 04021014.
Murray, M., & Langford, D. (2003). *Construction Reports*. Blackwell Science, Oxford. doi: 10.1002/9780470758526
NACF. (2014) KPI's Frameworks 2014 Review. National Association of Construction Frameworks. Retrieved 13th November, 2016, from [http://www.nacframework.org.uk/pages/documents-nacf.html]
Namadi, A. (2019). *A framework for collaborative costing in the UK construction industry* (Doctoral dissertation, Nottingham Trent University).
NAO, U. (2011). Lessons from PFI and other projects. *Report by the Comptroller and Auditor general, HC*, *920*, 2010-2012.
Naoum, S. G. (2013). Dissertation Research and Writing fo Construction Students. *Routledge Taylor & Francis Group, New York*, 160.
NASCIO. (2003). Enterprise Architecture Maturity Model. *Architecture*, *58*, 21. doi: 10.1002/mrm.21403
Nathans, L. L., Oswald, F. L., & Nimon, K. (2012). Interpreting multiple linear regression: A guidebook of variable importance. Practical Assessment, Research & Evaluation, 17(9).
National Audit Office. (2001). Modernising construction. *UK: National Audit Office*.
National Economic Development Office. (1970). Large Industrial Sites. In *Report of the Working Party on Large Industrial Construction Sites*, London: HMSO.
NATSPEC. (2015) BIM value tool. SBEnrc Australia. Retrieved 13th November 2019, from: [https://bimvaluetool.natspec.org/]
Navendren, D., Manu, P., Shelbourn, M., and Mahamadu, A. (2014) Challenges to Building Information Modelling Implementation in the UK: Designers' Perspectives. In: Raiden A.B .and Aboagye-Nimo, E. (Eds) Proceedings the 30th Annual Association of Researchers in Construction Management (ARCOM) Conference, Portsmouth, UK, pp.733-742
Navon, R. (2005). Automated project performance control of construction projects. *Automation in construction, 14(4)*, 467-476. doi: 10.1016/j.autcon.2004.09.006
NBS. (2016) *NBS BIM Toolkit.* Retrieved 13th November, 2019, from: [https://toolkit.thenbs.com/]
NBS. (2016). National BIM report 2016. Retrieved 13th November, 2016, from: [https://www.thenbs.com/knowledge/national-bim-report-2016]
NBS. (2018). National BIM report 2017. Retrieved 13th November, 2016, from: [https://www.thenbs.com/knowledge/nbs-national-bim-report-2018]
NBS. (2019). *National BIM Report 2019.* National BIM Report 2019 The definitive industry update. https://doi.org/10.1017/CBO9781107415324.004
NBS. (2020) *The 10th annual NBS BIM report*. Retrieved 26th May, 2020, from: [https://www.thenbs.com/knowledge//national-bim-report-2020]
NBS. (2021) Digital construction report. Retrieved 15th Nov, 2021, from: [https://www.thenbs.com/digital-construction-report-2021/]
Neely, A. (1999). The performance measurement revolution: why now and what next?. *International journal of operations & production management*, *19*(2), 205-228. doi: 10.1108/01443579910247437
Neely, A., & Adams, C. (2001). The performance prism perspective. Journal of Cost Management, 15, 7.
Neely, A., Richards, H., Mills, J., Platts, K., & Bourne, M. (1997). Designing performance measures: a structured approach. *International Journal of Operations & Production Management*, *17*(11), 1131–1152. doi: 10.1108/01443579710177888
Nepal, M. P., Jupp, J. R., & Aibinu, A. A. (2014). Evaluations of BIM: frameworks and perspectives. Computing in Civil and Building Engineering (2014), 769-776. doi: 10.1061/9780784413616.096
Newcombe, R. (2003). From client to project stakeholders: a stakeholder mapping approach. Construction Management and Economics, 21(8), 841-848. doi: 10.1080/0144619032000072137
Newton, K., & Chileshe, N. (2012). Awareness , Usage and Benefits of Building Information Modelling (Bim) Adoption – the Case of the South Australian Construction Organisations. *Procs 28th Annual ARCOM Conference*, (September), 3–12. doi:10.13140/RG.2.1.2352.3363
NFB. (2013). Client Readiness Survey UK.
NFB. (2016). *BIM online maturity assessment*. Retrieved 13th November, 2019, from:

[https://www.builders.org.uk/business-and-skills/building-information-modelling-bim/bim-online-maturity-assessment/]

Ng, S. T., Rose, T. M., Mak, M., & Chen, S. E. (2002). Problematic issues associated with project partnering — the contractor perspective. International Journal of Project Management, 20, 13.

Ngulube, P., Mathipa, E. R., & Gumbo, M. T. (2015). Theoretical and conceptual frameworks in the social and management sciences. *Addressing research challenges: Making headway in developing researchers*, 43-66.

NIBS. (2007). United States National Building Information Modelling Standards Version 1 – Part 1: Overview, principles and Methodologies. Washington, DC. Retrieved 13th November, 2016, from:

NIBS. (2012). United States National Building Information Modelling Standards Version 2. Washington, DC. Retrieved 13th November, 2016, from: [http://www.bim.org.tw/ThesisFile/20120629001/National%20BIM%20StandardUnited%20States%20Version%202.pdf]

NIC (2021) *THE SECOND NATIONAL INFRASTRUCTURE ASSESSMENT: BASELINE REPORT.* Retrieved 18th Apr, 2022, from: [https://nic.org.uk/app/uploads/Revised-Second-National-Infrastructure-Assessment-Baseline-Report.pdf]

Nilsen, P. (2015). Making sense of implementation theories, models and frameworks. *Implementation Science*, *10*(1), 53. doi: 10.1186/s13012-015-0242-0

Nisbet, N., & Dinesen, B. (2010). International Alliance for Interoperability; Constructing the business case, Building information modelling. *British Standards Institution*, 20. doi: ISBN 978 0 580 70935 7

Noble, K. M. K. and D. (2014). Building Information Modeling: BIM in Current and Future Practice.

Nolan, R. L. (1973). Managing the computer resource: a stage hypothesis. *Communications of the ACM*, *16*(7), 399–405. doi: 10.1145/362280.362284

NOMIS (2018). *Employment by Occupation*. Retrieved 13th November, 2019, from: [https://www.nomisweb.co.uk/datasets/aps168/reports/employment-by-occupation?compare=E92000001]

Nudurupati, S., Arshad, T., & Turner, T. (2007). Performance measurement in the construction industry: An action case investigating manufacturing methodologies. *Computers in Industry*, *58*(7), 667–676. doi:10.1016/j.compind.2007.05.005

NWCH. (2009). *About Us.* We solve construction procurement problems through our suite of Construction Frameworks. Retrieved 13th November, 2016, from: [http://www.nwconstructionhub.org/about/]

NWCH. (2015). *Key Performance Indicators.* North West Construction Hub KPI handover and interim reports, North West, UK.

Oates, B. J. (2006). *Research Information Systems and Computing.* SAGE Publications Ltd: London.

O'Connell, A. A. (2006). *Logistic regression models for ordinal response variables.* Thousand Oaks, CA: Sage.

Office for National Statistics. (2007). The ONS productivity handbook: a statistical overview and guide. Palgrave Macmillan.

Office of Government Commerce (1999) *Achieving excellence in construction*, London: Office of Government Commerce.

Office, C. (2016). Government Construction Strategy 2016 - 2020. UK Government Report, Cabinet Office, London.

Ofori-kuragu, J. K., Baiden, B. K., & Badu, E. (2016). Key Performance Indicators for Project Success in Ghanaian Contractors. *International Journal of Construction Engineering and Management*, *5*(1), 1–10. doi: 10.5923/j.ijcem.20160501.01

Ojo, A. O., Rahimian, F. P., Goulding, J., & Pye, C. (2015). Construction Education Requirements for Achieving Level 2 and 3 Bim. *ARCOM Doctoral Workshop on Construction Education in the New Digital Age*, 34–48, in: ARCOM Doctoral Workshop, Birmingham City University.

Oktay, J. S. (2012). *Grounded Theory*. *Oxford University Press*.

Olawumi, T. O., & Chan, D. W. (2019). Building information modelling and project information management framework for construction projects. *Journal of Civil Engineering and Management*, *25*(1), 53-75.

Olawumi, T. O., & Chan, D. W. (2019). Development of a benchmarking model for BIM implementation in developing countries. *Benchmarking: An International Journal*. Doi: 10.1108/BIJ-05-2018-0138

Olawumi, T. O., & Chan, D. W. (2019). Development of a benchmarking model for BIM implementation in developing countries. *Benchmarking: An International Journal.*

Olawumi, T. O., Chan, D. W., & Wong, J. K. (2017). Evolution in the intellectual structure of BIM research: A bibliometric analysis. *Journal of Civil Engineering and Management*, *23*(8), 1060-1081. Doi: 10.3846/13923730.2017.1374301

Olugboyega, O., & Windapo, A. (2019). A COMPREHENSIVE BIM IMPLEMENTATION MODEL FOR DEVELOPING

COUNTRIES: COMPREHENSIVE BIM IMPLEMENTATION MODEL. *Journal of Construction Project Management and Innovation, 9*(2), 83-104.
Olugboyega, O., & Windapo, A. (2019). Framework for managing BIM benefits: a benefits breakdown hierarchy approach. In *September 2018 Conference: 10th SACQSP International Research Conference 2018 At* (pp. 68-82).
Olugboyega, O., Edwards, D. J., Windapo, A. O., Omopariola, E. D., & Martek, I. (2020). Development of a conceptual model for evaluating the success of BIM-based construction projects. *Smart and Sustainable Built Environment.*
ONS (2019). *Construction Statistics*. Retrieved 13th November, 2019, from: [https://www.ons.gov.uk/businessindustryandtrade/constructionindustry/articles/constructionstatistics/number192018edition]
ONS (2019). *Employment and Employee types*. Retrieved 13th November, 2019, from: [https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/datasets/employmentbyindustryemp13]
ONS. (2009), Construction Statistics Annual, Office of National Statistics, 2009.
Ophiyandri, T., Amaratunga, D., & Keraminiyage, K. (2016). Advantages and limitations of community-based post-disaster housing reconstruction projects. *International Journal of Disaster Resilience in the Built Environment*, *7*(4), 420-431. doi: 10.1108/IJDRBE-08-2014-0066
Oppenheim, A. N. (1992). Designing Attitude Statements & Attitude Scaling. *Questionnaire Design, Interviewing and Attitude Measurement*. doi: 10.2307/3172892
OSMAN, M. K. (2016). *Implementation and potential benefits of building information modeling (BIM) in Sudan construction industry* (Doctoral dissertation, Sudan University of Science and Technology).
Oti-Sarpong, K., Pärn, E. A., Burgess, G., & Zaki, M. (2021). Transforming the construction sector: an institutional complexity perspective. *Construction Innovation.*
Ozorhon, B., & Karahan, U. (2016). Critical success factors of building information modelling implementation. *Journal of Management in Engineering*, *33*(3), 04016054. doi: 10.1061/(ASCE)ME.1943-5479.0000505
Pala, M., Edum-Fotwe, F., Ruikar, K., Doughty, N. and Peters, C. (2013) Contractor Practices for Managing Extended Supply Chain Tiers. *Supply Chain Management: An International Journal, 19*, pp.31-45. doi: 10.1108/SCM-04-2013-0142
Parfitt, M. K., & Sanvido, V. E. (1993). Checklist of critical success factors for building projects. *Journal of Management in Engineering*, *9*(3), 243-249. doi: 10.1061/(ASCE)9742-597X(1993)9:3(243)
Park, C. H., Ahn, J. S., Lee, D. M., Cha, Y. N., & Chin, S. Y. (2013). Key performance indicator on benefits of BSC-based BIM and validation methods. *ISARC 2013 - 30th International Symposium on Automation and Robotics in Construction and Mining, Held in Conjunction with the 23rd World Mining Congress*, 1101–1109.
Parmenter, D. (2015). *Key performance indicators: developing, implementing, and using winning KPIs* (3rd edn). John Wiley & Sons.
Parmenter, D. (2019). *Key performance indicators: developing, implementing, and using winning KPIs* (4th edn). John Wiley & Sons.
Parmenter, D. (2020). *Key performance indicators: developing, implementing, and using winning KPIs*. John Wiley & Sons.
Parnell, S. (2009). Building Information Modelling. *Architects' Journal*, *230*(4), 38–39. doi:10.1002/9780470432846
Parvan, K. (2012). Estimating the Impact of Building Information Modelling (BIM) Utilization on Building Project Performance. *Journal of Business Adminisration*, *3*(5), 189–197.
Pathirage, C. P., Amaratunga, R. D. G., & Haigh, R. (2005). Knowledge Management Research Within the Built Environment: Research Methodological Perspectives. *5th International Postgraduate Conference in the Built and Human Environment*, (May 2016), 479–493.
Patton, M. Q. (2015). *Qualitative Evaluation and Research Methods*. John Wiley & Sons, Ltd.
Paulk, M. C. (1995). The capability maturity model: Guidelines for improving the software process: Addison-Wesley Professional.
Paulk, M. C., Curtis, B., Chrissis, M. B., & Weber, C. V. (1993). Capability maturity model, version 1.1. *IEEE Software*, *10*(4), 18–27. doi: 10.1109/52.219617
Peterson, E. T. (2006). *The big book of key performance indicators*. Web analytics demystified.
Pidgeon, A., & Dawood, N. (2021). BIM Adoption Issues in Infrastructure Construction Projects: Analysis and Solutions. *Journal of Information Technology in Construction (ITcon), 26*(15), 263-285.
Pidgeon, A., & Dawood, N. (2021). Bridging the gap between theory and practice for adopting meaningful

collaborative BIM processes in infrastructure projects, utilising multi-criteria decision making (MCDM). *Journal of Information Technology in Construction (ITCON), 26*, 783-811.

Piroozfar, P., Farr, E. R., Zadeh, A. H., Inacio, S. T., Kilgallon, S., & Jin, R. (2019). Facilitating Building Information Modelling (BIM) using Integrated Project Delivery (IPD): A UK perspective. *Journal of Building Engineering, 26,* 100907. doi: 10.1016/J.JOBE.2019.100907

Pitt, M., Tucker, M., Riley, M., & Longden, J. (2009). Towards sustainable construction: promotion and best practices. *Construction innovation*, *9*(2), 201-224. doi: 10.1108/14714170910950830

PlanBIM (2019) *MiBim organisational BIM maturity assessment*. Retrieved 18th Apr, 2022, from: [https://www.globalbim.org/information-collection/mibim]

Poirier, E., Staub-French, S., & Forgues, D. (2015). Assessing the performance of the building information modeling (BIM) implementation process within a small specialty contracting enterprise. *Canadian Journal of Civil Engineering*, *42*(10), 766–778. doi: 10.1139/cjce-2014-0484

Powell, R. A., Single, H. M., & Lloyd, K. R. (1996). Focus groups in mental health research: enhancing the validity of user and provider questionnaires. *International Journal of Social Psychiatry*, *42*(3), 193–206. doi: 10.1177/002076409604200303

Prabhakaran, A., Mahamadu, A. M., Mahdjoubi, L., Andric, J., Manu, P., & Mzyece, D. (2021). An investigation into macro BIM maturity and its impacts: a comparison of Qatar and the United Kingdom. *Architectural Engineering and Design Management, 1-20.*

Pregibon, D. (1981). Logistic regression diagnostics. *The Annals of Statistics*, *9*(4), 705-724.

Prion, S., & Haerling, K. A. (2014). Making sense of methods and measurement: Spearman-Rho ranked-order correlation coefficient. *Clinical Simulation in Nursing*, *10*(10), 535-536. doi: 10.1016/j.ecns.2014.07.005

Procurement, O. F. (2015). Collaborative, Efficient, Sustainable and Outcomes Focused Procurement in Construction Building Information Modelling (BIM) Implementation Plan, (September). Retrieved 13th November, 2016, from: [https://www.scottishfuturestrust.org.uk/files/publications/BIM_Implementation_Plan_-_September_2015.pdf]

Proverbs, D., & Gameson, R. (2008). Case study research. Advanced research methods in the built environment, 99-110.

Proverbs, D., Holt, G., & Cheok, H. (2000). Construction industry problems: the views of UK construction Directors. *Proceedings of the 16th Annual ARCOM conference*, *1*(September), 73–81. Retrieved 13th November, 2016, from: [http://www.arcom.ac.uk/-docs/proceedings/ar2000-073-081_Proverbs_Holt_and_Cheok.pdf]

Proverbs, D.G.P. (1998) *A Best Practice Model for High-rise in situ Concrete Construction based on French, German and UK Contractor Performance Measures,* PhD Thesis, School of Engineering and the Built Environment, University of Wolverhampton, UK.

PwC. (2018) *BIM Level 2 Benefits Measurement Methodology*. Retrieved 13th November, 2019, from: [https://www.cdbb.cam.ac.uk/news/2018JuneBIMBenefits]

Pythagoras. (2014) *Scatter Graphs* Retrieved 13th November, 2019, from: [http://www.pythagorasandthat.co.uk/scatter-graphs]

Quick, K. S. (2014). *Advancing Relational Leadership Research: A Dialogue among Perspectives*. *Public Administration Review* (Vol. 74).

Race, K. E. H., Hotch, D. F., & Packer, T. (1994). Rehabilitation Program Evaluation: Use of Focus Groups to Empower Clients. *Evaluation Review*, *18*(6), 730–740. doi: 10.1177/0193841X9401800605

Radujković, M., Vukomanović, M., & Dunović, I. B. (2010). Application of key performance indicators in South-Eastern European construction. *Journal of Civil Engineering and Management*, *16*(4), 521–530. doi: 10.3846/jcem.2010.58

Ragab, M. A., & Marzouk, M. (2021). BIM Adoption in Construction Contracts: Content Analysis Approach. *Journal of Construction Engineering and Management, 147*(8), 04021094.

Ragin, C. C., & Becker, H. S. (Eds.). (1992). What is a case?: exploring the foundations of social inquiry. Cambridge university press.

Ramırez, R. R., Alarcon, L. F. C., & Knights, P. (2004). Benchmarking System for Evaluating Management Practices in the Construction Industry. *Journal of Management in Engineering*, *20*(3), 110–117. doi: 10.1061/(ASCE)0742-597X

Rankin, J., Fayek, A. R., Meade, G., Haas, C., & Manseau, A. (2008). Initial metrics and pilot program results for measuring the performance of the Canadian construction industry. *Canadian Journal of Civil Engineering*, *35*(9), 894–907. doi: 10.1139/L08-018

Ravitch, S. M., & Riggan, M. (2016). *Reason & rigor: How conceptual frameworks guide research*. Sage Publications.

Razali, M. F., Haron, N. A., Hassim, S., Alias, A. H., Harun, A. N., & Abubakar, A. S. (2019, November). A Review: Application of Building Information Modelling (BIM) over Building Life Cycles. In *IOP Conference Series: Earth and Environmental Science* (Vol. 357, No. 1, p. 012028). IOP Publishing.

Reddy, K. P. (2012). BIM for Building Owners and Developers: Making a Business Case for Using BIM on Projects. John Wiley & Sons.

Reddy, O. C., & Alemayehu, E. (2015). Ordinal logistic regression analysis to assess the factors that affect health status of students in Ambo University: a case of natural and computational sciences college, Ambo University. *International Journal of Modern Chemistry and Applied Science*, *2*(3), 153-163.

Reed, D. (2016). Overview of BIM in the UK. TEKLA CAMPUS, Retrieved 13th October, 2016 from [https://campus.tekla.com/overview-bim-uk]

Republic, C., & Indicator, K. P. (2008). Application of Key Performance Indicators in the Construction Industry : a comparison of the United Kingdom with the Czech Republic. *Training*.

Rezaei, J., Pourmohammadzia, N., Dimitropoulos, C., Tavasszy, L., & Duinkerken, M. (2020). Co-procurement: making the most of collaborative procurement. *International Journal of Production Research*, *58*(15), 4529-4540.

RezaHoseini, A., Ahmadi, E., Saremi, P., & BagherPour, M. (2021). Implementation of Building Information Modeling (BIM) Using Hybrid Z-DEMATEL-ISM Approach. *Advances in Civil Engineering*, 2021.

Rhodes, C. (2019). Construction industry: statistics and policy. *House of Commons Library*, (01432), Retrieved 26th May, 2020, from: [https://commonslibrary.parliament.uk/research-briefings/sn01432/]

Richard, J., Singer, J. D., Willett, J. B., & Light, R. J. (2009). By design: Planning research on higher education: Harvard University Press.

RICS (2020). *The Future of BIM: Digital transformation in the UK construction and infrastructure sector.* Retrieved 15th Nov, 2021, from: [https://www.rics.org/uk/news-insight/research/insights/the-future-of-bim-digital-transformation-in-the-uk-construction-and-infrastructure-sector/]

RICS. (2011). BIM survey report.

Riley, M. (2000). *Researching and writing dissertations in business and management*. Cengage Learning EMEA.

Roberts, M., & Latorre, V. (2009). KPIs in the UK's Construction Industry: Using System Dynamics to Understand Underachievement. *Revista De La Construccion*, *8*(1), 69–82.

Robeyns, I. (2005). The capability approach: a theoretical survey. *Journal of human development*, *6*(1), 93-117.

Robinson, H. S., Anumba, C. J., Carrillo, P. M., & Al-Ghassani, A. M. (2005). Business performance measurement practices in construction engineering organisations. *Measuring Business Excellence*, *9*(1), 13-22. doi: 10.1108/13683040510588800

Robson, A., Boyd, D., & Thurairajah, N. (2014). UK construction supply chain attitudes to BIM. In 50th ASC Annual International Conference Proceedings.

Robson, C. (2002). *Real World Research (2nd edn)*. United Kingdom: John Wiley & sons.

Robson, C. (2011). *Real World Research (3rd edn)*. United Kingdom: John Wiley & sons.

Rock (2016) CONSTRUCTION: THE EIGHT PILLARS OF LEVEL 2 BIM. Real estate development, UK. Retrieved 15th November 2017, from: https://hsfnotes.com/realestatedevelopment/2016/05/04/the-eight-pillars-of-level-2-bim/

Rodriguez, J. (2011). Building Information Modeling (BIM) Benefits. About.com Construction. Retrieved 13th November, 2016, from: [http://construction.about.com/od/Technology/a/Building-Information-Modeling-Benefits.htm]

Rojas, M. J., Herrera, R. F., Mourgues, C., Ponz-Tienda, J. L., Alarcon, L. F., & Pellicer, E. (2019). BIM use assessment (BUA) tool for characterizing the application levels of BIM uses for the planning and design of construction projects. *Advances in Civil Engineering*, *2019*.

Rosemann, M., & Bruin, T. De. (2005). Towards a Business Process Mangement Maturity Model. *ECIS 2005 Proceedings of the Thirteenth European Conference on Information Systems*, (May), 26–28. doi: 10.1109/EUROMICRO.2007.35

Rummler-Brache Group. (1995). Overview of 3 levels of performance. 1-12, Retrieved 13th November, 2016, from: [https://www.rummlerbrache.com/sites/default/files/Chapter3.pdf]

Sackey, E., Tuuli, M. M., & Dainty, A. (2013). Bim Implementation : From Capability Maturity Models To Implementation Strategy. *Sustainable Building Conference 2013*, (2013), 196–207.

Sacks, R., Eastman, C., Lee, G., & Teicholz, P. (2018). BIM handbook: *A guide to building information modeling for owners, designers, engineers, contractors, and facility managers*. John Wiley & Sons.

Saini, M., & Shlonsky, A. (2012). *Systematic synthesis of qualitative research*: OUP USA.

Samson, M., & Lema, N. M. (2002). Development of construction contractors performance measurement framework. In 1st International Conference of Creating a Sustainable.

Sanchez, A. X., Mohamed, S., & Hampson, K. (2016). Delivering Value with BIM: A Framework for Built Environment

Practitioners. *CIB World Building Congress 2016*, (June), 1–12.
Sarantakos, S. (2012). Social research: Palgrave Macmillan
Sarkar, D., Raghavendra, H. B., & Ruparelia, M. (2015). Role of key performance indicators for evaluating the usage of BIM as tool for facility management of construction projects. *Interational Journal of Civil and Structural Engineering*, *5*(4), 370–378. doi:10.6088/ijcser.2014050034
Saunders, M., & Tosey, P. (2012). The layers of research design. *Rapport*, *2012/2013* (Winter), 58–59.
Saunders, M., Lewis, P., & Thornhill, A. (2016). Research Methods for Business Students. Essex: Pearson Education Limited.
Saunders, M., Lewis, P., & Thornhill, A. (2019). Research Methods for Business Students. Essex: Pearson Education Limited. 8th edn.
Saxon, R. (2005). Be Valuable: A guide to creating value in the built environment. *Constructing Excellence, London*, 1.
Saxon, R. G. (2013). Growth through BIM. *Construction Industry Council*, 51.
Schuler, R. S., & Jackson, S. E. (2003). Managing human resources through strategic partnerships. *Ohio: Thomson*.
Scott, J. (2014). *A matter of record: Documentary sources in social research*. John Wiley & Sons.
Scottish future trust. (2013). BIM tools, BIM compass. Retrieved 13th November, 2016, from: [http://www.scottishfuturestrust.org.uk/our-work/sft-build/construction-procurement-review/building-information-modelling-bim/resources1/]
Scottish future trust. (2017a) BIM Client information model. Retrieved 15th November 2017, from: https://bimportal.scottishfuturestrust.org.uk/level2/stage/2/task/7/create-the-client-information-model
Scottish future trust. (2017b) BIM Grading tool. Retrieved 15th November 2017, from: https://bimportal.scottishfuturestrust.org.uk/page/bim-grading-tool
Scottish future trust. (2017c) BIM Return on Investment calculator tool. Retrieved 15th November 2017, from: [https://bimportal.scottishfuturestrust.org.uk/page/roi-calculator]
Scottish Government. (2012). Development of Key Performance Indicators to support the Building Standards Verification System. Retrieved 13th November, 2016, from: [http://www.gov.scot/Topics/Built-Environment/Building/Building-standards/publications/pubresearch/researchgeneral/resgenverif]
Scriven, M. (1986). Evaluation as a paradigm for educational research. *New directions in educational evaluation*, 53-67.
Sebastian, D. R. (2013). Building Information modeling Summary. *Journal of Chemical Information and Modeling*, *53*(9), 1689–1699. doi:10.1017/CBO9781107415324.004
Sebastian, R. (2011). Changing roles of the clients, architects and contractors through BIM. *Engineering, Construction and Architectural Management, 18(2)*, 176-187. doi:10.1108/09699981111111148
Sebastian, R., & Berlo, L. V., (2010). Tool for Benchmarking BIM performance of design, engineering and construction firms in The Netherlands. Architectural Engineering and Design Management, 6(4), 254–263. doi: 10.3763/aedm.2010.idds3
SEI. (1993) Key Practices of the Capability Maturity Model, Version 1.1, Software Engineering Institute.
Sekaran, U., & Bougie, R. (2013). Research methods for business. In *Research methods for business* (p. 436). doi: 10.1017/CBO9781107415324.004
Sekaran, U., & Bougie, R. (2016). *Research methods for business: A skill building approach*. John Wiley & Sons.
Selby, S. C., Roos, I., & Wright, L. (2000). Investigation of the application of frontline management training in the community services and health industry: a progress report. In *Victorian Community Services and Health Industry Training Board Conference, Melbourne* (Vol. 22). sn.
Sexton, M., (2007), PhD Workshop: Axiological purposes, ontological cages and epistemological keys, Postgraduate research workshop, November 2004, University of Salford, UK
Shafiq, M. T. (2021). Client-Driven Level 2 BIM Implementation: A Case Study from the UAE. *The Open Construction & Building Technology Journal, 15*(1).
Shah, S. (2015). Difference Between Public Sector and Private Sector. Key differences.
Sharp, J. (2015). Clients need to be educated on BIM. CIOB.
Shehabuddeen, N., Probert, D., Phaal, R., & Platts, K. (1999). Representing and approaching complex management issues: Part 1 - role and definition. SSRN Electronic Journal. doi:10.2139/ssrn.1923155
Shepherd, D. (2019). The BIM Management Handbook. Routledge.
Shih, S., Sher, W., & Williams, A. (2012). Using a BIM Maturity Matrix to Inform the Development of AEC Integrated Curricula. *Australasian Universities Building Educators Association (AUBEA) 37th Annual International Conference*, 124–131.
Shillcock, P. (2019). What is ISO 19650? Retrieved from https://www.thenbs.com/knowledge/from-bs-1192-to-iso-

19650-and-everything-in-between
Shin, J., & Choi, J. (2016). Development of Key Performance Indicators of BIM Performance Measurement in Design Phase. *International Information Institute (Tokyo). Information*, *19*(10A), 4469.
Shin, J., & Choi, J. (2017). Comparable Assessment System for BIM Performance in the Construction Industry. *International Information Institute (Tokyo). Information*, *20*(4B), 2903-2912.
Shin, J., & Choi, J. (2017). Comparable Assessment System for BIM Performance in the Construction Industry. *International Information Institute (Tokyo). Information, 20*(4B), 2903-2912.
Shin, J., Choi, J., & Kim, I. (2015). Development of BIM Performance Measurement System for Architectural Design Firms. In International Conference on Computer-Aided Architectural Design Futures. The Next City - New Technologies and the Future of the Built Environment, *527*, 348–365. doi: 10.1007/978-3-662-47386-3_19
Sibiya, M., Aigbavboa, C., & Thwala, W. (2015). Construction Projects' Key Performance Indicators: A Case of the South African Construction Industry. *ICCREM 2015: Environment and the Sustainable Building*, 521–531. doi: 10.1061/9780784479377.111
Siebelink, S., Voordijk, H., Endedijk, M., & Adriaanse, A. (2021). Understanding barriers to BIM implementation: Their impact across organizational levels in relation to BIM maturity. *Frontiers of Engineering Management, 8*(2), 236-257.
Siebelink, S., Voordijk, J. T., & Adriaanse, A. (2018). Developing and testing a tool to evaluate BIM maturity: Sectoral analysis in the Dutch construction industry. *Journal of construction engineering and management, 144*(8), 05018007.
Silverio Rodriguez, A. K. (2020). *Implementation of building information modelling in the Dominican Republic construction industry* (Doctoral dissertation, University of Wolverhampton).
Silverman, D. (2006) *Interpreting Qualitative data: Methods for Analyzing Talk, Text, and Interaction.* 2nd ed. London: Sage Publications.
Simon, S. E. (1944). *The placing and management of building contracts: report of the Central Council for Works and Buildings*. HM Stationery Office.
Sinclair, D. (2012). BIM Overlay to the RIBA Outline Plan of Work, (May), 1–20. https://doi.org/http://www.ribabookshops.com/uploads/b1e09aa7-c021-e684-a548-b3091db16d03.pdf
Sinclair, D. and Zairi, M. (1995). Effective process management through performance measurement. Part III-an integrated model of total quality-based performance measurement. Business Project Re-engineering & Management Journal, 1 (3) pp 50-65. doi.org/10.1108/14637159510798239
Singh, S. (2021). *Stakeholder management within BIM implemented projects in the UK construction industry* (Doctoral dissertation, University of Wolverhampton).
Singh, V. (2019). Digitalization, BIM ecosystem, and the future of built environment: How widely are we exploring the different possibilities?. *Engineering, Construction and Architectural Management.*
Singh, V., Gu, N. and Wang, X. (2011) A Theoretical Framework of a BIM-Based Multi-Disciplinary Collaboration Platform. Automation in Construction, 20 (2), pp.134-144. doi:10.1016/j.autcon.2010.09.011
Sinoh, S. S., Othman, F., & Ibrahim, Z. (2020). Critical success factors for BIM implementation: a Malaysian case study. *Engineering, Construction and Architectural Management*.
Skibniewski, M. J., & Ghosh, S. (2009). Determination of Key Performance Indicators with Enterprise Resource Planning Systems in Engineering Construction Firms. *Journal of Construction Engineering and Management*, *135*(10), 965–978. https://doi.org/10.1061/(ASCE)0733-9364(2009)135:10(965)
Skoyles, E. R., & Skoyles, J. R. (1987). *Waste prevention on site*. BT Batsford Limited.
Smith, D. K., & Tardif, M. (2012). Building information modeling: a strategic implementation guide for architects, engineers, constructors, and real estate asset managers: John Wiley & Sons.
Smits, W., van Buiten, M., & Hartmann, T. (2016). Yield-to-BIM: impacts of BIM maturity on project performance. Building Research & Information. doi: 10.1080/09613218.2016.1190579
SOC Statistics. (2019a) *Kruskal Wallis Test.* Retrieved 13th November, 2019, from: [https://www.socscistatistics.com/tests/kruskal/default.aspx]
SOC Statistics. (2019b) *Mann Whitney Test.* Retrieved 13th November, 2019, from: [https://www.socscistatistics.com/tests/mannwhitney/]
Social Research Methods. (2006). Descriptive and inferential statistics. Retrieved November 13, 2016, from [http://www.socialresearchmethods.net/kb/statdesc.php]
Soetanto, R., Proverbs, D. G., & Holt, G. D. (2001). Achieving quality construction projects based on harmonious working relationships-Clients' and architects' perceptions of contractor performance. *International journal of quality & reliability management*, *18*(5), 528-548. doi: 10.1108/02656710110392836

Sohail, M., & Baldwin, A. N. (2004). Performance indicators for "micro-projects" in developing countries. *Construction Management and Economics*, *22*(1), 11–23. doi:10.1080/0144619042000186022

Songer, A. D., & Molenaar, K. R. (1997). Project characteristics for successful public-sector design-build. *Journal of construction engineering and management*, *123*(1), 34-40. doi: 10.1061/(ASCE)0733-9364(1997)123:1(34)

Sousa, S. D., Aspinwall, E. M., & Guimarães Rodrigues, A. (2006). Performance measures in English small and medium enterprises: survey results. *Benchmarking: an international journal*, *13*(1/2), 120-134. doi: 10.1108/14635770610644628

Sowden, R., Hinley, D., & Clarke, S. (2008). Portfolio, Programme and Project Management Maturity Model (P3M3®): Introduction and Guide to P3M3®. London: Office of Government Commerce

Spearman, C. (1904). The proof and measurement of association between two things. *The American Journal of Psychology*, *15*(*1*), 72-101.

Spearman, C. (1910) Correlation calculated from faulty data. British Journal of Psychology 3:271–295

Speedcars (2012) KEP PERFORMANCE INDICATORS. KPI definition, Retrieved 13th November, 2016, from: [https://www.slideshare.net/speedcars/key-performance-indicator-11582069]

Stake, R. E. (1995). *The art of case study research*. SAGE Publications Ltd: London.

Stanley, R., & Thurnell, D. (2014). The benefits of, and barriers to, implementation of 5D BIM for quantity surveying in New Zealand. *Australasian Journal of Construction Economics and Building*. doi: 10.5130/ajceb.v14i1.3786

Statista (2019a). *Construction in the UK*. Retrieved 13th November, 2019, from: [https://www.statista.com/study/42057/construction-in-the-uk/]

Statista (2019b). *Constructions firms Size*. Retrieved 13th November, 2019, from: [https://www.statista.com/statistics/564807/construction-firms-size-region-great-britain/]

Staub-French, S. et al. (2011) Building Information Modelling (BIM) 'best practices' project report. University of British Columbia and École de Technologie Supérieure report. 1–176.

Stewart, D. W., & Shamdasani, P. N. (2014). Focus groups: Theory and practice (Vol. 20). SAGE Publications Ltd: London.

Stocks, T. (2016). BIM Level 3 in the Digital Built Britain. Retrieved 13th October, 2016, from [http://digital-built-britain.com/DigitalBuiltBritainLevel3BuildingInformationModellingStrategicPlan.pdf]

Strauss, A. and Corbin, J. (1990) Basics of Qualitative Research: Grounded Theory Procedures and Techniques, (1st edn), Newbury Park, CA: SAGE Publications Ltd: London.

Strauss, A., & Corbin, J. (2008). *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory. Basics of Qualitative Research Grounded Theory Procedures and Techniques* (Vol. 3).

Strauss, A., & Corbin, J. (2008). Basics of qualitative research, 3rd edn. SAGE Publications Ltd: London.

Stringer, E. T. (2013). Action research. SAGE Publications Ltd: London.

Succar, B. (2009). Building information modelling framework: a research and delivery foundation for industry stakeholders. Automation in Construction, 18(3), 357–375. doi:10.1016/j.autcon.2008.10.003

Succar, B. (2010a). *Building information modelling maturity matrix*, in J. Underwood and U. Isikdag (eds.), Handbook of Research on Building Information Modeling and Construction Informatics: Concepts and Technologies, Hershey, PA: IGI Global, pp. 65–103.

Succar, B. (2010b). The Five Components of BIM Performance Measurement, paper presented at CIB World Congress 2010, Salford, UK, 10–13 May.

Succar, B. (2013). Building Information Modelling: conceptual constructs and performance improvement tools. School of Architecture and Built Environment Faculty of Engineering and Built Environment University of Newcastle.

Succar, B. (2016a). 201in BIMe Initiative Competency Table, (May). doi:10.13140/RG.2.1.2413.2726

Succar, B. (2016b). *Building Information Modelling Maturity Matrix*. doi:10.4018/978-1-60566-928-1.ch004

Succar, B., Kassem, M. (2015). Macro-BIM adoption: Conceptual structures. *Automation in Construction; 57:64-79*. doi: 10.1016/j.autcon.2015.04.018

Succar, B., Sher, W. and Williams, A. (2012). Measuring BIM performance: five metrics. Architectural Engineering and Design Management, 8(2), pp. 120–142. Individual Discovery. doi: 10.1080/17452007.2012.659506

Succar, B., Sher, W. and Williams, A. (2013) An Integrated Approach to BIM Competency Assessment, Acquisition and Application. *Automation in Construction, 35,* pp.174-189. doi:10.1016/j.autcon.2013.05.016

Suermann, P. C., & Issa, R. R. A. (2007). BIM effects on construction Key Performance Indicators (KPI) survey. Journal of Building Information Modeling, 1(1), 26-27.

Suermann, P. C., & Issa, R. R. a. (2009). Evaluating industry perceptions of Building Information Modelling (BIM) impacts on construction. *Journal of Information Technology in Construction*, *14*(2009), 574–594. Retrieved 13th October, 2016, from

[http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.212.786&rep=rep1&type=pdf]
Suermann, P.C., Raja, M., Issa, R. A. (2007). An introduction to Building Information Modeling. *Journal of Building Information Modeling*, *Fall 2007*, 12–14.
Sullivan, C. (2007). Integrated BIM and design review for safer, better buildings. Architectural Record.
Sun, C., Xu, H., Wan, D., & Li, Y. (2021). Building Information Modeling Application Maturity Model (BIM-AMM) from the Viewpoint of Construction Project. *Advances in Civil Engineering, 2021.*
Sun, W., & Zhou, G. (2010). KPIs: Analyzing the impact of Building Information Modeling on construction industry in China. *Industrial Engineering and Engineering Management (IE&EM), 2010 IEEE 17Th International Conference*, 354–356. doi:10.1109/ICIEEM.2010.5646595
Supply Chain Sustainable School. (2017). *BIM maturity self assessment*. Retrieved 13th November, 2019, from: [https://www.supplychainschool.co.uk/uk/bim/construction/assessment/bim-assessment.aspx]
Survey System. (2012) *Sample Size Calculator.* Retrieved 13th November, 2019, from: [https://www.surveysystem.com/sscalc.htm]
Survey4BIM. (2015) Big5 Geopatial challenges for BIM level 2. Retrieved 13th November, 2017, from: [http://www.formbysurveys.com/docs/Geo-enabling%20BIM-Big%205.pdf]
Survey4BIM. (2016) The Big5 Challenges. Retrieved 13th November, 2017, from: [https://survey4bim.wordpress.com/the-big5-challenges/]
Sutrisna, M., Proverbs, D., Potts, K., & Buckley, K. (2004). A knowledge based system for valuing variations in civil engineering works: a user centred approach. *International Journal of IT in Architecture, Engineering & Construction*, *2*(4), 285-302.
Swan, W., & Kyng, E. (2004). An introduction to key performance indicators. Center for Construction Innovation.–2004.
Takim, R. (2005). A framework for successful construction project performance (Doctoral dissertation, Glasgow Caledonian University).
Takim, R., & Akintoye, A. (2002). Performance Indicators for Successful Construction Project Performance. *Association of Researchers in Construction Management*, *2*(September), 2–4. doi:10.1017/CBO9781107415324.004
Tang, L., Shen, Q., & Cheng, E. W. (2010). A review of studies on public–private partnership projects in the construction industry. International Journal of Project Management, 28(7), 683-694. doi:10.1016/j.ijproman.2009.11.009
Tashakkori, A. and Teddlie, C. (1998) Mixed Methodology: Combining Qualitative and Quantitative Approaches. California: SAGE Publications Ltd: London.
Tayler, C. J. (1992). Ethyl Benzene project: the client's perspective. *International Journal of Project Management*, *10*(3), 175-178. doi: 10.1016/0263-7863(92)90008-W
Taylor, J. E., & Bernstein, P. G. (2009). Paradigm Trajectories of Building Information Modeling Practice in Project Networks. *Journal of Management in Engineering*, *25*(2), 69–76. doi: 10.1061/(ASCE)0742-597X(2009)25:2(69
Team, C. P. (2010). CMMI® for Development, Version 1.3, Improving processes for developing better products and services. Software Engineering Institute, Carnegie Mellon University.
Team, S. U. (2011). Standard CMMI Appraisal Method for Process Improvement (SCAMPI) A, Version 1.3: Method Definition Document.
Teddlie, C., & Tashakkori, A. (2009). *Foundations of Mixed Methods Research: Integrating Quantitative and Qualitative Approaches in the Social and Behavioral Sciences*. *Book* (Vol. 1)
That, M., & Performance, D. (1992). The Balanced Scorecard Measures That Drive Performance The Balanced Scorecard Measures That Drive Performance, (1), 1–11.
The Scottish Government. (2013). *Review of Scottish Public Sector Procurement in Construction*.
Thomas, R. M. (2003). Blending Qualitative and Quantitative Research Methods in Theses and Dissertations. *Crown Press*, 240. doi: 4135/9781412983525
Thompson, W. R. (2017). The UK BIM Revolution.
Thomsen, C., Darrington, J., Dunne, D., & Lichtig, W. (2009). Managing integrated project delivery. *Construction Management Association of America (CMAA), McLean, VA*, *105*.
Tian, C., Chen, Y., Zhang, J., & Cox, R. F. (2019). Global Building Information Modeling Maturity. In ICCREM 2019: *Innovative Construction Project Management and Construction Industrialization* (pp. 82-92). Reston, VA: American Society of Civil Engineers.
Tiruneh, G. G., & Fayek, A. R. (2021). Competency and performance measures for organizations in the construction

industry. *Canadian Journal of Civil Engineering, 48*(6), 716-728.
Toor, S. u R., & Ogunlana, S. O. (2010). Beyond the "iron triangle": Stakeholder perception of key performance indicators (KPIs) for large-scale public sector development projects. *International Journal of Project Management*, *28*(3), 228–236. doi:10.1016/j.ijproman.2009.05.005
Trochim, W. M. K., & Donnelly, J. P. (2006). *The Research Methods Knowledge Base*. *WebRef* (Vol. 3rd).
Troiani, E., Mahamadu, A. M., Manu, P., Kissi, E., Aigbavboa, C., & Oti, A. (2020). Macro-maturity factors and their influence on micro-level BIM implementation within design firms in Italy. *Architectural Engineering and Design Management, 16*(3), 209-226.
Tsai, M., Mom, M. and Hsieh, S. (2014) Developing Critical Success Factors for the Assessment of BIM Technology Adoption: Part I. Methodology and Survey. Journal of the Chinese Institute of Engineers, 37 (7), pp.845-858. doi:10.1080/02533839.2014.888811
Tulubas Gokuc, Y., & Arditi, D. (2017). Adoption of BIM in architectural design firms. *Architectural Science Review, 60*(6), 483-492.
Ugwu, O. O., & Haupt, T. C. (2007). Key performance indicators and assessment methods for infrastructure sustainability—a South African construction industry perspective. Building and Environment, 42(2), 665-680. doi:/10.1016/j.buildenv.2005.10.018
Uhl-Bien, M., & Ospina, S. (2012). *Advancing relational leadership research: A dialogue*
UK BIM Alliance (2018) *Going digital report.* Retrieved 15th Nov, 2021, from: [https://www.ukbimalliance.org/wp-content/uploads/2018/11/UKBIMA_Going-Digital_Reportl.pdf]
UK BIM Alliance (2019) *Upskilling briefing paper.* Retrieved 15th Nov, 2021, from: [https://www.ukbimalliance.org/upskilling-briefing-paper/]
UK BIM Alliance (2020) *UK BIM Alliance Annual report 2020*. Retrieved 29th April, 2021, from: [https://www.ukbimalliance.org/uk-bim-alliance-annual-report-2020/]
UK BIM Alliance (2021) *State of the National Survey.* Retrieved 15th Nov, 2021, from: [https://www.ukbimalliance.org/ukbima-state-of-the-nation-annual-survey-report-2021/]
UK BIM framework (2019a) Standards & Guidance. Retrieved 13th November, 2019, from: [https://ukbimframework.org/]
UK BIM framework (2019b) Resources. Retrieved 13th November, 2019, from: [https://ukbimframework.org/]
UK BIM Standards. (2012). AEC (UK) BIM Protocol Implementing UK BIM Standards for the Architectural, Engineering and Construction industry. (pp. 46). UK.
UK Commission for Employment and Skills. (2013). Technology and Skills in the Construction Industry. United Kingdom Retrieved 13th October, 2016 from: [http://www.ukces.org.uk/assets/ukces/docs/publications/evidence-report-74-technology-skills-construction.pdf.]
UK Industry Performance Report. (2015). Based on the UK Construction Industry Key Performance Indicators. Retrieved 13th November, 2016,from: [https://www.glenigan.com/sites/default/files/UK_Industry_Performance_Report_2015_883.pdf]
UK Industry Performance Report. (2016). Based on the UK Construction Industry Key Performance Indicators. Retrieved 13th November, 2016, from: [https://www.glenigan.com/sites/default/files/UK_Industry_Performance_Report_2016_LR.pdf]
UK Industry Performance Report. (2016). Based on the UK Construction Industry Key Performance Indicators. Retrieved 13th November, 2016, from: [https://www.glenigan.com/sites/default/files/UK_Industry_Performance_Report_2016_LR.pdf]
UK Industry Performance Report. (2017a). Based on the UK Construction Industry Key Performance Indicators. Retrieved 13th November, 2017, from: [https://www.glenigan.com/wp-content/uploads/2017/11/UK_Industry_Performance_Report_2017_vF.pdf]
UK Industry Performance Report. (2017b). Based on the UK Construction Industry Key Performance Indicators. Retrieved 13th November, 2017, from: [https://www.glenigan.com/wp-content/uploads/2017/11/UK_Industry_Performance_Report_2017_vF.pdf]
UK Industry Performance Report. (2018). Based on the UK Construction Industry Key Performance Indicators. Retrieved 5th March, 2019, from: [https://www.glenigan.com/wp-content/uploads/2018/11/UK_Industry_Performance_Report_2018_4456.pdf]
UKRIO. (2014). Procedure for the investigation of misconduct in research. UK Research Integrity Office. Retrieved 13th November , 2016, from: [http://www.ukrio.org]
Ullah, K., Lill, I., & Witt, E. (2019). An overview of BIM adoption in the construction industry: Benefits and barriers. In *10th Nordic Conference on Construction Economics and Organization*. Emerald Publishing Limited.
Ullathorne, P. (Ed.). (2019). *Being an Effective Construction Client: Working on Commercial and Public Projects.*

Routledge.
Underwood, J. (2010). *Handbook of Research on Building Information Modeling and Construction Informatics : Concepts and Technologies*. *Bim*.
Underwood, J., & Shelbourn, M. (2021). Handbook of research on driving transformational change in the digital built environment. *Advances in Civil and Industrial Engineering* (ACIE).
Underwood, J., Chomeniuk, J., Brady, L., & Woodcock, D. (2017). *7 Manchester Central Library and Town Hall Extension Project: the BIM journey so far of a public sector client*, in Perera, S., Ingirige, B., Ruikar, K., & Obonyo, E. (Eds.). Advances in Construction ICT and E-Business. Taylor & Francis, Routledge, London and New York, pp 131-152.
Van der Waldt, G. (2020). Constructing conceptual frameworks in social science research. *TD: The Journal for Transdisciplinary Research in Southern Africa*, *16*(1), 1-9.
Van Nederveen, S., Beheshti, R., and Gielingh, W., (2009) Modeling Concepts for BIM. (In: J.Underwood, and U.Isikdag, (Ed.), *Handbook of Research on Building Information Modeling and Construction Informatics: Concepts and Technologies*, (Hershey, PA: Information Science Reference, 2009) 1-18.
Van Wassenaer, A. (2017). *A practical guide to successful construction projects*. Taylor & Francis.
Vantage, B. Construction Clients' Group (2009). *Equal Partners–Customer and Supplier Alignment in Private Sector Construction*
Vargha, A., & Delaney, H. D. (1998). Kruskal-Wallis test and stochastic homogeneity. *Journal of Educational and behavioral Statistics*, *23*(2), 170-192.
Varghese, P. (2020). Influence and Adoption of BIM within the AEC Industry.: A study into how policies, workflows and process can set the tone towards adoption and implementation of BIM within the AEC industry and how the future of BIM and Data Validation can influence the future of Architects.
Vass, S., & Gustavsson, T. K. (2017). Challenges when implementing BIM for industry change. *Construction management and economics, 35*(10), 597-610.
Velleman, P. F., & Wilkinson, L. (1993). Nominal, ordinal, interval, and ratio typologies are misleading. *The American Statistician*, *47*(1), 65-72. doi: 10.1080/00031305.1993.10475938
Vennström, A. (2008). The construction client as a change agent. Contextual Support and Obstacles. *Environmental Engineering*, 136. PhD Thesis, Construction Engineering and Management, Luleå U. of Technology.
Vennström, A., & Erik Eriksson, P. (2010). Client perceived barriers to change of the construction process. Construction Innovation, 10(2), 126-137. doi:10.1108/14714171011037156
Vico. (2011). Calculating Your BIM Score. Retrieved 13th November, 2016, from: [http://www.vicosoftware.com/resources/calculating-bim-score]
Vidalakis, C., Abanda, F. H., & Oti, A. H. (2019). BIM adoption and implementation: focusing on SMEs. *Construction Innovation*. DOI: 10.1108/CI-09-2018-0076
Vidalakis, C., Abanda, F. H., & Oti, A. H. (2020). BIM adoption and implementation: focusing on SMEs. *Construction Innovation.*
Vilutienė, T., Kiaulakis, A., & Migilinskas, D. (2021). Assessing the performance of the BIM implementation process: a case study. *Revista de la construcción*, *20*(1), 26-36.
Voordijk, H. (2009). Construction management and economics: The epistemology of a multidisciplinary design science. *Construction Management and Economics*, *27*(8), 713–720. https://doi.org/10.1080/01446190903117777
Voordijk, H. (2011). Construction management research at the interface of design and explanatory science. *Engineering, Construction and Architectural Management*, *18*(4), 334–342. https://doi.org/10.1108/09699981111145790
Vukomanović, M., Radujković, M., & Nahod, M. M. (2010). Leading, lagging and perceptive performance measures in the construction industry. *Organization, Technology & Management in Construction: An International Journal*, *2*(1), 103–111. Retrieved 13th November, 2017, from: [http://hrcak.srce.hr/65030]
Walters (2021a) *Skills and competency framework.* Retrieved 18th Apr, 2022, from: [https://www.cdbb.cam.ac.uk/files/010321cdbb_skills_capability_framework_vfinal.pdf]
Walters (2021b) *The approach to delivering a National digital twin for the United Kingdom.* Retrieved 18th Apr, 2022, from: [https://www.cdbb.cam.ac.uk/news/approach-delivering-national-digital-twin-united-kingdom]
Wang, G., Liu, H., Li, H., Luo, X., & Liu, J. (2020). A building project-based industrialized construction maturity model involving organizational enablers: A Multi-Case Study in China. *Sustainability, 12*(10), 4029.
Waterhouse, R., & Philp, D. (2016). National BIM Report. *National BIM Library*, 1–28. https://doi.org/10.1017/CBO9781107415324.004
Wei-zhuo, S., & Guo-qiang, Z. (2010). KPIs: Analyzing the impact of Building Information Modeling on construction

industry in China. *Industrial Engineering and Engineering Management (IE&EM), 2010 IEEE 17Th International Conference on*, 354–356.

Westerveld, E. (2003). The Project Excellence Model®: linking success criteria and critical success factors. *International Journal of project management*, *21*(6), 411-418. doi: 10.1016/S0263-7863(02)00112-6

Weygant, R. S. (2011). *BIM content development: standards, strategies, and best practices*. John Wiley & Sons.

Wild, A. (2003). The working party report to the Minister of Works: The Phillips Report on building 1950. InM. Murray &D. Langford. *Construction reports 1944*, *98*.

Wilkinson, S. (2011). Analysing focus group data. *Qualitative research*, *3*.

Winfield, M. (2018). The winfield rock report: Overcoming the legal and contractual barriers of BIM. In *Proc. Winfield Rock Report Overcoming the Legal and Contractual Barriers BIM* (pp. 1-60).

Winfield, M. (2020). Construction 4.0 and ISO 19650: a panacea for the digital revolution?. *Proceedings of the Institution of Civil Engineers-Management, Procurement and Law*, *173*(4), 175-181.

Winfield, M. (2020). Construction 4.0 and ISO 19650: a panacea for the digital revolution?. *Proceedings of the Institution of Civil Engineers-Management, Procurement and Law, 173*(4), 175-181.

Winter, S. G. (2000). The satisficing principle in capability learning. *Strategic management journal*, *21*(10-11), 981-996.

Wolstenholme, A. (2009) Never Waste a Good Crisis: A Review of progress since rethinking construction and thought for our Future, London: Constructing Excellence.

Won, J., & Lee, G. (2014). Goal-driven method for sustainable evaluation of BIM project success level. *eWork and eBusiness in Architecture, Engineering and Construction - Proceedings of the 10th European Conference on Product and Process Modelling, ECPPM 2014*, 33–38.

Won, J., & Lee, G. (2016). How to tell if a BIM project is successful: A goal-driven approach. *Automation in Construction*, *69*, 34–43. doi: 10.1016/j.autcon.2016.05.022

Won, J., Lee, G., & Lee, C. (2011). Comparative analysis of BIM adoption in Korean construction industry and other countries. *Iccem & Iccpm*.

Wong, P. F., Salleh, H., & Rahim, F. A. M. (2016). A Relationship Framework for Building Information Modeling (BIM) Capability in Quantity Surveying Practice and Project Performance. *Informes de La Construcción, 67(540), e119.* doi: 10.3989/ic.15.007

Wood, S. K. (1975). The public client and the construction industries. *A Report of the Joint Working Party by the Economic Development Councils (EDCs) for Building and Civil Engineering 1st Ed. HMSO, London*.

Wu, C., Xu, B., Mao, C., & Li, X. (2017). Overview of BIM maturity measurement tools. *Journal of Information Technology in Construction (ITcon), 22(3)*, 34-62.

Wu, W., Mayo, G. K., McCuen, T. L., Issa, R. R., & Smith, D. K. (2021). *Developing BIM Talent: A Guide to the BIM Body of Knowledge with Metrics, KSAs, and Learning Outcomes*. John Wiley & Sons.

Xiao, H. (2002) *A Comparative Study of Contractor Performance Based on Japanese, UK and US Construction Practice*, PhD Thesis, School of Engineering and the Built Environment, University of Wolverhampton, U.K.

Yan, H., & Damian, P. (2008). Benefits and Barriers of Building Information Modelling. *Proc. of 12th International Conference on Computing in Civil and Building Engineering*.

Yang, H., Yeung, J. F., Chan, A. P., Chiang, Y. H., & Chan, D. W. (2010). A critical review of performance measurement in construction. *Journal of Facilities Management*, *8*(4), 269-284. doi: 10.1108/14725961011078981

Yeung, J. F., Chan, A. P., Chan, D. W., Chiang, Y. H., & Yang, H. (2013). Developing a benchmarking model for construction projects in Hong Kong. *Journal of construction engineering and management, 139*(6), 705-716. doi:10.1061/(asce)co.1943-7862.0000622

Yilmaz, G., Akcamete, A., & Demirors, O. (2019). A reference model for BIM capability assessments. *Automation in Construction*, *101*, 245-263. doi: 10.1016/j.autcon.2018.10.022

Yin, R. (2009). *Case study research: Design and methods* (4th edn). SAGE Publications Ltd: London.

Yin, R. (2014). *Case study research: Design and methods* (5th edn). SAGE Publications Ltd: London.

Yin, R. K. (2018). *Case study research and applications*. Sage.

Young, N. W., Jones, S. A., Bernstein, H. M., & Gudgel, J. (2008). SmartMarket report on building information modeling (BIM): Transforming design and construction to achieve greater industry productivity.

Yuan, H., & Yang, Y. (2020). BIM Adoption under Government Subsidy: Technology Diffusion Perspective. *Journal of Construction Engineering and Management*, *146*(1), 04019089. Doi: 10.1061/(ASCE)CO.1943-7862.0001733

Yuan, J., Zeng, A. Y., Skibniewski, M. J., & Li, Q. (2009). Selection of performance objectives and key performance indicators in public-private partnership projects to achieve value for money. *Construction Management and*

Economics, *27*(3), 253–270. doi:10.1080/01446190902748705

Yun, S. H. (2018). BIM Service Level Assessment in Construction Phase. *International Journal of Pure and Applied Mathematics, 118*(19), 1677-1689.

Zandi, F. (2013). A Country-Level Decision Support Framework for Self-Assessment of E-Commerce Maturity. *iBusiness*, *5*(2), 43–54. doi: 10.4236/ib.2013.51A008

Zarour, M., Alarifi, A., Abran, A., & Desharnais, J.-M. J.-M. (2012). Evaluating the assessment method of the software maintenance maturity model. *2012 International Conference on Information Technology and E-Services, ICITeS 2012*, 1–8. https://doi.org/10.1109/ICITeS.2012.6216681

Zayed, T., Elwakil, E., & Ammar, M. (2012). A Framework for Performance Assessment of Organizations in the Construction Industry. *International Journal of Architecture, Engineering and Construction*, *1*(4), 199–212. doi:10.7492/IJAEC.2012.022

Zhang, S., Teizer, J., Lee, J. K., Eastman, C. M., & Venugopal, M. (2013). Building Information Modeling (BIM) and Safety: Automatic Safety Checking of Construction Models and Schedules. *Automation in Construction*, *29*, 183–195. https://doi.org/10.1016/j.autcon.2012.05.006

Zhao, X., Chen, L., Pan, W., & Lu, Q. (2017). AHP-ANP–fuzzy integral integrated network for evaluating performance of innovative business models for sustainable building. *Journal of Construction Engineering and Management*, *143*(8), 04017054. doi: 10.1061/(ASCE)CO.1943-7862.0001348

Zomer, T. (2021). *Institutional pressures and decoupling in projects: The case of BIM level 2 and coercive isomorphism in the UK's construction sector* (Doctoral dissertation, University of Cambridge).

Zou, P. X. W., Chen, Y., & Chan, T.-Y. (2010). Understanding and Improving Your Risk Management Capability: Assessment Model for Construction Organizations. *Journal of Construction Engineering and Management*, *136*(8), 854–863. doi: 10.1061/(ASCE)CO.1943-7862.0000175

Zuppa, D., Issa, R. R. A., & Suermann, P. C. (2009). BIM's Impact on the Success Measures of Construction Projects. Computing in Civil Engineering, 503–512. doi: 10.1061/41052(346)50

Appendix A: Ethical approval

University of Salford MANCHESTER

Research, Innovation and Academic Engagement Ethical Approval Panel

Research Centres Support Team
G0.3 Joule House
University of Salford
M5 4WT

T +44(0)161 295 5278

www.salford.ac.uk/

10 July 2017

Ahmed Abou Moemen

Dear Ahmed,

RE: ETHICS APPLICATION STR1617-87 - A Level 2 BIM Maturity/KPI assessment model in support of the BIM level 2 construction strategy adoption for the UK

Based on the information you provided, I am pleased to inform you that your application STR1617-87 has been approved.

If there are any changes to the project and/ or its methodology, please inform the Panel as soon as possible by contacting S&T-ResearchEthics@salford.ac.uk

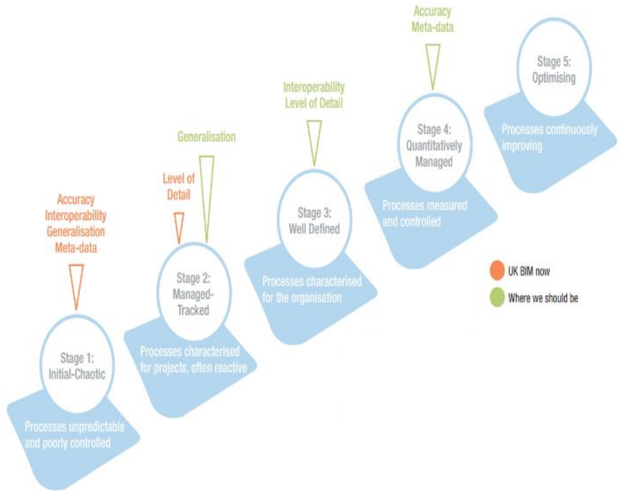
Yours sincerely,

APHigham.

Dr Anthony Higham
Chair of the Science & Technology Research Ethics Panel

Appendix B: Chapter 3 Additional information on maturity & BIM maturity

Based on the UK BIM Task Group, Survey4BIM, an open collective of geospatial professionals, has been looking at what it means to geo-enable BIM. It has identified 5 challenges: accuracy, generalisation, interoperability, level of detail and metadata. These challenges are the building blocks for geo-enabling BIM Level 2. The benefits are clear: avoiding risk, reworking, delay, extra costs and clashes. The capability maturity and its relationship with UK Level 2 BIM mandate in 2016 and a description of each level is presented in Figure 3.2 (Gleeson and Penney, 2016; Godfrey, 2008; Humphrey, 1988; Nolan, 1973; Survey4BIM. 2015).



Maturity level explanation and its relation with Big5 BIM level 2 (Gleeson and Penney, 2016; Survey4BIM. 2015)	
Maturity levels	**Explanation**
Accuracy	Accuracy in a geospatial sense is specific and well defined. In a BIM context it is rarely, if ever, so well defied other than using the term 'accurate data'.
Generalisation	Generalisation is the selection and simplified representation of detail appropriate to the scale and/or purpose of its end use without reducing the accuracy of the captured data or distorting the context.
Interoperability	Interoperability and exchange of geospatial data varies depending on the deliverable required and the software used. Some data transformation programs result in poor quality data.
Level of Detail	Geometric level of detail and graphical representation is critical to the underpinning of space allocation in BIM, both for proposed and existing features, and for client decision making.
Meta-Data	Meta-data is the information which defies other data and is essential when understanding the accuracy, provenance and critical information associated with a piece of data.

Maturity level explanation with Big5 BIM level 2 (Gleeson and Penney, 2016; Survey4BIM. 2015)

This shows that in 2016, the UK was up to stage 2 of the 5 staged BIM levels (Initial Chaotic and Managed tracked). 4 challenges existed in the 1st stage, with Level of detail being present in the 2nd stage, but there was a vision to move forward with the stages for an advanced implementation of BIM. This was aimed to move along to Stages 3 and 4 (Well defined and Quantitatively managed) where Generalisation would be linked with Stage 2, Interoperability and Level of Detail linked to Stage 3, and Accuracy and Meta data linked to Stage 4.

By mapping out the maturity levels of the applications of geo-enabled data in stages and relating them to the BIM road map, we can clearly identify where the opportunities for development lie and, in so doing, focus on what actions we need to take as a professional.

It must be remembered these challenges are viewed in the context of applying BIM in the UK as a whole, as opposed to the UK geospatial sector alone. Applying this staged process of adoption to a BIM road map helps to clarify the gaps, and the steps necessary to achieve BIM Level 2.

The next step is to see on which actions the geospatial industry can focus, and which to prioritise. There is a chance to geo-enable BIM over the next 5 years.

Complete list of most popular maturity models available in literature

Most common maturity models available in the literature			
The start of Maturity Models	**Types**	**Description**	**Purpose of Usage**
Quality Management Maturity Grid (Crosby, 1980): A management maturity grid that is used to pinpoint an organisation in relation to quality. It assess management attitude, organisational status, problem handling, cost of quality, improvement actions, and summation of company quality posture. 5 stages are presented in this grid: 1) Uncertainty, 2) Awakening, 3) Enlightenment, 4) Wisdom, and 5) Certainty. The quality management maturity grid represents a starting point to a maturity perspective which has been used differently amongst the addressed maturity models in the literature	**Process Maturity Model** (Rummler-Brache Group. 1995)	***"A holistic approach that recognizes the interdependence of the Nine Performance Variables. The way to understand these variables is through the application of the systems view to the Three Levels of Performance".*** (Rummler-Brache Group. 1995). The 3 levels consist of the following outcomes: 1) Organisational level, 2) Process level, and 3) Job/ Performer level. Within the 3 levels, there are 9 performance variables embedded within them grouped into 3: 1) Goals, 2) Design, 3) Management.	The Process Maturity Model relies on 9 performance variables within 3 major performances levels that are related to Processes and organisations. This model has not considered the usage of a 5 level maturity assessment within its model, and thus it shall not be not be suitable for the maturity assessment.
	Project management (PM2) model (Kwak and Ibbs, 2002).	The model focuses on 9 project management areas: 1) Integration 2) Scope, 3) Time, 4) Cost, 5) Quality, 6) Human resources, 7) Communications, 8) Risk and 9) Procurement. Along with these there are 5 set of processes embedded with them: 1) Initiating, 2) Planning, 3) Executing, 4) Controling, and 5) Closing. Together with those 5 levels of maturity are being used: 1) Ad-hoc, 2) Planned, 3) Managed at project level, 4) Managed at corporate level and 5) Continuous learning. Those could represent Key Performance Indicators (KPI) of projects. According to Kwak and Ibbs, (2002). ***"The (PM)2 model provides a means for identifying and measuring different PM levels by integrating nine PM knowledge areas with five project processes under a quantified scheme.".***	This model is more related to Project management issues that is based on Project outcomes related to Time, Cost, Quality, etc..., and hence this model shall not be considered as a maturity approach in this study, but it may be considered as a KPI approach for the assessment selection.
	NASCIO Enterprise Architecture Maturity Model (NASCIO. 2003)	***"The model follows the path of an organization as their enterprise architecture program matures, and sets benchmarks to measure the performance and path that is a natural progression in the development of enterprise architecture. The intent of this model is to supply a tool that can be used to benchmark the effectiveness of an Enterprise Architecture program ".*** (NASCIO. 2003). The assessment is based on 8 categories: 1) Administration, 2) Planning, 3) Framework, 4) Blueprint, 5) Communication, 6) Compliance, 7)Integration, 8) Involvement. The model consists of 5 levels that are assessed amongst each other	This model presents a tool that relies on requirements of an architectural perspective and technological uses. although it is based on 8 categories related to Architectural environment and technological outcomes, and uses a 5 level maturity for its assessment, however this model focuses on an architectural side and neglects other perspectives, and thus may not work for a BIM or KPI assessment, and shall not be suitable for the maturity assessment.
	Project Management Maturity Model (Cooke-Davies, T. 2004).	According to Cooke-Davies, T. (2004) ***"The model is descriptive, with the express intention of providing organizations with guidance to support their process improvement initiatives, and the document describing the model is at pains to point out that the model itself is not to be confused with any questionnaire that may be used to establish an organization's current maturity level".*** The Model could be used by any organization wanting to improve its capability to manage projects effectively for the purpose of developing maturity questionnaires, or by accredited service providers in assisting teams to perform project management process assessments They are based on 5 process levels of maturity: 1) Initial, 2) Repeated, 3) Defined, 4) Managed, 5) Optimised.	This model is based on a project management environment that assesses project management issues according to levels of managing the projects amongst the organisations that uses the 5 levels of maturity for that purpose. Although it has used 5 levels of maturity in this model, however it has focused on project management related issues and hence this model may not be suitable for maturity assessment in this research, but may be considered for KPI development in the assessment selection.
	Business process maturity model (Fisher, 2004)	The model focuses on 2 main dimensions: 1) The 1st one associated with organisational core that consists of 5 Levers of change: 1) People, 2) Technology, 3) Process, 4) Strategy and 5) Controls. The 2nd one is associated with the 5 states of process maturity: 1) Siloed, 2) Tactically Integrated, 3) Process Driven, 4) Optimized Enterprise and 5) Intelligent Operating Network. According to Fisher, (2004) **"This assessment, based on the two dimensions of this model, provides clear direction to a company in this condition as to what needs improvement in order to reach the desired state.".**	This model focuses on 2 dimensions related to business needs. Although it requires BIM maturity related outcomes such as People, process, technology, and uses a 5 level maturity approach, however it is focused more on companies needs and based on 2 dimensions only, and thus it shall not be relevant for the maturity assessment in this research but may be considered for development of the assessment selection set for this research.
	Supply chain Maturity model (Lockamy III and McCormack, 2004).	This model comprises of 5 maturity levels: 1) Ad-hoc, 2) Defined, 3) Linked, 4) Integrated and 5) Extended. Along with this, a set of deliverables related to supply chain that are grouped under each of the 5 maturity levels. are : 1) Suppliers, 2) Customers that are placed in one end along the 5 levels, and in between them a set of requirements: 1) Source, 2) Plan, 3) Make, and 4) Deliver. According to Lockamy III and McCormack, (2004). ***"The model is an extension to a previous developed model (Business Process Orientation). A BPO maturity model was developed based on the concepts of process maturity, BPO, and the capability and maturity model developed by the Software Engineering Institute"***	This model is based on supply chain management issues that although it has used a maturity approach, but was related mainly on supply chain outcomes such as suppliers, customers, and their requirements related to source, plan, etc... and thus the maturity model approach shall not be relevant for the maturity assessment set for this research.
	Portfolio, programme and project management maturity model (P3M3®) (Sowden, Hinley, & Clarke, 2008)	For the maturity model, there are three models that underpin the guidance and assessments. These are for portfolio management (PfM3), programme management (PgM3) and project management (PjM3). They have followed the SEI 5 levels of maturity: 1) Initial, 2) Defined, 3) Managed, 4) Integrated, 5) Optimised. P3M3 focuses on seven perspectives that exist across the three models and are assessed at all five maturity levels. According to Sowden, Hinley, & Clarke, (2008) ***"Perspectives associated with the maturity models are as follows: 1) Organizational governance, 2) Management control, 3) Benefits management, 4) Risk management, 5) Stakeholder management, 6) Finance management and 7) Resource management."***	This model was based on an integration of previous developed model and has enhanced its model to a more comprehensive one that assess different perspectives of industries. Although it has used the 5 levels maturity assessment in the presented model, however it addressed higher and complex outcomes that needs to be measured, and thus this maturity model shall not be selected for the maturity model basis and assessment in this research, but may be considered in the development of the assessment selection of this research.
	Capability Maturity Model Integration (CMMI) (Paulk, Weber, Curtis, & Chrisses, 1994; Chrissis et al., 2003)	The Capability Maturity Model developed by Software Engineering Institute (SEI), which describes the evolution of software development processes, has been used by most of the organizations as the basis for maturity models in these various areas. The CMM has gained such global acceptance that high maturity scores are one of the requirements for accepting off-shoring partners. The SEI has created six maturity models in total and has recently incorporated three legacy CMMs into one maturity model now named the Capability Maturity Model Integration – CMMI. Both the defined processes and the organisation's set of standard processes are targets of measurable improvement activities. **They are based on 5 levels of maturity: 1) Initial, 2) Defined, 3) Managed, 4) Integrated, 5) Optimised.**	Most of the presented maturity models in relation to BIM in the literature has adopted the CMMI approach within there models and BIM has been defined as a software process in some areas where BIM was used as a software and so the CMMI was used to assess the maturities. The model has been used frequently by organisations as a maturity model basis. For this thesis, it is believed that the maturity should follow the CMMI since this is more relevant and related to the background of BIM than the rest of the types, and should follow the concurrent developments of maturity models that was adopted in the previous literature.
	European Foundation for Quality Management (EFQM) Excellence Model (EFQM. 2012)	According to EFQM. (2012) ***"The EFQM Excellence Model allows people to understand the cause and effect relationships between what their organisation does, the Enablers, and the Results it achieves. To achieve sustained success, an organisation needs strong leadership and clear strategic direction.*** "The model consists of 2 criteria: 1) Enablers and 2) Results. Within each criterion there are a set of steps required to be done. For the enablers: 1) Leaderships, 2) Strategy, 3) People, 4) Partnerships and resources, 5) Processes, products and services. For the results, a set of results will be related to the enablers that expect to achieve results relevant to: 1) Customer, 2) People, 3) Society, 4) Business.	The EFQM excellence model is a maturity model that allows people to see effects of organisations through enablers and results. Since it is related to maturity models, then it is expected to be presented in the literature related to either BIM maturity assessments or combined BIM / KPI. The model was presented in the KPIs literature, which shows that not only will this model operate through the maturity measures, but could operate as well through the KPIs distribution, and although it will not be considered as the maturity approach for BIM only, but will be considered as a modelling approach to be applied.

A complete list of the evaluations for a selective number of studies

Existing most popular BIM maturity models/ assessment / tools / frameworks						
Legend	**Model Name**	**Maturity type**	**Maturity measure**	**Elements and Categories**	**Strengths**	**Weaknesses**
Assessment framework BIM competencies and capability assessment – self	NBIMS Capability Maturity Measure. **US (2007)**	**Organisational** (Model) Maturity	Levels 1- 10, and Percentage scoring on BIM model that lead to a certificate of achievement.	Calculating 11 Areas of interests for models in organisation, total of 100% achievement.	This assessment displayed great results that will be presented in relation to organisation and model errors will be reviewed for later editions and it can work elsewhere, which shows that it was a success approach to assess a model outcome, and thus deliver a comprehensive result for the model assessment.	The model outcome will not assess the performance within organisations, which shows that the assessment shall work on models and not on projects and organisation, and therefore it may not be eligible for assessment within other projects and organisations and hence outside the US
Assessment method – other	Maturity index. **UK (2008)**	Project Maturity	Levels 0-3.	UK government mandate of projects and applying BIM level 2 by 2016. 4 Maturity Levels (additional levels may be added)	The set of guides, processes and standards presented shows the need for the UK industry to consider visiting the presented guidelines to achieve their goal in achieving level 2 on time, and thus a set of BIM level 2 guidelines were covered appropriately within this study.	The matrix displays the UK vision of achieving BIM level 2 through guides and processes but does not present an assessment approach to assess BIM projects or organisations to achieve BIM level 2, and thus the matrix may not be valid as an assessment tool globally as well as within the UK.
BIM Functional model (tool)	**Succar BIM Maturity Matrix- Australia (2009)**	**Organisational Maturity**	**Levels 1-5 known as: a) Initial, b) defined, c) Managed, d) Integrated, and e) Optimised**	**Technology, process, policy for organisations. Knowledge Tool intended to identify the current BIM Maturity of an organization or Project Team.**	**This study has presented BIM as components of the maturity that is made for purpose of the performance measurement and improvement, and thus a practical steps towards assessing the BIM components existed through the 5 levels of maturity.**	**The maturity matrix will not be subjected to work outside Australia, and the models are not formally endorsed where it does not include any level of details, and therefore the need to revisit the maturity matrix to include the level of details to be then subjected for validity globally.**
Maturity model on levels 1-5	IU's BIM Proficiency matrix. **US (2009a)**	**Project** (Model) Maturity	Percentage Scoring on 8 areas of model and a certification on BIM model.	Evaluation Tool for BIM Proficiency, 8 model areas of interest, 32 is total achievement, evaluative tool for projects	The presented matrix displays a progression on a BIM model through a scoring criteria with percentage of achievement, and thus this tool shall be suitable to operate within different models presented in different projects.	The percentages presented shall be meaningless and wont reflect on organisation performance, and therefore the need to consider revisiting the matrix in order to deliver a realised reflection on organisations to benefit from the assessment.
Scoring criteria percentages for projects	BIM Quickscan TNO. Netherlands (2010).	Organisational Maturity	BIM performance level in organisation through 4 chapters and 50 measures (KPIs).	Please refer to the BIM approach in Combined BIM/KPI section for additional information	The author has reviewed the previous assessment tool and outlined that no previous attempt has managed to measure the BIM maturity of both the model and the organization, and thus the BIM approach in this study shall be comprehend well to avoid previous failure of BIM assessments.	It will be interesting to see how this tool shall be adaptable and operated outside the Dutch industry since this tool met the requirements of the Dutch industry, and thus the need to review the KPIs used in this study to be then examined amongst other disciplines and to be tested out for validation and reliability.
Scoring criteria percentage on a model with possible certification Combined BIM / KPI [driven from other categories	BIM Characterisation framework. **US (2011)**	Project Maturity	Framework on BIM implementation in projects into 3 categories, 14 factors and 74 measures.	Through case studies on 40 construction projects, this research provides a framework to characterize why, when, for whom, in what level of detail, with which tools, how, for how much, and how well BIM implementations are done on projects.	the delivered framework can be a guide to enhance the BIM implementation amongst projects for different practitioners, and thus the framework could be relied on the BIM implementation aspects for other organisations and projects.	This study has not delivered a maturity assessment based on the BIM implementations amongst the 14 factors and 74 measures, which addresses an issue on the implications of the BIM implementation framework and its adaptability with the maturity levels to be assessed on for projects and organisations.

Existing most popular BIM maturity models/ assessment / tools / frameworks continued					
Model Name	**Maturity type**	**Maturity measure**	**Elements and Categories**	**Strengths**	**Weaknesses**
VICO BIM score. **US (2011).**	Project and Organisational (model) Maturity	Percentage Scoring assessment on BIM models in the areas of functionality and capability, best practices and enterprise integration.	To assist organisations to compare their performance against their competitors. categories and 27 questions.	The tool is on online software that is available to everyone across the industry, and thus everyone shall be able to undertake the assessment to examine the tool amongst their industry, and therefore enhance the operations of BIM within the industry and support the validation process of the tool across the market.	The software focuses on modelling aspects of BIM that has included BIM components related to BIM models, which shows that it has treated BIM as a software use, and thus neglected the approach to BIM as a modelling process which could be tested out amongst different organisations.
CPIx BIM assessment- **UK (2011).**	Organisational Maturity	Self assessment on BIM capability Questionnaire of Projects in organisation	4 sections including 12 BIM areas. Based on working documentation provided by Skanska	This self assessment presents 12 BIM areas that are assessed on completion, which shows a potential attempt to reflect individuals on the BIM areas that have been achieved within their projects and organisations.	This assessment will only be eligible for assessment within the particular organisation. It shall not be valid elsewhere since it follows the requirements of the selected organisation, and therefore this assessment may be the weakest assessment that existed within all the presented assessments in this research.
CIFE VDC Scorecard. **US (2013)**	Project Maturity	A percentile scoring system broken into five tiers. A maturity divisions amongst the technological area.	4 areas, 10 sub areas, 56 measures. 5 maturity areas of (1) visualization, (2) documentation, (3) model-based analysis, (4) integrated analysis, and (5) automation and optimization.	this study has managed to deliver a standardised score that can be comprehended well amongst projects, and thus a practical approach towards validating the delivered scorecard.	The area related to maturity was limited to the technological area, which raises a concern of its applicability amongst other areas of BIM in this study, and hence the need to consider revisiting the scorecard to include maturity as a main area that will be examined.
BIM Capability Maturity Model Toward performance assessment of BIM technology implementation. Taiwan (2011)	**Organisational Maturity**	**6 BIM components, 5 Maturity levels, and 4 Capability levels .**	**Please refer to the BIM approach in Combined BIM/KPI section for additional information**	**This study has introduced BIM through a performance assessment of 3 steps (Strategic decision, BIM implementation, Assessment) that has clearly considered the practical steps towards implementing BIM within this study.**	**This study has considered the usage of 6 BIM components mainly based on people, processes and model. But a concern on how has BIM being approached in this study and their limitation on a selective models, processes and tools and not considering other BIM components such as (BIM Execution Plan, Common Data Environment, etc..)**
Penn State CIC organisational BIM assessment profile- US (2013)	Organisational Maturity	Level 0-5, known as: 0) Non existent, 1) Initial, 2) Managed, 3) Defined, 4) Quantitatively managed, and 5) Optimising	Organisation stage, 5 strategy planning elements, 2 BIM uses, 25 is total achievement.	a decent approach to establish essential organisational needs were clear, and thus a comprehensive assessment through maturity levels was presented. the assessment is subjective to validation globally, and thus the results obtained could be relied amongst projects and organisations.	Organisation and project needs may differ from one to another, and hence the assessment may be valid in a selective projects and organisations than others, which raises a concern on the adaptability and operations of the assessment profile within various organisations.
BIM excellence individual assessment Change agents AEC. **Australia (2013).**	Project and Organisational Maturity	BIM competency self assessment with percentage distribution	BIMe includes multiple modules for assessing the performance of individuals, organisations, projects and teams.	BIM was covered decently throughout those stages, and the presented certificate shall help define the current status of each individual and thus improve individual expertise.	This study did not follow the maturity stages required and depended on 8 stages of individual assessment, and therefore the need to consider inclusion of maturity levels within the assessment

Existing most popular BIM maturity models/ assessment / tools / frameworks continued					
Model Name	**Maturity type**	**Maturity measure**	**Elements and Categories**	**Strengths**	**Weaknesses**
BIMscore- **US (2013).**	Project Maturity	BIMScore evaluates BIM practices across ten dimensions, grouped under four areas.	1 score, 4 areas, 10 divisions, 50 + measures, commercial update for the VDC scorecard.	the tool is easy to access across disciplines in the construction industry that also aims to assess a maturity perspective within it, and thus a practical approach to validate the product.	non existence of the previous study could have resulted of the product to not be delivered and examined, which shows that the model depended mainly on the development of the previous one, and thus the need to consider additional features that will differ from it.
Owner's BIMCAT- **US (2014)**	Organisational Maturity	Framework for evaluating the BIM Competency of owners.	3 areas, 12 sub areas, 66 factors. BIMCAT is targeted towards facility owners and includes 12 competency categories and 66 factors measured against six maturity levels.	the author has managed to approach the necessary expertise to conduct this framework with, and thus deliver outcomes that could be valid within other organisations.	This study has neglected the approach towards delivering a related maturity assessment that the BIM factors could have been examined upon, which signifies the importance to revisiting the framework to visualise the areas where maturity levels assessment could have existed.
Goal-Driven Method for Sustainable Evaluation of BIM Project Success (SLAM BIM) Level. Korea (2014)	Project Maturity	Framework for assessment model for BIM projects through BIM KPIs. 25 BIM uses, 6 main KPIs and 34 sub KPI areas.	Please refer to the BIM approach in Combined BIM/KPI section for additional information	BIM has been considered carefully through the usage of a previous studies BIM example, and thus there was a clear direction on how BIM shall be included within the SLAMBIM process and has been linked with the Penn state study.	There has been absence of the BIM elements that the SLAMBIM process shall include according to this study, which raises a concern on duplicating other researcher's work within this process for using BIM, and thus success to the SLAMBIM process will be regarded to the usage of the Penn stage BIM organisational profile.
Measurement model for BIM Maturity. **US (2014)**	Organisational Maturity	The five factors of BIMM reduced to four dimensions and 16 BIM maturity areas.	16 BIM maturity areas existing in the model development.	the tool can operate within other organisations in the US and globally, and thus a practical approach towards validating the model elsewhere and relying wisely on its outcomes.	Raises an issue on the adaptability of this model within other projects that are available, and thus the need to examine the model within various projects to validate it.
ARUP BIM Maturity Measure- UK (2014)	**Project Maturity**	**Levels 0-5 known as: 0) Non existent, 1) Initial, 2) Managed, 3) Defined, 4) measured, and 5) Optimising. Percentage of 100%**	**Project stage, Disciplines scored, and Extranet / CDE, Project Information Management, 4 primary, 21 secondary. 5 maturity levels from 0 (Non existent) to 5 (optimising).**	**BIM elements related to BIM level 2 outcomes for the UK, as well as including a scoring system which was similar to a previous study, which shows that they have managed to reflect on the previous study and enhance their maturity measure tool, and thus deliver a tool to be used for other organisations in the UK.**	**It was recognized that this tool was complex as it contained a set of assessment for the secondary project discipline, which address an issue on combining the assessment for the project in total so that all disciplines could reflect upon and avoid confusion on the 21 secondary project disciplines.**
BIM cloud score. **US (2014)**	Project (Model) Maturity	BIM performance score on BIM projects. The model includes 6 categories: modelling productivity, effectiveness, model quality, accuracy, usefulness and economy	BIM Cloud Score allows an overall view of BIM utilization in the AEC industry and facilitate performance improvement for individual companies.	the delivered application shall be applicable to all BIM users in the industry since they will use it effectively, and thus an effective approach towards validating the application amongst the wider industry.	the cloud score shall focus on the model outcomes and neglect the project along with the organisational level, which may reflect on the delivered application, and thus may be required to examine it amongst different levels of the construction industry.

Existing additional BIM maturity models/ assessment / tools / frameworks					
Model Name	**Maturity type**	**Maturity measure**	**Elements and Categories**	**Strengths**	**Weaknesses**
BIM deliverable matrix, ACE Building Information Modelling: An Introduction and Best Methods Approach. **US (2008)**	Organisational Maturity	The BIM Deliverables Matrix includes 15 other applications that create data that can be used in BIM models.	BIM deliverable matrix lists BIM services and deliverables at each phase of a typical BIM project against three implementation levels, as well as the types of software used by different stakeholders.	ACE (2008) presented the BIM deliverable matrix that ***"indicates the many types of modeling tools used by different members of the project team at each phase of the project"***, and thus the matrix shall serve the purpose to distribute the modelling tools that could be used different phases of the projects by different team members.	According to the ACE (2008) ***"A single model must contain all the stakeholders' information"***, which shows that stakeholders information may be spread in multiple models, and therefore result in missing information being delivered to the models.
Paradigm trajectories of building information modelling practice in project networks. **US (2009)**	Project Maturity	4 paradigms, Known as: 1) **Visualization Paradigm, 2) Coordination Paradigm, 3)** ***Analysis Paradigm, 4) Supply Chain Integration Paradigm***	It demonstrates that with increasing project experience, firm-level BIM practice paradigms evolve cumulatively along a trajectory from *visualization*, to *coordination*, to *analysis*, and finally to *supply chain integration*.	According to Taylor and Bernestein, (2009) not only this presented a new aspect of view BIM as paradigms, but to understand its influence amongst organisations and its evolvement within them, and thus this may be validated across the industry.	There was an absence to the BIM elements that are required to represent the BIM formation in this model, and as a result this study may not be eligible for BIM maturity assessment outcomes elsewhere.
A multi-standpoint framework for technological development- The 'BIM Schema. **Slovenia (2011)**	Project (Model) Maturity	**Technological advancement through 3 lifecycles: 1)** The lifecycle of a building project, 2) The lifecycle of BIM technologies, and 3) The lifecycle of a BIM Model	A BIM cube framework (The 'BIM Schema) on 1) BIM Schema development, 2) BIM Schema implementation, 3) BIM Model sharing and 4) BIM Model Development. The development 'BIM Schema' should improve gradually.	This study has managed to deliver new perspective to view BIM maturity as a BIM schema cube framework that aims to track development on a BIM model from, and thus a new method to assess a BIM model has been introduced in this study.	According to Cerovsek (2011), external data structures could reflect negatively on the BIM cube framework and cause redundancy, and thus a review on the BIM schema may be required to avoid this implication.
A study on BIM capability evaluation for design organization- **Korea** (2011)	Organisation Maturity	Diagnose tool related to BIM project execution ability.	Diagnose tool related to BIM project execution ability, based on the CMM BIM's ability to perform domestic architectural design organization diagnostic.	Since the only information available was the relation of the diagnostic tool with the CMMI BIM, then it may be stated that the assessment managed to consider a previous assessment to develop its tool, which was informed that it was able to perform domestic architectural design organization diagnostic.	The researcher did not manage to collect the necessary data for this assessment method, and thus the main weakness of this study was the unavailability of sources to evaluate the assessment and compare it with others.
Building information modelling (BIM) framework for practical implementation - BIM Practical Implementation Model. **Korea** (2011)	Project Maturity	Practical implementation with six major variables classified into three dimensions in a hierarchical structure. The three dimensions include 'BIM technology', 'BIM perspective', and 'construction business functions'.	Among the three dimensions, 'BIM technology' is then further divided into six categories; 'property (D0)', 'relation (R0)', 'standards (S0)', and 'utilization (U0)'. Perspective (P0) and Construction business functions (F0).	This study delivered a comprehensive framework that was based from the literature reviewed, and therefore a practical step towards validating the framework in the Korean construction industry.	According to Jung and Joo (2011), a complex BIM framework has been presented which has not relied that much on the maturity requirements, and thus this framework may not be eligible for comparisons with other BIM maturity assessments , and therefore may not be used in other industries.
A BIM Integrated Management Model. Design process maturity level. Brazil (2011).	**Project (model) Maturity**	**4 Levels of maturity on a model, 1) Level of development, 2) Business goals, 3) Geometric compatibility, 4) Design process planning and control**	**Please refer to the BIM approach in Combined BIM/KPI section for additional information**	**The proposed BIM Integrated Management Model (B.I.M.M) through its 4 loops and 11 steps along with their goals and measures helped to deliver a full understanding on how the proposed cycle shall operate within this study, and therefore the cycle was examined successfully within the selected case studies.**	**This study has treated BIM as a LOD, which shows that the study has narrowed down the areas of BIM to specific area within a delivered model through a set of quantitative measures, and therefore there has been a lack of coverage to the elements of BIM within the presented study.**
Roadmap for implementation of BIM in the UK construction Industry- **UK** (2012)	Project Maturity	3 maturity stages: (1) Stage 1 (object-based modelling). (2) Stage 2 (model-based collaboration). (3) Stage 3 (network-based integration).	BIM implementation focuses on 3 areas: 1) Organisation culture, 2) Education and training., 3) Information management. the UK construction industry has clear evidence of BIM use in Stage 1 maturity level.	The study delivered a roadmap that could be standardised across the UK, which was the 1st study to present BIM maturity through a cognitive map.	The presented study did not deliver an outcome that was related to BIM maturity assessment of 5 level maturity nor deliver as assessment across the case studies.

Existing additional BIM maturity models/ assessment / tools / frameworks continued					
Model Name	**Maturity type**	**Maturity measure**	**Elements and Categories**	**Strengths**	**Weaknesses**
BIM Capability Compass and Upskilling toolkit BIMTASKFORCE BIM Knowledgesmart.net- **UK (2013)**	Organisational Maturity	Capability assessment on 8 BIM documentation processes and based on the 5 maturity levels.	A capability assessment provided by the BIMTASKFORCE that aims to assess organisations on their maturity of 8 BIM documentations known as: 1) Collaborative Management: BS1192: 2007, 2) Design Management: BS7000-4:2013, 3) Library Objects: BS8541, 4) Information Management (CAPEX): PAS1192-2:2013, 5) Information Management (OPEX): PAS1192-3:2014, 6) Information Exchange: BS1192-4, 7) Soft Landings: BS8536, and 8) Security: PAS1192-5.	This study has managed to deliver as assessment criteria that assessed the 8 BIM documentation and their levels of adoption in the industries, and thus this assessment tool has been targeted amongst all construction industries, and therefore the presented results may reflect positively on the industries to enhance its adoptions of BIM.	The Capability Assessment examines organisations on 8 BIM documentation processes, which shows that there is lack of necessary coverage to the essential requirements of assessment on BIM, and thus this assessment may not be eligible for validation across the UK industries due to its narrowed focus on limited information related to the overall requirements of BIM.
Key Performance Indicator on Benefits of BSC-based BIM and Validation Methods- Korea (2013)	Organisational Maturity	10 performance areas of BIM based process . Classification of BIM functions by the construction stage for development of performance indicator through 4 stages.	Please refer to the BIM approach in Combined BIM/KPI section for additional information	This study has presented BIM in all of its stages from planning to the maintenance, which shows that the author has given a careful consideration on how can BIM be operated within different stages of an organisation	The poor Usage of KPIs in this study has delivered a weak linkage with the well presented BIM previously, and the data collected might not be valid for such a linkage.
Assessing the BIM Maturity in a BIM Infant Industry- **Sri Lanka (2013)**	Organisational Maturity	4 components: 1) Collaborative Processes, 2) Enhanced Skills, 3) Integrated information and Automated Systems, and 4) Knowledge Management	In-depth assessment of narrow scope of earliest BIM Maturity or immediate maturity or zero maturity. The Integrated Design and Delivery Systems (IDDS) was found to be definition of ultimate maturity of models for BIM.	This study has reviewed 2 previous models (Maturity index- (Bew and Richards, 2008) and Succar BIM maturity matrix- (Succar (2009a) and developed their maturity framework based on 4 components, which shows that there has been an attempt to link the framework with previous attempted models, and thus deliver a framework that shall be linked somehow with the previous maturity assessments.	It was stated that In-depth with each of the 4 components will be required to develop a proper assessment criteria and tool through embracing the 2 maturity models to develop a higher level of maturity assessment, which signifies an issue on the development of this framework and on what basis it was developed upon.
BIM ORGANISATIONAL READINESS FRAMEWORK **Malaysia (2013)**	Organisation Maturity	Organisational readiness based on a criteria of 4 elements to assess BIM maturity of organisation. A radar chart of 5 levels (Importance and Criteria) demonstrates the results	4 elements of People, Management, Process and technology, 3 categories under each element, and a set of criteria under each category	The readiness framework developed to assist the design consultant to identify the readiness gap of the company and support improvements in the design consultants practice through their implementation and use of BIM.	Limited information available on organisational readiness, and study conducted on just 4 companies. Depending on organisations knowledge with BIM, the framework would only work within a selective set of companies and wont be generalisable to others.
Evaluations of BIM: Frameworks and Perspectives (TOPC). **Australia (2014)**	Project Maturity	Framework on BIM enabled projects on 4 dimensions known as: 1) Technology, 2) Organization/people, 3) Process, and 4) project Context	A standardized method that accounts for contextual attributes will facilitate continuous improvement, the benchmarking project performance, knowledge sharing across the facility's lifecycle.	According to Nepal, Jupp, and Aibinu, (2014) , the TOPC evaluation criteria identified in the paper are critical for evaluating BIM-enabled projects and achieving this goal, and therefore a new approach to evaluate BIM-enabled projects has been identified in this study for future use.	According to Nepal, Jupp, and Aibinu, (2014), this study did not deliver a standard methodology for assessing BIM implementation in the project level, and therefore this study may not be permitted for standardisation in the construction industry.
Preliminary building information modelling adoption model in Malaysia: A strategic information technology perspective. **Malaysia (2014)**	Project Maturity	Collaborative processes between BIM perception and BIM adoption. BIM perception on People, Processes and Technology.	5 Hypothesis were made on the BIM perception and strategic IT in construction, 3 hypotheses were generated within BIM perception and collaborative processes, and 6 Hypothesis on the strategic IT in construction, collaboration and BIM adoption.	the findings were validated through the ongoing research targeted to enhance the BIM adoption suggested in this study, and therefore a successful approach towards delivering a validated model across the Malaysian construction industry.	This study lacked the approach to construction professionals and other construction industries, and therefore the delivered adoption model may not be eligible with all disciplines and within other construction industries, and as a result the model may not be suitable for applicability and might require changes to it.
iBIM- BIM capability self assessment tool- **UK-2014**	Project Maturity	4 Maturity levels	14 yes and no Questions responded over maturity levels	As the questions are answered, the users would able to identify where they stand when working with projects	There is no access to the tool, and questions asked would only work in the context of this study.
AHP Based Weighting System for BIM Implementation & Assessment Framework. **China (2015)**	Project and Organisational Maturity	BIM implementation framework on 5 dimensions 69 areas	The 5 dimensions as aforementioned has been relatively independent, which allow user to evaluate BIM's capability in each individual dimension e.g. project management, organisational management, data management, application management and stakeholder's involvement.	According to Chen and Li, (2015) "***a BIM usage maturity assessment framework is introduced from four main dimensions: BIM in project level, organisation level, application and stakeholder involvement"*** which shows that this framework shall serve different levels in the construction industry, and thus a practical approach towards validating it across various construction industries.	The delivered study may have not been regarded as a BIM maturity assessment framework if the author has not delivered the screenshot of the matrix used in this study, and thus this addresses an issue of the accessibility of the matrix amongst other industries, which may weaken the model and not be operated within other industries.

Existing additional BIM maturity models/ assessment / tools / frameworks continued					
Model Name	**Maturity type**	**Maturity measure**	**Elements and Categories**	**Strengths**	**Weaknesses**
BIM Macro Maturity components model. Australia (2015).	**Project and Organisational Maturity**	**5 Maturity levels driven from BIM Maturity Matrix Known as: a *(low)* b *(medium-low)* c *(medium)* d *(medium-high)* e *(high)***	**Assess the BIM maturity of countries holistically using a comparative matrix or granularly using component specific metrics. The *macro maturity components* model identifies eight complementary components for measuring and establishing the BIM maturity of countries and other macro organizational scales**	**According to Succar and Kassem, (2015) *"This paper introduced numerous new concepts, models and decision support tools for macro BIM adoption assessment and planning"*, which shows that the new additions delivered in this study supported the development of the model and has enhanced it, and thus a practical approach towards validating the model in the construction industry.**	**This study has introduced 8 BIM elements that were used in the assessment which seem to be relatively low, and they may not be linked with BIM level 2 requirements, and thus although the success of this model, but it may not be eligible in other countries like the UK , which expects its projects to be operated in a BIM level 2 environment, and thus the need to revisit the model to meet requirements of the global market.**
BIM Platform Maturity Model- **Canada (2015).**	Project Maturity	2 BIM areas, 4 Key process Areas for BIM Uses, and 3 Key process areas for General BIM Capability.	A comprehensive Model Uses List provides an expanded opportunity to assess the performance of organisations against specific Model Uses. The BIM maturity assessment could take place at any time independently from projects.	This study has managed to define the maturity levels presented for the certificate achievement that will reply on a scoring criteria through the reachability percentages, which shows that it has reflected on the BIM maturity and redefined them according to the study requirements, and thus an approach to adapt the model successfully on the projects.	According to Alaghbandrad et al. (2015), the mechanism presented may not be suitable for disciplines in the construction industry, and as a result reduces the reliability of the delivered mechanism amongst the construction industry.
A Study on BIM Performance Assessment Framework for Architecture Firm. Korea (2015)	**Organisational Maturity**	The 4 Perspectives and 16 BIM Critical Success Factors (CSF) have been set as a model of BIM performance assessment framework.	**Please refer to the BIM approach in Combined BIM/KPI section for additional information**	**The framework presented in this study has provided a good usage for the BIM elements that were presented in this study and the comparisons made between the 3 construction firms provides more validity on the data presented to be compared adequately.**	**This study has treated BIM as an investment in Information Technology (IT) and its elements as critical Success factors, which addresses a concern on what BIM CSF is being referred to?**
BIM Acceptance Model- **Hong Kong (2015).**	Organisational Maturity	Evaluation of BIM readiness within organisations and individuals through 9 factors.	Acceptance model that consists of 9 factor groups: 1) Organizational Competency, 2) Technology Quality, 3) Personal Competency, 4) Behaviour Control, 5) Perceived ease of use, 6) Perceived usefulness, 7) Consensus on appropriation, 8) Individual intention to accept BIM, and 9) Organizational intention to accept BIM.	According to Lee, Yu, & Jeong, (2015) ***"BIM acceptance is possible when an individual is willing to utilize BIM tools or information for their tasks and when their organization is willing to establish a cooperation system by utilizing BIM"***, which shows that utilizing BIM is an important factor that shall support the delivery of the acceptance model, and thus motivates organisations to utilize BIM.	According to Lee, Yu, & Jeong, (2015) ***"The research based on an investigation in a particular country"***, which shoes that the model was not delivered across different countries nearby, and thus a possibility that the model will not function in other countries that may weaken the models outcomes.
Development of a Multifunctional BIM Maturity Model- (2016)	**Project and Organisational Maturity**	**Stages 0-3, and sub domains related to Protocol, technology and Process**	**The BIM applications as documented are largely descriptive, i.e., in the format of qualitative data. By plotting the final scores/stages of the three domains of BIM maturity the overall picture of BIM maturity in a project can be perceived.**	**According to Liang et al. (2016), development of the multifunctional model was aimed to serve all levels of the Hong Kong industry, and thus a practical approach towards validating the model amongst different levels in the industry.**	**This study has assessed its delivered model in a single company, and hence absence of examining the model within other companies could result in the model being not functional, and therefore not being valid amongst other companies in the industry.**
BRE BIM Certification Scheme. **UK** (2016)	Project Maturity	BIM certificate of achievement through credit scores on BIM	BIM certificate of achievement through credit scores on BIM. BRE BIM Level 2 certification assesses business capability to utilise advanced 3D modelling tools and have the standards, methods, procedures, skilled staff and infrastructure in place for strict compliance with the Government's strategy.	The certificate program demonstrates compliance with PAS 1192:2 2013 and the ability to meet BIM Level 2 requirements, which shows the success of this certificate upon completion to meet the BIM level 2 requirements within the UK, and thus successful approach towards implementing BIM level 2 amongst different individuals in the construction industry.	The presented certificate shall require presence of certain requirements (i.e. BIM/CAD Procedures), which shows that not all users shall be eligible to conduct this certificate program, and thus will be limited to more qualified users, and as a result not delivered equally amongst the individuals.
BIM Level 2 Maturity / KPI assessment framework. UK (2016)	**Project Maturity**	**Maturity levels 1-3 known as (Awareness, Occasional application, Consistent application)**	**Please refer to the BIM approach in Combined BIM/KPI section for additional information**	**This study has presented a review of 6 maturity models that were believed to fit well in this study and has developed additional BIM elements (top and sub metrics) to be used for BIM Level 2, which shows that there has been additional development on the BIM through reviewing the existing BIM level 2 elements to be used for this study, and thus the approach towards delivering the necessary BIM elements.**	**The framework lacked the coverage of all available BIM level 2 maturities along with depending on a selected set of KPIs provided by them and therefore completion of this framework could have not been generalised across the UK.**

Sample of KPIs used in construction projects across the Globe						
Publication (Year)	**Method used in study**	**KPI Approach**	**KPI used in study**	**Measure level**	**Main Strength**	**Main Weakness**
Management perception for KPI in construction report (2003)	Survey of a 7 likert system to determine the perceived levels of KPIs being used	Key Performance Indicators (KPIs)are compilations of data measures used to assess the performance of a construction operation.	Quantitative, they consist of: 1) **Units/MH, 2) $/Unit, 3) Cost, 4) On-Time Completion, 5) Resource Management,** Qualititative, which consist of: 1) **Safety, 2) Turnover, 3) Absenteeism, 4) Motivation**	Organisational Level	This study has presented 15 Quantitative and Qualitative KPIs that were used, which demonstrates a decent usage of KPIs, and thus an approach towards relying on the delivered results.	There has been an absence of examining the KPIs on a project level, and therefore the need to deliver a survey on the KPIs performance on a project level.
Key performance indicators for measuring construction success (2004)	Listed set of KPIs related to project success	Measuring success of construction projects through a set of key performance indicators (KPIs)	1) Objective measures, a) Construction time, b) Speed of construction c) Time variation d)Unit cost 2) Subjective measures a) Quality b) Functionality c) End-user's satisfaction d) Client's satisfaction	Project Level	A benchmark for measuring the performance of a project has been achieved in this study, and thus the delivered data shall be permitted for validation and reliability in global construction industries.	The results obtained experienced some issues to be analysed, and thus the delivered results shall not be permitted to be validated across other projects.
Benchmarking system for evaluating management practices in the construction industry (2004)	Questionnaire with Professionals in the Chilean industry	Using performance indicators to measure the gap between individual company performance and that of the industry leader	1)Cost, 2) Due date, 3) Scope of project, 4) Safety, 5) Labor, 6) Construction, 7) Subcontracts, 8) Quality, 9) Procurement, 10) Planning	Organisational Level	The author has approached a relative high number of companies along with professionals to collect the necessary data from, and hence the factor and correlation analysis has helped to strengthen the collected data to demonstrate the KPIs, and therefore a successful approach towards validating the KPIs amongst the organisations.	This study has focused on the organisational level and has neglected the project level, and therefore the delivered results may not be valid across projects within the construction industry.
Initial metrics and pilot program results for measuring the performance of the Canadian construction industry (2008)	Rating criteria for 37 projects as a pilot study	KPIs are used as leading indicators of process performance to highlight opportunities for improvement during the process	Metrics that Cover aspects of 1) Cost, 2) Time, Quality, 4) Scope, 5) Safety, 6) Innovation, 7) Sustainability.	Project Level	Not only were the 7 KPIs suitable for this study, but the were easily understood and the information were regarded as valuable, and therefore a successful approach to rely on the delivered results.	The need to reconsider the approach to professionals and organisations to understand the necessary requirements and conduct the analysis amongst them to deliver the results that will enhance their understanding.
Performance measurement of construction firms in developing countries (2008)	Balanced Scorecard and SWOT analysis	There are different performance indicators that may affect a Critical Success Factor. Management has to select appropriate key performance indicators (KPIs) for each CSF.	KPIs from 1) Financial perspective 2) Customer perspective, 3) Internal process perspective, and 4) Learning and growth perspective	Organisational Level	The usage of both frameworks has helped to enhance the KPIs in this study and deliver a strengthened outcome that was validated in the case study, and therefore a successful approach towards considering the usage of multiple framework to deliver reliable data related to KPIs for organisations	The sample size approached in this study was not enough to examine all the KPIs delivered (i.e. customer satisfaction), and hence other KPIs might have not be examined well within the selected sample, and as a result the delivered results may not be reliable since a larger sample were required for some KPIs.
Beyond the 'iron triangle': Stakeholder perception of key performance indicators (KPIs) for large-scale public sector development projects (2010)	Iron triangle framework	Project success means different to different stakeholders which are then outlined through the KPIs	1) On time, 2) Under budget, 3) Meets specifications, 4) Efficiently (use of resources), 5) Doing the right thing (effectiveness), 6) Safety	Project Level	Alternative measures considered for the project performance supports the delivery of an enhanced KPI outcome on the project level, and thus a consideration of new measures beyond the traditional ones existed in this study that could reflect on other projects.	A lack of concentration of the CSF and KPIs existed which may reflect negatively on the projects, and thus the need to establish the necessary link between both
Leading, lagging and perceptive performance measures in the construction industry Organization (2010)	Surveys and interviews with construction companies professionals	KPIs are *indicative* performance measures that assess unfinished processes.	Key Performance Results known as: 1) KPI – leading performance measures 2) KPO – lagging performance measures 3) PerM – perceptive performance measures	Organisational Level	The author has managed to approach the necessary participants required to deliver the performance measures for, and thus delivering data that could be validated and relied on across other construction industries in Croatia for the organisational level.	Alternative strategies may be required to simplify the benchmarking system in construction companies to manage their performance, and thus lowering the scope of 3 measures which is the main goal of this study.
Project Performance Measurement on Building Construction in South Korea (2011)	Preliminary list of KPIs, In-depth survey and interviews,	To develop a framework for an effective performance measurement system that reflects characteristics of the individual project in order to accumulate a database.	24 KPIs, based on a set of 6 categories (Cost, Time, Quality, Safety, Environment, and Productivity) and 18 indicators were screened out as the set of key performance indicators.	Organisational Level	Companies have valued the performance assessment and their vitality to enhance their competitiveness amongst other companies, and thus increase the importance of the KPIs presented in this study.	The system seemed to be too complex since their relationship may influence the quantitative approach, and thus consideration on simplifying the measurement system to deal with specific performance categories that may not influence the quantitative approach.
Indicators for measuring performance of building construction companies in Kingdom of Saudi Arabia (2013)	Relative Importance Index (RII) and 24 surveys	For measuring the performance of companies and for applying benchmarking approach, that are most critical in determining the overall success of the company.	KPIs which include 1) Profitability, 2) Quality of service and work, 3) Growth, 4) Financial stability, 5) Cash flow, 6) External customer satisfaction, 7) Safety, 8) Business efficiency,	Organisational Level	The 10 KPIs presented in this study were driven from the literature and the analysis conducted amongst the industry has delivered the necessary KPIs to be benchmarked for the Saudi Construction industry, and thus a practical approach to deliver standardized KPIs amongst other construction industries in Saudi.	This study has neglected the necessary companies required to conduct the analysis with, and therefore may not valid the delivered results amongst multi functional companies in the Saudi construction industry.
Developing a Benchmarking Model for Construction Projects in Hong Kong (2013)	Reliability Interval method and Relative Importance Index (RII),	They are measures of performance, the results of which are used to predict future performance of the measured activity and to present the opportunity to change practice accordingly	KPIs: 1) Safety performance, 2) Cost performance, 3) Time performance, 4) quality performance, 5) Client's satisfaction, 6) Effectiveness of communication	Project Level	The new introduced analysis method has proved its success to deliver a benchmarked model to signify the 10 weighted KPIs to be used for the assessment of performance in construction projects in Hong Kong, and thus a successful approach towards standardising a new approach amongst construction projects in Hong Kong.	The KPIs may be interpreted differently amongst the construction industry, and thus the need to deliver appropriate quantitative indicators, and therefore a more complex approach towards validating the KPIs in the construction industry of Hong Kong.
Construction Projects' Key Performance Indicators: A Case of the South African Construction Industry (2015)	Questionnaire survey, Statistical ranking through Mean and Standard Deviations	Key Performance Indicators (KPIs) are one of the factors that constitute construction project success criteria	KPIs: 1) Construction time, 2) Profitability, 3) Project management, 4) Material ordering, 5) Handling and management, 6) Risk management, 7) Quality assurance, 8) Client satisfaction (product), 8) Safety, 9) Time predictability (project, design, construction).	Project Level	The comprehensive review of existing KPIs in previous studies were considered in this study to select the 11 important KPIs in the industry, and thus a practical approach to benchmark the KPIs in the South African construction industry.	The finding have been disagreed with similar findings from other researchers, and therefore absence of comparisons between the delivered results in this study and results that were obtained form other studies, which may weaken the KPIs delivered in this study.
KEY PERFORMANCE INDICATORS FOR CONSTRUCTION CONTRACTORS IN DEVELOPING COUNTRIES: A CASE STUDY OF JORDAN (2015)	Questionnaire survey was distributed to a sample of 550 construction stakeholders	Enabling both the measurement and comparison of a contractor's performance internally between projects and externally against other contractors	10 KPIs: 1) Cost, 2) Time, 3) Quality, 4) Health and Safety, 5) Environmental Sustainability, Socio/economic Contributions , 6) Financial, 7) Internal business factors, 8) Management and strategy, 9) Customer satisfaction, 10) Contractor Learning and Innovation.	Project and organisational Level	The 10 KPIs selected in this study were valid and valuable in delivering a benchmarking framework, and thus a practical approach to validate the KPIs amongst other industries in Jordan.	Deficiencies have existed in the project level, and thus the need to revisit the KPIs and Jordanian construction industry practices to reexamine them in the project level.

Sample of KPIs used in construction projects in the UK						
Publication (Year)	**Method used in study**	**KPI Approach**	**KPI used in study**	**Measure level**	**Main Strength**	**Main weakness**
PERFORMANCE INDICATORS FOR SUCCESSFUL CONSTRUCTION PROJECT PERFORMANCE (2002)	Framework development	Performance indicators in benchmarking projects at the project selection	KPIs that are related to 1) Client 2) Consultant 3) Contractor 4) Supplier 5) End-user 6) Community	Project Level	Not only shall this framework deliver a benchmarking system for the UK construction industry, but additionally shall consider stakeholders perceptions for the projects, and thus enhancing and strengthening the framework delivery across the UK construction industry.	Although there is the need to deliver a benchmarking system for the project performance success, however this system may become complicated if there were not reviewed carefully, and thus this may call for a complex system to benchmark project success which may affect its success in the future.
Introduction to Key Performance Indicators (2004)	Listed set of KPIs	Projects and organisations critical success are measured by number of performance measurements through the construction industry KPIs	10 KPIs know as: 1) Construction cost, 2) Safety, 3) Construction time, 4) Profitability, 5) Predictability—cost, 6) Productivity, 7) Predictability—time, 8) Defects, 9) Client satisfaction—product, 10) Client satisfaction—service	Project and organisational Level	The usage of a KPI engine helped to visualise where construction industries stands through the engine and measure levels of accomplishment within the industry, and thus a new approach to measure construction KPIs over the KPI engine was standardised in the UK.	The system provided in this study may not be suitable for the UK construction industry to try out, and thus the need to deliver a better understanding of the system and how it shall operate within the industry will be required to be provided.
KPIs: a critical appraisal of their use in construction. (2004)	EFQM excellence model	KPIs are being used within the industry as a marketing tool.	1) Time, 2) cost, 3) quality, 4) client satisfaction, 5) change orders, 6) business performance and 7) health and safety	Project Level	Usage of the EFQM model has helped projects to be benchmarked as delivery of Key performance outcomes and KPIs, which helped differentiate differences between both approaches, and thus todistinguish between the types of measures and against which criteria the measures are applicable.	The study signifies the importance for the KPIs to be fully understood in order for them to add values to be sustained amongst the construction industry, and thus additional effort required to explain the KPIs to the practice is needed.
Performance Measurement in Construction. (2004)	EFQM excellence model And Balanced Scorecard	Performance measurement framework that exist in the U.K. construction industry	1) Construction cost, 2) Safety, 3) Construction time, 4) Profitability, 5) Predictability—cost, 6) Productivity, 7) Predictability—time, 8) Defects, 9) Client satisfaction—product, 10) Client satisfaction—service	Project Level	This study highlighted a set of gaps in knowledge that aims to tackle then in future studies, which shows that the author has addressed what needs to be considered to be achieved in the future, and thus successful approach to achieve the target addressed in this study to be considered.	The selected frameworks in this study may not delivered a comprehensive performance measurement for the UK industry, and thus the need to reconsider alternative methods to enhance performance measurements within the UK construction industry according to this study.
Building a conceptual framework for measuring business performance in construction: an empirical Evaluation (2005)	block diagram, through process modelling technique (IDEF0)	Business performance measurement and success factors in construction	1) People; partners and suppliers 2) Project results 3) Customer and society, 4) Organizational business results	Project Level	The usage of IDEF0 modeling technique has helped to achieve the necessary results to trach performance measure and benchmark them, and thus the new delivered system could be used in various UK industries.	The framework may have delivered some inconsistencies related to scoring techniques, and thus reflect negatively on the delivered framework and its implication on the performance measurements in this study.
Development of Key Performance Indicators to support the building standards verification system (2012)	Follow SMART criteria: 1. Specific purpose 2. Measurable 3. Achievable 4. Relevant 5. Time-based	KPIs have been formulated to be measures of performance	KPIs that are related to the domains of : 1 - Professional Expertise & Processes , 2 - Effective Customer Experience , 3 – Operational Improvement	Organisational Level	This study presented a comprehensive KPIs distribution which was summarised in a diagram to show its reflection on the Scottish industry, and thus this presents a successful step towards benchmarking the Usage of those KPIS across Scotland in specific and UK in general.	Due to the extensive KPIs addressed in this study, this may not be eligible for the development of the assessment selection in this thesis, and thus this may not be considered in the KPIs selection criteria.
North West Construction Hub and NACF KPIs (2014)	Percentage Measures across contractors	Achievements of the High Value and Medium Value Construction Frameworks	15 KPIs	Project Level	The presented KPIs were delivered from several reports conducted within the case studies, that reflected on previous development of KPIs to deliver a UK summarised and comprehensive KPIs to be benchmarked amongst the UK	The presented KPIs may operate within the selected case study and not be generalised elsewhere, and thus more work should be required to match the KPIs along with others presented in the UK industry.
Key performance indicators (KPI's) for the construction industry (2016)	The KPI Engine provides comprehensive support for collecting, reporting and analysing data.	Performance measurement is an integral part of business management.	1) Client Satisfaction 2) Defects 3) Construction Time & Cost 4) Productivity 5) Profitability 6) H&S 7) Employee Satisfaction, 8) Staff Turnover 9) Sickness Absence	Project Level	This study has enhanced the previous one and has ensured that the usage of KPIs shall help validate the usage of KPIs, and thus a successful step towards considering the usage of the engine amongst other UK construction industries.	Due to the limited information delivered on the KPIs in this study, then this study may not reflect on the development of the KPIs in the assessment criteria selection, and therefore this may not be used in the KPIs selection criteria in this research.

Previous Literature on combined BIM/KPI metrics								
Legend	**Publication** (Year)	**BIM Approach**	**KPI Approach**	**BIM/KPI Approach**	**Data Collection Procedure**	**Findings**	**Main Strengths**	**Main Weaknesses**
BIM impact on construction projects- KPIs (9)	**BIM effects on construction KPIs. Doctoral thesis in University of Florida** (2007)	NBIMs maturity model scoring criteria	**6 KPIs Quality Control, On time Completion, Cost, Safety $ /Unit, Units /Man-hour**	Qualitative survey was administered to garner initial data about practitioners' perceptions **about the effects of BIM on construction key performance indicators (KPIs)**.	Boyd's model, which is widely known as the **OODA Loop (Observe, Orient, Decide, and Act)**	**BIM either helps them overcome design challenges or pose new challenges for integrating workflow**	Shows that BIM was linked to a previous attempted BIM maturity, and therefore an approach towards defining the process of BIM implementation in this study was clearly defined.	An implication on the necessity for BIM to effect on KPIs only or the possibility for the opposite way to occur (KPI effect on BIM), and thus the need to consider effects of BIM and KPIs together on construction industry to reflect on their combination
	KPIs: Analysing the impact of BIM in construction industry in china. (2010)	Process of sharing information in a facility life-cycle.	**5 primary BIM KPIs: (Quality, Cost, Time, Safety and Energy)**	In order to achieve the research goal based on the impact of BIM on construction industry KPIs model, a catalog of 5-KPIs was prepared in form of a questionnaire.	**Correlation test** was finally run to examine how various KPIs associate with each other.	**the core iron triangle is equally affected by BIM.**	BIM was regarded as a modelling process through a facility life-cycle, and therefore a successful approach towards adopting BIM in this study was clearly presented.	Delivery of the KPIs were also treated as BIM and was used in this study as BIM KPI, which raises a concern on approaching BIM as a modelling process through a facility life-cycle and using it as KPI outcomes and how shall both operate together.
KPIs impact on BIM implementation (8)	**The key performance indicators of the BIM implementation process.** (2010)	5 stage BIM implementation process	**11 KPIs**	How the **identified KPIs could influence the BIM implementation process**	Set of **questions** that aim to deliver KPIs.	**KPIs can form a method of comparing the success of different BIM adoptions.**	BIM was considered well within the presented study and there has been a mix usage of BIM through a set of decisions that expects to support BIM implementation process, therefore BIM has been used effectively in this study.	Usage of 1 case study throughout the whole process addresses a concern on the applicability of this linkage within other case studies, and thus signifies the need to consider other case studies to be compared within the existing selected one.
Assessment framework (5)	**Doctoral thesis in Arizona University and How To Measure the Benefits of BIM: A Case Study Approach**. (2012).	BIM as containing adequate life-cycle building information derived from the NBIMS.	**21 KPIs**	Most quantifiable benefits or KPIs chosen in this study are: **Schedule, change orders, and RFIs.**	The involvement of key stakeholders, such as Project Managers, was paramount to ensuring data was accurately captured through interviews	BIM's success is relative to the project and the organization.	BIM was linked to a previous attempted BIM maturity, and therefore an approach towards defining the process of BIM implementation in this study was clearly defined.	There has been an absence on how the KPIs could impact on BIM, and thus the need to include additional KPIs that could strengthen the linkage with the BIM outcomes.
Assessment method (5)	**Impact of BIM on KPIs in Gulf Corporate Council countries projects. Master thesis in Heriot-Watt.** (2012).	BIM is not only software but also a process that begins with the design and construction phases	**3 KPIs (Time, Cost, Quality)**	A set of questions to question BIM awareness within the GCC construction industry and Identifying the impact of BIM on KPIs.	The selection of **descriptive research** with **quantitative approach** and **electronic questionnaire via online survey** for data collection.	**BIM will have direct impact on the construction KPI'S** which will be reflected on getting better performance	Focused on collected data on what are the main drivers of BIM in the Construction Industry in GCC, which indicates consideration of regional aspects that its data could be valid.	There has been a low identification of the KPIs which were limited to 4, and thus more KPIs could have influenced the BIM implementation.
	BIM implementation throughout the UK construction project lifecycle: An analysis. (2013).	Measure the impacts of BIM use throughout the project lifecycle	**6 BIM KPIs.**	Further work on identifying a specific set of BIM related metrics and KPIs are general, but they may also be applied to BIM.	**A web-based survey package, 3 semi structured interviews** with key BIM adopters, **a five point ranking scale, the relative importance index (RII)**	Measures the metrics used to measure BIM's success in the construction industry, but wide use of metrics are being used.	The approach of BIM as a process and not a software, and therefore an effective approach towards identifying BIM and its adoption within this study.	The need to examine the delivered KPIs amongst project performances, therefore provision of correlation between the BIM and KPI deliverables.
BIM implementation within Organisations (4)	**An evaluation of the impact of Building Information Modelling (BIM) on Project Performance in the UK Construction Industry** (2014)	The impact of BIM as authoring and digital tools on UK construction Industry	**Iron Triangle of Cost, Time, Quality**	The impact of BIM on project performance in the UK construction industry by evaluating how it assists the project manager to deliver projects to budget, on schedule and to the specified quality.	Quantitative Survey was conducted to Collect data on Documentation and Current tools, BIM Awareness and Benefits, and Challenges of BIM	BIM improves general project performance. Project managers see the value and benefit of BIM more in terms of the entire life cycle management of the capital investment.	The study shows that BIM can assist project managers in their decision making and subsequently improve project performance in terms of time, cost, quality, communication and other project aspects.	Greater focus need to be placed on discussing BIM from the project managers' perspective. Greater awareness needs to be created for project managers regarding the benefits of BIM adoption. BIM's effect on project management functions are more indirect that direct.
Assessment tool (2)	**Assessing the Performance of the BIM Implementation Process within a Small Specialty Contracting Enterprise.** (2015)	BIM interactions between the project, the organizational, the institutional and the industry contexts.	**7 KPIs 1) Cost, 2) Time, 3) Productivity, 4) Quality, 5) Safety, 6) Scope, and 7) Organisational.**	To assess the performance of the BIM implementation process within the organization by measuring the predictability of key performance indicators on 8 different projects that were aggregated at the organizational level through a centralized database	The hypothesis that, over time, the implementation of BIM would improve predictability of project scope (less RFIs and Change Orders), of project budget (actual vs. estimated cost), of project schedule (actual vs. estimated duration), of project quality (less rework) and of labor productivity within the organization.	1) The analysis of the quantitative data provides an empirical view of the performance of the Organization's BIM implementation process. For the KPIs that were targeted, it is challenging to draw conclusions on the performance of BIM within the projects.	This study has presented a mix of 7 main KPIs from previous studies that were identified clearly on how they will be measured through this study, which shows an enhanced attempt to display the KPIs to be then linked with the BIM in the FM tool of the project lifecycle.	BIM was viewed as model requirements, which raises a concern on how was BIM identified and the reasons they were limited to model outcomes, and thus its expected relationship to reflect with the KPIs.

Previous Literature on combined BIM/KPI metrics							
Publication (Year)	**BIM Approach**	**KPI Approach**	**BIM/KPI Approach**	**Data Collection Procedure**	**Findings**	**Main Strengths**	**Main Weaknesses**
Role of Key Performance Indicators for evaluating the usage of BIM as tool for Facility Management of Construction Projects. (2015)	BIM is the technology being used mainly for initial phases of construction	**15 KPIs which were grouped into 5 components**	This study is an attempt to identify the Key Performance Indicators (KPI)s that affects the usage of BIM as a FM tool.	A nationwide survey was conducted. A structured questionnaire was prepared to explore the BIM usage beyond the construction phase.	in India currently BIM is used primarily in conceptual, design and development phase of a project (50%), followed by construction phase (30%) and operation phase (20%).	BIM shall be examined amongst the FM process within the project, and thus a strong relationship between the BIM and FM has been presented to link them both together.	Concerns on the BIM and KPI elements expected to be used in this study, and how they shall reflect the FM process of the project lifecycle, and therefore the need to identify the BIM and KPIs used within this study without conducting the factor analysis.
The development of KPIs to monitor early facilities management performance through the use of BIM technologies in public sector projects (2015)	The BIM process through models and the beneficial impact of the earlier involvement of the Facilities Manager.	**11 KPIs 1)** Skills and Knowledge Development, **2)** Trust, **3)** Time, **4)** Safety, **5)** Budget, **6-9)** Early FM Involvement (4 KPIs, **10)** Client Satisfaction, **11)** Waste	A set of unique KPIs to help measure the benefits of the BIM process	An extensive online survey was conducted. This was complemented by on-going interactions with all the pilot team members to help further validate the KPIs accuracy.	Percentage distribution across the identified 11 KPIs to outline client's views. The Facilities Manager can help advise the design team of the clients overall needs and should be engaged by the client at early design stage to assist in evaluating the design from initial concepts onwards.	A review of BIM processes were established to measure the impact of KPIs on the BIM process that reflects back on the client's needs and the early engagement of Facilities management teams.	The alignment of 11 KPIs on BIM through models, which although explains how this will reflect back on clients and on the early engagement of FM teams, only identifies the BIM process through models which limits the recognition of BIM as an overall process and how it would then relate further to the identified KPIs
Yield-to-BIM: impacts of BIM maturity on project performance. (2016)	6 BIM elements (i.e., strategy, BIM uses, process, information, infrastructure and personnel)	**3 KPIs 1) Time, 2) Cost and 3) Quality performance.**	The goal to explore the relation between the two aspects of BIM maturity and organizational performance between perceived elements of BIM and KPIs	A large-scale survey research among 890 Dutch AECO professionals. A Pearson correlation analysis was conducted to check for multicollinearity. Multiple regression analysis was used to test if BIM elements significantly predicted participants' ratings of performance.	The results suggest that the impact of BIM maturity on project performance may be limited. Surprisingly, few statistically reliable associations were found between maturity of BIM elements and KPIs, with strategy maturity as a reliable predictor of time and cost performance being the notable exception.	This study has used 6 BIM elements along with 20 sub-elements of BIM maturity; although the relative low number of BIM elements used within this study, however this study managed to present the BIM elements required for this study and it was used successfully to demonstrate how BIM shall be used amongst the Dutch industry.	BIM elements were limited to 6 and KPIs to 3, which raises a concern that although there has been a strong linkage between them but the need to include other elements of BIM and KPIs along with the existing ones and to examine if the linkage shall be strengthened or remain the same, since there was a limited usage of BIM and KPIs within this study.
Critical Success Factors of Building Information Modeling Implementation (2016)	BIM implementation is defined as digital modelling of a construction project for one or more purposes such as cost estimating, green building design, and facility management.	**16 Critical Success factors under the domains of human, industry, project, policy, and resource - related factors.**	This study investigates the critical success factors (CSFs) of BIM implementation in developing countries where BIM is fairly new to the construction industry.	A questionnaire survey was designed and administered to construction professionals in Turkey. Correlation analysis and an exploratory factor analysis was conducted to reveal the elemental factors that contribute to the success of BIM implementation.	Three most important factors are availability of qualified staff, effective leadership, and availability of information and technology. Human, technical, technological, and financial resources are the primary sources of success.	Beneficial for guiding senior managers of construction companies and BIM consultants in developing countries for a better implementation process and guide the industry practitioners in developing proper strategies for effective management of the implementation process.	The necessary data for the study reported in this paper was collected from Turkish firms and therefore reflect their perceptions and experiences. Data collected from a different country might produce different results. A need to producing case studies to have a better understanding of the implementation process.
A Relationship Framework for Building Information Modeling (BIM) Capability in Quantity Surveying Practice and Project Performance (2016)	11 BIM capabilities in quantity surveying practice during pre-construction stage.	Cost and Time	This research aims to identify the BIM capabilities in quantity surveying practices and examine its relationship with project performance by developing a relationship framework.	Interviews were used to serve as a purpose of pilot study to verify the BIM capabilities that identified. Questionnaire through correlation and regression was used to examine the relationship between BIM capabilities and project performance to provide a better understanding of the relationship.	Project performance in the aspect of time and cost were improved when QSs adopted BIM capabilities in their practice during pre-construction stage. it is important for QSs to focus these capabilities for project performance improvement	A relationship framework has been established to present the relationship between BIM capabilities in quantity surveying practice. This study helps to increase the awareness of BIM capabilities in the quantity surveying profession.	BIM application in quantity surveying practice has received less attention as most of the studies focused on BIM application in terms of design perspectives. QSs are still unsure of the capabilities of BIM. Specific capabilities of BIM in quantity surveying practice are the area that needs further study.
Critical success factors for facility management employer's information requirements (EIR) for BIM (2018)	Testing an employer's information requirements (EIR) template designed to meet client and facility management (FM) needs in the building information modelling (BIM) process.	CSF related to key topics of Leve 2 BIM and EIR	Research needs to focus on establishing how support can be given to clients and facility managers to help them develop well thought through OIR, AIR and EIR which align with their wider asset management strategy.	A qualitative design approach was used and triangulation of methods which included a focus group with the British Institute of Facilities Management (BIFM), semi-structured interviews with the case study Glasgow Life Burrell Renaissance Project who trialled the EIR and peer-reviews and interviews with BIM/CAFM experts from the BIM-Academy and FM180.	Specific guidance to help clients and facility managers prepare key BIM documents like the EIR are needed. They are aware of industry BIM standards and guidance but often not in detail. The Glasgow Life case study illustrated the EIR as a useful collaboration-tool to bring together stakeholders in early planning stages to understand client information needs.	This paper provides a new EIR template and guidance document ideal for practitioners in industry as a practical starting point to plan the client information requirements for BIM projects. A well-structured EIR will help ensure the right information is available to enable optimisation of running costs and utility-use over their whole life, thus contributing to long-term sustainability.	People are often overwhelmed by the sheer volume of information and do not know where to start when they need to prepare an EIR. Trying to fully understand and comprehend the BIM process is not easy due to the amount of information individuals need to read, understand and internalise. Many stakeholders are not sure where to start when it comes to preparing an EIR.
Building information modelling (BIM) impact on construction performance (2018)	Factors/dimensions of Building Information Modeling Maturity (BIMM) to be Technology, Information, Process and People (Yunfeng. Chen et al., 2016).	KPIs (result and process oriented) Cost, Time, Quality, Safety, Satisfaction, productivity the management of the following: Cost, Time, Quality, resources, Safety, communication, resources, and HR	Impact of BIM on Construction Project Success Attributes. The quantified benefit on Project Success for Contractors on BIM-assisted projects.	The methodology used for this study was a sequential mixed method approach using both qualitative and quantitative research methods. The qualitative approach was a content analysis and the quantitative approach was a descriptive analysis based on certain demographic groupings.	The BIMM indicators that were ranked consistently among the top ten by Academics were: Information Delivery Method, Data Richness, Information Accuracy, Work Flow, Document and Modeling Standard, and Quality Control. The impact of BIM on Construction from the perspective of Other AEC practitioners seems to also be largely positive.	This study added to the body of knowledge by identifying and evaluating a Key Construction Performance Indicator (CKPI) matrix. The matrix indicators and attributes were tested for the impact of BIM, and it is found that BIM has a positive impact on Project Success and Construction Project Management. As a result, BIM is found to have a positive impact on both Result oriented and Process oriented Construction Performance and the Building Information Modeling Project Success Ratio (BIM-PSR) benchmark is recommended for further study and industry use.	there appears to be multiple BIMM indicators that did not meet the criteria for being adequately addressed on BIM-assisted projects. This may be caused by a lack of knowledge and information on how BIM and its capabilities could be maximized for project adoption and implementation.

Previous Literature on combined BIM/KPI metrics							
Publication (Year)	**BIM Approach**	**KPI Approach**	**BIM/KPI Approach**	**Data Collection Procedure**	**Findings**	**Main Strengths**	**Main Weaknesses**
Qualitatively Exploring the Impact of BIM on Construction Performance (2018)	Factors/dimensions of Building Information Modeling Maturity (BIMM) to be Technology, Information, Process and People (Yunfeng. Chen et al., 2016).	Labor efficiency, construction cost, construction time, RFI's, profitability, material wastage, site management, construction re-work, and decision making, client satisfaction, worker morale, quality management and communication.	The top BIMM factors that had a positive impact on construction performance was People, Process, Information and Technology. The top 5 construction performance indicators construction re-work, communication, client satisfaction, quality management, profitability, construction safety, construction time, construction cost, decision making, labor efficiency, and material wastage.	The methodology used for this study was qualitative interviews and qualitative data analysis. Questions were designed and developed for the interview component of this study	The ranking of BIMM factors based on its influence on construction performance was: People, Process, Information and Technology. The findings also showed consistency between both academics and industry practitioners as it relates to the ranking and order of BIMM factors that influence construction performance.	Project workflows, risk and quality management along with aspects that relate to strategic planning throughout all phases of the project was identified as a very important aspect of BIM. the expected outcome from BIM as identified in the list of construction performance with a positive impact from the use of BIM, has to be mostly driven by the People and Process aspects of BIM	The initial drivers of BIM still seems to be mostly focused on the need for Technology and Information aspects of BIM. It would be more beneficial to understand what influences better construction performance and accordingly strategize implementation for an increased return on investment.
Empirical Approach to Identify Operational Critical Success Factors for BIM Projects (2019)	BIM across Project resources, project collaboration, Project life stages. 8 BIM Competency Areas.	38 CSFs.	BIM project strategy is developed around the BIM project's objectives, criteria for success, and performance measures or metrics. Proposed approach to designing the framework of IFs, and defining project objectives, CSFs and OCSFs for successful delivery of BIM projects in Taiwan.	Ten Taiwanese BIM experts were identified and invited to take part in this study. relationship analysis, ranking analysis, and mapping CSFs against the factor groups.	This study determined CSFs and OCSFs for successfully delivering BIM projects in the Taiwanese AECO Industry. Four hundred fifty-four IFs were classified under nine factor groups and eight competency areas Thirty-eight CSFs and 13 OCSFs were identified for BIM project delivery in Taiwan.	The developed framework of IFs can be adjusted to fit the needs of design, construction, and operation organisations. The proposed approach is not only generally applicable for identifying OCSFs in countries other than Taiwan, but also is capable of enabling a small team of BIM experts to identify OCSFs.	Defining performance measures for all 38 identified CSFs and monitoring the performance of BIM projects would consume too many resources and are not productive. a need to extend the approach to derive meaningful performance measures, such as key performance indexes (KPIs), from the identified OCSFs for projects and DCO organizations.
BIM applications toward key performance indicators of construction projects in Iran (2019)	Preliminary list of 15 aspects of BIM performance aspects in the construction stage.	Five key criteria of project performances of Time, Cost, Quality, Safety and environmental Sustainability.	Identify and prioritize the BIM applications toward KPIs in light of the construction stage of projects life cycle. Associations among the construction KPIs with BIM capability criteria and their relative importance are developed through Fuzzy-AHP approach.	Delphi method to customisation of the key criteria of construction project management and the preliminary list of BIM performance aspects through number of rounds. to quantify the level of importance of construction KPIs and the BIM benefits in the construction stage of the building projects via Fuzzy- AHP method by statistical means Saaty's normalization technique and triangular Fuzzy intervals.	It was identified that quality improvement, sustainable construction and construction cost reduction are top three KPIs that can be benefitted from BIM applications in the construction stage of building projects. It was also concluded that project coordination, clash detection, 4D and 5D BIM are the subsequent beneficial effects of BIM on construction project KPIs in Iran.	A basis to fill a gap in the body of knowledge namely lack of studies on the BIM based applications toward driving the KPIs in the construction stage of project life cycle. A new method introduce to allow measure of BIM and KPIs together. The proposed Fuzzy-AHP model can enhance the experts' ability in identifying the most influential aspects of BIM in the construction KPIs.	The results may not be directly applicable to the other phases of project life cycle as the scope was solely focused on the construction stage. The sample selected was relatively small and thus might not reflect the perception of the large community of Iran's construction industry.
Building information modelling and project information management framework for construction projects (Olawumi and Chan, 2019)	The capacity of BIM and its users to manage project information at both the (1) BIM Process level and (2) the BIM Product level.	Nine BIM-PIMF key indicators developed (knowledge transfer, support and improvement, regular facility upgrade, standardization of project features; and trust and open communication) that covers key areas of Cost, Time, Quality	The BIM-PIMF assessment matrix is a stratified spectrum of deliverables that is set up to evaluate the level of implementation and adoption of the BIM-PIMF framework in construction projects. Maturity assessment of 5 levels to assess BIM across the PIMF indicators.	An Explanatory Case Study (ECS) approach which involved both a "desktop literature review and pattern-matching using causal-process tracing (CPT) mechanism" (Blatter & Haverland, 2012) helped to elicit necessary data for the study augmented with four (4) case study BIM projects.	The study identified and established the three sub-criteria of the BIM-PIMF model which are the BIM process level factors, BIM product level factors, and the key indicators for a successful BIM deployment on construction project sites	To develop an effective BIM-project information management framework (BIM-PIMF) and associated assessment model for construction projects with a view to enhancing the functional management of project information.	The current framework is conceptual for use by industry practitioners. The scope of the BIM-PIMF could be extended by providing additional process level and product level factors that could be considered in assessing the level of BIM-PIMF implementation in a project.
Critical success factors for building information modelling (BIM) implementation in Hong Kong (2019)	BIM as a model, and process, and client's perspective on adoption of BIM across the industry	KPIs have been identified as CSFs of BIM processes (BIM training programs, etc..).	To identify the CSFs of BIM implementation by quantitatively analyzing the correlations between the perceptions of the major project stakeholders.	A mixed research method (structured empirical questionnaire survey and expert interviews). The study applied several statistical tools to evaluate the data and opinions collected through structured questionnaire surveys and expert interviews.	The most influential success factor relates to the client's acceptance with BIM projects, proper organizational structure to support a BIM system within the company and financial aid from the government to set up the BIM system. The expert interviewees also stressed the need for willingness from project staff members to learn and utilize BIM.	This study has contributed to the establishment of more practical and effective strategies for ensuring full adoption of BIM in Hong Kong. It has established the key drivers leading to the success of BIM implementation in Hong Kong, as well as in the perspective of construction experts on how to enhance its uptake in construction projects.	The approach of KPIs as CSFs BIM that does not address the aspects of Cost, Time, Quality for KPIs, and how it impacts on the BIM implementation process.
Exploring the critical success factors influencing BIM level 2 implementation in the UK construction industry (2020)	BIM Level 2 as per the UK industry requirements and mandate. BIM is approached based on the Bew and Richards BIM maturity levels from Levels 0 – 3.	Twelve CSFs were confirmed. • Human factors • Organisational factors • Process factors • External factors	To investigate the CSFs for BIM Level 2 implementation in SMEs, and then according to their degree of influence on the process determine their importance.	25 professionals from small and medium sized companies who were experienced in using BIM Level 2 were interviewed. The interviews were designed specifically for this study and allowed the participants to express their opinions freely.	Three new CSFs were identified from the interviews, which were: support from an external consultant, control of performance and knowledge transfer. These new factors were classified under: external factors (external consultant and knowledge transfer) and process factors (control of performance).	This study contributes to theory by identifying 15 CSFs influencing the implementation of BIM Level 2 in SMEs. This will enrich the body of knowledge of BIM due to the limited research on this topic, and the identification of three new CSFs can be considered to be a significant contribution.	This study has found that the true potential of BIM for SMEs in the UK construction sector has not yet been realised. Limitations of the study are firstly that only three case studies were taken into consideration, which will make the generalisation of the results difficult, and secondly that well as only a qualitative method was used.
Critical success factors for BIM adoption during construction phase: a Singapore case study (2021)	BIM is identified as a technological process that focuses on the adoption of BIM models across the Singapore industry	KPIs have been identified as CSFs of BIM processes (BEP, CDE, etc..). 35 KFs	To identify the CSFs of BIM adoption and implementation in Singapore's construction industry. Ranking and factor analysis for examining the CSFs on the BIM processes	This study adopted structured empirical questionnaire survey. Data analysis was done using SPSS Statistics software in order to identify the key factors (KFs) based on which the CSFs were derived for BIM adoption and implementation during the construction phase.	From a set of 45 influencing factors, 35 KFs were derived after performing ranking analysis, from which a set of 26 CSFs were finally obtained based on the factor analysis methodology.	This study has identified the CSFs of BIM adoption in Singapore, as well as in the builders' perspective on how to enhance the digitalization in construction projects.	This study has approached the identification of BIM as a technological process and KPIs as CSFs BIM, that does not address the aspects of Cost, Time, Quality for KPIs, and how it impacts on the BIM implementation process

Previous Literature on combined BIM/KPI metrics (Driven from the BIM Maturity Table)							
Publication (Year)	**BIM Approach**	**KPI Approach**	**BIM/KPI Approach**	**Data Collection Procedure**	**Findings**	**Main Strengths**	**Main Weaknesses**
BIM Tno Quickscan tool. (2010).	The development of BIM performance metrics is a pre-requisite for BIM performance improvement.	KPIs were used in a set of questions that were treated as BIM. Consists of **4 chapters and 50 measures (KPIs)**	**BIM Quick Scan'.** Introducing a new tool that can serve as a standard BIM benchmarking	**The analytical method** is a unique combination between quantitative measure and expert opinion. Each KPI also carries **a certain weighting factor.**	The BIM QuickScan is providing insight in the level of BIM within a company	The author has reviewed the previous assessment tool and outlined that no previous attempt has managed to measure BIM maturity of both the model and the organization, and thus the BIM approach in this study shall be comprehended well to avoid failure of previous BIM assessments.	Due to inaccessibility of those questions, there are issues to what are the questions that were asked, and how they shall help to deliver the necessary information for the tool, and thus the need to present the questions.
Key Performance Indicators To Analyze And Improve Management Of Information Flow In The BIM Design Process (2011).	BIM was mainly approached as a **Level of Development (LOD)**.	7 KPIs : **1) AR: Action Rate, 2) PS: Package Size, 3) WIP: Work In Progress, 4) BS: Batch Size, 5) DV: Development Velocity, 6) BN: Bottlenecks and 7) RW: Reworks.**	**A BIM Integrated Management Model** that consists of 4 loops (**1) Process Model Loop, 2) Planning Loop, 3) Control Loop, 4) Modeling Loop).**	LOD and ID key performance indicators were used in 2 case studies in this study, A set of calculations are prepared for the LOD where the aim is to assess the design's level of development as a whole	Main goal is to specifically define the KPIs for a BIM environment, and to establish how information flow evaluation will be measured in the management model	This study has presented BIM as a LOD and KPIs as ID aspects of a given model along with a set of calculations to measure the impacts of each on the given model.	This study has treated BIM as a LOD, which shows that the study has narrowed down the areas of BIM to specific area within a delivered model through a set of quantitative measures, and therefore there has been a lack of coverage to the elements of BIM within the study.
BIM Capability Maturity Model Toward performance assessment of BIM technology implementation (2012)	A conceptual assessment framework is proposed for BIM technology adoption. Six components of two-layer BIM adoption /performance metrics and four BIM adoption stages	KPI metrics can directly or indirectly represent performance characteristics	The BIM performance model aims to derive and use KPIs for BIM performance measurement.	Set of **questions** that aim to deliver KPIs.	Development of BIM Performance Assessment (BIMPA), BIM unit, BIM value, model capability and maturity, and performance evaluation and assessment procedures.	This study has introduced BIM through a performance assessment of 3 steps (Strategic decision, BIM implementation, Assessment) that has clearly considered the practical steps towards implementing BIM within this study, and therefore an approach towards adopting BIM was presented well.	There has been absence on what are the KPIs that were used in that process, how many KPIs will be used, and how linkage between the BIM and KPIs were available through the delivery of that model, which raises questions on what were the KPIs used in this study that are expected to be driven from BIM performance model to the BIM value phase
Key performance indicator on benefits of BSC-based BIM and validation methods (2013)	10 performance areas of BIM based process.	Quantitative performance measure KPI (Key Performance Indicators) to be measured should be prioritized. Uses the BSC(Balanced Scorecards)	The KPIs which are used for measuring the effect of the BIM will be generated.	The involvement of key stakeholders, such as Project Managers, was paramount to ensuring data was accurately captured through interviews	The KPI created in accordance with the process presented by this study will become the key point in developing tools for performance measurement with objective quantitative and qualitative assessment,	This study has presented BIM in all of its stages from planning to the maintenance, which shows that the author has given a careful consideration on how can BIM be operated in different stages of an organisation.	There has been an absence of KPI identification through (Time, Cost, Quality, etc..) which raises an issue on the validity and reliability of presented data to be considered for future use within the organisation.
Goal-Driven Method for Sustainable Evaluation of BIM Project Success (2014)	25 BIM uses identified by the Computer Integrated Construction research program at Pennsylvania State University	6 main KPIs: **1) Number of change orders, 2) Happiness level of project participants, 3) Response time, 4) Cost overrun, 5) Schedule delay, and 6) Task productivity.**	SLAMBIM involves identifying the BIMKPIs. To identify the appropriate performance indicators (PIs) for assessing the success of a project, two steps are required.	The selection of **descriptive research** with **quantitative approach** and **electronic questionnaire via online survey** for data collection.	Collectability, measurability, and comparability of the candidate BIM KPIs were also investigated by the project participants of the two projects to extract the appropriate BIM KPIs for the projects.	BIM has been considered carefully through usage of previous studies BIM examples, and thus there was a clear direction on how BIM will be included in the SLAMBIM process and has been linked with the Penn state study.	There has been absence of the BIM elements that the SLAMBIM process shall include according to this study, which raises a concern on duplicating other researcher's work within this process for using BIM.

Previous Literature on combined BIM/KPI metrics continued (Driven from the BIM Maturity Table)							
Publication (Year)	**BIM Approach**	**KPI Approach**	**BIM/KPI Approach**	**Data Collection Procedure**	**Findings**	**Main Strengths**	**Main Weaknesses**
A Study on BIM Performance Assessment Framework for Architecture Firm (2015)	BIM considered as an investment in Information Technology (IT). 4 Perspectives and 16 BIM Critical Success Factors (CSF) have been set as a model of BIM performance assessment framework.	22 Key Performance Indicators (KPI) under the assessment model, as indexes to assess BIM performance.	Most of the KPIs are measurable, and that the BIM performance according to the size and characteristic of design firm can be represented by KPIs.	A web-based survey package, 3 semi structured interviews with key BIM adopters, a five point ranking scale, the relative importance index (RII)	This study developed the KPIs for assessing BIM performance and verified its validity.	The framework presented in this study has provided a good usage for the BIM elements that were presented in this study and the comparisons made between the 3 construction firms provides more validity on the data presented to be compared adequately.	This study has treated BIM as an investment in Information Technology (IT) and its elements as critical Success factors, which addresses a concern on what BIM CSF is being referred to?
BIM Level 2 Maturity / KPI assessment framework (2016)	A review on the BIM implementation in the UK construction strategy, outlining the BIM level 2 processes and guides, and selection of 6 maturity models	A review on the KPIs, An outline on a supply-chain procurement platform selected as a case study for this research. They have produced a total of 15 KPIs,	An attempt to deliver a framework for a BIM level 2 maturity / KPI assessment. A set of focus group meetings were conducted to deliver a practical framework to be applied within the platform that consisted of a 4 stage element.	The hypothesis that, over time, the implementation of BIM would improve predictability of project scope (less RFIs and Change Orders), of project budget (actual vs. estimated cost), of project schedule (actual vs. estimated duration), of project quality (less rework) and of labor productivity within the organization.	Due to the framework's complexity, then the scope of this research has been simplified since it was realised that more data will be required to link the collected BIM information with the KPIs. Due to the existence of several BIM level 2 criteria, then a selection criteria was suggested.	This study has presented a review of 6 maturity models believed to fit well in this study and has developed additional BIM elements to be used for BIM Level 2, which shows that there has been additional development on BIM through reviewing the existing BIM level 2 elements to be used for this study, and thus the approach towards delivering the necessary BIM elements.	The researcher could argue that since this framework depended mainly on the selected case study, then even if the framework was fully developed it would have not been generalised and thus been applicable in different UK construction industries.
MoJ BIM maturity assessment tool / KPI system (2016)	8 BIM level 2 outcomes used to measure the overall application of BIM level 2 maturity on projects:	KPIs will be developed at strategy stage and tested throughout programme. BIM treated as KPIs	The system aims to assess BIM maturity outcomes across 6 RIBA stages and the BIM maturity are treated as KPIs.	A nationwide survey was conducted. A structured questionnaire was prepared to explore the BIM usage beyond the construction phase.	No findings are currently available on this system, but it is expected that the set of questions is to be attempted for the MoJ (Client) to see how the Project BIM maturity, along with the Client and Supplier BIM delivery shall be scored across the UK construction industry for each of the RIBA stages	This study has presented a comprehensive review on the BIM level 2 maturity outcomes which were presented in the description overview of the system and have been classified and described to acknowledge users what is meant by each.	The researcher could argue that this framework is currently a BIM maturity assessment tool since it expects to assess BIM level 2 outcomes on Projects and aligned with client and suppliers outcomes.
Development of KPIs of BIM performance measurement in design phase (2016)	Assessment tool on 4 performance areas (Corporate Contribution, User Orientation, Operational excellence, Future Orientation. Radar chart presents the results. BIM score on 5 levels	21 KPIs that are BIM related under the 4 performance areas	An assessment of the 21 KPIs on the BIM performance areas that would provide the potential linkage of both	A set of questions with 5 point Likert scale used across 41 construction firms to assess the BIM performance through KPIs related	The findings show that the BIM scores were more towards the left with scores leaning between 2 to 3, indicating bad to normal. The study helped to deliver a guidance for construction firms to see where they are in regards to BIM	The BIM Performance Measurement system helps to visualise the BIM benefits and positive effects of BIM investment in a systematic way to support decision making. Provides fully information on integrated performance and improving competitiveness of firms	There has been an absence of KPI identification through (Time, Cost, Quality, etc..) which raises an issue on the validity and reliability of presented data to be considered for future use within the organisation.
BIM Service Level Assessment in Construction Phase (2018)	The assessment of the BIM Services may be broadly classified as an assessment of services and performance in the BIM implementation through a service assessment model	Cost, Time, Work efficiency, User satisfaction.	3 KPI for analysis of BIM service benefits, schedule performance, cost performance and work efficiency are suggested.	A Survey on BIM Services was carried out on BIM experts. Also, case study was conducted on how BIM maturity and BIM application effectiveness were analyzed to derive the evaluation methods of the BIM services.	The interference review between construction works using BIM is most frequently utilized and it is indicated that the quality and safety management using BIM techniques are "Minimum"or "Low".	This study suggested performance assessment of the BIM service and the effectiveness analysist hrough the fulfillment of the service.	There is no clear definition of how beneficial the utilization of BIM is to the overall outcome of the construction project
Development of a conceptual model for evaluating the success of BIM-based construction projects (2020)	BIM EFFECTIVENESS [Extent of BIM application on projects]. BIM maturity based on 4 levels very Low, low, High, very high	BIM IMPACTS [Appropriate project expectations]. Client, consultant, industry, contractor, supplier, and subcontractor satisfaction, and Time, Cost, Quality, health and safety performance,	Effects of the performance of BIM application on the performance of project success criteria. (PROJECT SUCCESS OF BBCPs)	A thematic-synthesis of published peer-reviewed research on the evaluation of PS and impacts of BIM on projects was selected for this study. The selection of this research approach was based on the need to achieve a fuller comprehension and interpretation of BIM impacts on project and PS evaluation	Eight success criteria for BBCPs were extracted and categorised according to BIM's ability to impact them across four levels of project application. the findings indicate that an increase in the number of PS criteria (PSC) for a BBCP is a derivative of BIM effectiveness, and not BIM impact.	The project will deliver a level of performance that can be measured against an initial set of success criteria. Improvement is to be expected in the performance of the targeted PSC, commensurate with the level of BIM application.	The existing concepts of evaluating the PS of BBCPs have only focused on the development of key performance indicators for measuring BIM performance on BBCPs. The key performance indicators that they propose for measuring BIM performance on BBCPs and the BIM impacts were not linked together

Appendix C: Chapter 4 Additional Information on BIM maturity assessment (Aboumoemen, 2016)

BIM Level 2 maturity assessment (The What)				
Organisation			Top Metrics	Sub Metrics
No #	level		Main BIM maturity levels and their descriptions that are expected to be measured for achieving BIM level 2	Secondary levels within the main BIM maturity levels that is expected to be measured and to achieve BIM level 2
1	STRATEGIC (Organisational and project levels that are being managed by the organisation team)	a	Collaboration (Collaborative behaviour strategies expected to be present in a complete project to meet BIM level 2)	1) Collaboration process
				2) Processes and Standards
				3) Roles and Responsibilities
				4) Contractual agreements
				5) Champion engagement
			(Implementation)	6) Level 2 Education and Training
			(Implementation)	7) Procurement route
			(operational)	8) Collaborative protocols
		b	Employers' requirements (Defining stakeholder needs for projects to be able to achieve BIM level 2)	1) Specialist Consultants engagement
				2) Design elements
			(Implementation)	3) Information Requirements (EIR)
		g	Facilities Management (operational)	9) GSL champion engagement

BIM Level 2 maturity assessment (The What)				
Organisation			Top Metrics	Sub Metrics
No #	level		Main BIM maturity levels and their descriptions that are expected to be measured for achieving BIM level 2	Secondary levels within the main BIM maturity levels that is expected to be measured and to achieve BIM level 2
2	IMPLEMENTATION (Implementing BIM across the organisation, placing data and setting up information in place)	a	Collaboration (both strategic)	6) Level 2 Education and Training
				7) Procurement route
		b	Employers' Requirements	3) Information Requirements (EIR) (strategic)
		c	Processes (Defining project needs to identify project requirements to achieve BIM level 2) (operational)	1) Information Management Documentation
				2) Uses
				3) Supplier assessment forms
				4) Implementation Plan (PIP)
				5) Execution Plan (BEP)
		d	Delivery (Setting out all deliverables that are required from team members to achieve BIM level 2) (operational)	1) Master Information (MIDP)
				2) Task Team Information (TIDP)
				3) Responsibility Matrix (RM)
				4) Construction Programme (CP)
		e	Sharing (Distribution of information amongst stakeholders that is shared effectively amongst them)	1) Document management stage (CDE) (both operational)
				2) Information Exchange
		g	Facilities Management (All operational)	1) Manuals
				4) COBie data
				8) Facilities management Training

BIM Level 2 maturity assessment (The What)				
Organisation			Top Metrics	Sub Metrics
No #	level		Main BIM maturity levels and their descriptions that are expected to be measured for achieving BIM level 2	Secondary levels within the main BIM maturity levels that is expected to be measured and to achieve BIM level 2
3	OPERATIONAL (Operating BIM across the organisation, and how is the collected information being achieved)	a	Collaboration (Strategic)	8) Collaborative protocols
		b	Processes (Implementation)	4) Implementation Plan (PIP)
		d	Delivery (Implementation)	4) Construction Programme (CP)
		e	Sharing (both implementation)	1) Document management stage (CDE)
				2) Information Exchange
		f	Capital Delivery (Model inputs, simulation and analysis for the Design and construction stages that is expected to be reviewed and verified by the project team to transfer to the next phase and achieve BIM level 2)	1) 3D – 6D inputs
				2) Component Drawings
				3) Level of Details (LoD)
				4) File transfer standards
				5) Project reviews
				6) Lifecycle Analysis
				7) Modelling simulations
				8) Project Information Model (PIM) exchanges
		g	(implementation) Facilities Management (implementation) (Operational, maintenance, and lifecycle building performances that is expected to be conducted by the FM team for asset management to achieve BIM level 2) (Implementation) (Strategic)	1) Manuals
				2) Information Delivery (AIM)
				3) FM and OM use
				4) COBie data
				5) Asset Reviews
				6) Handover requirements (GSL)
				7) Post Occupancy Evaluation
				8) Facilities management Training
				9) GSL champion engagement

BIM Level 2 maturity measurement (The How)			
stage	1?	2?	3?
	Awareness	Occasional Application	Consistency
	General knowledge and understanding of BIM level 2 implementation in the organisation	Partial Application of BIM level 2 implementation and is somehow recognised, but not embedded generally	Full application and maintaining BIM level 2 implementation, embedded across projects generally, consistently recognised

Level 2 BIM maturity assessment (The What and The How) for the Strategic, Implementation, and Operational levels (Aboumoemen, 2016)

Appendix D: Chapter 5 Additional information on research methodology

Sample Population and Sample size required (Krejcie & Morgan, 1970; Sekaran & Bougie, 2013)

N	*S*	*N*	*S*	*N*	*S*
10	10	220	140	1200	291
15	14	230	144	1300	297
20	19	240	148	1400	302
25	24	250	152	1500	306
30	28	260	155	1600	310
35	32	270	159	1700	313
40	36	280	162	1800	317
45	40	290	165	1900	320
50	44	300	169	2000	322
55	48	320	175	2200	327
60	52	340	181	2400	331
65	56	360	186	2600	335
70	59	380	191	2800	338
75	63	400	196	3000	341
80	66	420	201	3500	346
85	70	440	205	4000	351
90	73	460	210	4500	354
95	76	480	214	5000	357
100	80	500	217	6000	361
110	86	550	226	7000	364
120	92	600	234	8000	367
130	97	650	242	9000	368
140	103	700	248	10000	370
150	108	750	254	15000	375
160	113	800	260	20000	377
170	118	850	265	30000	379
180	123	900	269	40000	380
190	127	950	274	50000	381
200	132	1000	278	75000	382
210	136	1100	285	1000000	384

Appendix E: Chapter 6 Additional information on ethical approval for data collection

University of Salford
The Crescent
Salford
M5 4WT, UK
0161 295 5000

Date: [............]

Address: [............]

Participant details: [............]

Dear [............]

I am a student studying the PhD in BIM and Integrated Design programme at the University of Salford. As part of my course I am conducting a research study titled: A Level 2 BIM Maturity/KPI assessment The main aim of this is: *"to develop a Level 2 BIM Maturity-KPI assessment framework for the UK client local authority public sector to assess Level 2 BIM adoption in line with the UK construction strategy".* in support of the BIM Level 2 construction strategy adoption for the UK.

Prior to undertaking the study, I need your agreement to approach the targeted group members within your organisation to take part in the study. I will recruit people to the study using the data collection methods suggested by the researcher, which will include conducting a series of workshops to collect basic information relevant to my study.

I can assure you that I will make every effort to ensure the study does not disrupt the working environment or student lectures in any way and any data collected will remain confidential. I am applying ethical approval for the study from the University of Salford, College of Science & Technology.

If you have any concerns about my research, please contact my supervisor

Yours sincerely

School of the Built Environment
University of Salford
Salford
M5 4WT

University of Salford MANCHESTER

College of Science & Technology

College Ethical Approval Panel for Taught Programmes
Example Research Participant Consent Form

Title of Project: A Level 2 BIM Maturity-KPI assessment framework for a UK client local authority public sector

Ref No:

Name of Researcher:

(Delete as appropriate)

➢ I confirm that I have read and understood the information sheet for the above study (version x- date) and what my contribution will be.	**Yes**	**No**	
➢ I have been given the opportunity to ask questions (face to face)	**Yes**	**No**	
➢ I agree to take part in the workshop	**Yes**	**No**	**NA**
➢ I agree to the workshop being recorded	**Yes**	**No**	**NA**
➢ I agree to digital images being taken during the research exercises	**Yes**	**No**	**NA**
➢ I understand that my participation is voluntary and that I can withdraw from the research at any time **without giving any reason** and the data collected will be removed from the study.	**Yes**	**No**	
➢ **I agree to take part in the above study**	**Yes**	**No**	

Name of participant:

Signature

Date: [.............]

Name of researcher taking consent:

Researcher's e-mail address:

If you have any concerns about this research that have not been addressed by the researcher, please contact the researcher's supervisor via the contact details below:

Supervisor's name:

Supervisor's email address:

Invitation Letter for Interview Participants

Dear [………….],

My name is [………………………….] and I am a PhD researcher in the School of the Built Environment, University of Salford. Currently as a requirement of my PhD, I am undertaking research on developing *"A Level 2 BIM Maturity-KPI assessment framework for a UK client local authority public sector"* This research is being supervised by my supervisor. This invitation for participation in this research has been sent to you due to your expertise and experience in the focus area of the research.

BIM has been presented in several ways but has led to slow uptake and low awareness of BIM to UK disciplines, and thus, BIM maturities are developed to assess capabilities and measure their adoption since people are able to assess where they stand and where they want to reach. This shall help to extract the benefits that could be realised from the use of BIM maturity across organisations; however, those benefits could be meaningless. As a result, KPIs are presented through project and organisational types along with different levels of accomplishment, where KPIs could be used to link them with the BIM maturities; in order to demonstrate the benefits that could be extracted from the usage of BIM maturities amongst the disciplines. Therefore, this research is focused on developing a Level 2 BIM Maturity-KPI assessment framework for the UK client local authority public sector to assess Level 2 BIM adoption in line with the UK construction strategy.

Your participation will involve an in-depth interview focused on combining both BIM Maturities and KPIs into an assessment model, in order to assess capabilities and impacts on construction multifunctional performances. This will be used to develop a Level 2 BIM Maturity-KPI assessment framework for the UK client local authority public sector to assess Level 2 BIM adoption in line with the UK construction strategy; to evaluate and examine its practicability within the UK. The interview data will be used; maintaining anonymity. Moreover, this participation is voluntary and you can withdraw from it at any stage and the data collected will be destroyed and removed from the study. Also, the interview can be arranged at a date and time that is suitable for you. **Interviews shall take approximately 1 hour (unless additional time is required and upon your agreement)**. Once again I iterate that your valued contribution to the research will be very much appreciated.

If you are interested in this research and would like to participate, kindly confirm by replying to this email. Upon confirmation of participation you will be sent further information about the research, including a participation information, informed consent form and outline of the interview. You will then be contacted to arrange a suitable date and time for interview.

I look forward to hearing from you soon, and thank you in advance for your valued input.

Best regards,

[………….]

Contact details:

If you have any questions about this study, you can contact the person(s) below:
[………….] xyz@edu.salford.ac.uk
[………….] xyz@salford.ac.uk
[………….] xyz@salford.ac.uk

University of Salford MANCHESTER

College of Science & Technology

College Ethical Approval Panel for Taught Programmes
Example Research Participant Consent Form

Title of Project: A Level 2 BIM Maturity-KPI assessment framework for a UK client local authority public sector

Ref No:

Name of Researcher:

(Delete as appropriate)

➢ I confirm that I have read and understood the information sheet for the above study (version x- date) and what my contribution will be.	**Yes**	**No**	
➢ I have been given the opportunity to ask questions (face to face)	**Yes**	**No**	
➢ I agree to take part in the interview	**Yes**	**No**	**NA**
➢ I agree to the interview being recorded	**Yes**	**No**	**NA**
➢ I agree to digital images being taken during the research exercises	**Yes**	**No**	**NA**
➢ I understand that my participation is voluntary and that I can withdraw from the research at any time **without giving any reason** and the data collected will be removed from the study.	**Yes**	**No**	
➢ **I agree to take part in the above study**	**Yes**	**No**	

Name of participant:

Signature

Date: [.............]

Name of researcher taking consent:

Researcher's e-mail address:

If you have any concerns about this research that have not been addressed by the researcher, please contact the researcher's supervisor via the contact details below:

Supervisor's name:

Supervisor's email address:

A Level 2 BIM Maturity-KPI assessment framework for a UK client local authority public sector

PhD thesis Research Topic, PhD Building Information Modelling and Integrated Design, School of Built Environment, University of Salford, M5 4WT.

* Required

Section A- Background Information

I would like to invite you to take part in a research study on the above topic. All information which is collected from you during the course of this research will be kept strictly confidential and all data will be held securely and then destroyed after three months. All information will be used only for academic purposes. Any material used will be anonymised and only summary results will be disclosed. Participation in this study is completely voluntary; if you decide not to participate there will not be any negative consequences. Please be aware that if you decide to participate, you may stop participating at any time and you may decide not to answer any specific question.

This research is part of the PhD thesis research on: "A Level 2 BIM Maturity-KPI assessment framework for a UK client local authority public sector" at the University of Salford, UK. The main aim of this is: "to develop a Level 2 BIM Maturity-KPI assessment framework for the UK client local authority public sector to assess Level 2 BIM adoption in line with the UK construction strategy".

By submitting this form you are indicating that you have read the description of the study, and that you agree to the terms as described.
Please return the completed questionnaire by the date:[...................]

If you have a concern about any aspect of this study, please contact me:
Name:
Phone:
Email:

If you remain unhappy having spoken to the researcher, you should contact the researcher's supervisor
Name:
Phone:
Email:

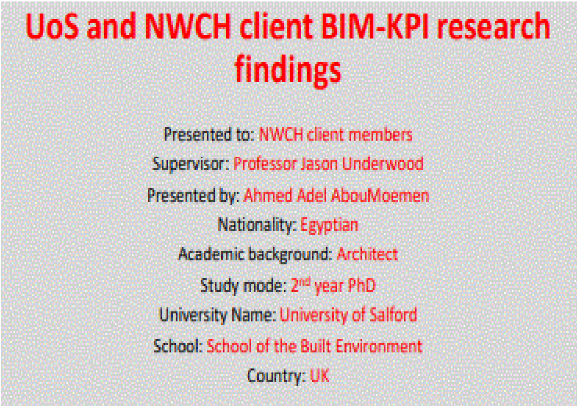
If you still remain unhappy and wish to complain formally you can do this through sending a letter setting out the details of your complaint to the researcher's Head of School:
Name:
Phone:
Email:

1) Do you agree to participate in this research study? *

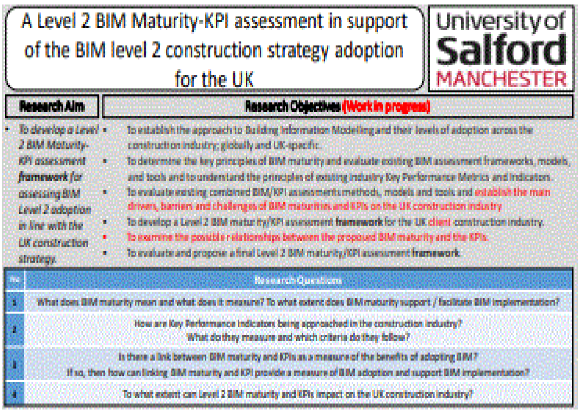
(I understand the purpose and nature of this study and I am participating voluntarily. I understand that i can withdraw from the study at any time, without any penalty or consequences.)

- ◯ Yes
- ◯ No

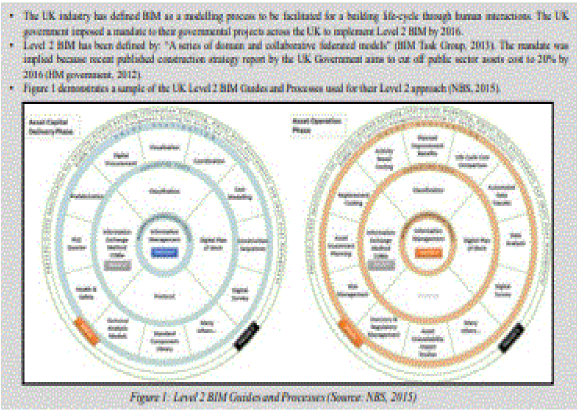
Pilot sessions presentation



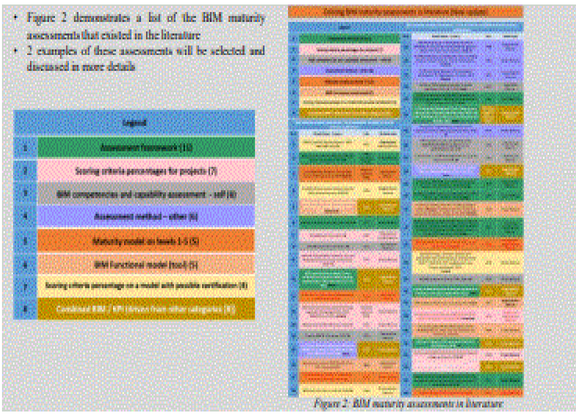
1



2

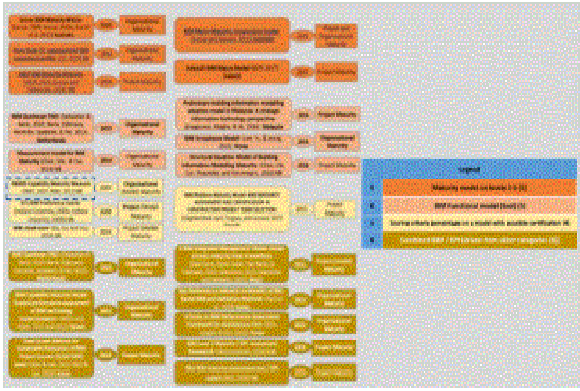


3

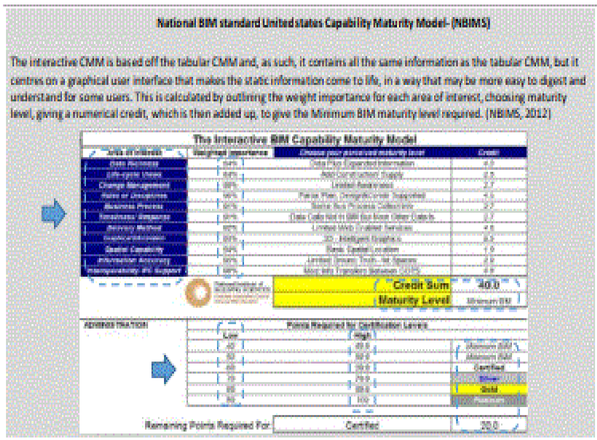


4

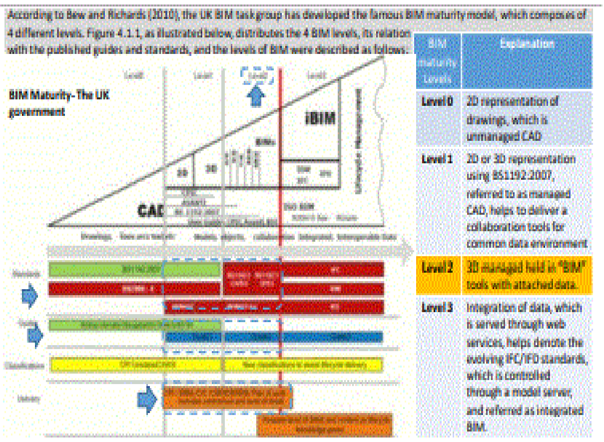
5



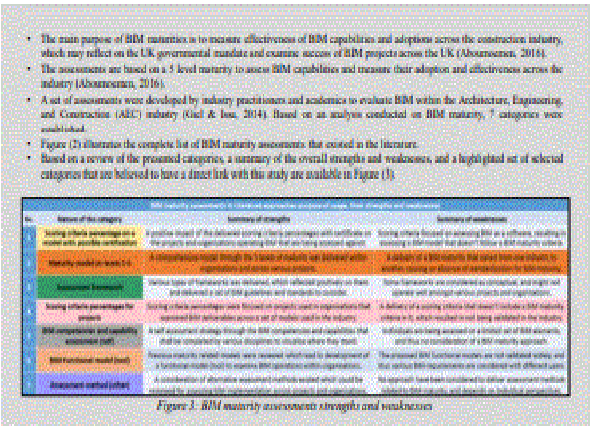
6



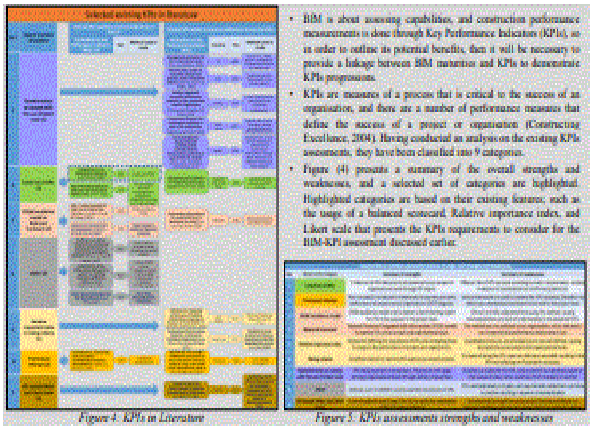
7



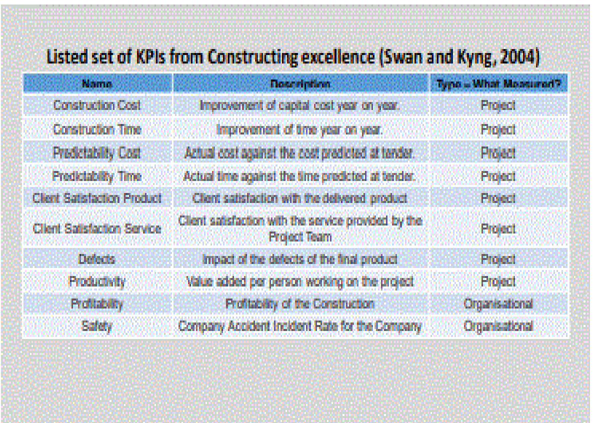
8



9

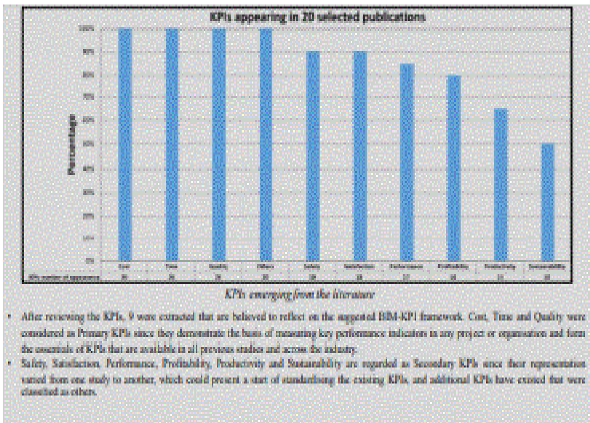


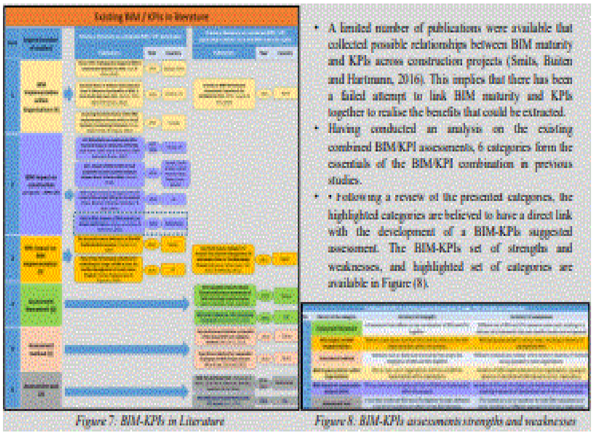
10

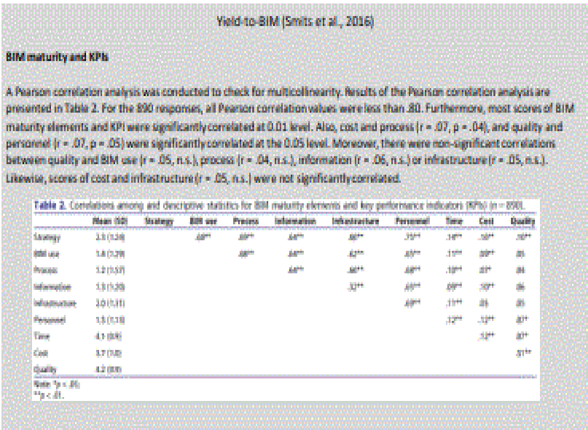


Listed set of KPIs from Constructing excellence (Swan and Kyng, 2004)

Name	Description	Type – What Measured?
Construction Cost	Improvement of capital cost year on year.	Project
Construction Time	Improvement of time year on year.	Project
Predictability Cost	Actual cost against the cost predicted at tender.	Project
Predictability Time	Actual time against the time predicted at tender.	Project
Client Satisfaction Product	Client satisfaction with the delivered product	Project
Client Satisfaction Service	Client satisfaction with the service provided by the Project Team	Project
Defects	Impact of the defects of the final product	Project
Productivity	Value added per person working on the project	Project
Profitability	Profitability of the Construction	Organisational
Safety	Company Accident Incident Rate for the Company	Organisational

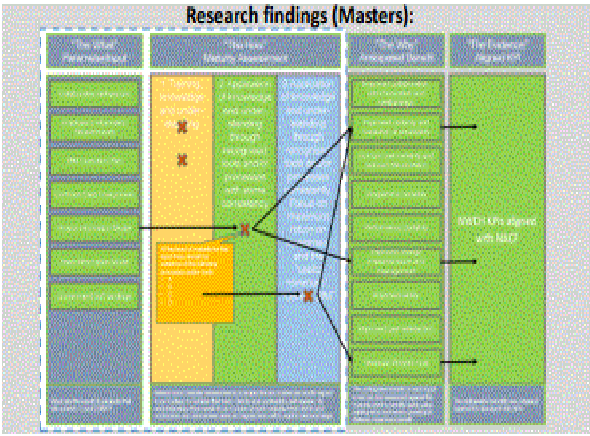






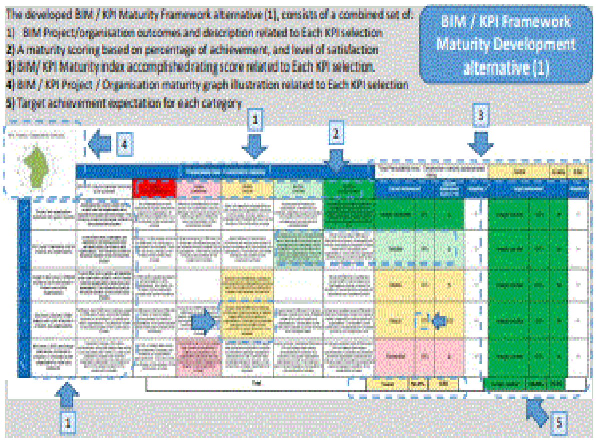
13

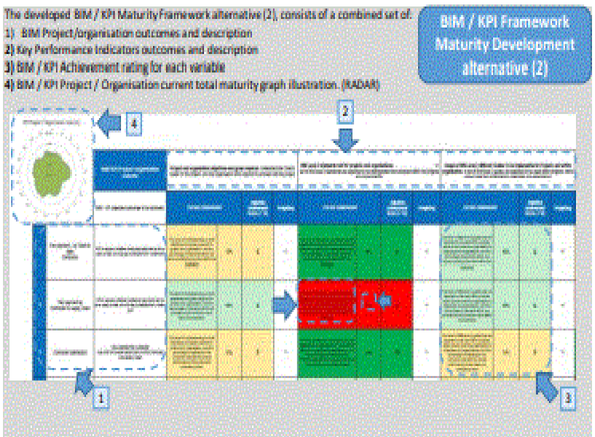
14

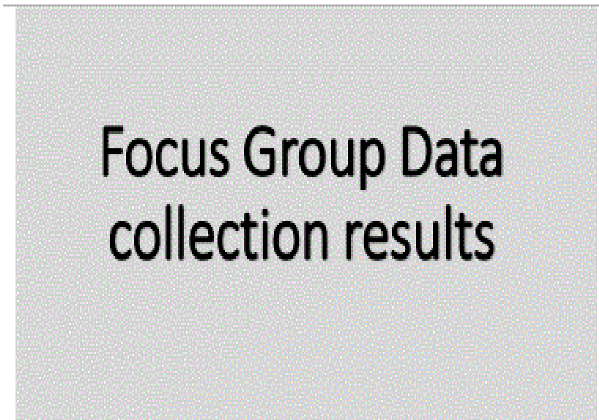


15

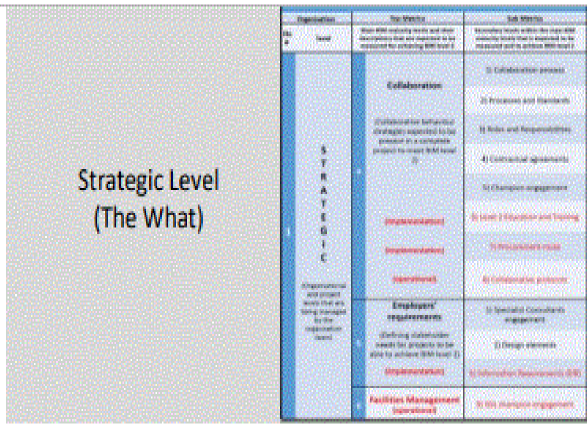
16



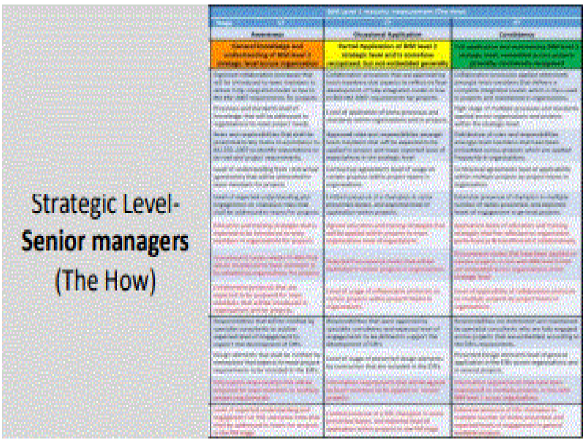




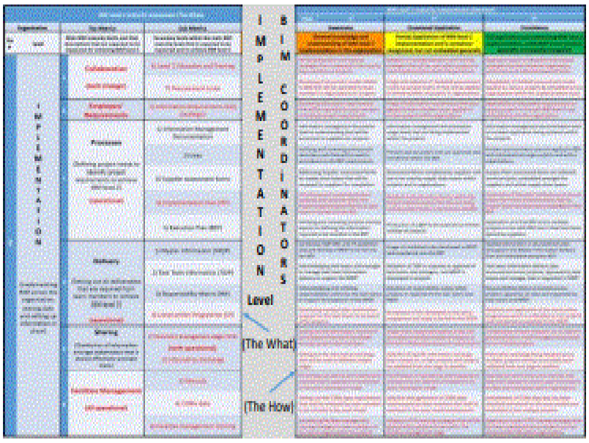
19



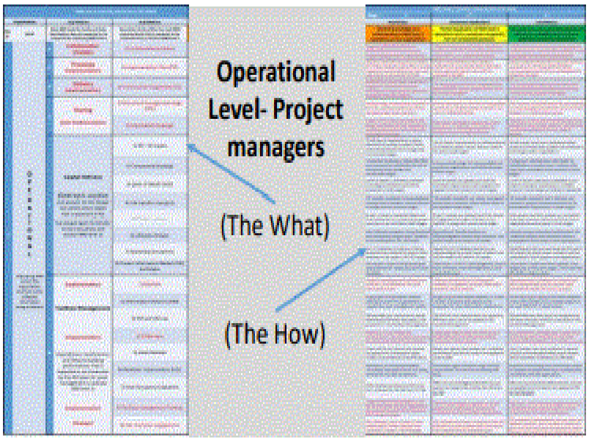
20



21

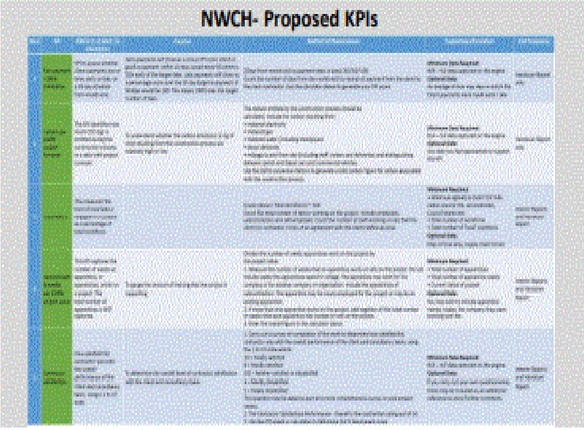


22

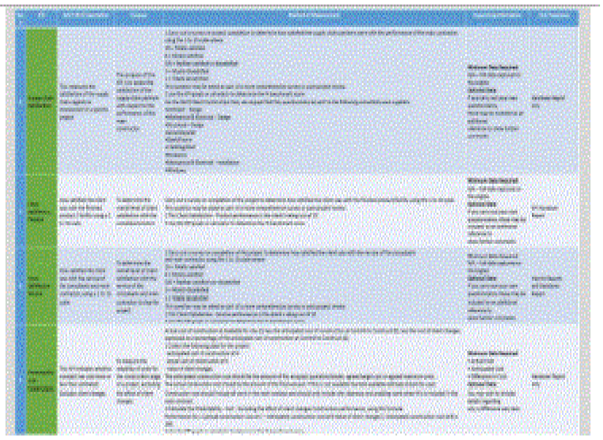


23

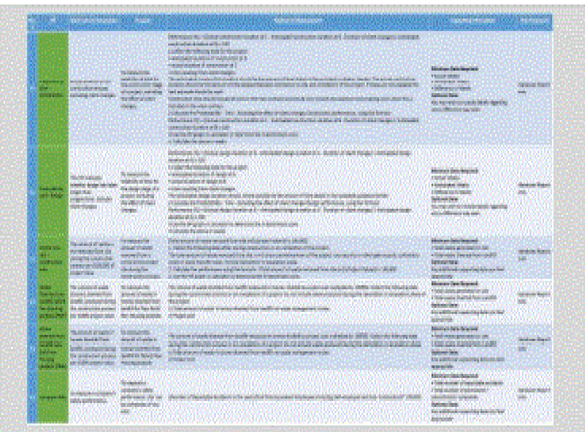
24



25



26



27

The approach to the framework (Phd):

Following a review and analysis presented in the literature, the framework has been distributed into 3 stages:

1) Level 2 BIM and KPIs begin the framework's 1st stage since it requires to identify essence of both elements.

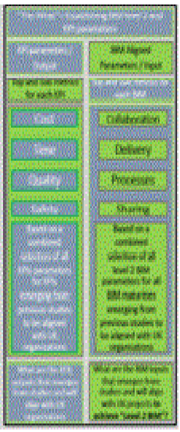
2) Level 2 BIM and KPIs assessment is then introduced to establish relationships and how assessments are expected to occur on both elements to deliver a standardised set of assessments to be considered.

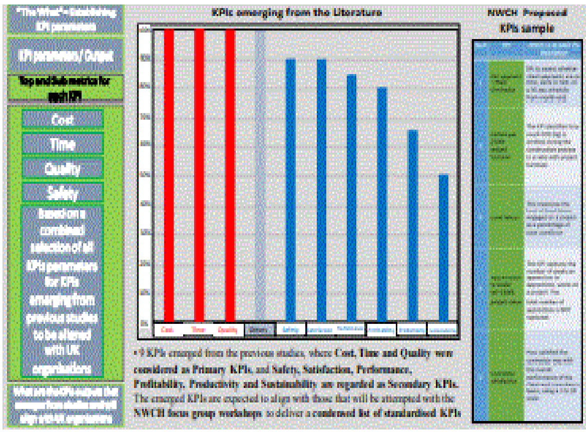
3) Benefits of aligned BIM and KPIs and their relationship assessment shall be presented to demonstrate benefits expected to emerge from the combination of both elements together.

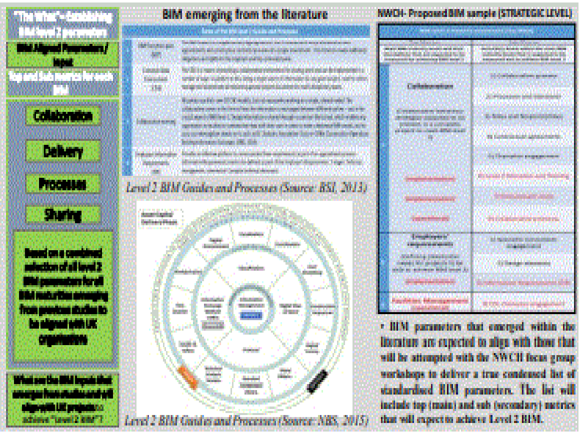
28

1st stage= Level 2 BIM and KPIs:

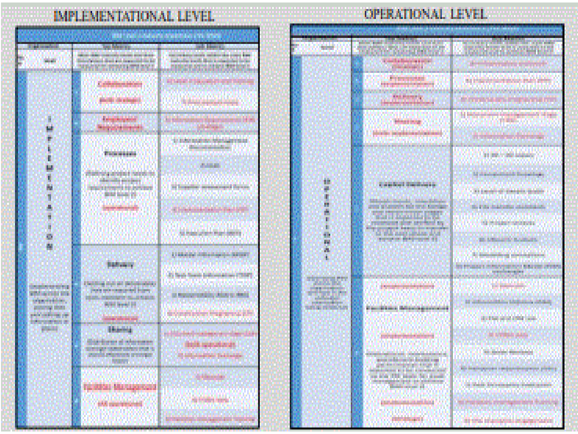
A preliminary list of BIM and KPIs separately are provided in the assessment's 1st stage, where some were presented in Figures (1 and 6). The stage has been identified as "The What" since it aims to outline what are the expected standardised elements to emerge that shall meet the UK governmental mandate on Level 2 BIM.



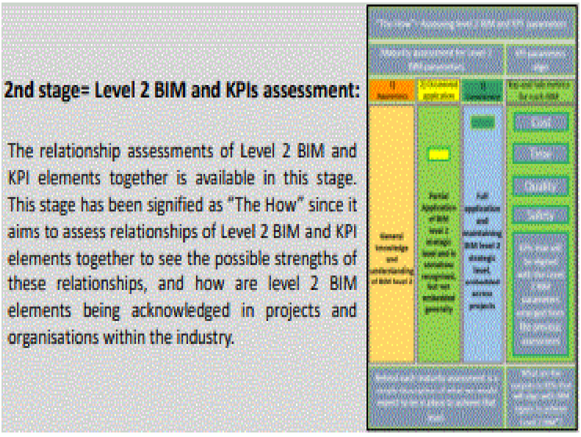




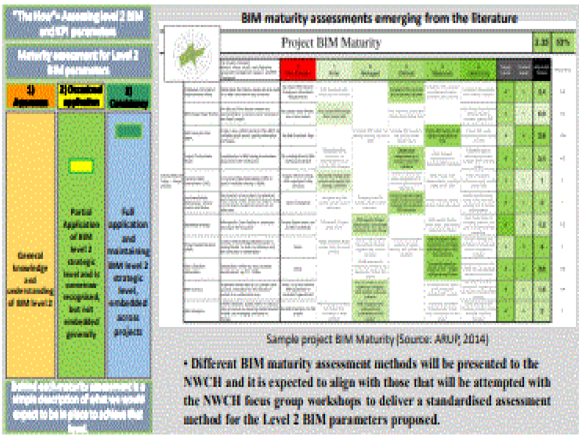
31



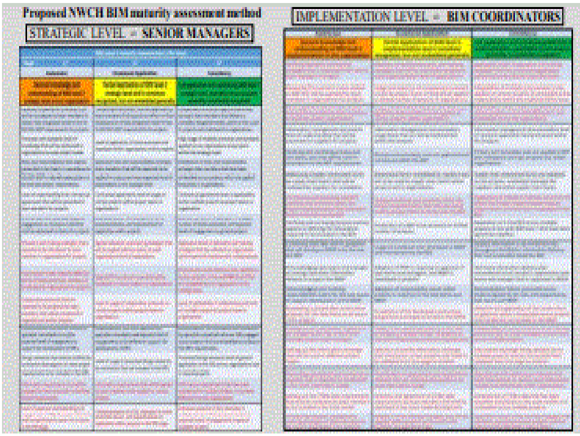
32

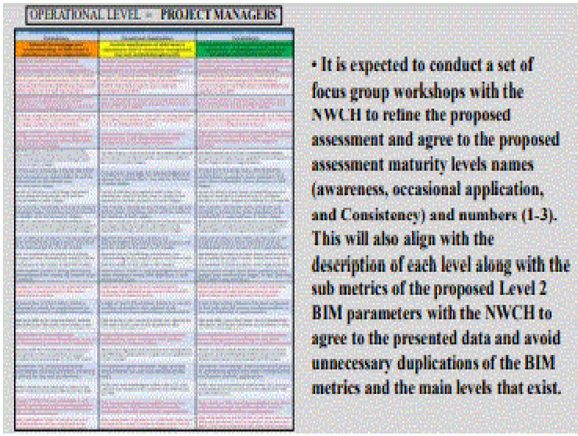


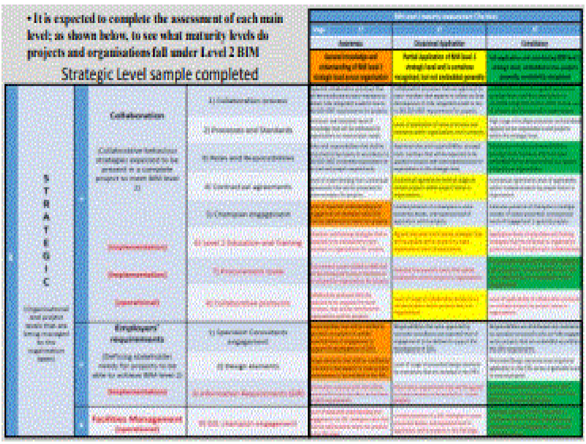
33



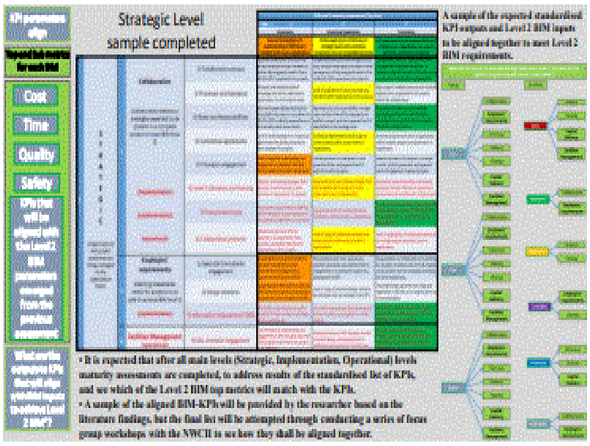
34



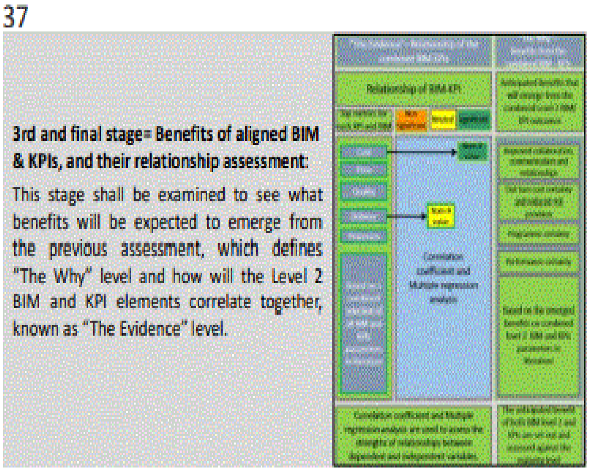




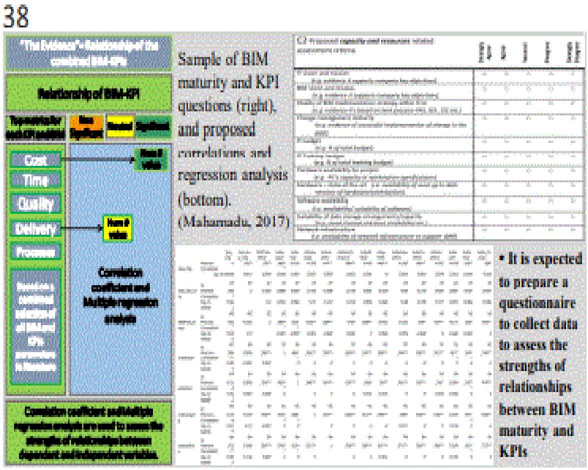
37



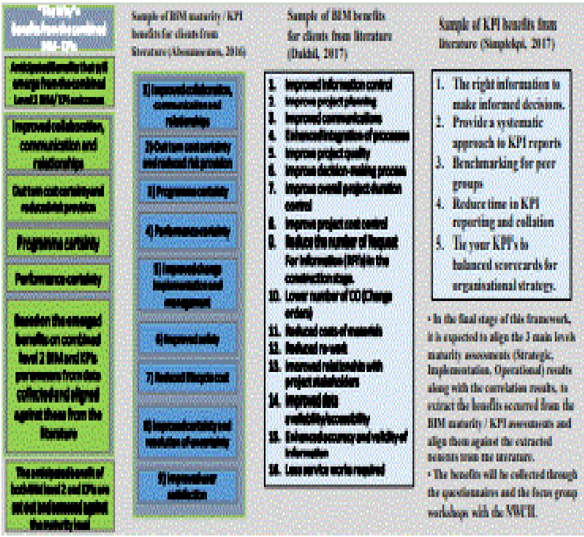
38

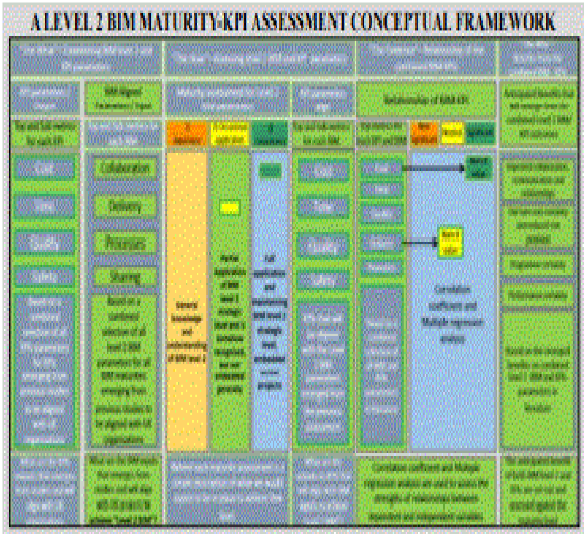


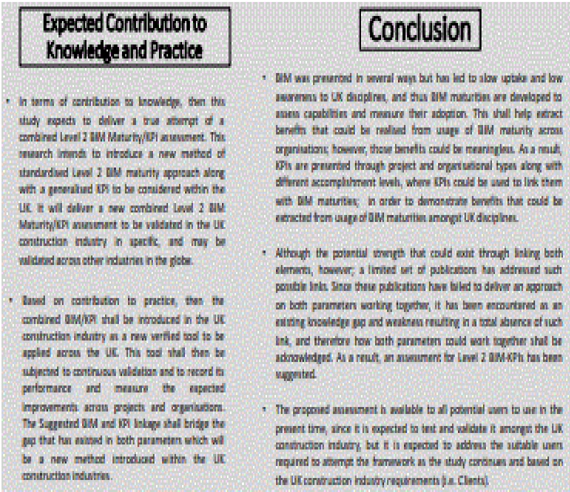
39



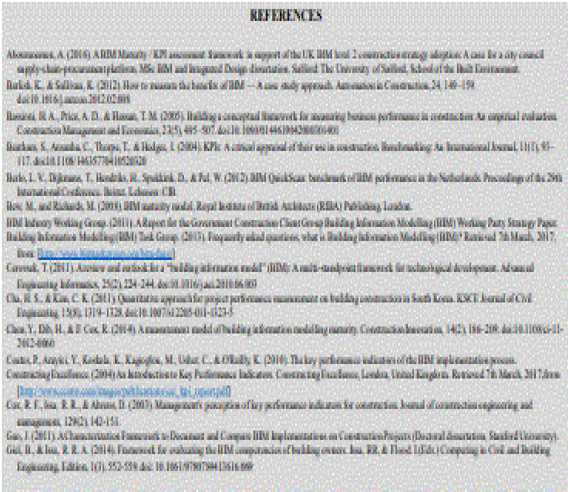
40


Sample of BIM maturity / KPI benefits for clients from literature (Aboumoemen, 2016)
Sample of BIM benefits for clients from literature (Dakhil, 2017)
Sample of KPI benefits from literature (Simplekpi, 2017)
Improved collaboration, communication and relationships
Programme certainty
Performance certainty
1) Improved collaboration, communication and relationships
2) Out turn cost certainty and reduced risk provision
3) Programme certainty
4) Performance certainty
6) Improved safety
7) Reduced lifecycle cost
1. Improved information control
2. Improve project planning
3. Improved communications
4. Enhanced integration of processes
5. Improve project quality
6. Improve decision-making process
7. Improve overall project duration control
8. Improve project cost control
9. Reduce the number of Request For information (RFI) in the construction stage.
10. Lower number of CO (Change orders)
11. Reduced costs of materials
12. Reduced re-work
13. Improved relationship with project stakeholders
14. Improved data availability/accessibility
15. Enhanced accuracy and validity of information
16. Less service works required
1. The right information to make informed decisions.
2. Provide a systematic approach to KPI reports
3. Benchmarking for peer groups
4. Reduce time in KPI reporting and collation
5. Tie your KPI's to balanced scorecards for organisational strategy.
• In the final stage of this framework, it is expected to align the 3 main levels maturity assessments (Strategic, Implementation, Operational) results along with the correlation results, to extract the benefits occurred from the BIM maturity / KPI assessments and align them against the extracted benefits from the literature.
• The benefits will be collected through the questionnaires and the focus group workshops with the NWCH.


A LEVEL 2 BIM MATURITY-KPI ASSESSMENT CONCEPTUAL FRAMEWORK


Expected Contribution to Knowledge and Practice
• In terms of contribution to knowledge, then this study expects to deliver a true attempt of a combined Level 2 BIM Maturity/KPI assessment. This research intends to introduce a new method of standardised Level 2 BIM maturity approach along with a generalised KPI to be considered within the UK. It will deliver a new combined Level 2 BIM Maturity/KPI assessment to be validated in the UK construction industry in specific, and may be validated across other industries in the globe.
• Based on contribution to practice, then the combined BIM/KPI shall be introduced in the UK construction industry as a new verified tool to be applied across the UK. This tool shall then be subjected to continuous validation and to record its performance and measure the expected improvements across projects and organisations. The Suggested BIM and KPI linkage shall bridge the gap that has existed in both parameters which will be a new method introduced within the UK construction industries.
Conclusion
• BIM was presented in several ways but has led to slow uptake and low awareness to UK disciplines, and thus BIM maturities are developed to assess capabilities and measure their adoption. This shall help extract benefits that could be realised from usage of BIM maturity across organisations; however, those benefits could be meaningless. As a result, KPIs are presented through project and organisational types along with different accomplishment levels, where KPIs could be used to link them with BIM maturities; in order to demonstrate benefits that could be extracted from usage of BIM maturities amongst UK disciplines.
• Although the potential strength that could exist through linking both elements, however; a limited set of publications has addressed such possible links. Since these publications have failed to deliver an approach on both parameters working together, it has been encountered as an existing knowledge gap and weakness resulting in a total absence of such link, and therefore how both parameters could work together shall be acknowledged. As a result, an assessment for Level 2 BIM-KPIs has been suggested.
• The proposed assessment is available to all potential users to use in the present time, since it is expected to test and validate it amongst the UK construction industry, but it is expected to address the suitable users required to attempt the framework as the study continues and based on the UK construction industry requirements (i.e. Clients).

43


REFERENCES
Aboumoemen, A. (2016). A BIM Maturity / KPI assessment framework in support of the UK BIM level 2 construction strategy adoption: A case for a city council supply-chain-procurement platform. MSc BIM and Integrated Design dissertation. Salford: The University of Salford, School of the Built Environment.
Barlish, K., & Sullivan, K. (2012). How to measure the benefits of BIM — A case study approach. Automation in Construction, 24, 149–159.
Bassioni, H. A., Price, A. D., & Hassan, T. M. (2005). Building a conceptual framework for measuring business performance in construction: An empirical evaluation. Construction Management and Economics, 23(5), 495–507.
Beatham, S., Anumba, C., Thorpe, T., & Hedges, I. (2004). KPIs: A critical appraisal of their use in construction. Benchmarking: An International Journal, 11(1), 93–117.
Berlo, L. V., Dijkmans, T., Hendriks, H., Spekkink, D., & Pel, W. (2012). BIM QuickScan: benchmark of BIM performance in the Netherlands. Proceedings of the 29th International Conference, Beirut, Lebanon: CIB.
Bew, M., and Richards, M. (2008). BIM maturity model. Royal Institute of British Architects (RIBA) Publishing, London.
BIM Industry Working Group. (2011). A Report for the Government Construction Client Group Building Information Modelling (BIM) Working Party Strategy Paper.
Building Information Modelling (BIM) Task Group. (2013). Frequently asked questions, what is Building Information Modelling (BIM)? Retrieved 7th March, 2017, from
Cerovsek, T. (2011). A review and outlook for a "building information model" (BIM): A multi-standpoint framework for technological development. Advanced Engineering Informatics, 25(2), 224–244.
Cha, H. S., & Kim, C. K. (2011). Quantitative approach for project performance measurement on building construction in South Korea. KSCE Journal of Civil Engineering, 15(8), 1319–1328.
Chen, Y., Dib, H., & F. Cox, R. (2014). A measurement model of building information modelling maturity. Construction Innovation, 14(2), 186–209.
Coates, P., Arayici, Y., Koskela, K., Kagioglou, M., Usher, C., & O'Reilly, K. (2010). The key performance indicators of the BIM implementation process.
Constructing Excellence. (2004) An Introduction to Key Performance Indicators. Constructing Excellence, London, United Kingdom. Retrieved 7th March, 2017 from
Cox, R. F., Issa, R. R., & Ahrens, D. (2003). Management's perception of key performance indicators for construction. Journal of construction engineering and management, 129(2), 142-151.
Gao, J. (2011). A Characterization Framework to Document and Compare BIM Implementations on Construction Projects (Doctoral dissertation, Stanford University).
Giel, B., & Issa, R. R. A. (2014). Framework for evaluating the BIM competencies of building owners. Computing in Civil and Building Engineering, 552-559.

44

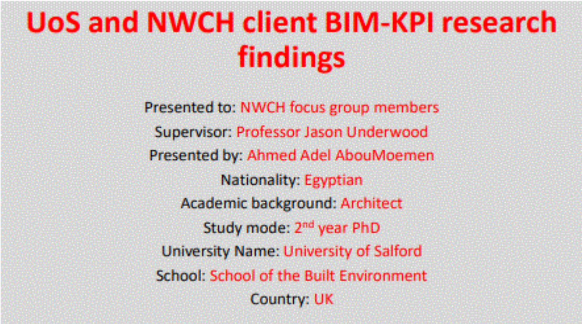

HM Government. (2013). Construction 2025, Industry Strategy: Government and Industry in Partnership URN BIS/13/955, Retrieved 7th March, 2017, from
Luu, T. V., Kim, S. Y., Cao, H. L., & Park, Y. M. (2008). Performance measurement of construction firms in developing countries. Construction Management and Economics, 26(4), 373-386.
Mahamadu, A.-M. et al (2017) Development of a decision support framework to aid selection of construction supply chain organisations for BIM-enabled projects. PhD, University of the West of England.
Mom, M., & Hsieh, S. H. (2012). Toward performance assessment of BIM technology implementation. In 14th International Conference on Computing in Civil and Building Engineering.
NBIMS (2012). United States National Building Information Modelling Standards Version 2. Washington, DC. Retrieved 7th March, 2017, from
NBS (2015). The level 2-BIM Package. NBS BIM toolkit, UK Government BIM Task Group, UK. Retrieved 7th March, 2017, from
Park, C., Ahn, J., Lee, D., Chi, Y., & Chin, S. (2013). Key Performance Indicator on Benefits of BSC-based BIM and Validation Methods. Proceedings of the 30th ISARC, Montreal, Canada
Paulk, M. C., Weber, C., Curtis, B., & Chrissis, M. B. (1994). The Capability Maturity Model: Guidelines for Improving the Software Process. 1995 Addison Wesley.
Sebastian, R., & Berlo, L. V. (2010). Tool for Benchmarking BIM performance of design, engineering and construction firms in The Netherlands. Architectural Engineering and Design Management, 6(4), 254–263.
Smits, W., van Buiten, M., & Hartmann, T. (2016). Yield-to-BIM: impacts of BIM maturity on project performance. Building Research & Information.
Succar, B. (2009). Building information modelling framework: a research and delivery foundation for industry stakeholders. Automation in Construction, 18(3), 357–375.
Swan, W., & Kyng, E. (2004). An introduction to key performance indicators. Center for Construction Innovation.
Takim, R., & Akintoye, A. (2002). Performance indicators for successful construction project performance. In 18th Annual ARCOM Conference, Vol. 2, pp. 545-555.
Vico. (2011). Calculating Your BIM Score. Retrieved 7th March, 2017, from
Wolstenholme, A. (2009) Never Waste a Good Crisis: A Review of progress since rethinking construction and thoughts for our Future. London: Constructing Excellence.
Won, J., & Lee, G. (2016). How to tell if a BIM project is successful: A goal-driven approach. Automation in Construction, 69, 34-43.
Yeung, J. F., Chan, A. P., Chan, D. W., Chiang, Y. H., & Yang, H. (2013). Developing a benchmarking model for construction projects in Hong Kong. Journal of construction engineering and management, 139(6), 705-716.

45

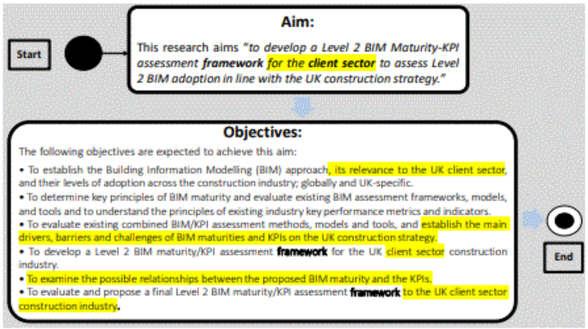

Thank you for listening!!!!
Any questions??

46

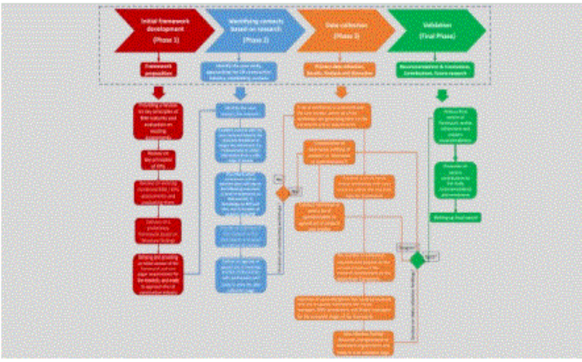
Focus group workshops presentation



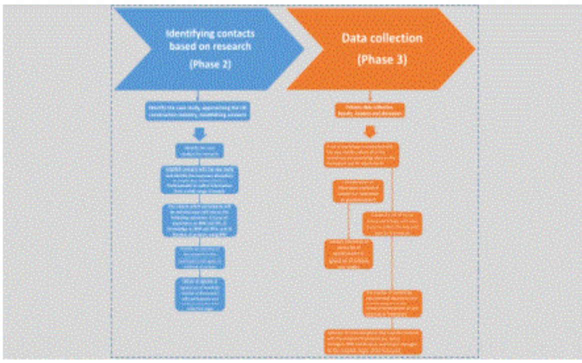
1



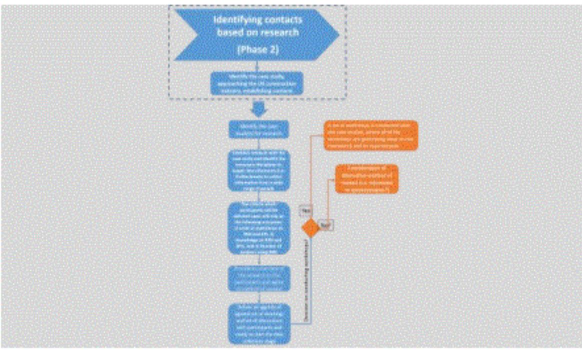
2



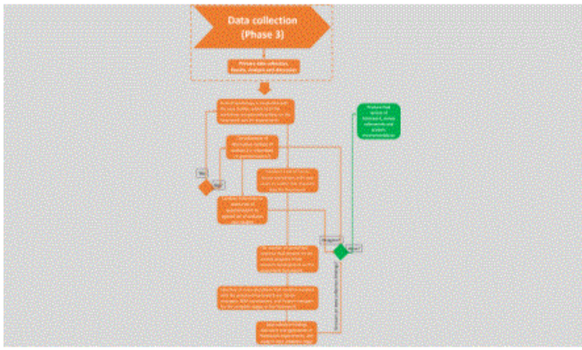
3



4

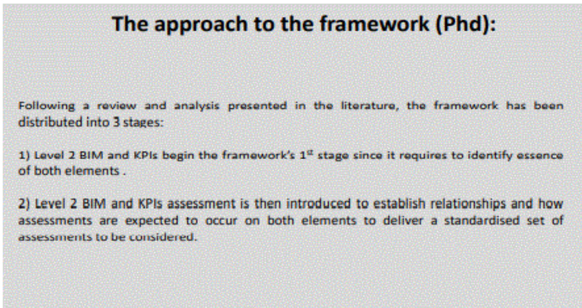


5

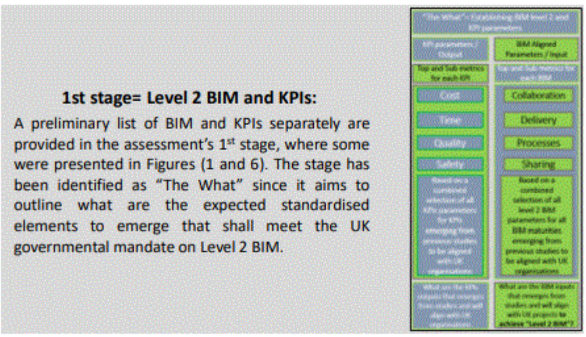


6

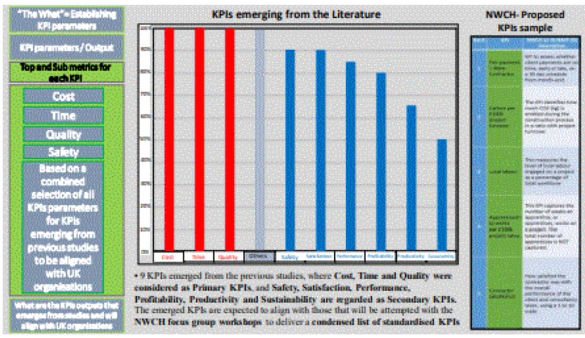
7



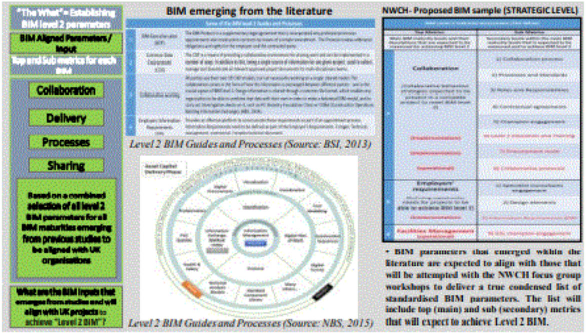
8



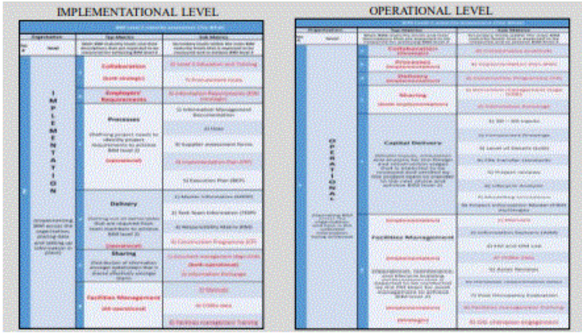
9



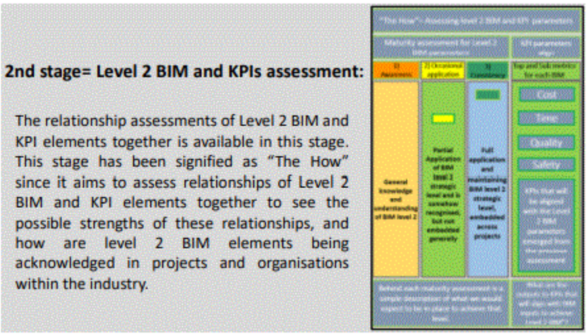
10



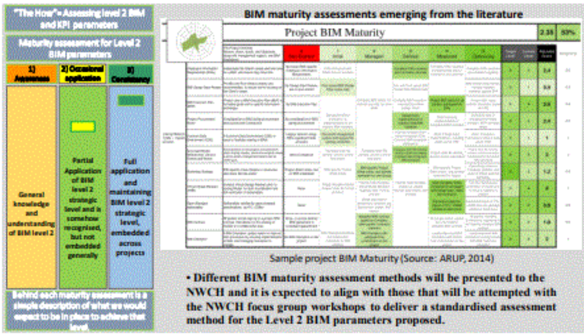
11



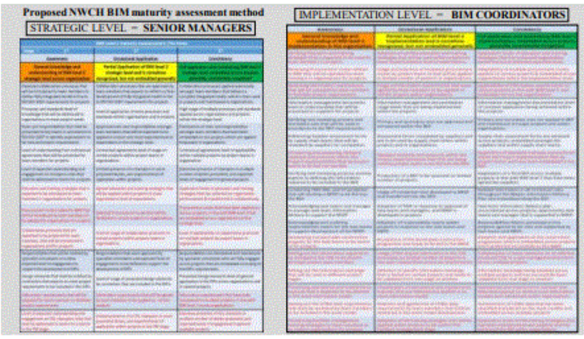
12



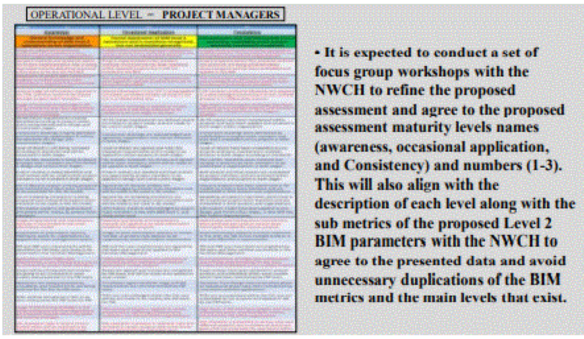
13



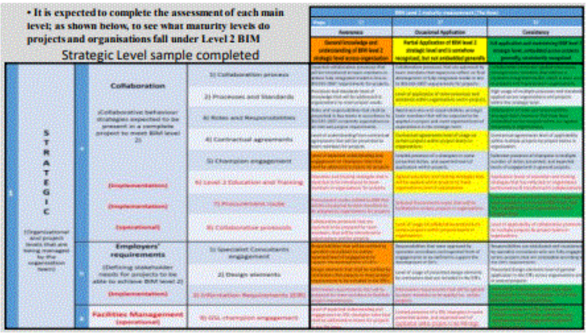
14



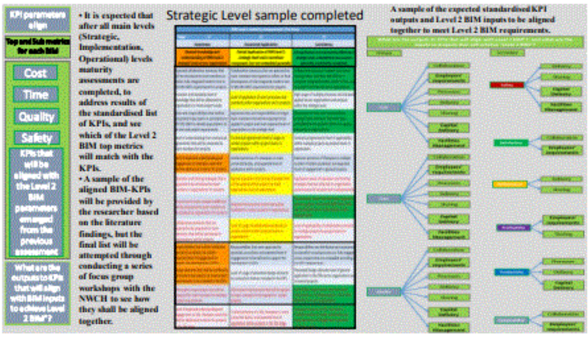
15



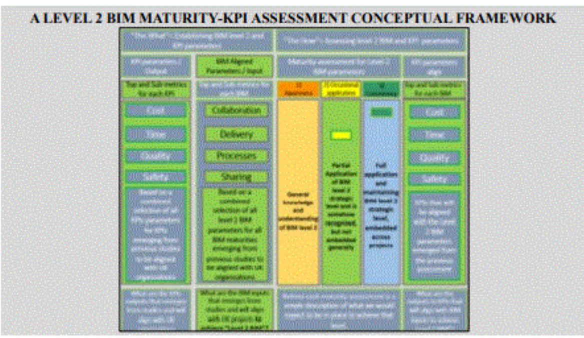
16



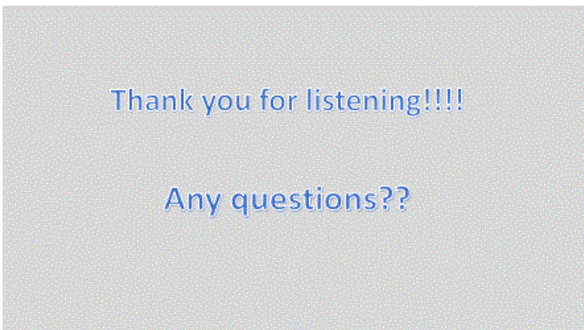
17



18



19



20

Focus group workshop notes for strategic level workshop 2:

0:00_4:00- Discussion on the technical procedures on how the tool will be used by stakeholders throughout the organisational levels.
4:00_7:00- Discussion on formula to be used for the total accumulative scores for maturity levels selection. **Formula has been changed to 1-1.7= Awareness, 1.71-2.4= Occasional, 2.41-3= Consistency. Usually whoever undertakes the assessment will score up to 2.4. BIM guide, BIM co-ordinator, design manager will probably score highly, whereas the technical guide could score up to 1.7, and other managers could score below than 1.7.**
6.00- Depending on the users in the project and their roles, what are their capabilities, so that gives an indication on where the assessment scores is going to be? Reviewing the results in 3-5 years to see where the company team stands in regards to the assessment.
7:00_10:00- A brief discussion over the audience targeted for this assessment and was initiated that its for the clients. More for organisational level. **The assessment should be given to users with some awareness and knowledge on Level 2 BIM for the assessment to be meaningful.** Contractors will be given the assessment to fill out, but then the completed assessment will be fed to the clients.
10:00_13:00- Discussion on the Collaboration Top metrics and specifically on collaboration process sub metrics: General discussion on how the spreadsheet was structured from previous work. Based on assigning top metrics for the organisational levels that are explained, then under the top metrics there are sub metrics related to them that the description for each is provided, then the 3 maturity levels that relate to each sub metrics and what does each level mean. Lowered down from 5 to 3 to provide necessary distinction of each level, where previously 2 and 4 did not differ that much from 1, 3 and 5.
13:00_17:00- A question on Collaboration process directed to collaborative behaviours or usage of software, so it was indicated that it's for the usage of software. British standards for BIM level 2 could include PAS part 2 and 3 together for the clients to be involved and consider the CAPEX and OPEX elements. Some confusion on the scoring scheme based on the maturity descriptors.
17:00_18:00- Some awareness on the model such as with Navisworks, Open the model. Occasional could be CDE setup to use with and operate with the model. Consistency could be everything is set up and integrated there is a collaborative system in place where it is compliant with the standards. But again its what is collaboration process.
18:00_21:00- **The need to have a tangible metric to score all the sub metrics otherwise they could all be scored as 3.** A question on existence of software in the implementation and operational levels. **There exist sub metrics related to those in the operational level. Preview software and see what it could accomplish. IFC formats. For organisational level it could mean if they have collaboration between different platforms and system, where every company will have different platforms such as enterprise systems that are related and not related to BIM.** Collaborative approaches and its behaviours, could be data management integration with the software. Generally the Collaborative process could be confusing for clients, as it has multiple meanings related to behaviours and software and could be directed into different routes. This may differ from one project type to another as it will reflect differently based on the project types. The software needs to be defined related to FM, to build assets.
21:00_25:00- Discussion on the Processes and standards: This means the standards itself (Pas documents and other documented standards related to Level 2 BIM). Then general discussion on the inputs to be included with each maturity level. It was also required to change the descriptor of the element in such that it includes some examples of Level 2 BIM standards and a possible link that users could access to find more details about the standards provided.
25:00_29:00- **Generally the Strategic level should be kept to its simplest forms to allow clients and users in that level to assess the sub metrics of Level 2 BIM.** Agreement on how the descriptors should be phrased to distinct each level accordingly.
29:00_30:00- Consider changing the description of the maturity level to comply with the descriptions provided for each sub metrics.

30:00_32:00- Agreement on the descriptions to be included for the Processes and Standards
32:00_42:00- Discussion on the Roles and Responsibilities with its descriptors. **It was stated that some overlaps could occur between sub metrics in one top metrics with another one in a different top metric (Roles and responsibilities with Collaboration and Employers requirements).** Several descriptors exist, such as for the 1st 2 levels the need to have a consultant, whereas no need to have consultant for last level. A set of descriptors were discussed to agree to a specific one to be included.
42:00_55:00- Discussion on the contractual agreements. Relation with Procurement route. Contracts such as CIC and BIM protocols. What forms of contracts align best with Level 2 BIM standards? Bridging the misunderstanding of the Contractual agreements sub metric with maturity descriptors and its relationship to Level 2 BIM.
55:00_56:00- Discussion on Champion engagement sub metrics. After explanation it was suggested to remove this sub metric from the whole spreadsheet as it is irrelevant and already covered in the roles and responsibilities. It might be needed for the implementation or organisational level.
56:00_1:03:00- Discussion on Level 2 Education and training sub metrics. General discussion on how the descriptors should fit with this metrics and what does it mean and how it reflects different users in regard to the education and training facilities, and how they will be assessed on.
1:03:00_1:09:00- Discussion on the Procurement route Sub metric. More clarification on what is meant by Procurement route. Project will be already BIM project. 2 stage tender could be different. General discussion on how the descriptors will shape this metric.
1:09:00_1:10:00- Discussion on the final element of Collaboration [Collaborative protocols] sub metrics. It is similar to the procurement route and the contractual agreements. It was requested to be removed as it is a duplicate of the previous. Could be available in implementation level. 1st part of Collaboration was revised. End of meeting.

Focus group workshop notes for strategic level workshop 3:

0:00_12:00- Discussion on the Employers Requirement Top metric. Revising the descriptor of it and including OIR and AIR as stated previously. Recap on the collaboration process from the previous meeting to finalise the descriptors required for it. It will be kept as systems and software.
13:00_15:00- Discussion on the Specialist consultants engagement sub metric. It was requested to be removed as it is not relevant with the EIR and difficult to assess. It is covered in previous top metrics.
15:00_19:00- Discussion on Design element sub metric. More clarification on what design elements mean and how it will be used to be scored. Big 5 was mentioned so examples of what they are were discussed (Groundworks, MEP, Architecture, Structure, external works).
19:00-33:00- Discussion on Information requirements (EIR) sub metric. General discussion on the descriptors to be included in that metric. Request of listing a sample of an EIR for the users to get a better understanding of what they are. Example is COBie 2012 template for issuing with each data drop and the requirements in the EIR section xx, requirements of a model covered in section xx. The complete EIR will specify Level of Details for each EIR. Ability to Deliver Complete EIR. Detailed discussion on what needs to be included in the descriptors for EIR since it’s a major sub metric.
33:00_39:00- Before moving to the Facilities Management Top metric, it was suggested that the Asset Information Requirement should be included with the Employers requirement metrics, and so it was added to finalise this metric.
39:00_43:00- Discussion on the Facilities management Top metric and GSL champion engagement sub metric. General discussion on the description and the maturity levels descriptors for the GSL. It was stated that most of the Facilities management sub metric are available in the Operational Level. Are you going to use the BIM model in operations.
43:00-44:00- **It was suggested that there should be a template that explains that not every part is applied to you therefore answer the metrics which applies to you so that the average scores will make sense and be meaningful, so where it is not applicable to you leave it blank.** Guidelines to be included to explain how the spreadsheet will be completed by users which gives a better explanation for the users on what they are required to fill out.

Focus group workshop notes for Implementation level workshops 4 and 5:

0:00_12:00- P5: The discussion in this workshop would focus on the Implementation Level. I have printed off the completed Strategic level, and since there would exist duplications to some metrics in the Implementation levels with those in the Strategic level, so we would have a review back at the Strategic level. **P1:** We'll try to smash through the Implementation level as much as we can. **P3:** It would be easier for us to fill out, since we've already done this process in the Strategic level. So where did we leave off last time? **P5:** We've completed the Strategic level. So last time, we've started the discussions on the implementation level, and the metrics filled out here are pretty much aligned to the BIM checklist that was given to me at that time. For the Implementation level, there would be some elements that are repeated with those in the Strategic level. **P1:** So this is kind of the project management role, isn't it? **P5:** No, we said in the masters that it would best fit with the BIM coordinators. The operational level would be for the project managers. But we would discuss and decide this. **P1:** This is not the delivery part of it. **P3:** You are still doing it on the client side. **P5:** Yes, it is. **P1:** Ooh ok. **P3:** Yes you need to focus the terminology on the Client side. **P5:** Yes, because in the masters, we didn't specify the client rather than it was just the general. **P3:** In here, you would need to focus on and aim this section for an information manager, because in terms of the client side, you'll get an information manager who would do aspects of BIM coordination a holistic thing. So some documents in a different meeting they would generally do and making sure that all your standards and procedures would be set up. They would probably produce a BEP from the client side as well. So they do kind a bit of both really. So I use it from my brain kind of what I do before. **P5:** Yes, because in the masters it was just a general discussion that didn't focus on the clients. So we said the Strategic would be (Senior or head management), and Implementation; BIM coordinators, and Operational; project managers. But because now it is directed to the clients so we can always change and reassign the roles. So as we said in this level, or as **P3** was saying that the implementation level, this would be filled out for the information managers. **P1:** So, I'm trying to get my heads to this, so for the operational level, is this for the FM people? **P5:** Yes, it would be more technical, so FM and technical staff. **P1:** So the people using the building afterwards and operating it. **P5:** Yes, and for the Implementation, more of the document handover and how the information is being handled.

11:00_18:00- So for example, the **Level 2 Education and Training**, we had it previously in the Strategic level, but in terms of the maturity level descriptors, then it would change slightly between both organisational levels. **P1:** So, is this about what qualification this would be doing there? **P5:** Yes, that's how it was described in the Strategic level, but I'm not sure if it will change here? **P1:** In here, this would be like the training to deliver BIM, so this would be like say; I'm the information manager, this person would be my manager who would say you need to be trained to do this training, so implementation would be how they will undergo training. **P3:** I'm not sure since you will be crossing it wise on both wouldn't we? If you do down the route of specific training and you cross with it in the strategic level. **P5:** So they would overlap? **P3:** Yeah. So how did you have it last time. **P5:** So last time in the masters, I had it as a duplication that it is mentioned here and in the strategic level, as you can say on both spreadsheets, and put it between brackets to show how they are repeated and crossed over. But we mentioned that the terminology used would differ from one organisational level to another. But we could decide if it would be the same or different and highlight where it would be different. **P1:** I don't think it would be same here, because the strategic person is the person who essentially decides everyone needs training, **P3:** Yeah, the strategic would be those who have done the trainings. **P1:** Yes, so it would be different. **P5:** Ok, so we would change the description slightly here then because it is the same as the one in Strategic level. **P3:** Yeah, so here we could say; **Level of education and training expected to be taken by an individual to understand level 2 BIM.** **P1:** I suppose what we're thinking here, so let's say the 1st done is done by the manager and the answers are on behalf of the department, would this one be given to individuals within a team, to then gage their individual ability rather than the team's ability? **P5:** Because the Implementation is more of how it's going to be used, so its more towards individuals, whereas the strategic is more towards a holistic or teams. **P3:** Could be an IT, or an influencer who would fill this out. **P1:** Because then this would measure, essentially if the scores in the strategic would be higher, then this would reflect somehow here and they would score similarly here, because this reflects on the individuals and teams. **P3:** Kind of, because the strategic level, you'd have kind of everything in place so the scores might not relate. **P5:** Yes, the scores might change. **P3:** Because for example at this company, we rolled out a training scheme, so if this was given at the time it was rolled out then we would score really high on the strategic level. Many of them would have taken it by that point. People may then score really low, because the strategic stuff is in place but not everybody is carried out, you'd probably get a **2** on the other one, because your 50-60% people haven't taken it. You see what I mean? You won't get a **3s** on this one. So in one way **P1** is right, think about what we put in the maturity level descriptors would make the difference. So we've put 60% done it in the strategic level, haven't we? **P5:**

Yes we have. **P3:** The way you could go on with this, it depends on if you need training or not, so if they score **1**, then whether you want to say No training, or still undergoing training, because for the other metrics, if they score **1**, then they would have done nothing, because no one has done the metric. **P5:** It could be nothing, or still undergoing or some or few, so for the **1** could be like this, **2** would be occasional, **3** full. **P3:** I would go **1** to be **fundamental training (In house or external).** And for **2** could be; well it depends on which company, because one company could be CADassist and go on their fundamental scores, whereas another company might get set up in house and get done, which is want you really want it to lead to. So for **2** it could be; they would be taking e-learning training for, not necessary advanced but intermediate BIM training. So; also there would be system trainings, like the CDE, FMs, Navisworks as they would undergo some of those trainings, so you can put some examples in there. Software based training. So the whole thing would read like; **There is internal training undertaken (i.e. Intermediate BIM or system training) CDE, FM, software based training.** For the consistency, you would then say; **All systems are applicable (Advanced training on most systems, i.e. CDE, FM).** Normally every people in every row would need to know how to use these systems for a Level 2 BIM project, but they'd learn the systems are applicable, yeah we're doing that. All systems are applicable to their role.

18:00_28:00- P5: So for the next one, we had **Procurement route.** So for the strategic level, this was how it was mentioned. **P1:** So would this be really relevant to the person filling this organisational level? **P3:** Depends on who from the client side would be filling it out. What procurement route they use? Very specific to a particular role rather than a particular set of people. **P1:** So in the public sector, would be, one project manager done everything, whereas private sector, you would need to have someone dealing with the procurement route and probably isn't the same person as those. **P3:** Yeah, so you're gonna have to tailor it, so that it fits both. If you can go back to the Strategic level. **P5:** Ok, this is what we said for Procurement route. **P3:** I'm trying to think about it…. Ok, so it could be something very simple, like implementing correct procurement route for project type. Maybe not correct, could be single. **P1:** So, if you think, it's very unlikely that the person would be choosing the procurement route, is the person who would be delivering this? Unless I'm thinking about this the wrong way. Like, is there other things within the… do we have one on contract type? **P5:** On the implementation level? No we don't have a contract. **P1:** Because on the Strategic, it would be the person has an understanding about how the route they are taking ahs an effect on how you would then implement BIM, whereas in the implementation, this decision would have already been made by the time it gets to this person. **P3:** Yeah I know what you are saying. It's a tricky one and its difficult to think about it in this way. **P5:** SO instead of procurement, we could have the contracts. **P1:** Yes, because instead of procurement, is what the type of the contract within has more probably an impact on. **P3:** It can do, it can, In terms of BIM there, the procurement route would define it really. Which one we'd pick. What type of project it is? Which one you need better implementation. If you implement BIM, like you use the 2 stage design bid build, your contractors would come up and use it like stage 3. Because your contractors would come earlier on a stage 2 than stage 3. So its repulsive really, you can have both, you can have neither. **P1:** So, is it about this person's understanding of how each different procurement can impact on a project. **P3:** My point of view would be that in the strategic level, it would be Understanding the procurement route and which one it would be best suited, whereas in the implementation one, it would be making sure you're going in the correct procurement route way, and the correct contract way that would go and fit with that contract. But again how would you score that? Because from my point of view, you can't score a 2, but even if you put the right procurement route, then it's not to do with right or wrong. So your **1** could reflect on the strategic (i.e. the client has no idea what relation to BIM any of the procurement routes have) So procurement route picked based on traditional methods. The 2nd one could be; awareness of Level 2 BIM but wrong procurement route chosen to enable it. 3rd one would be aware and chosen the right procurement route so you can include it and even measure it. So if you use it in a metric system, then the clients could go yeah procurement route is pretty wrong, you start again. **P1:** Yeah. I suppose if they didn't already know that is does affect it, then it makes them think about it. **P3:** Especially, if it's a public sector, it might get them to think about it for the next live project, so you would go, you realise how the procurement route may impact on BIM in a project wouldn't you? The next one might go and say enable this, this, this and so on. They would probably be aware of the traditional methods they would use. **P5:** So here, instead of awareness, we can say awareness and. **P3:** You would say awareness of Level 2 BIM process and procurement route chosen to enable BIM. Otherwise, you would have to scrap it completely, because there is no other way, you can go about it. It's a bit a woolly one. **P1:** Yeah. I think it shouldn't be included here.

28:00_31:00- P5: So for the next one, we had **Information Requirement (EIR).** So, again we had this in the Strategic level over here, and this was how we described it and put its maturity descriptors. **P3:** Ok, so in the Implementation, they know that AIR produced EIR basic template. **P5:** So Ok we would change the description here, and the maturity as well. **P3:** So for the maturity one, you would basically say for the 1st one; **No EIRs presented,** the 2nd one; **Basic template and external procured EIR**, and final one; **Fully developed EIRs in the AIR**. You can put in the final one an example like Asset register.

31:00_35:00- P5: So, now moving on to the next Top metric; what I mean by Processes here is; **(Defining project needs to identify project requirements to achieve level 2 BIM).** So what forms and so on. So some came from that checklist. So **Information management documentation**, is all under pre and post contract, PIP. It's all in this section. **P3:** Ok, so this would overlap with your EIR really, because part of these things are part of the EIR. SO your pre-contract BEP, post-contract is not relevant to client. Your pre-contract might be developed internally, if it is. Your responsibility matrix is not really pre-contract, BEP, so as your Project Implementation Plan (PIP). So Supply Chain capability review, you might provide a template document for that, like the CIC one. It solutions might expect to receive that and GSL requirements as well. For this, it's going to fall similar to the EIR really, these things on present, or no EIRs, pre contract BEP, and after that is predefined. **P5:** So this would be duplicating this, or it's kind of similar. **P3:** your EIR, is essentially your Information Management document really. Your BEP is how your going to do it. Your EIR outline how you want it done, because its pretty much as far as you can get with the client. **P5:** So, **I'll remove it** or highlight it for review, but I guess it would be removed.

31:00_47:00- P5: So the next one is **BIM uses**. So this is more like the BEP. So we can say similar to the EIRs, that No BEP is presented. **P3:** Your BIM uses is like in your EIR, so the section in the EIR, where the client states that these are my BIM uses, and it might be like a low-medium-high table, something like that, or like priorities or just the BIM uses. So for the client, 4D delivery doesn't matter too much. They might have that in low. So high requirement might be COBie uk 2012 output. Medium might be fully coordinated, so this is just an example on how it would be. **P5:** Ok, I got it now. **P3:** There would be a table like that with all descriptions, so generally that's what your uses would look like. So for the descriptors, you would get no present EIRs, present an EIR but kind of woolly, full understanding of what BIM uses are and what client requires table clearly defined and expectations of AIR and so on. The BIM uses should be in the EIR and the BEP should respond to it. So if you have a list of 20 BIM uses that you want on a project, a contractor might pick 4, and say we would do those 4 on a project, and these 6 we can't achieve. **P5:** So we could change this BIM uses. **P3:** No BIM uses is a good one, you would need it. **P5:** Ok, but it would go under the Employer's requirement top metric, isn't it? Not under the processes? Because you said it's pretty much related to the EIRs. **P3:** But your EIR defines your processes, so you can't differentiate them. The EIR would outline the processes that the clients would want to do on a project as well as standards, you can use all that kind of stuff. **P5:** So in the ER we said stakeholder needs, whereas in the process, we said project needs. **P3:** Your table in the BIM uses might differ for each project. You might want different things on each project. So, for example, if you are doing a 3 storey building, and then your doing a 20 storey building, the chances of a client wanting to do a 4D on a 3 storey building is higher than this of the 20 storey building, because its more to plan and more to get accurate than the other. So the BIM uses might be on one project, but not the other, and the table might change and go back and forth. So the BIM uses on a live project is really important, because if you didn't have it, for a client and you didn't put it in there, then your contractor would go, ok I'm not delivering on this. I'll do the basic stuff, why I have to do one contract to produce COBie. **P1:** So this is about the client knowing what it needs to ask for and not going over stuff. **P3:** Yeah, so basically, the client knows what aspects of BIM they want to implement on a project, which one's are necessary to implement, so some would be necessary and some won't. Some would be relevant and other won't. So, for example, a lot of clients admit that they don't ask for 5D (for costing) because they know they contract they can't do it, or the contracts are set for it, so that's one aspect to understand the industry, the other aspect is understanding their business needs and how BIM helps them out, "**so the score for this would be;** 1st one **who understands what BIM uses are being implemented",** so if they do, the 2nd one would be; are they putting any of them in the document, and if they do, because it's an efficient one. How they are changing project by project basis. And the final one would be there is a full understanding there is the table somewhere that clearly defines where they are asking for the right stuff… It's the same when we say to a client and turns around to you and says; I want COBie, BIM uses you can turn around and say I want BIM, and the overall spectrum of that is; I want COBie, I want the floors to be staged here and locations on 2D….half length width type and have an asset, I want to have a warranty information, that is a lot different than asking for COBie, BIM uses you've got to think about it the same, if you're gonna ask for BIM, you will get what they want, whereas if your asking for specific uses then to be implemented on a project then to score against and have a metrics against. **P1:** So could it be that the highest score on this to be that the clients have a standardised requirements that relate to what kind of building they are getting. **P3:** Yeah, so for example if it's a school project, then they would have a different standardised set of BIM uses. **P5:** So, I think we would need to change

the description here since it's not matching to what is being discussed here. **P3:** Yeah, so even there you've got an example of what might be in a table, so primary and secondary would be primary and secondary uses, so you can put level of **BIM uses expected to be achieved on a specific project**, not necessary primary and secondary, because you would get into a table, where normally it's a 3 case system. These are what we require, these we would like to introduce, these we are not asking for, but if you do it would be nice. **P5:** So, I would change it to this, and for the maturity level descriptor, I would put it similar to the previous one. **P3:** Here, you would write; **No BIM uses are outlined**. **P1:** in the end of the day it's a government initiative to deliver level 2 BIM isn't it, so its how they would go about to deliver a Level 2 BIM project in the end of the day. **P3:** Not all clients understand Level 2 BIM, even some people don't understand it, so for example, our design manager said we haven't really done BIM on this project, because we don't have this as level 2 BIM system requires, but I say no we have because the clients require to do these things, these 6 BIM uses, whether on more superior project is to do 25. So, it's still level 2 BIM. **P5:** it's still level 2 BIM. **P3:** Your still doing principles of Level 2 BIM, your still delivering COBie, your still working to BS1192, your still working to a CIC BIM protocol. **P5:** Yeah, that's right. **P3:** So the 2nd one would be like **P1** said; **BIM uses are outlined but not tailored for specific projects.** So the generic BIM uses, and the final one would be; **BIM uses are outlined and tailored for specific projects (i.e. school projects). P5:** Yeah, so the different types of projects. **P3:** Yes, because that's they way your gonna differ for each level.
47:00_1:05:00- P5: So the next one is **Supplier assessment form**. But before we get into this, if you have an example of maybe a BIM document or something that I can have a look at. **P3:** Yes, **I have an example for an EIR that I could share with you. So this would give you a good idea on what an EIR looks like.** Because at uni, I know its more of a theoretical stuff. So you would probably knows what an EIR is, but don't have a clue on what it looks like. It's not very useful when you get into the working practice. **P5:** I guess this is where the gap lies **P3:** Yes, **Because you would need to know how to write and review an EIR, if your in the working practice, in an architectural firm, structural company, etc… you need to know what should be in there, and what should be not missing, and what is missing. If you don't know what's in there and what's missing it's a risk, if you don't understand the EIR it's a risk. If you know what an EIR is, then great, but if you don't know what's in it, or understand it then it won't do good to anyone. So you would probably know what BIM uses, 4D, 5D loosely are, but you won't know how to apply it.** So the university are kind of in the strategic lievel, they know what it is, but we are in the Implementation level where we know how to apply it, so there is a massive distance where the universities are not passing this knowledge to bridge this gap. So instead of your gap being a little bit, so a little bit corporate training, little bit 1, 2, 3 positioning where you want to learn it. Then you're here, the gap is closed. But instead you got into a company and there is a massive gap of knowledge, and this is a fact. SO there is a disparity between the uni and industry of what you think you know and what you actually know. **P5:** So do you know where could someone get the necessary training on how it is being used. **P3:** I think the certified programs and certificates would be similar to a masters program, and the professional one would be more advanced and somehow related to industry. The Uni should give some kind of a month release, where they link you to companies to bridge this gap from theoretical knowledge to the practical. **P5:** Something like the **Knowledge Transfer Partnership (KTP). P3:** What is it? **P5:** transferring knowledge into practice. **P3:** Yeah something like that. **P3:** So like this work you have a broad understanding of it, but when you take it to practice and on how to measure the metrics, then you don't have a full understanding of the processes, because you haven't done or reviewed an EIR, it's very difficult to get that content you know what I mean. **P1:** We've got a few minutes left. **P5:** So getting back to this, this one is for the supply chain. So, it's kind of the forms that the supply chain use for the usage of the projects so for the assessment forms, it was more for the supply chain. **P3:** It's a bit of a difficult one this, because you can put none produced, some produced, and produced and being implemented. Like the industry you don't want to be diverting away from the supply chain forms really. They could use because they know what they need to put in there. So do they know what PAS1192 is, have to respond to an EIR to a project, and having produced a BEP, and then your individual supply chain assessment forms, like your type B project specific you use these type of documents and processes. Most construction companies have that, the CIC don't have the individual assessment forms. I don't know if that's the route you want to go down with. Of a client producing an assessment form to assess the individual rather than the company. **P5:** Yeah the individual. **P3:** Because here you have 2 types of assessment forms, the individual and the company. **P5:** Ok, so since there are 2 ways this happens, so for the implementation level, it could be for the individual, and for the strategic level, could be for the company, or even in the operational level. I don't know. **P3:** You're not assessing if they understand it, but you're assessing if they can deliver it. So the understanding is more strategic, but here it's the deliverable. **P5:** Oh yes, that's true. **P3:** So here you can say; **Supplier BIM assessment forms completed by companies to demonstrate BIM competence.** A lot of your

metrics will be similar to this, you know. So for the maturity descriptor it could go by; **No supply chain forms carried out or completed**, then the 2nd one could be; externally procured, but I don't know if the CIC has got an individual assessment forms, but they might produce something in the future, so might be using someone elses. Kind of the public sector ones, then the final one would be; Client own tailored supply assessments produced and being reviewed. A lot of these metrics would be the same, because it's like what these people may measure. **P1:** So you would have to word it in a way where it might sound simple and specific, in a way that how they can improve this. So yeah, they might externally procure the stuff, by doing this stuff, so maybe that's not the best way to word it. **P3:** So you can have it like externally procuring your supply chain but working on producing your own, and then the final one would be got our won supply chain forms and this is it. **P5:** Ooh ok. So yeah this how it could look like. **P1:** So, produce like standardised supply chain assessment forms. **P3:** So generally it's like a technical competency. **P1:** So, it could go like for the 2nd one, **Understanding the need of assessment forms but not in place**, and the final one would be; **Supply chain forms issued, being corrected and is completed.**

1:05:00_1:11:00- P5: So the next one is **Implementation Plan (PIP)**. It is to support the BEP, but I don't know now if it's for the BEP or for the EIRs, so yeah instead of the BEP, it would be for the EIR. **P1:** So, what is Implementation plan kind of data look like? **P3:** So, it's a plan of how you will implement the data and that kind of stuff, methods, procedures to implement BIM on projects. your PIP is how you pull it all together. So it's outlining this is what you are going to do. This is how we're going to do it. This is the procedures we will use or data we would produce. So PIP would include model federated process, exporting COBie output process, explaning that. So your standards and procedures like this what you're gonna use in the PIP, is like how you're gonna do it. So what you will do, how you will do, and where will you do it. So what you get, is more probably in your EIRs, so it's not in the BEP. EIRs state this is what we want from you, but we're not bothered on how you would do it, as long as we get this end product, which could be COBie, or Asset Information Model, or this is what we want from you, this is what we want you to do, and the PIP is how they are going to do it, from that we're producing that, and from that we're producing this. **P5:** Oh, so it's more a BEP side. **P3:** Yes, it's more a BEP side. **P1:** So, it's like having a standardised procedures close to be able to deliver what you essentially word into your EIR. **P3:** Yes, so it is something that the client may want something different to what you normally expect, or something that you have not done before. So it might be a case of PIP in a project you're doing what your doing, in a processes and procedures. So it's not like a COBie production, where people would know how they are going to get that information and data from and how they will deliver it. **P1:** So, we can't really do like, no procedures in place, some, and standardised procedures for this one. **P5:** In here? **P3:** I don't think you would really need it here, unless the clients you had a PIP section in the EIR where it states that you'd expect to outline this, we'd expect you to produce a PIP. But then the metric would be different way. **P1:** I think your right, because if you already specified what you want, then you don't have to care how it's done. It's not really the clients concern or how it's delivered. **P3:** No, it's not really how they will restrict you to a certain way. Because you might already know that doing that specific outputs, so they might say we want you to use Syncro to do 4D tracking, but it might come in a better way than you choosing software. So you see what I mean. So it's a difficult one. Maybe you can **remove that one since it's not really relevant here.** Because I'm not sure how you would include that.

1:11:00_1:16:00- P5: So the next one is **Execution Plan (BEP)**. **P3:** your metrics is gonna be similar to the previous ones. **P5:** So No, Basic and full. **P3:** You could relate the PIP to the Client's BEP, looking it at that way. **P5:** Ooh, ok. **P3:** So, in between brackets you can put PIP, which is the standard procedures, **P5:** What is SMP? **P3:** Standards Methods procedures (SMP).

1:16:00_1:17:00- P5: So the next Top metric is **Delivery**, which is (**Setting out all deliverables that are required from the team members to achieve Level 2 BIM).** So, again this came out of the checklist. **P3:** I think this checklist is not very good. It's not for the client side. **P5:** Yeah, because at that time, we didn't specify that its for the client side.

1:17:00_1:23:00-P3: So your MIDP and TIDP are generally 1 document, so you won't split them up. So let's say this is excel spreadsheet and the tabs down here, so your MIDP would be a big full list of tasks and all the documents and information that you're going to receive on a project on specific stages. And that list is a by product of each TIDP. So that TIDP could be for your architecture saying what they are producing, might be TIDP from this company, or from another company doing MEP and so they would all feed into that. So they are not generally like separate documents. **P5:** So it's all under one the Master MIDP, and TIDP is all they feed into the MIDP. **P3:** So I would just merge it, and put MIDP and TIDP. Because you can't have one without the other. You can have a MIDP without a TIDP, which would be a MPDT. So it's like you can't have a BEP without an EIR. **P5:** So I said Level of MIDP to be accomplished for the delivery stage, so now I can include the TIDP and add to

the description and say in the end for the delivery stage of the MIDP. **P3:** Yeah you need to change the description. Again, it's not easy this, because its if you are working towards producing a standard template, so I don't know how you'd word that one. So the first one would be; No MIDP / TIDP document presented, and your 2nd one would be; externally procured because or basic template. And final one could be having a comprehensive MIDP. So you still got template, because your basic one might be company name delivery data, whereas your comprehensive one would be company title, day, who produce this information, what size and scale it's in. What delivery dates you're going to get, so you agreed to dates. So it could get more complex to fit on purpose.
1:23:00_1:30:00- P5: So the next one was **Responsibility Matrix (RM)**, so it's actually for both, MIDP and TIDP. The discussions we had at that time. There isn't something specific, it was during the general discussions we had. **P3:** Oh, during your masters, so it's completely wrong. **P5:** So, it's under EIR. **P3:** I'll tell you why, so the RM is related necessarily to MIDP and TIDP. There is stuff in here that relates to procedures. **P5:** So, it might have been a mistake at that time, so I think it should be moved up here to the Information requirement, so what do you think? **P3:** It could fit here and there, because it would outline your process anyways, they say who is responsible for doing this in process anyways. How have you done this, who is responsible for this and so on and so forth, so it is a process that as far we put it. You're putting it under Delivery? **P5:** Yeah, here. **P3:** It can fall under here because your RM is setting out who does what, and at what stages so how you would deliver it. SO I think you would leave it where it is. But just change your description to the RM. **P5:** Ok, so I would change the description. **P3:** I think the CIC has got a Standard Responsibility Matrix, which you can have a look at, because CIC produce one. There is one online you can access. It's basic, but gives you an idea on what should the RM contain. **P5:** Ok, so I would change the description. **P3:** I think the RM is clearly outlining. **P5:** There was a set of definition here. **P3:** Yeah, so **Responsibility Matrix clearly outlining roles and responses for outputs and procedures.** Then the descriptors, No, Basic, Fully developed.
1:30:00_1:32:00- P5: So the next one was **Construction Programme (CP)**, **P3:** no, I think you would remove it. **P1:** This one could be about to use BIM to enable to be developed in a more defined program. **P3:** there is a different angle that you can go about with this, but we can leave it to the next time to get inputs from **P2 and P4**. It's an area that I don't get really heavily involved with.
1:32:00_1:36:00- P5: So the next one would be easily, for the **Top Metric Sharing, and for the sub metrics CDE, and Information Exchange. P1:** So, this is standardised protocols for standards and drawings. **P3:** More like electronic, filing system, where you got one implemented. Level 2 BIM standards, gateway checks in it, or using it internally, or using it just for projects. Because ideally for a CDE, you want everything to be perfect. **P5:** Ok, so its gonna be the same. **P3:** so the 1st one could be using design team or contractor CDE. **So you would say CDE supplied by you or others.** Because ideally your trying to say that you should provide it. SO you wanna work to that. Supplied by another. **P1:** So, the 1st one is about the files that stored about, because I think that's not the case. **P3:** I think the 2nd one would be implement CDE or is not BIM enabled. Gatway checks so it's line with the Leevl2 BIM stuff, because if it's named incorrectly, then it doesn't get uploaded. So here you can go CDE, not BIM enabled, and you can put example of docs and any other data, and the last one could be implement or even certified CDE system, **P5:** it's BIM enabled. **P3:** It's BIM enabled
1:36:00_1:38:00- P5: So the last one for this workshop, and we'll leave the FM for the next workshop, so the next one would be **Information Exchange.** It's very similar to the previous one. **P3:** So, you're information exchange would be not aware of them and not defined, briefly aware and defined, and then maybe 3 or 4 PLQs outlined, and the final one would be **clearly defined information exchanges with Tangible PLQ included.** So your Information Exchange might be nothing, then you might have some PLQs produced in them, so you say is all models coordinated. Is there any COBie information in them, so on and so forth, and then your deliverables might be COBie, IFC, stuff like that. Eventually revolve a full list of documents requirements and the purposes of them, and the purpose for each document produced is the information exchange that evolves around, sometimes clients don't know why you're doing the information exchange, what they relate to, or what their purpose are.
1:38:00_1:42:00- P1: So I think we will have to stop here. **P3:** So now you get an idea on how it is, so you can probably fill out that one yourself. Have a look at the documents I gave you so you can have an idea what an EIR is, and what the RM is. We can go through it and have a discussion on them the next meeting. **P5:** Yes, I will continue with filling and adjusting them out and publish it online for everyone, then the next workshop we would review them quickly with the other members and update the areas we left and finalise the whole organisational level, so thank you both for your time today and I shall see you in the next workshop.

Focus group workshop notes for Operational level workshops 6 and 7:

0:00_10:00- P5: The discussion in this workshop would revolve around the last organisational level (Operational Level) and populating it where necessary similar to the previous 2 levels. In this organisational level, there are a set of duplicates that exist between the parameters here and those in the 2 previous levels, and so I have printed off the completed Strategic and Implementation levels.
10:00_12:00- P2: This is targeted to which audience? **P5:** This is set to target the Project managers. This assessment is initially designed technically to be filled out by stakeholders with the expertise on the Operational stuff and working on the projects. **P2 Question to P3:** Would this fit the design managers? **P3:** from the client side, I am not sure to be honest. But I guess it won't fit. **P2:** I agree, this would best fit with the project managers.
12:00_21:00- P5: Elements of the Level 2 BIM metrics emerged from the checklist that was provided during the previous study. Definition to Capital Delivery as a Top Metric was provided, and a discussion on the 1st **Capital delivery sub metric (3d-6D inputs). P2:** What would be the maturity level? **P5:** As shown in the maturity descriptors; 1st would be some understanding of the 3D-6D inputs without application, 2nd would be partial application, and last would be full application. **P2:** What I am thinking, is that not all projects would have 3D-6D inputs in them, would that matter for the maturity level? **P5:** It wouldn't matter, and they would be placed all together. I am not sure if we would break down the inputs separately (3D, 4D, 5D, and 6D) or have them all together? **P3:** If you would separate them, then the scoring would differ, so one of them would be low and the other would be high. I would place a caveat that says that the scoring would not depend on having them all together, and it would be on all together not on each one separate. This would be ensuring that they would be used on the projects. **P2:** what would then be the 3-level maturity level? Would it be that 1st: Identifying and being using it, because what do you want to measure? Is it how do you use those? **P5:** Yes exactly. Previously the descriptors were given as: No, Basic, Full. For now, it can go as: Having a basic understanding of the 3D-6D inputs? **P3:** You could have, because it's a Client side, whose completing it, because if it's the client filling it out, depending on what the contractor has done in the end of the project, then your metrics would be slightly different. Because you can have at the end of the project, you list the KPIs (3D-6D) in wanting them all, then you can put (I didn't try it) (I tried it but it wasn't successful) (I tried and it was well implemented). It depends on who is filling it out, because that's how I would do it. Client scoring based on the contract, but I'm not sure if it's for the client to fill out and say yes, we've done it on this project and we've achieved it and it's slightly different. **P2:** Yes, but I assume if it's a project manager who's filling it in a BIM or a NON BIM project, then you could say; 3D and explain more. **P5:** We could say **Usage and achieving 3D – 6D elements in projects as the essence of descriptor**. **P2:** For the maturity level, the 1st one would be: **Simply identified 3D-6D elements, but not fully followed**. **P2 and P3:** 2nd: **Identified but not used in a certain degree over projects**, and 3rd: **Identified and used in multiple projects.**
21:00_28:00- P5: 2nd Sub metric is **Component drawings**. So this is related to the drawings that come from the 3D-6D inputs. **P2:** Do you want to say that the component drawings are coming from the inputs. **P3:** Driven. **P2:** Instead of component drawings, would you use Automated 2D CAD drawing production? Or use of the BIM models for production or drawings driven by the 3D model something like that? Component is more like a component **P3:** An air handling unit. You can even call them shop drawings or design intent drawings. **P2:** What we want to say is, you have the model in revit, you got the drawing from it and then you increase the level of details if we need for that specific area of the drawing. But if you change the model, then it would reflect on the others. So you can say Automated 2D, or you can say model 2D drawing driven by 3D model. **P5:** The naming convention of Automated 2D could be kept as it is, and then in the description we could say **P2:** Use of 3D BIM model for production of 2D drawings? **P3:** Except the schematics so they never come out in those. **P5:** What would we say in the 3 level descriptors? **P2:** Is that relevant for the clients? **P3:** We have clients in our projects that are involved with this. There are representatives. Like an e-consultant. **P2:** Because we are measuring the level of maturity of the client team, so we need to be careful on what we are saying here in terms of the levels. **P3:** This is not going in the same direction. **P2:** This is more technical. **P3:** To measure the maturity of the client wouldn't this do with the ability to check if the drawings are driven from there and if they are getting the information rather than them being there. I don't think the client would care about that. Maybe if they use it 10 year down the line then wouldn't get some plans out of it. Start, designing and extension of the building and stuff like that. **P2:** If they have the model, then they can extract the data point in time. **P2 and P3:** We don't know or think this would be relevant for the client, and thus it would be removed from the spreadsheet. **P2:** It doesn't matter whether this is executed from a drawing or a model, because this would be delivered to the client in a PDF format or a print off in whatever way it was designed.

28:00_37:00- P5: the next sub metric would be **Level of Details (LoD)** you will find that they are all pretty much linked together. for the 3 levels we can say they are aware. **P2:** They are aware of the level of details, or could be that for this 1st one; they have a basic / or no level of understanding that is relevant for the projects. That is relevant or appropriate for the project. **P3:** Is this the way your thinking of going with it? **P5:** Yes. **P2:** The next one could be a good understanding level of details and basic ability to check it, **P3:** I think checking is more important for this, and getting what they are paid for. **P2:** and basic ability to check, so they can open and visualise models. **P3:** you can put it in that way (visual checks) i.e. can spin around the model and see how the model works and its like floating in the air, that's not correct and there's no and missed details around it like LoD 500, and then you find a full understanding around the LoD 500, and the model presented in the end of the day how it would look like. **P2:** So it could be that they don't need the LoD 500 that they could be well maintaining this model and LoD that they need it. So it's not that the LoD needs to be high, but its their understanding on the LoD needs to be high. So they can say; Can you please include high level of details for this and that element because I need that one. **P5:** The final level we say that there is a full understanding. **P2 and P3:** Yes. **P2:** and you can say the capabilities to use and visualise the models. **P3:** The last one you want to put there is check the data. **P2:** but because he is saying level of details 4D and development so this would be just the graphical. **P3:** Oh is it just the details. **P2 and P5:** Yes. **P3 to P5:** Have you got another section for Level of Information (LoI) or have you got just LoD? **P5:** Just LoD. **P3:** Because LoI is important to the client, so if you ask me, you've got the wrong one. **P2:** So maybe if you put LoD and LoI? **P3:** You can put Level of Development (LoD) and then in the description you specify it by saying; The ability to check if the level of Details and Information are set up. **P2:** Because you are not looking just at the graphical side of it. **P3:** Change Details to Development. **P2:** In the description put Level of Development, then (Level of Details and LoI). **P5:** We did talk about this in the Implementation level. **P3:** If you can go back to the Implementation level. **P2:** Yes we talked about it in the MPDT (detailing LoDetails and LOI). **P3:** There in the implementation level they are producing the MPDT but they got to know what that actually means. It is MPDT you go and produce that, you got architects and contractors who are producing that, who still don't understand what this is. They need to know how to check it to make sure they are getting what they are asking for. **P2:** In the description there, you can link it back to the previous one (MPDT) if you want. So you can say; **The ability to check if the level of Details and Information are set up as stated in the MPDT**. Because this is what the clients think and they are asking how are they checking that.
37:00_38:30- P5: The next one is **File transfer standards**, so this is like the IFC and file transferring standards. **P3:** Is this to do with like what to ask for or where you are going with file transfers? **P5:** so transfer from CAD to revit to IFC and so on. **P2:** CDE, sorry to interrupt. **P3:** We have on previous slides haven't we? **P5:** Here in COBie. **P2 and P3:** NO CDE. **P5:** Oh sorry, CDE, yes we had it previously in the Implementation level. **P3:** I don't think it is relevant to have File transfer standards, so I think it should be removed. **P2:** I agree, and that's what I asked about the CDE, because I was thinking about the information exchange transfer. **P3:** They don't need to know how or why or what format because formats would be coming up elsewhere. Generally everyone knows what file transfers are used. So they would need IFC and excel that's all what they need, they might need if they got plan, then picksheet or COBie, so I think its not relevant.
38:30_58:00- P5: So then the next one is **Project reviews**. **P3 to P5:** Is this like gateway reviews? So do you know what it is? **P5:** No. **P3:** so during a project, you'll have data drops. So at a certain stage you will have a data drop that will hand over a specific information. Is it to do with previewing the information and handing it over or is it reviewing the whole project? **P2:** Is it relevant for BIM? Project reviews. **P3:** gateway reviews is, Project reviews isn't. **P5:** So maybe in the description I can write gateway, so I keep Project reviews and I include gateway reviews in the description. **P2:** Yes, so you can write **Project reviews in specified gateway intervals defined within a project**. **P3:** Yes, specify gateway intervals. To be fair, its quite important because then you need to know like what they are asking for in certain stages and what that looks like. It's not always easy. You'll have your PLQ's feed into it. **P5:** So, in the maturity descriptors we can say in the 1st one; there is some understanding of the reviews but not using them. **P2:** Basic understanding of the client role. **P3:** For the gateway reviews in stages 1, 2, and 3 you'd have a lead designer who would check that information and approve it and pass it to the client for them to understand what to do with it and to do checks and see if they are happen with it, and if not then they send it back to get it reviewed. So the way to go with this, is they need to understand it because the contractors and lead designer would need to check it, and then it doesn't mean they would approve it. So they've got to see and say yes we are happy with the information that is given from the contractor, so move on to the next step. **P2:** The other thing is that in a certain gateway, it could be that it's not just the approval that the client would need, it could be that for every stage, we need the client to issue their asset register or list and how they want to name it on their projects, so they have responsibilities on those

gateways. So if they understand their roles and responsibilities is on each of the gateways, so there could be a basic understanding of the gateways. **P3:** So not all of them need direction, some of them your giving them information and so others won't need direction. **P2:** and they get the handover and they say, OOOH, but I don't want this, but it's too late. **P3:** Because you didn't ask what you wanted before, but you've asked about this. **P2:** so you can say **the basic understanding of the roles and responsibilities for the clients on the gateway reviews.** The next one could be; **Good understanding of the roles and responsibility and acknowledging the clients on the gateway reviews to be applied. P3:** The last one would be; **Clients carrying out responsibilities on the gateway reviews. P3:** Out of curiosity, did they teach you these things at uni? **P5:** Yes, we learn the theoretical aspects of this, but not the practical **P3:** I think you need to know both the theory and practice. **P2:** There has been ways to link both together at the uni. Through guest lectures who come to deliver the lectures. But you don't get the practical work on it, because COBie is a perfect example. So I had to learn it through a real project myself not through uni. **P3:** You can learn it, because previous interviews with colleagues they had the knowledge about it, but if i was to hand out the
information without a title on it, would they know what it is? Probably not. So I would be concerned about this.

58:00_1:05:00- P5: So then the next one is **Lifecycle Analysis**. So examples to this is structural, acquistics, so some analysis being attempted. So instead of having each one separate, this was to group them all under a single name (Lifecycle) and this would be the examples to it. **P3:** so you don't mean lifecycle analysis itself, but rather the overall analysis of modelling, daylight simulations and things like that. **P5:** We can change this. **P3:** So definitely you would need a new term for this, because lifecycle analysis is its own thing, which is 6D and is covered already. **P2:** the analysis here are more related to the project, and it's not going to measure the maturity of BIM. For example, you can have writing analysis and you may not be using it for a model. So it's not going to be relevant for the maturity of BIM, whereas lifecycle is relevant. **P5:** It is covered already previously. **P2:** because previously that's 6D (Lifecycle) and not the analysis, so in this case the analysis would be how the client would then keep that model live for example. Keep the model live and use the 6D data for the lifecycle of the building in a way. So it could go in that direction with the lifecycle. **P5:** Yes previously that's what we've said, but now this is what it could be. **P2:** The lifecycle of the building itself or the model how they will get that information that they will receive and keep that across the lifecycle of the building. SO initially you can say that; we don't have the capability to measure or operate the building using the model. The next one could be they can use that but its not integrated to the system and fully integrated. So they can manage the lifecycle of the building using the BIM model as a baseline. That could be made available for the FM team or contractor whether they understand what they need.

1:05:00_1:13:00- P5: So then the next one is **Modelling Simulations**, which was pretty much similar to the previous one and taken out from the checklist. So simulations being prepared. So it's very similar to the previous one. After it was **Project Information Model (PIM) exchanges.** We had this previously in the Implementation plan, but then it was removed. **P2:** here you're talking about the level of model definitions which we just mentioned before in the LoD and LoI. So previously its about checking the model, but this is what you want to see here. So its kind of you can merge both modelling simulations and PIM together, I think they are overlapping somehow. **P3:** Yeah, I would merge them both together, because I think the descriptors you got there are originally good, but it is covered by the LoD and the LoI. They are always covered by the gateway checks. Part of the handing over gateway checks. So they can be merged together. So you can remove modelling simulations, and merge its description to the PIM. **P5:** So we would remove modelling simulations and then going back to the descriptors of LoD and project reviews, we can see how we can tailor the descriptors to the PIM. **P3:** Yeah, so in the PIM, you could say; **Model definition expected in brief, concept, definition, design.** Probably we'll add more stuff here, I'll just type it in for you. Because I guess you've got asset information model and an as built model for this somewhere else. **P5:** No I don't have an As built model. **P3:** so you can add another row there, replace modelling simulations with **As built model.** Then for the descriptors you can say; **As built model expected to be reviewed for the projects attempted in organisations.** I will type in for you what the maturity level descriptors would be. **P5:** Yes, that makes more sense now. **P3:** Then for the PIM you can add in the descriptor; **design, build and commission, handover and closeout, operation and in use stages.** I will type in for you what the maturity level descriptors would be here.

1:13:00_1:16:00- P5: Ok, so that's Capital Delivery done here, so the next top metric was Facilities Management. And under there we have 9 sub metrics. **P2 and P3:** Oh wow. **P5:** Yes, this was the most metric with sub metrics here, but offcourse it could changed and be reduced. So the 1st sub metric here is **Manuals. P3:** What do you mean by Manuals? Oh' im conscious of time. **P5:** It is meant by the asset information model, I took it from the checklist, and then I have **Information Delivery (AIM)** which is related to the asset

management system. **P2:** See, I think AIM is more relevant and needed here, but I think manuals is not that important. **P3:** Yes, I agree. **P2:** So I think you can remove Manuals and maybe merge its descriptor to the AIM. **P5:** Yes that's fine, so that's the descriptor of manuals. **P2 and P3:** Yes, so you can take that descriptor and tailor it here, and the descriptor for the AIM could go as; **Operational and Maintenance data for an Asset Information Model. P2:** that would cover manuals and therefore, you won't need it. And for the maturity level descriptors, it could be the 1st one; **Basic understanding of AIM but not aware what needs to eb done for the data.** I'll type it for you the 2 others.
1:16:00_1:18:00- P5: Ok, so the next one was **FM and OM use**, and this is how we described it. **P3:** I don't think this is relevant and you would not need it, so remove it. **P2:** Yes, I agree, I think this is not relevant for measuring the maturity level and you can remove it from here.
1:18:00_1:22:00- P5: Ok, so the next one was **COBie data**. This offcourse is a major one and should be there. **P2 and P3:** Yes definitely you need it here, and we wonder how people will measure themselves with this. **P3:** I really wonder, because a lot of people get it wrong with the COBie data, and sometimes they don't understand or know how to use it. So you might be getting low scores on this one. **P2:** Yes, some people struggle with COBie. **P5:** Ok, so thios was the descriptor for COBie. **P3:** I think you can tailor it a little by saying that; **COBie data requirements and reviews expected to be handed over for an asset model.** That would make it easier and clear to understand COBie. **P5:** Ok, so that would mean we need to change the maturity descriptors. **P2:** Yes, so the 1st one would be **basic understanding but not aware what needs to be done.** 2nd would could be; **Good understanding and using it in the basic level, but not fully integrated in the system.** So they extract some information from that, or they can set up some kind of filtering the data from the spreadsheet when they need to maintain this and that. So they are using it but it's not fully integrated with their system. The final one would be; Fully understanding the COBie scheme and full capability to integrate the asset data into the operation and maintenance process. **P3:** Yes, I agree with that. **P2:** because it could mean they don't have a system but they still could be using the process.
1:22:00_1:34:00- P5: Ok, so the next one was **Asset reviews.** This is pretty much close to the asset information model. So maybe we can just remove it. **P2 and P3:** Yeah we think so. So the next one was **Handover requirements (GSL). P2:** The soft landings could be related to BIM. But could also be an additional exercise. So I don't know if it will measure the BIM capabilities by including the soft landings. We had projects that had the handover soft landings, and they were not BIM projects. **P5 to P2:** Ok, so what your saying is we might not be able to measure the BIM capability on the GSL, is that what your saying? **P2:** Yes, but if they score high, it would be a good thing, but if they score low, then it would be a bad thing. **P5:** So jumping on, I had FM training here, which I had previously in the Implementation level. So I can take the same description and add it here. **P2 to P5:** What was the description on the previous one? **P5:** What was the description in the previous one? **P5:** Here you go. We said no internal or staff on facilities management and no full training plan created. **P2:** How that relates to BIM? **P5:** Because this is close to the level 2 education and training, so we had it in the Strategic level. **P2:** Let's say for example, I'm a city council and they don't operate their buildings they gather a manager and contractor to operate their buildings. How would it be relevant for them to get the Facilities Training? **P5:** If they don't know how to do the FM, so they would require to have some training to get a better understanding on how the FM is done. **P2:** but how would this be linked back to BIM? Because I think its not really related to BIM. Level of training on the facilities management process operating in BIM, then this would be linked with BIM. **P5:** Oh ok so adding BIM would make it related then. **P2:** Yes, because FM training is related to FM, so its not necessarily related to BIM. I know where you are coming from, which is to be able to fully understand BIM and do that on practice, but it is related to FM without BIM. **P5:** So I would have to go back in the previous level, and include BIM in the FM training description. **P3:** We already had that before, didn't we? **P5:** Yes, we had it with Level 2 education and training in the strategic level. **P3:** We already covered it somehow in that descriptor, but if you want to add CaFM then that's fine, it would cover FM. So if that's not the case and you wanna stick with Level 2, then you can **remove the FM from here and the Implementation level**, because in theory you've got most of the stuff in the strategic and Implementation, but in the Operational, should be very few things really. **P2:** Operational level, if you had that in strategic level, it would be something like deploying or delivering the training. **P3:** so you've had it in the level 2 and the consistency descriptors says it. **P5:** Ok, so we will remove this, and I think we could also remove the last one, GSL champion engagement from here, because we already have it in the Strategic level. And we had BIM champions before, and we removed it because we had roles and responsibilities. **P3:** Yeah I think it could be removed, and then you already have **Post Occupancy Evaluation (POE),** which would be important to have in here. What do you mean by Level of POE. **P5:** It's not Level of, its POE. **P2:** We have to decide if we are to keep the GSL or not. **P3 and P5:** Yes we would keep it. **P3:** Because we have a period of 18 months, after care of period that includes BIM as part of it

on most projects and part of it would be your evaluation and what has been handed in over. Is it working is it right? Is the COBie data given correct? Is it being used properly in the systems. So you'd sit down and get the systems working. So is this working? No, then Why? So by the end of your POE period you would have those BIM sections covered because your models would be rounded over and working. And the COBie data handed over and working. **P2:** so in this case, **leave the Handover requirements (GSL). P3:** So, I think what you've got in there looks fine. **P2:** Yeah it looks really shaping up well and I would like to see results of that. **P3:** Would like to see results from clients once they start getting it down and stuff. So would you be sending this out. **Recommendations= P5:** Yes, I would meet with the NWCH and decide who are the clients that we would target to send this out to and get it filled and reviewed back. **P2:** I suggest that the best way to test something is to give them to fill it out, so for example, if you have 3 different clients filling that out, then not just to score it, but to get the feedback of it, to see if they understand this or not. **P3:** Because some of them may say, you need to reword this or this doesn't make sense so on and so forth. But that's good, because you want your questions to be clear and to be fully understood and for someone to engage with it, and offcourse the important part, is what the scores are. **So you might get 1s, and some 3s, probably most 2s. P2:** I don't have any clients who have a COBie spreadsheet, the only Client that we hand over full level 2 BIM project that they are using that in their operations, they ignored the COBie because they are getting data straight from revit. So it's good as a scheme to organise the data. But they forget about COBie. They ask us to name a few fields in revit and what they need there. They are using the BIM model, which is what you want to use. But we've putting effort more into COBie and then suddenly, no more COBie. It took so long for them to get to this point. Now the CaFM systems are clever enough to cover up data from revit.

1:34:00_1:56:00- P5: Ok, so do you think we would need to have the duplicates here? So In collaboration, there was **collaborative protocols** in the strategic level and here. **P3:** For the **Information Requirements**, probably, because you'd put the post evaluation of whether your contractors have met the information requirements, so the client would need to know how to evaluate that, and **CDE**. We've had that elsewhere, **P5:** Yes in the Implementation level.

P3: so yes, I think you would need to have those both here and remove the other duplicates from there. **P2:** CDE, I would definitely have that here. **P3:** You would need to have this data stored wouldn't you? You need to know how to check that and whether they are compliant with standards (BS1192).

1:56:00_2:03:00- P5: We would need to fill for the **As built model. P3:** for this, it could go as; **As built model expected to be reviewed for the projects attempted in organisations.** I will fill out for you the maturity level descriptors. But the 1st 2 levels would be very similar to the PIM description, and the last one would slightly change to **(As built model reflected on what is being constructed and being able to check and confirm.)** Which is fairly easy, you get issued the drawings, review the drawings and check to see if that information is the same as that in the model. You might have a specific manufacturer there that is handling a unit and you model it. **P5:** I would remove some of the duplicates such as Collaborative protocols, Implementation Plan, Construction programme, and Information exchange, and would keep Information requirements and CDE. And this concludes the Operational level. So I will fill out the remaining descriptors and adjust the whole level, and share it along with everyone on the google drive. So now, we have completed the 3 organisational levels and I would go about to meet clients to give this to them to be filled out. If you can have a quick look at the KPIs and tell me what do you think about them? **P1 and P4** have already agreed to this list, so what do you guys think? **P2 and P3:** Yes, we initially agree to the list of KPIs being provided and they could be set as a standardised list for linking the KPIs with the BIM metrics. **P5:** That would be the next step that to give them the organisational levels to be scored and see how it would be linked. **P3:** Yes, it would be interesting to see the scoring of the metrics along with the KPI links. **P2:** Yes I agree as well. **P5:** Ok, well this is the end of the workshop, and I would like to thank you for your participation through the workshops, it was an honour to hold these sessions with you, and I would update you with the outcomes of this research as it progresses. **P2 and P3:** It was nice to work and participate with you and good luck with your research.

Appendix F: Chapter 7 Additional information on Sample of Interview Transcripts

Interview Transcripts: A Level 2 BIM Maturity-KPI assessment for UK client sector

Section A: Understanding BIM maturity and KPIs and its impact on the organisational and project needs.

Organisation and project, what are they currently doing and where do they stand

1) Where does BIM stand in your company in terms of its levels of adoption and Level 2 BIM compliance?

[Interviewee (I1)] = *2 questions here. When it comes to **Level of adoption**, then it is **done in a structured way** for the last 10 years, and then we **fall out to be unstructured**, and more of Prototyping type of work. In regards to Level 2 BIM, from a process point of view; **we are doing it for the last 3 – 4 years*** **[1]**. *From the deliverable of BIM level 2, we **receive COBie data and this is a lot** and is more recent* **[2]**. ***I don't think** there is any company that **could comply with Level 2 BIM*** **[3]**. *I think its **project based**, its **e-projects** in time. We **drive it on most of our live projects**, the way we look to implement **BIM and digital engineering*** **[4]**. *Even if it's not a requirement, then we will still target **it on our jobs** for **value towards the business, because we see value*** **[5]**. ***Digital engineering in the company** I work for, we have 4 key drivers of our unique selling point, and **digital engineer is one of the things that enable everything** in the business* **[6]**. *It's fundamentally we go to work, it is **not digital technology and not necessary using the Level 2 BIM process**, but we use **digital technologies with models**, we see value in everything we do* **[7]**.

[Interviewee (I2)] = ***I would like to say we are fully compliant**. **From our point of view, we are**, but it depends on the team we are working with* **[8]**. ***We can't deliver compliant COBie** for instance if designers or subcontractors are not **providing BIM information*** **[9]**. *This is where it gets tricky, we know how to do it, but we must get it by in the full team.*

[Interviewee (I3)] = *An **Audit of all the internal projects**. Auditing and conducting checks on **whether the folders and files are BS1192-2 compliant** or not* **[10]**. ***Looking at models** themselves and how projects are set up and seeing what sort of checks **have been done and tools that are being used**. 2 sides for auditing projects themselves; **data and information compliances, and how model is put together*** **[11]**. ***Creation of all the documents required to be Level 2 BIM compliance**, **all the capability assessments, protocols, BIM execution plans template, as well as project execution plan template**, so if not public sector project, still **using the same method** of auditing, **process and procedures** for any project* **[12]**. *Not necessary having to be a **public sector project**. **Delivering projects to Level 2 BIM compliance**, including COBie-data* **[13]**. *But as an **Architectural practice**, it is required **only to set up the COBie data fields** for what we are responsible for; just 1 element* **[14]**. ***Definitely compliant to Level 2 BIM*** **[15]**.

[Interviewee (I4)] = ***There is a BIM implementation strategy in my company*** **[16]**. *It started with the aim to **achieve BIM level 2**, and there are all the **strategic and BIM implementation workflows in place** and implementing it in our projects* **[17]**. *We are **seeking the delivery of BIM level 2** while having all the processes and documentation in place* **[18]**.

[Interviewee (I5)] = *In terms of adoption, there are **2 strands to our company**. Internally, we have a group of people who **primarily work on minor work projects**, maintenance projects, small scale things* **[19]**. *Their brief is **to turn around the project's information** very quickly. Their brief is not to meet COBie or meet any government initiative, in terms of BIM* **[20]**. *So that being the case and **being more than 50% of the workload that we currently have**, we haven't elected to pursue BIM in any great detail* **[21]**. *2 years ago, we had a slightly different strand, **2 major works with 32 schools**, all which were brand new, although majority of them were **being done outside the department and some work being done inside**, in that point of time we were **looking to develop a team of people that would rule out BIM as an initiative and standard** across the department* **[22]**. *Since that program is completed**, there has been a big change in personnel,** and with it some of the experienced staff were gone* **[23]**. ***So, what we're left with now are just limited number of people (2) who know about BIM**, which is not enough to drive forward in an organisation this size in a big program* **[24]**. *The 2nd strand externally, we have a lot of projects that are design and build, so we **use the construction hub to go out to contractors and consultants**, and where we **do impress upon them through briefs*** **[25]**. *We say to them you must **provide us with BIM documents** to **cover Level 2 standards**. So, getting projects going back, which are **starting to be BIM and building upon our BIM library information and experience** using, manipulating and interrogating **BIM models**, so in terms of our maturity, we are doing it kind of a 3rd party through others* **[26]**. *I was asked to produce a strategy document which forecasts some milestones and how long it takes us roughly to a position where **we could stand on our feet and deliver a full Level 2 BIM project**, and I'd say that would take 5 years. Because we have to maintain not only our workload, but also this **new skillset*** **[27]**. *There are lots of constraints which impact upon us; **fees and time** being a couple of them* **[28]**. *With that in mind, I can put together*

a report of which has illustrated some of the ***bottlenecks some of the problems and issues that we've got to overcome****, so we can* ***get to a position that say we can do it*** **[29]***. That information that I have obtained from the private sector, architects, engineers, we've been down already that process, how they developed it and delivered it. The difference between them and us is that we are a department of 80 staff, 40 technical staff, we deliver a program of an excess of £60M a year where some of these other places are done, so there is a big difference of what we do in scale. The 2nd thing is, as we are a small cog, and a large engine, so CMPP are a very small department, housing, social services, children services, finance, they are all much bigger than us. They have 1st call on any IT issues and resources so they could face a problem, because they face the public, its typical that they would get the resources to help resolve it. So, we get a back service* **[30]***.*
So, anything we want to implement, in terms of ***software, getting that computer set up, making sure the network is capable of running all these things, takes us a long time****. There is a* ***problem with the network****, it has been upgraded, the servers have been upgraded, but the way it was set up, it wasn't set up for any graphics to run on any program, and as soon as we started* ***putting our BIM models*** *in it, the network is slowing down* **[31]***. We have a* ***limit*** *on what we can* ***store on our network servers, so in our research on how we can store data on the cloud*** *somewhere, to be secure. This is another strand, which is* ***security****. There should be a* ***security strategy*** *in place so any data they have on their personal, or building running operation is held securely. So, this impacts on using a CDE, we got to check with the supplier where about their servers are, are they somewhere which is* ***reliable****, are they in a place where if we wanted to* ***change the location of the server****, the provider will agree to do so* **[32]***.* ***So, in terms of adoption, part of the answer is yes, and part of it is no****. So, there is no black and white on this* **[33]***.*

<u>[Interviewee (I6)]</u> = ***BIM is being talked through****, it's part of capital programs aims to implement it more efficiently. In the minute its more of* ***overload projects, where we get information on BIM and BIM level 2*** **[34]***. As a council,* ***we are nowhere near BIM level 2, so we see ourselves under Level 1*** **[35]***. There is a lot of* ***talking and trying with this, they want to employ*** *a BIM manager in the future, as we currently operate with Level 1* **[36]***.*

<u>[Interviewee (I7)]</u> = ***15 years framework with Stockport Council. 5-year clause*** **[37]***.* ***Awareness of BIM but no understanding*** **[38]***. Asset managers, FM, M and E, QS and Architects are very limited. Multidisciplinary. We are* ***educating the client on BIM****, and there is an* ***eager to implement and be compliant with Level 2 BIM*** *according to the UK government mandate* **[39]***. They heard* ***about the government mandate on BIM, but there was no strategy in place*** **[40]***.*

<u>[Interviewee (I8)]</u> = ***It doesn't, and we are struggling*** **[41]***. We've not got* ***clear EIRs****, we don't* ***have clear CDE****, and we're still doing as it's something that the contractor should do.* ***We're just not there****. That's why I said people are obsessed with that part* **[42]***. BIM is about the* ***feed for these buildings****, it's about managing them and* ***looking forward*** *and looking after them. So, you* ***are building right, so you can manage it right, and maintain right*** *going forward* **[43]***. So many people think* ***it's the 3D****, so few people think* ***it's the value on the future****. We haven't got* ***a system that's capable of managing this*** **[44]***. The problem is as you produce these* ***models in an infinite detail****, you scared that with the IT department,* ***how many amounts of data you need to design and manage the 3D*** **[45]***. What we need is a download from that, we need* ***to recognise the phases of a project****, and we're just* ***overloaded with data, so people are panicking, and nothing is happening*** **[46]***. We are* ***not BIM or even Level 2 BIM compliant*** **[47]***.* ***No EIRs, CDEs,*** *we are struggling with the electronic communications. We are still in the* ***old-fashioned emails****, so as MCC, we don't* ***use proper information transfer methods****, BIW conject, so we pier it on the contractor versions, we're* ***a lot way short and being capable*** *to run this* **[48]***. That's not just us, because other* ***councils are struggling*** *with the same issue. There is a struggle because* ***you haven't got the understanding*** *and the real senior levels that this is the next stage of investment* **[49]***. If you step aside from BIM for a moment, and look at the* ***IT that we have****, is that industry leading? No, its miles behind. We talk about* ***flexible working****, but we* ***don't provide a flexible work with a telephone that links to mobile working or an instant laptop accessibility*** **[50].** *We need to* ***invest in this huge strategic piece to use BIM properly****, so you need the FM team in, the estate management team, and the built team* **[51]***. It comes from us putting them in, but there is* ***this threshold and gap to get over****, so we're just now* ***getting BIM 3D models*** *with files attached* **[52]***. But where do you put that? How do you* ***run that building on a BIM system****, when you've got another 150 building out? 20 years from now, there will be a* ***shift towards that****, but BIM will have* ***disappeared in the future****. So, there is a* ***huge shift****, and it's because we're actually building owner and building manager that is a* ***reluctance*** *to make this huge investment into it* **[53]***.*

<u>[Interviewee (I9)]</u> = *The 1st question is probably the hardest for me to answer because we're* ***not directly engaged on project delivery as such*** **[54]***. What we do is we provide* ***strategic advisory, primarily at the client*** *or policy* ***level****, but that naturally has an* ***impact on the supply chain*** **[55]***. We are very* ***high in terms of our level****, but we are* ***working with lots of clients*** *that are much of a lower level* **[56]***. We are* ***compliant to Level 2 BIM*** **[57]***. I am promoting that so that we have to be at that top level.*

[Interviewee (I10)] = *There is* ***no projects done to the Level 2 BIM requirements*** **[58]**. *There is the New Adelphi building at the university, but what we got out of that was a model* **[59]**. ***None of the people in the working environment have the necessary experience*** *to enable them to* ***use Revit to do the BIM model*** *or change it* **[60]**. *It's not* ***in any of our capabilities****, we're just a linked team involves FM and just* ***a small number of our team is involved in the projects*** *around the campus* **[61]**. *BIM was done on the Adelphi building and* ***we received O and M files****, and* ***we got a model*** *and plenty of paper files* **[62]**. *So, we are* ***aware of the Level 2 BIM*** *government mandate, but it was* ***never used in our projects*** **[63]**.

[Interviewee (I11)] = *As a* ***practice****, we work on the* ***PAS1192-2, information management structures and BIM structures*** **[64]**. *This is based on 3 offices, one is in London, which is the main headquarter and* ***deals with major projects, such as Wembley park, 5000 units going around Wembley*** *stadium* **[65]**. *The practice is* ***much more BIM integrated****, so that* ***office leads the BIM journey****. They have the* ***BRE BIM certification****. They developed our* ***BIM information and protocols****, we have those in place for the practice* **[66]**.

Personal notes from the interviewee= ***BIM level 2 compliant for several projects*** *in the London office* **[67]**. *Major schemes* ***with large contractors / developers fully integrated*** *with Structural & Mechanical & Electrical Consultant / Subcontractors* **[68]**. ***Data models including COBIE outputs*** **[69]**. *BIM Manager is BRE Certified Professional.*

[Interviewee (I12)] = ***No consistency*** *around Manchester City Council* ***with level 2 BIM*** **[70]**. *I can only talk around* ***projects I'm already involved in.*** *However, on the Our town hall project, there's* ***a real desire for us to achieve BIM level 2*** **[71]**. *The* ***foundation is being put in place to enable that*** *to happen. We are really working towards that* **[72]**.

[Interviewee (I13)] = *The company has been* ***running for 155 years old practice****, we are comprised of* ***28 staff, 2 directors, 1 of them is a managing director, we have 4 associates, and a mixture of architects and technologists'*** *technicians throughout the building* **[73]**. *BIM is at the heart of our company and* ***we are compliant to level 2*** **[74]**. *We've been using* ***Revit*** *for the last 10 years,* ***as a piece of software****, Revit doesn't equal BIM, but the* ***process is something that has been continuously in development*** *since we've began the adoption of* ***this piece of software*** **[75]**. *We took on the piece of software because* ***we wanted the practice*** *more reliable way of bringing to tendering construction, large amounts of* ***repetitive design data****, and obviously Revit was the time that seemed to be the right thing, back in 2007* **[76]**. *So, we did a test project on a 500-apartment scheme in Gibraltar, and we immediately started seeing the benefits of working using data database modelling. From there, we finished the job of the tender stage information a month quicker than we thought we could, with 2 less people than we thought we needed* **[77]**. *BIM is again in the heart of what we did, it is* ***done on every single project that we have****, it doesn't matter whether* ***its size, scale, typology*** *or whatever it is. Our education team have* ***done over a dozen of level 2 BIM projects*** *in the last 5 years, all the way across north wales and more recently across Manchester* **[78]**. *Some examples of that will be we've done one in Hollyhead, Hollister kerby, and that was restoring a great two listed wardien building from 1901 into a junior's block and then create a new extension on the back of that. That was the* ***council's first extension of a Level 2 BIM project****. Hollyhod, and teacher in Vaughan, which is* ***flitcher's first Level 2 BIM project*** **[79]**. *I've been in the lead of Manchester's city council* ***Educational Basic Needs (EBN) framework project*** *in the last 2 years. We've done 2 in the 1st batch and 6 in the 2nd batch, so* ***8 EBN framework Level 2 BIM projects with the ISG and MCC****. I've been* ***working with one of your focus group members*** *on these projects* **[80]**. *Every* ***education project*** *in the sector that* ***we are doing is obviously Level 2 BIM****, because it's a* ***standard requirement that comes through EIRs*** *of all our clients* **[81]**. *As a practice, we are in a process of going through a* ***BIM level 2 certification ourselves*** **[82]**. *So, we have a* ***Standard BIM Execution Plan, Project Implementation Plan, Master Information Delivery Plan, Model Production Delivery Tables*** **[83]**. *I gave a lecture at the NBS conference in Manchester last week on* ***our modelling methodologies and our approach to Level of details****, Level of Information,* ***Level 2 BIM training****, we were responding to EIRs* **[84]**.

[Interviewee (I14)] = *All our procedures and standards are set up* ***aiming for Level 2 BIM compliance with projects*** **[85]**. *We've got that kind of strategy in place when it comes with* ***naming, standards, adoption of BS1192****. All of the projects that will start new,* ***98% I would say are using revit, so always within that 3D environment*** *and we also like to see other consultants also working* ***in a 3D environment*** *and trying to push projects into a Level 2 BIM project* **[86]**. *We are* ***using revit as a tool****, but it kind of goes hand in hand, because* ***revit isn't BIM****, we see as a 3 Dimensional drawing to it (tool)* **[87]**. *We see the* ***advantages of using that 3D tool****, whether we're* ***required to perform to Level 2 BIM or not****, and we see the benefits of that* ***collaborative process with other consultants****, also engaging with that* ***3-Dimensional coordination process****. So we're always trying to push that* **[88]**. *In terms of* ***adoption with standards****, we're getting on top of it,* ***coming to the end of finalising our standards and protocols which adopt all the BS standards and the PAS documents****, basically the 1192 suite of documents and* ***all the kind of British Standards that go alongside with that****, in terms of for example BS 8546* **[89]**.

[Interviewee (I15)] = ***I don't know much about BIM**, so we are trying to **learn it based on lessons learned**, an external is **placed and doing BIM strategy**, which is generic and not being used* **[90]**. *There are **existing projects which had BIM requirements** for level 2 BIM* **[91]**. *Working on **projects to develop a built in BIM, for example**, we have EIR templates, **trying to work with COBie**, and we are getting **some of the documents in place*** **[92]**. *However, we are **not compliant to Level 2 BIM*** **[93]**. *There is small team of us and it is seen as a bolt on. There are workshops being done, new frameworks started* **[94]**. *We are **working to put the BIM requirements in the contracts** and works information. We have **good information requirements for the data*** **[95]**. *COBie is **delivered to date. We are defining COBie structure**, in choosing and locating things* **[96]**. *We are trying to **implement the standards, our documentation has been reconfigured to BS1192 compliant**, and we are pushing this to make all our projects consistent* **[97]**. *Some of the managers **understand it**, but don't know **how to fully drive it** and this **reflects negatively on the working environment*** **[98]**. *We are trying to put **validation checks*** **[99]**. *We are not **mandated to Level 2 BIM**, but we are technically mandated, because we **fall out of the mandate** because we are centrally funded* **[100]**.

2 b) if not, then why are you not currently using it? What is your BIM maturity assessments when getting into a BIM level 2 project?

Prompt: Lack of Understanding, less significance and with less importance, the methods are too complex, existence of a huge collection of methods and tools, not aligned to Level 2 BIM requirements.

[Interviewee (I01)] = *We **developed our internal formal one**, and we **use our own one**. We **create our own one from lessons learned** as in **looking at the things on what went wrong**, what is not suitable, or what is more suitable. We **don't use anything that is produced by somebody else**, we would **look at all of them and make our version on it**.*

[Interviewee (I02)] = ***Resources, software and organisation BIM maturity questionnaire**. We have **3 forms**, looked at the **Penn state**, and **ARUP** and **different maturities** and we are **working with contractors such as Morgan Sindall, b & K, to develop a tool that actually makes sense**, because **some of the questions that come out of the Penn state questionnaire**, **does not make sense**. Questions like **what is BIM for you? Doesn't do anything for the questionnaire**. From our point of view, **it is complete bias**. So we made the **forms quite clear** so people **can fill it out** and we could **record their answers in their databases**. Definitely using it as a daily basis.*

[Interviewee (I03)] = *Looking at and **how to create internal checklist**, so I am **doing it based on my experience** in the industry. There is **no formal QA procedure**, so I am **looking to develop that** at the moment and I am **basing it** very loosely **in terms of the model correctness, basing it on the AEC protocols**. In terms of **documentation**, it will be **based on technology more**, because **there is a lot out there** to **make sure we are compliant**. At the moment, based on **me understanding what is required**, it's not necessary **about a set of documents**, but it **needs to be developed**. **There is no awareness or knowledge on Level 2 BIM maturity assessments (i.e. Penn state, ARUP)**. **I don't think it is widely known**, it is **well known with the academia**, but **not necessary known within the industry (practice)**. **Awareness of the Academics on BIM** in general **is** very **different to what is happening in the industry**, since it is **driven by BIM alliance**, **BIM government, and BIM level 2 website**; which is very limited and the **content** over there is **generic standards and templates**. There are **many tools** but is **not widely known within the industry** and **limited knowledge on the assessments taught in the institutions**, whether is it being acknowledged, or is it shared amongst the practice. **ARUP may have an excellent tool**, but **would they share their tools with BAM construction** as an example. The tool **could be available online**, but **due to copyrights and restrictions might not be shared amongst practices**. It might be **shared with the public**, but you **don't know what you don't know**. So if you **don't know it's there**, then you won't know **when & where to look for it**. If working on it in **Academia**, then you **will look for it**. Your **work is great**, and is **very much needed**, but **Academic institutions need to bring it to the table**. Bring the **work forward** to the industry and **having it shared**. The **industry is siloed**. Even with work being done by digital construction and **sharing the data, it is still traditionally much siloed**. People **don't necessary share** in this industry.*

[Interviewee (I04)] = *There are **pilot projects being done on 2 projects**, so once they are **completed**, we will **conduct a maturity assessment on them** to see where we are at the **journey of BIM** and if the **workflows and BIM standards are in place** or not. There is **no BIM maturity assessment alternative in place**, but there will **exist an assessment along with Lessons learned after the pilot projects are completed**.*

[Interviewee (I05)] = *I've taken some of the **headings**, and put them on **my report**, and these are some of the **comments that I generated** and came up with. For examples; **Roles and discipline**, that **would require a lot of work** in terms of sitting down with our HR people to **implement if we are going to have an internal provision**. If we want to **advertise externally**, there are **2 obstacles to it**, one is **what we want and what the market could provide** could vary. So what we want **could be different from the outside world**. Might be **different to a method of operation** to a private sector practice. We have a much **bigger workload**, we have a much wider base of **clients who have different***

***requirements**, so sometimes when we look for a resource in person, it doesn't necessarily mean that what's in market place is what we want. So we have to hire people or appoint people on the basis that we can try merge them up or they can **upskill**. So that raises a set of questions because what the **market demands** in terms of the **payment** and what the MCC **is prepared to pay** are too different things. Local authorities **aren't particularly our payers**. Some are argued with allies. We have other benefits instead. So our working hours are slightly less than the private sector and we get more holidays. Depends on how you look at a job. So If we are **trying to appoint people**, we send out our **terms and externally we tend to get very few responses**, so that's a **big problem for us** because the market for people **who have skills** in this area is quite provirus. **Lifecycle views**, we have an **issue with our FM guys**, the sector I'm almost **familiar with is the education**. The face of Public sector and ownership is **changing in the educational sector** particularly. The government is trying to **move local authorities away from building to building,** so they are run by 3rd parties, **so you have academies, education trust,** who are now building these buildings and running themselves and **are separate from local authorities**. So we tend to get **fewer jobs**. In terms of looking after buildings, we get a **very variety of people**. It's very **difficult when we have a model with lots of BIM information** to **convince people** that this is what you need and putting your fingers on any kind of **bits of information on this building**, so we have to put a very convincing argument together. Internally, the City Council's project people have **a fair understanding** on what is required, and what **can be achieved by using BIM**. Basically it revolves around **GeoSpace awareness**, the **spaces required for materials**, so when tendering takes place, we know how much. We try to **investigate cost** in use. **Whole lifecycle and lifecycle replacement costs**, so we got an idea that after N number of years, we know **we will spend x amount on replacements**. We try to plan for these things, and we are aware that on **a strategic level that there are more things** that we can do, **more intelligence that we can get out of a BIM model**. We use data at a **macrolevel** and it is something that we **try to develop**. In terms of **elements in this maturity**, **some we apply** and some we don't. **The delivery method** tends to be the same, whether its design build or in house, so **we elaborated** on this and used it to **develop our own strategy**.*

[Interviewee (I06)] = *I am **not seeing** we've improved with **any of this at the moment**. I know we have, because **we've got better data issues** that I'm looking at the data side of this. But as far as **being assessed by sharing the data, I'm not sure**. So, I could say that **the organisation is willing to continue using this particular assessment** within their organisation for **future projects**.*

[Interviewee (I07)] = *There is a flagship project within the council, and I was **pushing the council by convincing them** that it's a great opportunity to **do their project as a BIM project**, not as **a Level 2 strategy**, in order **to do a BIM 3D model** to see it from **a client perspective** and how the **building works**, and how it will be **extended and refurbished**. Ultimate **drawback to BIM is the cost and the software technology**. There **isn't the technology to implement BIM**, so they had to **invest a huge amount on the technology** to enable them to implement BIM. I am continuing and trying to **implement BIM and educate the client and providing them with the basics**. There was a perfect structure in place where all the **disciplines work together to use the BIM tools (software). BIM is considered as a software**, since the team understood **Revit to be BIM**. It was a perfect infrastructure in the organisation to **be a collaborative process to use BIM** but not all of them are **educated well enough**, due to **lack of interest**. The **mentality of not wanting to use the BIM** in the future, Change management.*

[Interviewee (I08)] = ***Because we don't know what's happening**, so somebody might have **picked up on that tool** previously and **use it occasionally**, but we **don't use that tool in here** on a regular basis. Because BIM is still a foreign language, so **assessing out maturity because we're immature**. Those of us **who understand BIM**, will **understand how immature we are, and how far away we are from compliance**. We **don't need a tool** to tell us that, because we actually **know what's missing at a real problem**, but **its communicating that** and **getting the bay of change and shift atmosphere**. If you could say you **need to be at that rate**, to get **BIM level 2 compliant** you need to be there, and your accounting here, it might **be a tool it could be used**, but there is a **bigger piece about the selling of BIM**, the **understanding of BIM which is missing**. **A tool of spider diagram**; like that, can **show me what we think and where we think we are**, "I think somebody is lying to get to those levels", but **they're much more mature than the rest of the industry.** Where I was, and what I was doing in 2011, the rest of the industry was way ahead from where we are now.*

[Interviewee (I09)] = *What we use now is **documentation within the EU BIM Handbook.** The website where you can get **addition information about it** and it is considered as the **nearest maturity assessment** is(http://www.eubim.eu/handbook/). **It covers a way of implementing BIM**, so the things you need to **put in place as a process to make the implementation**. As well as the **elements that needs to be in place in terms of proceed technical services and people**. It doesn't give measures against that, **it covers the areas that needs to be implemented**. Most of the **maturity models I mentioned earlier are about project delivery**, and are **quite tactical**, and what my **role** is concerned with is more strategic. I'm concerned with everything from National policy all the way down to clients' schools development. The **work that we did** in HS2 is kind of a **low end, more detailed**. In Latvia,* *Giving advisory data on how to **write a national strategy,** similar to the **UK** government **construction strategy** 2011. So in top level we will **do BIM nationally**, I am advising them. The levels kind of measures the attributes in the KPIs that would be in their national program for BIM implementation.*

[Interviewee (I10)] = *The university and its developments **stagnated for around 20 years**, up until about 5 years ago. There **wasn't a massive amount of new built**. The new build that took place was around the late 90s early 2000, which was before **BIM was in place**. We've built only 1 major built thing when **BIM was a tool** and that past us by a bit. If we **both worked for ARUP**, who were delivering building after building, we'd be **exposed to BIM** constantly. For the university, a major new build that **would have major Level 2 BIM** on it, has historically been heredity. So we are not really exposed to it. We **did project management**. It was somebody else who did it. What I know, is it was **used for clash detection**; we are aware of that, but **it's more of a construction phase**. It was used **more in the construction rather than how we can help the university in the management of the building** afterwards. I think that's what the focus may have been from what we've seen. **During the construction period rather than construction team how can we help the university in managing the building** itself.*

[Interviewee (I11)] = *The **own assessment is about the periodic reviews of the project practice**, there is the **BIM Execution Project templates and BIM Execution Plan templates**, and there is the **BIM information protocol**, which outlines **the practice's procedures and how they proceed with training and developments and the speed on BIM projects**. The firm has their **own BIM guidelines and they are based on PAS1192**.*
Personal notes from the interviewee = ***PQ Questionnaires + BIM Information policies & Review of BEP**. **Pre-Qualifications, Investigated NBS BIM Toolkit** for project management but not been adopted Practice Wide – existence of kNET project Management app.*

[Interviewee (I12)] = *I'm involved in a single project, we are on **our BIM journey** as a project team. I think we are in adopt in **a very mature and a realistic approach to BIM** because the project was a 7 year and got cut down to 5, so to **work through it** in a theoretical way through Mark BEW, then **the BIM task force, Digital built Britain**. We've got to think that **whatever we have to do**, if we do very **strict EIRs**, if we did them back 2 years ago, they will be **outdated now**. And if we did it now, it will **outdate in 2 years' time**. So we were **adopting quite a collaborative approach** to it. I read a lot of **BIM theories about BIM levels**, but I think its not real. I think **what we've done is we've developed the BIM EIRs where there were gaps**. During my task in the project, I was asked to **close the gaps in the BIM EIRs**, but my conclusion was you **can't close them because if you close them, then that's going to be a snapshot of time, 2017-2019**. So what we've decided is we **created a digital pilot exchange group**, because that's what we were reading from the city's perspective, we were **concerned about the legacy**, the information is going to come to us in the end of the project, so it **brings digital exchange pilot group and that involves and has got representation from all the design team**, so we've got the architects, the design engineers (everybody), and it also includes a digital information manager. That's made a really good start, so they're just doing **trials on things**, getting the **naming conventions** right, just establishing how the information should be structured, how it needs to come across, is it an our3, is it a uniclass, how has it been structured, I feel that's **a really good way of starting. Very slowly and then building up**. The team we have on board, their **competency on BIM is up there** and are good so I think during the design process and then the construction process, **BEP will be used to a high level**. What we are doing, is we are focusing on a certain; **great holistic building**, so the works we're doing is quite limited, but we are doing **some key interventions around the main entrances**, so there will be 4 entrances, and we will do **some vertical circulation on the lifts going up**. That's where we hoping to get a **BIM point cloud model** really good, so for the designers and everything, and **I feel the team will be very competent on that**. There are just **a few challenges** with that point cloud.*

[Interviewee (I13)] = *Since the Level 2 BIM Mandate came in, people **started throwing BIM maturity assessments that were like of going out fashioned**, they have in a wild single page with a dozen of questions, into **20 pages of toe brakers because they require far too much time to fill in**. They massively vary **depending on whom we are sending them out to**. Their actual knowledge of what they are asking for or whether they are doing it cause someone has told me they've got to do it. We **work with clients to develop their BIM maturity**, but we **haven't developed an assessment tool ourselves**. There is a standard **set of Level 2 BIM criteria** that are required for a **Level 2 BIM project in the UK**. So they are the criteria that **we will work to if the client says they want it to be Level 2 BIM**. That requires certain boxes to be ticked isn't it. In terms of using **data database modelling, agreed depth levels of details definition and information, Using PAS1192 – 2 and 3, and specifically PAS1192 – 2** to make sure our processes of passing data around are in accordance with that. We have **Master Information Delivery Plan, for the projects, we have our Task information delivery plans on every Workstage** of the job. We have a very truthful understanding of **what is required on a Level 2 BIM project**, so that's how we **apply standards to any projects** that they fall at, but in terms of you are always **looking at your clients EIRs for what they actually want**, and we've got to **tailor our service depending on what it is that the clients** are actually asking for. Because in the end of the day, **we find an awful lot of our clients***

don't really know what they are asking for. *Specially in terms of their asset information requirements at the end of the project. In terms of what the* ***actual deliverables are for an AIM (Asset Information Model),*** *we have to come with a standard offering for them if they don't know what they want, so they can* ***understand the level of information****, do they need about that element (door), to allow them to maintain it. Needing to know the specification of that element, such as the colour, density, size, and it all* ***comes down to the client coming up with what do you actually want****. We've developed* ***standard asset information sheet*** *for documenting that as part of or sort of our briefing process. So they have a set* ***of asset information as we go to them with each sort of individual type o****f object that they may have in a building, get them to go through it and say what they want and what* ***sort of information do you want us to provide*** *at the end of the project about each asset. There is no point in giving them* ***useless information that will not help them with maintenance****, its got to meet the information provided isn't it.*
<u>[Interviewee (I14)]</u> = *This is something that we are looking at, we like to get to that stage where we* ***are self-assessing****. I suppose we just try to follow the* ***BEP as part of our self-assessment****. As long as that encompasses all of the aspects,* ***I suppose what will be the Mark Bew's triangle about Level 2 BIM****, which includes everyone working in every 3D environment, that* ***clash detections that coordination and in also the kind of COBie requirements****, the Employers* ***Information Requirement would feed into the model****, and the* ***output is the COBie data*** *in the end. We are following the* ***Information Delivery Cycle****, but nothing on with assessment. What we are doing is the project starts off from* ***a client or a contractor point of view*** *and its always like we're* ***going to do it to Level 2 BIM*** *and slowly we surely see there is kind of* ***the main parts of what BIM level 2 is and is falling away slightly as the project develops****. That's never in the end when somebody goes, well actually* ***have we achieved the outcome of this project which will fully Level 2 BIM compliant*****.** *I'm not yet* ***seeing any contractor going back and saying this is the assessment and that was a Level 2 BIM project****, and even if we done that individually we find* ***that the contractors and clients do try and drive the requirements of Level 2 BIM****. We'll always* ***ensure that the BEP is always followed*** *by the life span.*

<u>[Interviewee (I15)]</u> = *There is a* ***very basic one done within the BIM strategy group*** *where Mott did it for us, but it did not use any of the standards and it was quite high level. We have not done major assessments, because we only had in* ***deficiencies****.* ***We have a Level 2 BIM project****, but… I look to it from the sort of the basics in place, in terms of* ***consistent ways of working and numbering****, we did that on* ***the asset information requirements****, so it is worked well on the project phase, not everything is fully compliant in terms of you looking for the basic standards……****. We have not done any assessments yet****, bear in mind that there is* ***no one in house who's got the time to do the assessment****, because it's just myself and some others who is driving the business requirements on projects…. There is a* ***station project*** *that is due to open soon and we are* ***reviewing their handovers (the asset information model) and its*** *definitely* ***not Level 2 BIM compliant****. We engaged Mott to do a* ***model review check of the project****. This was the assessment done to see what was compliant and* ***not to the EIRs produced for this project****, and the basics that should be compliant with Level 2 BIM.* ***There was an assessment that is not compliant****, but when it takes place, we* ***will go back*** *in that and check and see what* ***things didn't go right*** *and where we can improve to upskill to be compliant…****.*** *We are driving* ***lessons learned*** *from that into other projects that is not formalised at the moment, because there is no time given my position. I am responsible for a range of 50 – 60 jobs who will put metric requirements. They have just* ***embedded BS1192****, which is harder then what everybody thinks, because it relies on having a really good asset hierarchy which we don't. We have* ***20 million different systems*** *where it is* ***maintained with metro links****, they manage the system, and they don't have installation dates or asset data… It is all being done as business usual, and is not part of a change program, it is slow…..*

4) What are your core (Key) KPIs that are being used within your organisation, and how do you measure them? Are they internal or national KPIs? Are you able to assess the impact of KPIs on project / organisational performance?
Prompt: If you use Construction Excellence KPIs, then which of the CE KPIs do you use? All? Some?
(If answer= Yes, then answer the question and proceed to question 5),
(If answer=No, then proceed to Question 6)

<u>[Interviewee (I01)]</u> = *We have our* ***own digital engineering venue in our business****. Changes each year, we run version 5. There are around* ***20 things we measure against on every project****. We* ***measure it on a monthly basis*** *on 20 different elements. A* ***template of the KPIs*** *and* ***how it is being measured*** *was provided. It sets up what* ***we have from a modelling perspective****, then it outputs where we see value in a framework. It is subjective, we would* ***assess that*** *by and then* ***feeds back to our lessons learned reviews****. It is difficult to do a KPI on cost, because what's the* ***benchmark alternative*** *is very subjective. (i.e clash) there is a* ***clash there that saves us an X amount of cost****, but you might have not had a clash in reality.* ***Expected saving*** *amongst that. So,* ***it is difficult to put a KPI against cost****. We are thinking about it, and* ***we do have an insight system (Internal developed tool) which monitors out turn costs on projects****, what* ***they are actually built for****, and we can map them* ***against the plan cost and the end cost****. We can see the* ***planned and end result****. We do the* ***assessments on that****. It's not a general* ***KPI****. So* ***internal KPIs are being used****.*

*Based on the **internal KPIs**, most of our **projects** have a **feedback on where we save money, and specific activities, and there will be specific results** in there and will be clear, but it won't be managed by a **case study feedback**. **Based on the list of KPIs provided**, it doesn't align.*

<u>[Interviewee (I02)]</u> = *__When it comes to KPIs__, we __don't know__ how we __measure__ it, or __others are measuring it__. The easiest way to do it is __you give a form__, people will __fill the form__, and you __draw from what they say__. If they __deliver the project__, so yeah everything is fine. We need to __provide them the training__. Those guys are good, we are __recording it in the database__, and __If you don't have the database, then your kind of screwed__, but if you __do have a database, then in the next project you're doing more or less the same work__, so you would know who to invite. But __as KPIs__, usually how it works is basically __someone gives a project that it needs to be Level 2 BIM__, and __deliverables are a federated model__ and __COBie__. The guys who are saying yes, __we can deliver that and deliver on time__, I know they will get the job on the next scheme, but the guys who are __not delivering the job on time, or the quality is shite, then they would not get the next job__. Based on __the list of KPIs you provided__, these are __good KPIs you have__, but the main ones that are considered in this context are __(Time, Quality, and Cost).__ So __KPIs is the Time and Quality of the information they are providing__, but definitely it has to be on time, because if it is __not on time, people are not getting paid, and the quality is not right, so then the employers representatives are checking the information more and more__, so if the quality is bad and they can't accept it, then __they will postpone their payments__, so it all links back to __Time, Quality and Cost__. If you __fail on 1__, then __it will affect the others__, but the major one is Time, so it has to be on time, then the next one is quality, because you won't get something of good outcomes, and the final one is cost, and in reality everyone is looking to the cost, time and quality, but __it should be Time, Quality and Cost__.*

<u>[Interviewee (I03)]</u> = *No, we __don't use BIM / KPIs specific__. There are __internal QA procedures__. Adapting the internal __QA procedures with previous processes__. Cultural Digital Construction. __No formal KPIs__, the __KPIs are not measured__, and in this context the __culture within the organisation is to work with the cultural digital construction__ methodology. We don't measure what benefits are versus previous method. __No impact of the KPIs on organisational project performance__. In a small company, it is __very difficult to spend time creating extra procedures in addition to the normal procedures, such as making sure we've got all the BIM or KPI documentation__ and got all the models, and then __to look for the KPIs is a huge time resource, which will divert us from our current work__. We measure our __time on projects__ being a commercial __thing but is not related to the use of BIM__ as a process. __Based on the list of KPIs provided__, it __doesn't work here__.*

<u>[Interviewee (I04)]</u> = *__KPIs are based on what BIM level 2 requirements are__, and the market competitors. __Another KPI is the available of digital technology__. After the __pilot project is completed__, we will __measure our Time and Cost__. __Adopting Laser scanning for our site activities__, so we will see the __benefits of this__, __but we are spending quite a lot of money on this__, so we are __not sure how much benefits will be received__. A __measurement scene will be done__ to see; for the cost, __if the cost__ of the laser scanning is bringing value for the money. __Based on the list of KPIs provided__, there is __not much awareness of KPIs in industry and it doesn't align__.*

<u>[Interviewee (I05)]</u> = *__There are no KPIs as part of the council's BIM process__. __Looking at the CAD side of things and its demand here, there are KPIs that exists__. __We have a standard template__, we have a standard set of __information requirements, and we have briefing documents__. So, if we __issue out a project, for a consultant, we give them a template__ that they have to follow. We have a means of __auditing when that comes back in.__ If we __issue information out in terms of variation on our instruction__, then we have a means of recording that in terms of when, what was said, and how long it takes to respond. __Those are a set of KPIs that we have__. __Based on the list of KPIs__, in terms of the __EIRs, sharing and collaboration__, definitely we are using those because we're trying to ensure that the design team collaborate and talk to each other, so we don't get 1 group out and step with the other. So, we have a __preferred method of using a CDE__, the process and the way the thing is issue and what format we should issue. In terms of __delivery__, we have a prescribed method of after the building is completed, we want __a delivered O and M manual__, have a safety manual, we have a set of content that we want format. There is electronic and a hard copy. One of the other ones that have some thoughts around is __Predictability__, and it could come under __risk and predictability__. There are number of risks which we identify in everything we do. Whether the projects are for building and KPIs, or if the project is to deliver a BIM implementation scheme because we will look at and analyse the risks, to see whether or not we can either eliminate them or reduce them. So that is key for us to make sure everything we run, and when we think back with predictability, is about if it's going to be delivered what we say it is to the cost and the quality. So if we can't, then we have to come up with a solution near, so we have to quantify it. Note on: NWCH KPIs being measured, do you feel using BIM within the projects have improved the KPI outcomes that are measured there? We've had half a dozen of projects, so it's a bit difficult to say. Projects we've done were small medium school extensions, and 3 of them are very similar in terms of the layout, We've got more which are due to be produced. I'm trying to do it using Data drop points in development of the model, as a means of saying is it meeting what I'm asking* *for it in the EIRs.* ***Health and Safety,*** *yes, our contractors have noticed we've started to use our* ***BIM models as part of 4D programming****. So, they have an idea on when delivery is coming in, what access points the deliveries are.*

[Interviewee (I06)] = *Previously informed the interviewer with less knowledge on KPIs, so* ***no KPIs exist****. The* ***list of KPIs done in the research*** *was given to the interviewee, so based on* ***this list, from the estates side, no****, but everything we do in the estates is about* ***Cost, Time, and Quality****. So, they will have something in place with it. But whether it* ***links with the BIM and that side of it****, that's what we're focusing on and* ***I'd say not really****. But there's elements out there, so* ***processes we do want to make sure that we've done just surveys*** *across these data. We have got* ***asset data and special data.*** *That's where I am focusing on. Keeping it basically initially and we can get clever and start getting* ***3D models*** *in it in the future. But, in order to do that, we need to make sure that the* ***processes*** *are improved. So, for example, partial embedded surveys haven't got* ***measured CAD plans in them****. I'd rather just* ***give it to anyone who looks after CAD****, since we've got the CAD team now.* ***The link between the CAD and the estate property system is linked with the special data,*** *the asset data who capture those quantity surveys stuff is the property system. So the process to keep that up to date between us and the CAD manager is good, because when* ***it comes to the 3D modelling stuff,*** *we've already made that link. But there aren't any* ***key areas that focuses on KPIs****.*

[Interviewee (I07)] = *The KPIs we have are In house standard.* ***KPIs is a process that follows key stages*** *that are* ***related to council protocols.*** *Before a feasibility is done, then a client commissioning form is taken place. Tender takes place and before it is Construction 2 initiate, then Client 2 Construction. Stages of a process of a project, where there is a feasibility study, then you take it out for tendering, and follow a procurement path. Contractors on a tendering list verified by the council, being on a framework to meet certain budgets (costs) for projects. With regards to the KPIs* ***I try to implement BIM****, in terms of* ***its feasibility by giving them a 3D model****, going out to planning, but it has never been used, when it came to tender the BOQ could have been done, but it was never done.* ***The list of KPIs that you showed me*** *pretty much covers what my organisation has, in terms of* ***safety, client satisfaction, performance, profitability*** *done on the type devoted for each project and the costs implemented and time for the project, depending on a timesheet, and* ***Productivity*** *correlated with the timesheet. KPIs are covered within the organisation but has to do nothing with BIM, a set of processes set within the organisation standards.*

[Interviewee (I08)] = ***I'm not aware of any BIM related KPIs****. However, we have a* ***whole series of KPIs*** *that can probably be filled by the NWCH better than we can,* ***things like social value, post contracts assessments****. I believe we are measuring* ***[Time, Cost, and Quality]****, we're measuring* ***social value****, we're measuring* ***Customer satisfaction****, but we're no point of time that we are measuring BIM as a KPI. How* ***suppliers tie in with that as well, in their KPIs*** *and how they do the KPIs, they're driven to make sure they are* ***managing measure (KPIs)****. We don't measure the department as KPI, but* ***we measure the project in a KPI****. So the department has* ***its business plan, and I have 1 KPI, the business plan****. Along the way to do that, I need to satisfy client on project by project versus.* ***The provided list complies*** *with some of the KPIs we have, and for us we measure this through the PSP report. So here you* ***measure Cash flow,*** *you* ***measure Quality,*** *and you* ***measure Health and Safety****.* ***What you don't have in there is contractual compliance****. To allow us to* ***measure the compliance of the contractor*** *in doing all the legal documents, etc… Huge section on program, huge section on risk management, and early risk. So you can see,* ***we do a lot of measuring those KPIs****. This is* ***measured through checking on a monthly basis, we check if the contractor is staying to plan****. You've got variety of things to keep to, and this is our monitoring of that.* ***Alongside that, then the framework has people who can manage KPIs****. So, I meet the people every month and go through the KPIs that they have for the contractors.*

[Interviewee (I09)] = *In the perspective of* ***BIM, we are more focused on outcomes rather than anything else****. We do* ***see an element of KPIs around cost being measured****. Unfortunately, that still tends to get emphasized towards capital costs rather than whole life costs. There is an* ***obsession with the clients I work with*** *around the cost benefit of BIM. So how* ***much it will save me, on one side, and how much it will cost me****, on the other side.* ***There is always a focus on cost and what we are trying to look at is more of a focus on outcome****. We tend to look at that, and there is* ***a model on the EU BIM handbook*** *on this. We tend to* ***look at benefits*** *in terms of economic / environment / social.* ***There is a personal interest*** *on the social. Trying to measure outcomes, some of that could be related to soft landings, has BIM been used to aid relationship between the design / construction / operation phases.* ***There is always a KPI around cost****, and people want to know they are not wasting money. We are trying to push towards social outcomes.* ***Based on the social outcomes, we are able to assess the KPIs across project / organisation performance****. I think* ***all BIM related KPIs are difficult to measure****, cost is probably the easiest, but* ***it's still difficult because you don't do 2 identical projects, one with BIM and one without****, and look at the cost's implications. On the cost side, one of the* ***metrics that I am interested in is the amount of variation on a project,*** *because one of the symptoms of the all way was low entry price, a lot of change and variations. I'm hoping that the target and exit costs are close together, that's probably the one with cost, because it isn't necessarily cost per square meter and has that changed. The problem with that kind of benchmark is the* ***market fluctuates****. So it's* ***difficult to know where the cost went down or no****, because of BIM or the market.*

We are keen to see more emphasis put on whole life costing, because of ***being able to measure both forecast and whole life cycle cost****. What I hope to see with* ***BIM introduction and KPIs*** *is do you start to refine the methods of calculating that because you start with a forecast then you start to get the* ***actual data and then you can start to compare the actual data with the forecast****, then you can either refine the model, because the reality is different to what you expected or you can start to diagnose why there is the difference because maybe the A.C* ***costs are going high*** *because the users haven't been trained to keep the windows closed.* ***Social is harder, I guess in the first instance, it's always subjective customer perception and satisfaction, so are the end users happy?*** *It's not an objective measure or a scientific thing, but it's really important that are the client and end users happy with the end result? I think the closest about the social is the client and end user's perception I suppose.* ***Surveying them and seeing if we are happy with the end result and the process that we went through to achieve that****.* ***Based on the list of KPIs provided, yes*** *and certainly,* ***Time and Cost*** *are related to the cost one that I mentioned (whole life vs capital). Typically, if you see a variation in cost, then you'll see a variation in time.* ***Quality*** *is an interesting one. There is a specification quality, the physical elements of the projects (Doors / finishes). There is also ISO 9001 definition of quality, which fits in for purpose so is it what has been delivered for purpose, and the way of working fits for purpose? That fit for purpose is definitely the quality. This then comes back to* ***(customer) satisfaction****. We are trying to encourage the implementation of methodology where clients can get something better. But suppliers can be something profitable, so also* ***Profitability****. It feels like historically, there has been zero sum situation. I win, and you have to lose. Win-Win is a bit cliché but it's what we are trying to achieve. Saying let's get something for the client, but let's do it in a way that the suppliers can be profitable.* ***Performance*** *is interesting because it depends on whether you mean (Performance of the project, or the asset). If asset, then links to the social benefit discussed earlier and links with quality, so how end is the fit for purpose? Is the end user happy with it and does it perform?.*

[Interviewee (I10)] = *We have a Computer Aided Facilities Management (CaFM) system, and we have KPIs on response times, because we are the help desk situation whereby a member of the university staff will phone up like a clause that has come up the door, that then goes on the CaFM. All the trade staff has a tablet. We have joiners, MEP, we have an internal team who respond to that kind of stuff quickly, which is different to the CaFM team. They will receive a notification on a tablet and they go to the door and they fix it and the time it takes is recorded, and that goes to a series of tables and graphs at the end of each period of time. We have something like 95% to do after a certain response time. It's mainly on the response Time, and Time is the driver, but not Cost or Quality.* ***Based on the provided KPIs list****,* ***Safety*** *is a big thing, we have risk assessments coming out, and safe systems of work and we're all very highly trained, even we do like a training scheme. We find space training, everything and obviously that's rolled on a 6 monthly basis and all that trade staff. Getting that, we all have Construction Skills Certification Scheme (CSCS) cards. Safety is a big thing for me. Actually, I have a manager who sits in the estates and she's our* ***Health and Safety*** *officer, so we have a lot of in house. When it comes to* ***Satisfaction****, as part of the response time, there is a satisfaction element tied into that, but I'm not quite sure how it's measured, because we don't work in the FM team. We see the results in graph in the end of it, but the actual calculation of that, we're not close to it.*

[Interviewee (I11)] = ***With using KPIs with BIM****, if we got coordination with the consultancy, your looking into* ***integrating 3D models, and better reviews, clashes and coordination with structures.*** *So basically, using* ***BIM to improve design & production qualities****. They'd have a quick review of the* ***Construction Excellence KPIs****, so those are quite contractors KPIs. I would say* ***Client Satisfaction****,* ***production of design and information****, services we provide, providing the client with* ***predictability of the cost*** *from the design, and* ***predictability of the time*** *of how long the process was.* ***From the list of KPIs****, they all* ***fit well with the design process****.*
Personal notes from the interviewee= *Internal* ***KPI****: We believe* ***its processes improves collaboration, coordination and quality with BIM in terms of the design, procurement and management of buildings and infrastructure****.*

[Interviewee (I12)] = *We have a range of KPIs across projects, but the* ***big KPIs are around collaboration****. I have to look at BIM related KPIs,* ***I'm not sure if we have*** *any specific KPIs. What we've developed* ***in regard to BIM, is EIRs, BEPs****. With* ***the list of KPIs provided****,* ***Safety*** *should be in the primary KPIs. Another big thing is* ***Sustainability****. That was a bit of the* ***lessons learned around this project****, what we've come up at the start of the project is with project values, which is an important dialog, and we work with the team to come up with these values, and share the documents, and what we have is a list of things that we must do. Values, and go home healthy, every voice listen to.* ***Big emphasis on the safety one. We came with values, we have a safety guy coming up to follow with what we have****. It is being put in a certain level, where it should be on the top level.*

[Interviewee (I13)] = *KPIs in terms of what?* ***Client feedback or how you quantify success of a project****?* ***So yes, part of our standard systems that we have is standard checklists****, standards that we undertake under 1); at the end of every work-stage (the closeout) and 2);* ***Client feedback survey****. So, we've got sort of* ***raft documentation in there so at the end of each work-stage, we've got sort of a checklist.*** *This checklist is part of the management team, are all* *of our billing done, have we met all the requirements that the client asked for, have we delivered to our own program. Have we* ***delivered fees that we have set out for the business or for that work-stage****. So, we go through that by a checklist with our management team, and with our staff as well, and usually there is an independent 3rd party who is not been necessary involved with the project and have sort of an outsider's view. We sit there and have a view of the* ***lessons learned*** *and with our consultants how is that relationship worked, and will we use them in our projects again. This is done at the end of each work-stage. We have a (Closeout 1), then we have a* ***client satisfaction performer*** *for our clients to give us feedback on our performance. In regards to* ***the list of BIM KPIs,*** *so with* ***Collaboration****, we talk in the end of each of our workstage about what's going well, how's everything being gone to a program, have we collaborated effectively. On like a school project, when we design our model, our Master Information Delivery Table, we arrange what we call modelling tasks on what needs to be done. We link those down to our deliverables so as each element is done it will allow us to develop each set of drawings, etc.. But as while what comes into that, is actually looking at what our consultants that we're working with what they need from us as well. We work collaborative at each work-stage in terms of our model development.* ***Employer's Requirements****, we used to work with EIR documents, AIR documents, we've helped clients to develop those to be familiar with.* ***Processes and Delivery****, PAS1192 – 2 that's what we breath and live doing of our education projects down here. All of our internal processes and delivery are BS1192 compliant as well. In terms of the way we document all of our projects in a volume name, in terms of delivery with bringing it in the correct way. For a BIM project and in terms of the PAS1192 – 2 we actually have our own CDE that we've been developing with using BIM 360 docs, which is a new online collaboration platform. We're actually rolling that out on a live project that we got on site in brexon. So that covers Process and Delivery and we fill it on the way of CDE works, the gateways so we can raise issues and put things for our client approval so S4, S3, whatever the workflows need to be to make sure we are working on an internal process.* ***Sharing,*** *this is where the CDE comes in as well, very useful. We always share all of our models in IFC format, as the primary format because that's the exchangeable one between all different disciplines that working on a project, we also provide NWC (Navisworks), clash files, clash detections at stage 4. Obviously, the native Revit files, standard methodology for purging and tidying up the model for that. It goes out to make sure everything is verifiable at the other end.* ***Capital Delivery*** *is a big deal here, we work collaboratively trying to get working with subcontractors if we work on a D & B as early as we can. Us bringing them as part of our team so we can make sure that we're delivering the very best for our client as capital expenditure, CAPEX. We brought in the subcontractor who sat there with the revit model and threw how they were proposing how they would fill in, how we could economise, amend details, amend the earlier stage 3 model, so we can get down to the figure that we got without losing the design integrity of our building. So, we've got great use to working with tight budget. We used to work with Manchester's capital expenditure. With* ***_Facilities management*** *(FM) systems, yes, I was providing all the COBie data drop information required as part of Level 2 BIM process. We've done that for a countless project, we used to do it as a standard part of our deliverables on task 4. We work with technologist and another FM platform that they can able to accept COBie, take all the parameters and take some of them. In regards to* ***the list of KPIs****,* ***Health and Safety****, we do our work to PAS1192 – 6, we do in house reviews as each workstage of the CDM, we do a standard part of our deliverables, we do a design risk assessment, we do a maintenance access drawings so we use BIM to deliver in that way, a lot of our design team meetings we have a CDM section that will bring the model on screen and go through all of the issues as a team collectively and find out everything that we can. So, we used to work and using BIM to leverage the ability to work into 3 Dimensions, go through the access points, go out the roof and see how that works.* ***Satisfaction and Performance,*** *we've got a client satisfaction survey, which we send out on each project. In terms of our satisfaction and the consultants we've worked with, we have a standard register of all the consultants that we work with and review that annually as part of our business processes and taking into account all lessons learned and information fees back from our projects back to look at them. 1) We assess whether we think they're performing well, can they do Level 2 BIM in terms of being able to work with us on the project, so we keep a register for every revit project we work with, and update that annually as part of our internal processes.* ***Profitability****, we have an in-house piece of software (CMap) that we use to undertake all of our internal management so that allows us to feed the proposals in there, or accounting in there, allow us to do our project management in there, so we can review live project vs expenditure for any given project, so we always got this data to hand to them on where we are, in terms of the work that we done and mark the money that we've got to spend on this particular work-stage. So, we're very doing in that to keep our profitability.* ***Productivity,*** *I've touched in that, we've got our processes we've got an awful lot of well homed processes that have development and delivery of BIM level 2 projects.* ***Sustainability,*** *that's an interesting thing part of architects by in trade as far as we are concerned with for the building to be highly sustainable and whatever the right methodology is. We always opt for naturally ventilated buildings whenever we can, solve the orientation, think about furnished striation and specification size, all the shading, ventilation strategies, so in that project, ventilation panels of air tightness and reducing energy demand for the OPEX phase of the project. As design team, we all consider what's the best way to meet the client's requirements.*

[Interviewee (I14)] = *There is* ***little self-assess on KPIs in our organisation****. We're trying to sell* ***model reviews*** *in* *terms of **model compliance** and that test kind of the naming standards. It's quite easy the use of likes of **dynamo** to run a script on the **models** and make sure that all the naming standards are already into. So that's kind of the technological assessment, but **in terms of KPIs, I don't think there is anything we've got within the organisation. I think we're terrible with assessment, we're very poor**. Based on **the list of KPIs**, Obviously, we conduct **Profitability** reviews on all of our projects, so in the end of the project, we'll sit down and look at was it profitable, was it not. How could we have done better. Good examples in the minute, we've done a couple of projects which went into BIM level 2, in fact they went into 3D. They've not be profitable at all. We've took a look at that and said well could we have been more profitable if we have worked in 3D from the start. If we'd have done it in revit and there isn't anything black and white that says we would have been profitable if we have done it from the beginning like this, so it's more of a feeling. You would say on these projects we're going to perform well in terms of profitability and productivity or we don't. We're not as strategic we would say. We can kind of see the benefits that BIM brings to those set of indicators. **Health and Safety**, so for example in the minute we're putting a 3D warning triangle into our models, which are the health and safety issues. So, they feed into the health and safety, or risk assessment. So, there's even more contractors who are asking more about these to be put into a model, when they see the plans, they can highlight instantly visual sense, some of the risk areas, but they also in the 3D environment; say for example, we're doing clash detections and they see a warning sign, then everybody is aware of those risk elements. so, I see more of that coming, and I think that for us is good. **Satisfaction,** I think the contractors they see more of satisfaction in terms of the de-risking their projects are carrying out this 3D coordination before the project even hits the site. That's a massive benefit to them because its de-risks the project. In terms of **Productivity**, I think initially trying to get going on working on 3D and Level 2 BIM, it takes a hit, because your trying to set the standards, but once you get going, we find the productivity increase. Why? Because as your productivity increases, you got more time to spend on doing the next thing. For example, VR, so we're taking the technology that we're using and going what can we do next. What we're find is that we're still spending the same time in projects, it's just what we do, is either that productivity is such that the main time that we're doing decreases. But we're just putting extra bits of pieces of work and other things that come to. Clash detections, we're spending more time on. **Sustainability,** it's one of those that nobody goes above or beyond, it's purely down to the client. I find that we as a client, can't influence sustainability enough. It's all down to the client, cost and regulations. So, it's the regulations there that we have to follow, then there's an obligation for the design team, contractors and the clients to meet certain criteria. If the client comes and say I want to come above and beyond, then fair enough. As a contractor or design team, they will never go above or beyond. It always hit that level that they need to attain. So, it's the cost at the end of the day. We don't have anything to assess ourselves against those indicators, but I hope those are ok. It's good to see this kind of level of thinking and there is a **personal interest** on this work.*

[Interviewee (I15)] = *We **don't have internal KPIs, not yet. It is not established enough**. The issues **lie on our ways of working. KPIs are far too much considered on Cost (Project cost)** but they highlight on other issues. Our KPIs **are like integrity ways of working**, how quickly we close change request or stuff like that. In terms of project groups, **KPIs in terms of the business are very financial driven**. **From the provided list of KPIs**, **Health and Safety** is in, **Satisfaction and Productivity isn't**, we **don't do Performance KPIs** very well because we don't feedback and assess our suppliers, **Profitability** yes, **Sustainability** will be one.*

6) Do you think that there a link between your level of BIM maturity and its impact on your KPIs? How?
Prompt: Based on your point of view, or based on projects being used within your organisation

[Interviewee (I01)] = *Yes I think so, there is definitely a link*. *And it comes down to **the way we deploy** on how we do it on projects**,** how much **supporting and set ups is needed** to get them there**,** how much **training is needed** and aid to deliver the KPIs**.** Because if it is the same team for the 3 to 4 projects, I'd like to think we don't need to step in.*

[Interviewee (I02)] = *Obviously, **there is a link.** If you're **not capable of delivering something (BIM)**, then it **will affect the cost of the delivery and maybe the time and might affect the overall quality (KPIs)**. So it's all bonding together, but in terms of specific examples, you say the organisation is **using a tool (inventor) or Autocad (3D)**. They are really good, they delivered projects for X amount of years, and now you are **asking for BIM deliverable**, which is **a federated model**, so they can still **provide a 3D model**, but **COBie has to be extracted** out of this model, and **they have no capability**. They are brilliant at what they do, they are brilliant at the operational and maintenance manners, but they **don't know how to deliver a COBie deliverable**, and suddenly they **need to use BIM accredited tools**, so they decide to use **Revit**. They need **to ensure they can deliver in revit**, so they **need training**. For training, they are **spending money and time**. Obviously, the 1st time they are going to **issue the design + information**, most likely **will be incorrect**, so that **affects the quality of the work**, because **it is not correct**, so we will **tell them its not correct**. You will **have to correct it**, and that will **affect the time scales**, so it all links but its their **initial cost** that they have to **invest in training themselves, Quality and Time**.*

[Interviewee (I03)] = ***YES**, **based on what we measure (Time, Cost, etc…)**. The **more mature you are** in the process, the **more you understand the process**, the **better you will perform**. With **BIM maturity, the more experience you have, the better you'll perform**. (**With experience that people have on BIM maturity, it will enable better performance**, which will **reflect on delivering projects on time and budget**). If you **don't understand BIM** as a concept, then there **won't be any benefits**, it could **result in rework** (**rewriting documents due to not understanding them** well). Depending on your **BIM maturity, it will affect the KPI**.*

[Interviewee (I04)] = ***Yes**, there is **a link between both**. **BIM is a way to do things with less cost and time**, to **achieve savings in cost and time**. If **BIM is adopted in the right way**, we should **realise those savings**, and this could **enable to establish the potential link between the BIM and KPIs**, to **review and measure what is done** in order **to establish the KPIs and the BIM maturity**.*

[Interviewee (I05)] = *I think **there will be**. One of the things we picked up after **discussions with practices that have BIM in place, is changes** in the way **they do things with the processes.** They are **able to measure more things now**. So they can say is that **project delivered on time**, and **within our fee bid**. They can say did we **meet standards for this**. Are we able to **provide this information about whole life costing**. They were able to **provide us with a lot more information** because they **got that behind it**. This is what I'm trying to get through the senior managers, is **any intelligence that we want, we can put through a BIM model.** It's very **difficult to retrofit through it**. But if we **leave the gap**, if we have some blank parts of the flyout section on one of the elements, then if **we don't allow that for now then we can't add it**. It's **difficult to do so**, we **have to think about things in advance**, and we **might not be able to do this now**. But we need to know how many people cross the threshold, do we have a counter, do **we have some means of checking out to see if someone has referred to the model**. That would be a good test, because some of the **reactions that have been experienced from the building managers have been quite extreme**, so it **depends on the level of understanding of the guys operating the building**. The **success for us is if** one of the **guys can turn around and say "yeah that model that you gave me, I was able to find out where the problem was]**. Looking in print out could take hours.*

[Interviewee (I06)] = *I'd imagine **YES, there is a link**. **If** the **data richness is better** or the **information is more accurate** or coming **through the project and the turnaround and the processes is to do that**, then you'll **get better maintenance scheme**, you've **got building lifecycle costs**, **quick response for repairing stuff**. You got **problems on information** which would **enable you to tackle them**. The actual **process of the information is to keep it to 1 place**, whether it's **in a 3D model or in a system**. If people are **sharing that data in capital program** and if its management and in estate, **they won't share that source**, **due to it being efficient**. **Between this and that, yes there is a link**.*
[Interviewee (I07)] = ***Absolutely**, without a shadow of a doubt. Because people don't see the **benefits of what BIM is about**, in the **collaboration within the team and the organisation**. **The openness and sharing the model with whatever BIM tool is being used**. The **SHARING**, and the **information that could be extracted; clash detection, getting FM team on an earlier stage of the project**. **BIM is** very much **based on the technology**, even **if you know the technology**, there **needs** to be **a good level of understanding on what the technology could be done** and **what information could be extracted**, and for **the benefits of the clients**. Clients are **looking for the Return On Investment (ROI)**. With **BIM**, the **cost has to be put up front**, where the **infrastructure has to be set**, which represents a challenge in my organisation. **Working in siloes**, **no one talks to the other**, **disciplines are segregated and don't collaborate**. **More projects in the public sector needs to be used**, and **see real cost savings** use to it (ex.. **Townhall in Manchester**, **flagship project** but it **educates councils** that **it could be embraced**).*

[Interviewee (I08)] = ***No, I don't think they are related** in the minute**,** because we are **looking at** the **traditional KPIs**, traditional **building industry KPIs, (Time, Cost, Quality, Health and Safety), and BIM is detached**. **BIM is** how we **manage and run the job**, **KPIs are** how we **measure the success**, and those **2 things are completely different**. **BIM is the process** and the **KPIs is to do with the measuring and the monitoring**. **Based on the previous information, I don't see any linkage between both…***

[Interviewee (I09)] = *I think **there is a correlation**. The **challenges is** the **number of other factors that could affect the KPIs**, because we **don't have that kind of laboratory conditions**. **With those laboratory conditions you can** do a **Non-BIM vs BIM or different levels of maturity on the SIG on identical projects**. Even if you are **focusing on** things like **standard design** and so it **is repeatable in terms of the asset**. The **people (project team) would be a variable**, so really **good project team may give a different result in terms of the KPIs, in respect of the maturity**. It's not the only **factor that affects the KPIs**, that's **the challenge**, but the **other variable**, from my perspective, **is people's experience**. **The 1st BIM project that somebody does,** their **learning is a new way of working, and** they **won't be** as **effective as the 2nd, 3rd or 4th project**. They **will learn, improve, and refine the way they work**, they'll be **better because it's the way they work**. So my expectation is even **if the maturity is flat**, that the **KPIs would improve over***

time *because* ***people are becoming more familiar with this way of working****. I still think* ***maturity is important to gear up****, there is a* ***number of contributing factors that improve the result****.*

[Interviewee (I10)] = ***Yes, there is a potential link****. We held a* ***series of meeting with partners*** *involved in the project and we* ***discussed on how we're going to use BIM, and what will they deliver to us****. The FM has spoken to them, and I think* ***the main focus on it is that*** *yes* ***they will do the model for clash detection****, but we said that* ***we will never amend that model****.* ***We can't just physically do it, we can't do it****. So what they are going to do is* ***have the model linked to a database essentially****, so you* ***can go into the model****,* ***click on a door or a light fit in****, and* ***a datasheet will pop up****, so it* ***won't be populated with all the information****. When you* ***click on the database****, it will* ***take you somewhere*** *around, and I think that will be a great thing because we* ***will change the database****, because we can* ***import and change the database****, so* ***even if the model might not be up to date****, but the* ***database will be and we can keep up to date****. That's the thing that all* ***our trade staff have a tablet****, so it can be that if they are* ***going somewhere or a job does pop up****, that they can quickly* ***get it from the database****. They can* ***order it from the tablet****, and it will be here, so it's that* ***sort of integration of the database with the CaFM,*** *rather than us having to put a job in here. For someone to* ***look*** *on the* ***model or the database and to say*** *that's that. We go back to* ***trade staff and someone orders the database****, and we* ***have it integrated with our CaFM system****. But now* ***we don't think it's capable of doing that****.* ***There are like add-ons and bolt-ons that you can put to the CaFM*** *apparently* ***and*** *will mean* ***it can be integrated together****.*

[Interviewee (I11)] = *In relation to the process, possibly* ***it could be linked****. It depends on* ***how the projects are developed*** *and could be* ***integrated to project management****.*
Personal notes from the interviewee= *Yes,* ***improvement in Coordination through 3D Model & Later Clash detections & BIM Collaboration products****.* ***Improvement in design 4 presentations with rendering and Endscape****.*

[Interviewee (I12)] = *Yes* ***there is a link****, absolutely.* ***BIM should enable*** *us to* ***get it right*** *at the first time.* ***Avoid mistakes, respecting the building****, it's a heritage building.* ***Building*** *on to* ***the model*** *and* ***building*** *on to* ***the real****. It* ***will work well*** *if we do things like* ***using the BIM model*** *to see how to* ***solve the vertical circulation*** *that will* ***aid with communication****. The* ***model gives people confidence*** *and makes them to* ***respect the building****, which* ***speeds the process*** *up there. If we* ***use the model*** *for* ***works method statements*** *and having a* ***trade of specific statements****, so its* ***each work element*** *that the* ***model will identify what the requirements are for each element****. With some* ***people working on site****, they* ***won't understand the language (English),*** *but* ***showing them something visual****, they* ***will understand it****. This will* ***enable clarity****,* ***communication****, so it's* ***a good communication tool*** *and is* ***a good saving time and money****. They* ***all link together****, and also,* ***is about efficiency****.*
[Interviewee (I13)] = *Completely* ***yes****.* ***It is*** *very* ***tangible in terms of BIM processes*** *just* ***allows*** *you* ***to create efficiencies*** *and all* ***across the construction sector and*** *certainly* ***what we do,*** *whether that's* ***efficiency*** *in terms of* ***planning and using the models*** *or* ***having*** *some sort of* ***information*** *that* ***feeds into various elements****. We* ***use*** *our* ***model*** *not just for* ***construction detailing*** *or* ***preparation of construction information*** *but* ***goes out on 3rd party pieces of software for rendering****, for* ***legalisation, for interactive walk through using BIM 360****.* ***That one piece of information makes it very efficient*** *and keep* ***creating custom content*** *for everything, for* ***all the information*** *also around that* ***one information source****, as long as that is* ***well maintained*** *and then you can* ***pull that out for cost in phase*** *and use* ***that to help for logistics planning****. The* ***efficiency*** *is really good as far as your* ***creativity can stretch****. I think* ***it's*** *very* ***tangible****,* ***measurable benefits*** *in terms of* ***using BIM across*** *your* ***projects****.*

[Interviewee (I14)] = *In terms of,* ***it's a very good question.*** *I think* ***yes,*** *but its kind of getting to the route of how they link together I suppose.* ***Collaboration (BIM) is productivity (KPI)****, because the* ***more you can collaborate****, the* ***less you have to double handling of things****, and that* ***makes productivity better****, because the* ***more we can work together****; instead of* ***almost fighting against each other****, the* ***more productive it is for everybody****. That's huge for us, that's* ***the biggest part of Level 2 BIM*** *is that* ***collaboration*** *to be honest. We* ***spend a lot of time*** *on the* ***start of the projects****, actually* ***more say we spend 2 hours now*** *and* ***collaborating with the rest of the design team****, it will* ***reduce the time*** *upfront. It's a* ***pain for us****, we take that* ***approach every time*** *and it's* ***trying to work with organisations*** *to have that* ***similar ethos*** *I suppose. If they* ***have that collaborate ethos****, then it will be* ***great for the team****, but you do* ***get some organisations*** *such as* ***M&E engineers****, that's just an example. You don't have that and you're* ***constantly battling with them****, it's* ***timely*** *and you* ***end up not getting any quality*** *out of it. I suppose* ***that comes with sharing****, where we've got 1 contractor* ***we're working with*** *(from Wilmott Dixon) and they* ***try to share as much as possible with their kind of standards with the design teams*** *that they* ***keep going back to****, so with consultants as well. Because they know that* ***collaboration and sharing*** *from them,* ***feeding that to the design team*** *and* ***bringing these things together****, and it means they* ***get the product they want*** *at the end of the day. They* ***get a model or a series of models*** *that is* ***easier to federate*** *and* ***easier for them to work with*** *and something they* ***can use to do other processes*** *such as* ***time and cost planning****, so its all about that collaboration and sharing.* ***Facilities management*** *is a* ***weird one****, because we* ***rarely get EIRs sent through****, very rarely, despite* ***some projects wanting to be Level 2 BIM****. The*

Department for Education, they ***got all that sorted out****, we always* ***get their EIRs*** *through the contractors that* ***we're working with in a framework****. Whether any of the* ***Facilities Management teams*** *across the UK, the various councils, schools,* ***end up using the information that we got into the models*** *the very minute,* ***I doubt it****. I think there's* ***a lot of wasted time in COBie****, I think in the minute it is* ***a huge investment in our time****, to* ***input the information that is often irrelevant****. We have a much bigger workload, it doesn't necessarily mean that what's in market place is what we want. They've actually* ***talked to the client and said, do you actually need all of this?****. A lot of* ***clients go, yes give us COBie****. We say what* ***is it that you want from it****, what are* ***you going to use it for?****. In the private sector, as I suppose to the public sector, we're doing a lot of schools in the minute.* ***The projects*** *that the contractors are trying to* ***push for Level 2 BIM*** *they're also* ***asking for COBie information****. But these are* ***projects*** *in the private sector that* ***don't have an end user to in mind****, so there's* ***no Facilities Management team,*** *there's* ***no EIR I suppose****, and there's* ***no engagement in terms of who's going to be writing the building****. A good example, a lot of* ***schemes*** *that are* ***going around*** *here* ***are PRS schemes (Private Rented Sector),*** *which are* ***built by developers who will end up selling the buildings eventually to an operator****, who will then* ***operate a building and rent out apartments****. They* ***don't know*** *that until the* ***building is complete****. They* ***don't know*** *who they're* ***selling it to****, or who* ***will be operating those buildings until they have been signed off****. So we're finding on those projects, its almost* ***a complete waste of time doing COBie****, because* ***nobody knows*** *what's it gonna* ***be used for****,* ***nobody's got any idea****, there's not that kind of (Stage 1: Strategic, this is what we want in the end of the project).*

<u>[Interviewee (I15)]</u> = ***Yes*** *and* ***linking the BIM with KPIs*** *will* ***improve your profitability and productivity, sustainability, basically all of your KPIs****. It should* ***be an enabler for all of the KPIs****, in terms of Benefits, it will* ***reduce cost certainty****, it will* ***reduce your programme****,* ***reduce your risk****.* ***I see the benefits of this****. I'm pushing these to everybody and anyone because* ***most of it focuses on facilities management****, and because* ***we have a massive issue with delivering stuff then we realise how much more it's going to cost to operate it****, because* ***its twice the size, twice amount of people****, and they could actually* ***manage it better if they better information and pass this on them and KPIs out there****. We are just* ***developing our asset management office capability in the same time****, which hopes to* ***put some of the KPIs against the benefits that BIM brings because part of our asset management and asset information strategy in a higher proper level; BIM is and all the standards of Level 2 BIM is highlighted as a key enabler for our business operations****. I'm assuming* ***there is KPIs that will come out of this****. So* ***the current ones are Profitability and Safety****. I would imagine that* ***sustainability will be****, and this year it will be definitely* ***in our KPIs****, because* ***there's a lot going in there*** *and that stuff and* ***all the main focus congest on deal*** *and all the* ***stuff to do with environment****. But it is* ***not filtering them down to project strategy and people****, and we* ***have got to hit certain targets****, but* ***there not, there's not type of****, I mean you know if you notice on the interchanges that* ***we have doing on our sustainable*** *and we've* ***got this out of the other****, but it's, yeah* ***I'd say sustainability*** *as well***.**

Section C- Level 2 BIM Maturity-KPI assessment feedback

BIM maturity and KPIs working together, benefits expected to emerge from combining both, and recommendations

8) Do you feel measuring your Level of BIM maturity allows you to determine its impact on the KPIs? Why?

<u>[Interviewee (I01)]</u> = *I think so***.** *We don't assess ourselves enough. We assess the supply chain. We used to assess our teams more. The assessment we can do a lot, but it's the results that what we're gonna do to meet the change. That change takes time. In that productivity, availability and whatever reason there is. Our business time disappeared. Some of the things we have to fix on how to upskill the business. We don't have the time to teach the business, or actually learn. It could help. We know how our businesses is set up. Might adapt a little bit for individual businesses. It gives you a high-level view, but it doesn't give me what I do to fix, and how do I resolve this. KPIs don't provide a way to resolve it either. So it's that next level, there is a piece in there that what needs to happen next, how do we drive change then to our business. We're driving learning contracts with people or setting personal goals, offering them a career to give them requirement and have these competencies within them. So if you're a QS, you need to do these actions with a model to comply with a QS in the business, and if you don't then you need to go on courses, you need this support***.** *We have a training strategy, we have a training matrices that we we've done for the whole business. So we offer back in this, and maturity of our business, and our internal one. We then go away by each function that has a box, and it goes in there and tells you where do you need to be, and the function sets themselves targets (in 2 years, I need to be competent in that level, and competency means this, so you need to go on this training to help on your career development. Doing the next step. Action plan.***.**

<u>[Interviewee (I02)]</u> = *Yes, there is a direct impact, if you know someone is not capable of delivering something, which has not been implemented, at least you know how to improve it***.**

<u>[Interviewee (I03)]</u> = *Yes, definitely***.** *If you have something that you can look at and reference and have on paper,* *you can measure against that (BIM assessment). Could use that as a basis for the KPIs. Ex.. I need to look at project reviews, you can start to measure against project reviews; put something in place to make sure it happens*.

[Interviewee (I04)] = *YES. Because you can measure your BIM maturity through the KPIs and improve your BIM maturity based on the KPIs that you established. So in the process will be measure your BIM maturity, create your KPIs, and find out where the problems are, improve it, and then re-measure it. [Continuous improvement cycle (LEAN)]*.

[Interviewee (I05)] = *Questions with the KPIs, who am I targeting? So the client is asking the question, where am I with BIM and what am I getting out of BIM? And with your KPIs, you say here is a series of measures to reflect on those things that you valued and tell you where you are in this chart (Low, High). Note: So I think ultimately, the outcome of what we are doing by talking out to the clients is so we can get an idea of; if you fall under Consistency, then we know your KPIs measuring Time & Cost certainty. Something to consider with the spreadsheet: One of the dangers of doing this, is if you have a top level, people scoring at consistency level, then where do they go? What's the next step, just plateau. Where is with BIM, the way I understand it that it's a part of a developing process, is that you keep on learning and keep on adding information. So you get cog 2, 3, 4. You've got to have a reason why and making sure that when you come to do a scoring index, that there is room to go to the next level or a flowchart that you've come to the end of that process, so you go around again. But this time, we want 10% better. You keep on getting 10% all the time. So there is a reason why your doing it and next time it's a little bit harder. Otherwise, we're just going to do the same thing year after year*.

[Interviewee (I06)] = *YES. It does something to aim for. We could see where we can benefit, where we at, and where we're weak*.

[Interviewee (I07)] = *YES. It has a major effect on the project and to the client*.

[Interviewee (I08)] = *We haven't got the BIM model in place. The KPIs doesn't fit to tie with BIM. How we apply the KPIs is very simplistic, and is it cheaper? On budget? Have you had any accidents? So we are not measuring what impacts the KPIs or what drives the KPIs. Because we're not moving forward with BIM and understanding what it's doing and what it's NOT doing for us, then we are not compliant to measure that impact*.

[Interviewee (I09)] = *Yes, I think so. The variable that plays a critical role in this is referred to as (Capacity). How much experience does the team that's delivering this have. In terms of maturity, you got the tangible elements listed here, but there is a maturity of so how many of these projects has the project teams done before? Which I think is still an element of maturity is about the maturity of the skill of the participants. Which I think is that level on top of all of this. So if you have the right way of working and people have done it multiple times, then you'd expect that to have an impact as well. So I think that's just the other dimension of this that would fit, so I think that the way we would normally see this happening is through the trial projects strategy. Because we're looking at programs in a national level, we would see BIM being introduced incrementally, and there is 2 reasons for that: 1) For learning; to unlock learning and one of them is to minimise the risk. We introduce change gradually, not because we couldn't go to the final solution, but because we want to learn quickly, and minimise the risk of doing big change. So I think that might be a way of, rather than going (We only got 2 stage, start and where we want to be) we've got that possibility of having different levels of maturity in the process through the trial project strategy, and being able to see the correlation between where we are on that particular project vs what the benefits are*.

[Interviewee (I10)] = *The more mature the BIM model, if it's in the green column, will give you better data to analyse to get more accurate KPIs. So now this is how we use ourselves, but it will be interesting that when the project is finished, to come back and see if we will give it the same scoring numbers, because sometimes we don't have that what we want in the beginning, but sometimes we don't/ visit that back in our project in the end, and say yes we achieved that, so I think KPIs could be used as measuring tool every 6 months or something and go back and say do we still fit in, are we still on track for this, in the end we see if we did hit on what we said we're going to do, so it's like a measuring indicator*.

[Interviewee (I11)] = *Yes it gives you a greater appreciation, that could be done as a part of a management process throughout a project that would be ideal. As architects, we would want to be designing and buildings and not doing too much processes. That would be ideal for us. As BIM levels develop, we should see greater efficiencies, in terms of the production of the information. And hopefully more savings in terms of past issues on site and reworking of items. Rebinding to the same level of production of BIM information would by into the subcontractors if they won't be develop the same level of details and integration into 3D models, which is where things start to fall down*. ***Personal notes from the interviewee=*** *Yes, probably. Greater integration of Services & design with the whole supply chain should generate more efficiencies & savings. However, it is important that additional complexity is not adopted for* *the sake of greater integration as a "tick box" exercise. _ e.g. Are all Consultants or Client's going to make use of the additional data?*.

[Interviewee (I12)] = *Yes it allows*. *What you've done is looking at the organisational levels holistically, looking at the requirements associated for each one. So if you look at that critically and your identifying what's important for you or for BIM maturity, so you then pull the KPIs out of that and structure with something nice to have, so yes I think this is quite smart in that it really defines what's important*. *For me there is certain thing I see in here that are important and by bringing in Culture and Safety into it, I think it is good*.

[Interviewee (I13)] = *To a degree, yeah, but it becomes down to who is reviewing this*. *Linking to question 10- Study weaknesses and recommendation??: you as a knowledgeable student looking at BIM has an ability to look at this, numbers are 1 thing, bit of responses are also useful because you can sort of pick through it and see what everybody understands, and whether see if they are copying and pasting something from the internet, but again it requires someone knowledgeable to actually be assessing these in the end*. *If it is just done by a project manager in a local authority who doesn't understand this, the process and have the experience to understand what all these documents are, how they are arranged and how they're updated and reviewed and provided that part of the process. There's an awful lot of companies out there who say they can do things, like I write all this stuff down and you read it and then fill it and yep he knows exactly what he's talking about, as a result of both of us sitting through this, we know how this works and what the outcomes of it are*. *But you are having this, because you are having to get 1 to 1 engagement on this and talking it through. So how do you get that level of cognisance from a bunch of tables and numbers. That's the tricky point, because these are all great, they are all useful tools, but there's nothing stop anyone from writing or answering that*. *It's only if it doesn't come out of the KPIs, at the end of it, then you can say its by that point that they already lost you millions of pounds through inefficiencies in terms of process delivery and management on any project*. *So as well as this, I think there needs to be an interview process that goes through it, or some sort of a knowledge bank or some sort of a Q & A, it's kind of becomes to our practice as an interview process to revit test. Because you can say you can use revit, but using and understanding revit is a different task. You can use you know what an EIR is, or what Master Information delivery plan is, but until you actually start to use and seeing the benefits of it then you can start realising it. Maybe you need some sort of evidence base to go on site something like this*.

[Interviewee (I14)] = *I think so yeah, I think; I've got an intrigue which is how we go about reassessing our BIM maturity internally and then what benefits are we getting from BIM, and those benefits I suppose are the KPIs, we don't have any strategy internally, for reviewing*. *We don't have any internal KPIs I suppose, in a formal sense that they're all very vague. I think you've got a good link here, and I think what will be interesting is, I'll go away to our BIM manager Keith and have a chat about those BIM organisational levels*.

[Interviewee (I15)] = *Without maturity, we're not able to see that link. Things like speed and success of handover and how they measure that. Obvious is programme certainty could all be linked back to this*.

9) Do you think there is any core benefits that enables you to assess the impact of the level of BIM maturity on the KPIs? If not, then why?
Prompt: As a concept, do you feel this would be a benefit, and if it isn't, then why not and how it could be improved?

[Interviewee (I01)] = *I'd like to think we'll get to the clients, we're clearly delivering exactly what we are doing, Level 2 without any additional specialist skills, we don't have to have a BIM expert in place. We want to go to that point, where we have client satisfaction, and we don't have the battles and having to see. You see where the drivers are enabling you for, and that's where I feel where you look at a BIM maturity, that's why you can't have somebody on the business, because that should be hidden now, and every company has a BIM expert*. *We're not there, we're not business usual, without the experts. Clients will be more satisfied, you get all projects, and you actually see the differences in the industry*. *To make a positive change, you need to measure maturity, you can't do this just wiley niley. What we are trying to achieve, where are we, the action plan to fix it, give yourself a timescale, and the KPI could be (Has it changed)*.

[Interviewee (I02)] = *Yes*. *But you need to implement this in an organisation, for instance, even with this spreadsheet; on the question of having a BIM Execution Plan, how would you identify the KPIs on having a BEP. It is understandable if you have; let's say, 20 projects, and you have the questions like that saying: well in project 1, there was a BEP, project 26 there was no BEP, looking at the cost then this is how it is affected, so in the KPIs this is how you would say that by having BEP and EIR were delivering a better project, and you will need some kind of a matrix of compare it with*. *On the moment, on a project basis, I can just guess but I am not sure what will be there. On an organisation basis, if I had all this information recorded project by project, so your giving an outline for a project, this is what* *information they are interested in, so these are the core key questions that we will measure against. So, having the set of questions asked in each organisation level, and assessing it across 20 projects for example, you could identify what went better, you will have your KPIs; Quality, Time and Cost, that would define whether you're doing correct or no*. *But you will need to have this on the project, so for somebody to answer those questions, someone would need to put it on a database, somebody needs to make sense out of it. Identifying who is that person, is it their additional role or their main role*. *I think this assessment is more on a project by project basis, since the questions are mainly directed to projects status. When you need to provide examples, such as could your organisation provide 3 Level 2 BIM projects? this would be grade system to record those questions for BIM examples within the organisations*.

[Interviewee (I03)] = *Yes there are. Benefits: There is a list of targets to achieve. Achieving maturity 3 (consistency) all the time. To achieve consistency, what needs to be done to get there? There is a training requirement, people got too much work to do, to measure these against the targets. Beneficial*.

[Interviewee (I04)] = *Yes there are benefits*. *Such as improve overall project delivery, add value to the client, spreading more knowledge across the project team, spreading more BIM related stuff and they will be more aware. The provided list of benefits does align with this, but they will not be measured*. *The provided list of benefits does align with this, but they will not be measured*.

[Interviewee (I05)] = *Yes*. *I think one of the drivers that I seem to recall on the early part of the development of BIM, in a strand that we have problem with is Health and Safety. It's just not on the design stage, but it's also on site*. *One of the things I've raised with the contractors is, going through their offices and going to the design team offices, you see BIM being used. When you go out on site, when was the last time you've seen an operative walking out with a computer, and they might be able to benefit from these things. I know a couple of contractors a restarting to think about how we could link the model to Health and Safety*. *What happens is we put some sort of censor that links to danger areas in the model, when you know in a certain day an operation is taking place, and you put a buzzer in someone's helmet, so when you walk into the area and it starts buzzing then you would know that you're in the wrong area. So that kind of links that I think should be made. Guys on site, there are too many desks in the construction industry. the guys in the drawing office its very rare that they have to be hit by another contractor. On site, it something that needs work. The more that we can develop the linkages in between the model and what goes on site, the better. Whether it's just something simple or not, whether you get text message on the phone to say where are you, why are you working in here? You should be here or be aware that at that certain time of the day, we are expecting certain materials to be delivered in trucks on site, so watch out. You can link the program and the model, and all the operations going on site, that would be of tremendous value. These things are very beneficial and worthwhile, and Health and Safety is the biggest one*.

[Interviewee (I06)] = *Yes there are*. *These are some of the benefits that we've got from that particular project. Complex design solutions, sequencing and programming. The list of benefits will match and fit with those. [Refer to Manchester Town tall complex study for a list of benefits; (Section 4.7; BIM benefits expected for clients, and Section 4.8; BIM benefits explored in the MCC project p. 45-46)]*.

[Interviewee (I07)] = *Yes, there are benefits*. *Such as working collaboratively, there will be openness, projects will work on a smoother pace, and not have hiccups. With providing a list of anticipated benefits that are expected to emerge from this, I think because I haven't implemented it, then It is difficult to see the benefits since I haven't seen a project that is fully absorbed to BIM, using all their protocols*. *I would agree that if there is a BIM project, then all the provided benefits will be achieved, but due to not obtaining the experience, then it's difficult to say*.

[Interviewee (I08)] = *I don't think there are any benefits, at least on the short term, because we've got to get through the real basics stuff of agreement on what we need to do with BIM*. *What we need to do to make ourselves BIM level 2, I think the contractors could outrun us, they would be saying I'm doing this with BIM level 2, because where they are going with Revit software, intelligent modelling, data communications using conject and data line reasons, etc.. we don't have access to it here*. *They are ahead of where we are now, and probably will be head of where we will be in a year or 2 years' time. They have the facilities to do more than we ask of them now. They develop this even further*.

[Interviewee (I09)] = *Yes, I think so*. *I think that if you have that program of projects, then you've got a ligament reason to do a number of projects on a number of different levels of maturity. In order to do that incremental change and learning, and I think then you can start to see, (well we did a partial on process, but when we did the next project, we did it fully, so we got more benefits). So I think that's valuable and would work. The other thing around collaboration is we've seen high levels of KPIs where the collaboration isn't just about working with the CDE and that kind of thing, but it's also about the client and supply chain working together on how we are going to change*. *How are we going to introduce these maturities, what are we going to change, how do we write EIRs if the suppliers are* *involved in that, even though it's a client responsibility, then when it gets issued, it's not a surprise, its achievable, people feel like they've been involved. So, there is something around collaboration in setting the maturity on a project. Also, participating in what requirements are going to be, that can also have an impact on the KPIs as well.*

[Interviewee (I10)] = *I think there is benefits. Safety and change management and things like that definitely comes in the construction period, along with the KPIs. I think it's based on what stage the KPIs are related, because you will have some that are related to the actual construction period, so the safety and things like that, because we'd hope our project is safe, we'd need a KPI on that and move forwards. Based on the list, some relate more to the construction period, so like* ***improved communication and collaboration*** *that would be construction phase,* ***improved certainty and reduction and programme certainty*** *is construction phase,* ***performance certainty*** *comes after, it's a KPI that we can put on the contractor and say we want to achieve coordination of this. Performance and Improved user satisfaction- as an occupancy KPIs. We don't particulate build on safe buildings, it's the process of constructing where the main risk is, once that the building is handed over to you. I think that's how we use the KPIs pf what we set out in the 1st place, and is it being achieved and has it being achieved in the end. Complaints on occupancy that it's too hot or its too cold, it's these sort of things that very much once we complete the building like new Adelphi, whilst there's a period of time for staff to get used to the new environment, there will be a lot of issues in for us, where people will say all the lights are too bright for me, or its too cold in here, but when I go over there, it's too warm. So the actual performance of the building working as it was intended or designed to be; is an important KPI. It's also about culture and change management, because when we take people to different building, it's not just about the technology of it, but is it about the environment. Sometimes what we do, is we train the building managers, and everything like this is how it will work, and they get it, but not the uses. So if we are in Computing Science and Engineering (CSE) we need from everybody how the building works, for example in New Adelphi, the windows are automatically open, and based on CO2 levels and temperature. When New Adelphi was built, there wasn't a mass thing. Any new technologies or anything that we use in the new building, we will sit down with the whole school and explain to them about it. We need to manage the change in people, that's the thing that we will face. Managing the change and culture in people. That is very technical, but that's the same with our technical staff in the FM team. We need to take them on the journey with us. Now you've got the tablet, then we need to step it up a level; this is how we're going to use the BIM, this is how we're going to operate BIM in the building and make a move forward.*

[Interviewee (I11)] = *Yes. Allow directors to assess any time and cost savings benefits, and this could be reflected on more competitive quotes for future work.* ***Personal notes from the interviewee=*** *Allow the Directors to assess time savings or cost saving benefits of BIM and reflect this in more competitive quotes to clients to extra business.*

[Interviewee (I12)] = *The big thing that is lacking from the industry is the evidence and case studies, where BIM is being delivered to a high standard and KPIs like safety, project delivery, and that is something that has been lacking for quite a long time.*

[Interviewee (I13)] = *Yeah, its good as a general maturity assessment, and it's a lot easier to fill in rather than the lot non-winded ones that you get a lot from contractors and suppliers they go on the supply chain list. I think there is benefit to it. Linking to Questions 10- but I think you need something out as well. They need evidence, or you need some sort of documented interview, or something else that proves somebody's competence in the subject. Otherwise, it's easy to review and going (Oh look at those numbers) but there is no validation in there. It needs to be this with a 2-part thing, case study, or something out.*

[Interviewee (I14)] = *It's awareness really isn't it, it's kind of that's the whole point of assessment I suppose.* ***Based on the list,*** *absolutely* ***improved collaboration, communication and relationships****, I've kept touching with that, its relationship with clients, contractors, consultants and others, we do find that a big part of BIM, and we see the benefits of that.* ***Improved certainty and reduction of uncertainty****, absolutely. Contractor's side that's the biggest win in terms of BIM. It's doing that kind of 3D work upfront, reducing the risk on site by improving the clash detection process, its removing risks before getting on the site before it gets to cost more. As a consultant, we never see the benefits of that. Where the information we do the clash detection process. We're probably saving the contractors thousands of pounds, so if on site if something goes wrong, that hits their deadline, then their huge financial consequences for them. What do you mean by that? Clarification on (****out turn cost certainty and reduced risk provision****) and fits with the previous benefit with the certainty and beyond the cost level I suppose.* ***Programme and Performance certainty****, yeah, I suppose because it's all about the standards you know what you're getting from it, it's that performance certainty that your knowing what you're getting, especially in that LoD and LoI, if it set out from the start, what the deliverables are, there's no argument. So that the certainty of the product, is almost guaranteed I suppose on meeting those standards.* ***Improved change implementation and management****, I'm not sure if we really see that.* ***Improved Safety****, I think it will get there, I think it's getting more integrated, safety is getting more integrated with that design in a 3D sense as I mentioned earlier. So I can see that as a massive benefit going forward,* *I think that will increase and get better and better.* ***Improved user satisfaction****, even just working in a 3D world where we're able to walk lines through buildings, the user satisfaction of clients is huge, because they get to see and realise what that building will be before its even built. That I think is huge.* ***Reduced lifecycle cost****, that will come in, and I think over the next 20 years there will be a massive drive in that, in terms of that***.** *As long as the procurement routes are set up to integrate lifecycle analysis, that could be massive. I think that will be a huge benefit for the construction industry as a whole CAPEX, not OPEX. I think it is all covered, and the risk is the biggest thing, I think the contractors are taking it on, and that's how they can get a competitive edge. If they can reduce their risk allowance on a project, in terms of financially, they can be more competitive within the marketplace. If they know they got a supply chain, as a consultant team, we're all working to Level 2 BIM. Your producing that 3D model of a building that's clash detected and before you get to site, their continuance can be reduced, which means they can be more commercially operative in the market place, they could get the cheaper price, which means they win more projects. That to me is a massive benefit for them, and it's a massive benefit for us because it means, if we can reduce our risk in projects in terms of things going wrong on site when the building finally gets constructed, then we get less loads sits I suppose***.**

<u>[Interviewee (I15)]</u> = *I think for clients in general, if you can link them all together, then it can make it easier to put a business case for it. I would need to revisit the KPIs and see where I could say it mapped well on us. If you did all of this then we could do all of this a lot better. Because ours is roles based on programme, cost, not as much quality, it is based on meeting our obligations of opening dates and that kind of stuff, but obviously this will all greatly help that, it provides a nice roadmap to it***.** *Based on the list of benefits, if they could be tied to the KPIs, then that could improve the KPIs***.** *In general, it's a client organisation, and if the benefits of BIM are realised, then this is meant to happen. Everybody knows the benefits, but nobody is sure of getting there. So I suppose you will have maturity mapping that will take you there. It will take you to the point on how this drives that, to that, to take you there….***.** *This is the sort of workshops that I have to run with my engineers and say to them "you need to specify a bit of design that you need a bit modelling, and what doesn't need to be modelled, and the benefits of this modelling". In terms of project managers, what do you want to see modelled, is it realistic to ask for everything to be modelled, and it's not, but what is the sort of things that need to be modelled or would like to be modelled***.** *We went to the BIM test day and decide which was poorly, and with the signage, and we will see how people will experience through the model, which will bring big benefits to us***.** *How working through that and understand that 1) Not understanding the BIM uses, and detailing it off, which could have a massive effect on our KPI for our opening dates and handover process because we might not be able to take over the building. Through a mapping process, the BIM elements could all be linked with the KPIs***.**

NWCH
North West Construction Hub
DIGITAL CONSTRUCTION CASE STUDY

EXPLORING LEVEL 2 BIM MATURITY & KPI'S

Collaborative engagement with academia

LOCATION
Salford

PEOPLE CURRENTLY INVOLVED
Ahmed Adel AbouMoemen - University of Salford

Over the last two years the NWCH Digital Construction Special interest Group has been collaborating with the University of Salford on the journey to explore BIM maturity in relation to the derived benefits for Client organisations, with Ahmed Adel AbouMoemen.

This work is being taken forward through a PhD, which builds on Ahmed's MSc. BIM & Integrated Design dissertation, to further develop a Level 2 BIM Maturity-KPI assessment framework that facilitates UK public sector local authority clients with assessing their Level 2 BIM adoption in line with the UK construction strategy.

'Maturity' refers to the degree to which organisational processes and activities are systematically executed within a framework that encourages repeatable outcomes by following principles of good practice. BIM maturity assessment formally measures the level of capability and adoption, based on specific criteria, in order to facilitate deriving benefit and value through developing their organisational maturity in relation to the implementation of BIM.

The study is currently focused on establishing a diverse and comprehensive set of BIM maturity metrics (criteria) that are more aligned to the UK Level 2 BIM requirements/ compliance., In addition, the maturity metrics are assessed at 3 organisational levels that are targeted to specific industry stakeholders involved in the implementation and adoption of Level 2 BIM:

1.Strategic: Senior Managers, responsible for setting up the strategic goals and gearing up the department to deliver BIM, are expected to complete the assessment at this level.
2.Implementation: Information Managers responsible for ensuring that the strategic goals set out in regards to implementing BIM are delivered, and systems (i.e. people, processes, technologies) are in place to facilitate this, would be expected to complete the assessment at this level.
3.Operational: Project Managers responsible for the day-to-day users operating within a Level 2 BIM environment, would be expected to complete the assessment at this level.

Ultimately, the study proposes a framework that aims to bring together the concept of BIM maturity and Key Performance Indicators (KPIs) assessment, whereby BIM maturity provides a measure of the level of organisational/project BIM capability (i.e. 'input') and the KPIs measures the impact of the BIM capabilities on organisation/project performance (i.e. output). Having developed the BIM maturity part of the framework, the next stage of the study is determining the link between BIM maturity and KPIs.

"Working with the NWCH has helped me to gain the necessary knowledge associated with Level 2 BIM, to understand how companies are currently working with Level 2 BIM, and allowed me to understand and see how industry stakeholders work with Level 2 BIM, which is facilitating the success of my PhD". **Ahmed Aboumoemen, University of Salford**

In collaboration with:

University of Salford MANCHESTER

For more information please contact:

Case study One Pager template

12% complete

Background Information

List of Abbreviations:

MEP- Mechanical Electrical Plumbing
QS- Quantity Surveyor

2. Type of your Organisation * *Required*

Please select

3. What is your current position in the Organisation? * *Required*

Please select

4. Where do you see your role in relation to BIM? * *Required*

5. How much working experience do you have in terms of working with BIM? * *Required*

Please select

6. **Where does BIM stand in your organisation in terms of its adoption?** (e.g. *Organisations are working on BIM projects)* * *Required*

7. Within which type of project(s) do you utilise BIM within your organisation? *Required*

- ◯ Residential
- ◯ Commercial and Institutional
- ◯ Infrastructure (Highway & Heavy Construction)
- ◯ Industrial
- ◯ Other

8. Is your organisation compliant to the UK Level 2 BIM governmental mandate? [(http://bim-level2.org/en/about/)](http://bim-level2.org/en/about/) *Required*

Please select ▾

9. Are you aware of any BIM maturity assessments? *Required*

- ◯ Yes
- ◯ No

a. **What are the BIM maturity assessment(s)/tool(s)/model(s) that you use within your organisation?** *Required*

Please select at least 1 answer(s).

- ☐ Interactive Capability Maturity Model (NIBS)
- ☐ BIM Maturity Matrix (Succar)
- ☐ CPIx BIM assessment form (CPIc)
- ☐ Maturity Index (UK BIM wedge)
- ☐ BIM Maturity Measure (Arup)
- ☐ BIM capability compass and Upskilling tool (BIMTASKFORCE)
- ☐ BIM certification (BRE)
- ☐ BIM grading tool and Return On Investment (Scottish Future Trust)
- ☐ BIM maturity assessment tool (MoJ)
- ☐ BIM Capability Model (Atkins)
- ☐ None
- ☐ Other

10. Which BIM maturity element(s) are being used within your organisation? *Required*

Please select at least 1 answer(s).

- ☐ Collaboration (Collaboration processes, Level 2 Education and Training, roles and responsibilties)
- ☐ Employers requirements (EIR, AIR, OIR)
- ☐ Delivery (MIDP, TIDP, MPDT, RM)
- ☐ Processes (BEP, BIM uses, Supplier assessment forms)
- ☐ Sharing (CDE, Information exchange)
- ☐ Capital delivery [LoD, PIM, Project reviews, 3D (Models), 4D (Time), 5D (Cost) inputs]
- ☐ Facilities Management (AIM, COBie, GSL, POE)
- ☐ None
- ☐ Other

11. **In your opinion, what could be the possible challenges of implementing further BIM elements (as selected above) within your organisation?**

General Information on Key Performance Indicators (KPIs)

12. **What are the current KPIs that are used in your company to evaluate the success / performance of your organisation?** * *Required*

Please select at least 1 answer(s).

- [ ] Cost
- [ ] Time
- [ ] Quality
- [ ] Health and Safety
- [ ] Satisfaction
- [ ] Performance
- [ ] Profitability
- [ ] Productivity
- [ ] Sustainabililty
- [ ] Collaborative Culture
- [ ] Other

b. **How do you measure these KPIs that are used in your company to evaluate the success / performance of your organisation??** (e.g. The process itself, scoring criteria?) * *Required*

13. **What are the current KPIs that are used in your company to evaluate the success / performance of construction project(s) on an individual basis?** * *Required*

Please select at least 1 answer(s).

- [ ] Cost
- [ ] Time
- [ ] Quality
- [ ] Health and Safety
- [ ] Satisfaction
- [ ] Performance
- [ ] Profitability
- [ ] Productivity
- [ ] Sustainabililty
- [ ] Collaborative Culture
- [ ] Other

b. **How do you measure these KPIs that are used in your company to evaluate the success / performance of construction project(s) on an individual basis?** (e.g. The process itself, scoring criteria?) * *Required*

14. **Are you able to assess the impact of the KPIs on your project / organisational performance?** * *Required*

- ( ) Yes
- ( ) No

Your view on combining BIM and KPIs

This part of the survey uses a table of questions, view as separate questions instead?

15. In order to facilitate the BIM implemetation, please indicate your opinion: * *Required*

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
BIM maturity assessments and KPIs Could Work Together and help to assess organisational / Project performance	☐	☐	☐	☐	☐
There is benefits in bringing together the BIM Maturity assessments and the KPIs, in order to demonstrate the values on the core KPIs	☐	☐	☐	☐	☐

a. Please expand more on your above response(s)

16. Please rate how strongly you agree to the following statement: * *Required*

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
BIM maturity assessments could have a direct impact on the organisations' overall performance	☐	☐	☐	☐	☐

17. What is the current organisational level position that best suits you in your organisation? * *Required*

◯ Strategic Level: (Senior Managers responsible for setting up the strategic goals and gearing up the department to deliver BIM, are expected to complete the assessment at this level.)

◯ Implementation Level: (Information Managers responsible for ensuring that the strategic goals set out in regards to implementing BIM are delivered, and systems (i.e. people, processes, technologies) are in place to facilitate this, would be expected to complete the assessment at this level.)

◯ Operational Level: (Project Managers responsible for the day-to-day users operating within a Level 2 BIM environment, would be expected to complete the assessment at this level.based on determining the possible links between BIM maturity and KPIs.)

◯ None of the above

It is expected to collect a diverse list of BIM elements that focuses on the Level 2 BIM outcomes, and as a result, it is proposed to split them into 2 metrics that will fit into each organisational level:

- **Sub Metrics-** Secondary levels within the main BIM maturity levels that is expected to be measured and to achieve Level 2 BIM.
- **Essence of descriptors-** Full description of the Secondary levels within the main BIM maturity levels of to provide a clear definition of each level, which will then be expected to be measured and to achieve Level 2 BIM.

18. You are filling this assessment based on: ✱ *Required*

- ◯ Organisation performance Level
- ◯ Level 2 BIM Project performance Level

a. Determining your Level 2 BIM maturity assessment level: **1) Collaboration; 1.1) Collaboration process;** (Common Data Environment (CDE), Softwares required for the design team to use (BIM 360) and aligning softwares with the hardware (BS 1192:2007, PAS 1192-2:2013, PAS 1192-3:2014) ✱ *Required*

Please select ▾

This part of the survey uses a table of questions, view as separate questions instead?

i. Determine the strength of the relationship between **1) Collaboration; 1.1) Collaboration process and the required outcomes (as per KPI if applicable),** based on your Level 2 BIM maturity assessment level **(Awareness / Occasional Application / Consistency)** ✱ *Required*

	NO Relationship (None)	Not Significant (Weak)	Moderate (Medium)	Significant (Strong)
Cost	☐	☐	☐	☐
Time	☐	☐	☐	☐
Quality	☐	☐	☐	☐
Satisfaction	☐	☐	☐	☐
Health and Safety	☐	☐	☐	☐
Performance	☐	☐	☐	☐
Profitability	☐	☐	☐	☐
Productivity	☐	☐	☐	☐
Sustainability	☐	☐	☐	☐
Collaborative Culture	☐	☐	☐	☐

21. You are filling this assessment based on: **Required**

Please select

a. Determining your Level 2 BIM maturity assessment level: **1) Collaboration; 1.1) Level 2 Education and Training;** (Level of education and training expected to be present within a team to achieve Level 2 BIM) * *Required*

Please select

This part of the survey uses a table of questions, view as separate questions instead?

i. Determine the strength of the relationship between **1) Collaboration; 1.1) Level 2 Education and Training and the required outcomes (as per KPI if applicable),** based on your Level 2 BIM maturity assessment level **(Awareness / Occasional Application / Consistency)** * *Required*

	NO Relationship (None)	Not Significant (Weak)	Moderate (Medium)	Significant (Strong)
Cost	☐	☐	☐	☐
Time	☐	☐	☐	☐
Quality	☐	☐	☐	☐
Satisfaction	☐	☐	☐	☐
Health and Safety	☐	☐	☐	☐
Performance	☐	☐	☐	☐
Profitability	☐	☐	☐	☐
Productivity	☐	☐	☐	☐
Sustainability	☐	☐	☐	☐
Collaborative Culture	☐	☐	☐	☐

24. You are filling this assessment based on: * *Required*

- Organisation performance Level
- Level 2 BIM Project performance Level

a. Determining your Level 2 BIM maturity assessment level: **1) Employers' requirements; 1.1) Information Requirements (EIR);** (Ability to understand the project needs and tailor the EIR accordingly.Level of accomplishment of pre-contract, post-contract, Project Implementation Plan, and supply chain reviews expected to be accomplished.) **Required**

Please select

This part of the survey uses a table of questions, view as separate questions instead?

i. Determine the strength of the relationship between **1) Employers' requirements; 1.1) Information Requirements (EIR) and the required outcomes (as per KPI if applicable),** based on your Level 2 BIM maturity assessment level **(Awareness / Occasional Application / Consistency)** * *Required*

	NO Relationship (None)	Not Significant (Weak)	Moderate (Medium)	Significant (Strong)
Cost	☐	☐	☐	☐
Time	☐	☐	☐	☐
Quality	☐	☐	☐	☐
Satisfaction	☐	☐	☐	☐
Health and Safety	☐	☐	☐	☐
Performance	☐	☐	☐	☐
Profitability	☐	☐	☐	☐
Productivity	☐	☐	☐	☐
Sustainability	☐	☐	☐	☐
Collaborative Culture	☐	☐	☐	☐

27. You have just completed a BIM Maturity assessment. **Do you feel measuring your Level of BIM maturity would allow you to determine the impact of BIM on KPI measured outcomes?** * *Required*

◯ Yes ◯ No ◯ Maybe

a. Why? * *Required*

28. In terms of BIM maturity metrics and KPIs, **are you able to establish the impact of your level of BIM maturity on your KPIs scores?** * *Required*

◉ Yes ◯ No

a. What is the impact? **Required**

29. Please rate how strongly you agree with the following statements: **The Anticipated Benefits that will emerge from the combined Level 2 BIM metrics and KPIs are:** * *Required*

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1) Improved Collaboration, Communication and relationships	☐	☐	☐	☐	☐
2) Improved certainty and reduction of uncertainty	☐	☐	☐	☐	☐
3) Out turn cost certainty and reduced risk provision	☐	☐	☐	☐	☐
4) Programme Certainty	☐	☐	☐	☐	☐
5) Performance certainty	☐	☐	☐	☐	☐
6) Improved change implementation and management	☐	☐	☐	☐	☐
7) Improved safety	☐	☐	☐	☐	☐
8) Improved user satisfaction	☐	☐	☐	☐	☐
9) Reduced lifecycle cost.	☐	☐	☐	☐	☐

a. **Are there any further benefits?** * *Required*

◯ Yes ◯ No

30. **Do you think your organsation would adopt the suggested Level 2 BIM maturity assessment?** ✱ *Required*

- ◉ Yes
- ◉ No

b. What overall impacts shall happen and how will it help measure the performance of organisations

a. Why?

31. **Do you think that combining both (Level 2 BIM and KPIs) together could help improve the current performance levels within your organisation?** ✱ *Required*

- ○ Yes
- ○ No
- ○ Maybe

a. Why?

32. **How would you introduce the suggested assessment in your organisation?** (e.g. Educational and Training schemes) ✱ *Required*

33. **Please rate how strongly you agree with the following statement:** * *Required*

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Client organisations will benefit from this assessment	☐	☐	☐	☐	☐

a. If you **Disagree or Strongly Disagree**, then why?

34. **Who within the client organisation will benefit the most from this assessment and therefore, recommend the most to use the suggested assessment?** * *Required*

Please select

b. **Why and How?** * *Required*

35. **If necessary, please add any comments / observations / recommendations / any other inputs, for taking this work forward?** * *Required*

BIM-KPI relationship assessment across all organisational levels

The Evidence = Relationship of BIM and KPIs													Legend
Strategic Level			(The Strategic goals and gearing up of the delivery of BIM at the organisation / project Level, and Organisational and project levels that are being managed by the organisation team.)										No Relationship (None) 0
Sub Metrics		Maturity level and descriptor	Relationship with KPIs										Not Significant (Weak) 1
Secondary metrics associated with the main BIM metrics that is expected to be measured to achieve BIM		Awareness											Moderate (Medium) 2
		Occasional Application											Significant (Strong) 3
level 2 BIM	ISO19650	Consistency	Cost	Time	Quality	Satisfaction	Health and Safety	Performance	Profitability	Productivity	Sustainability	Collaborative Culture	Current KPI relationship total
Collaboration process		No awareness of systems to be used	1										1.00
Processes and Standards													
Roles and Responsibilities	Function												
Contractual agreements													
Education and Training													
Procurement route													
Design elements													
Information Requirements (EIR)	Exchange Information Requirement (EIR)												
Asset Information Requirement (AIR)													
GSL champion engagement													
Facilities Management Education and Training													
Currrent Maturity level (Total)			1.00										

The Evidence = Relationship of BIM and KPIs													Legend
Implementation Level			(Implementing BIM across the organisation / project level, in line with the organisation / project strategic goals in relation to BIM implementation.)										No Relationship (None) 0
Sub Metrics		Maturity level and descriptor	Relationship with KPIs										Not Significant (Weak) 1
Secondary metrics associated with the main BIM metrics that is expected to be measured to achieve BIM		Awareness											Moderate (Medium) 2
		Occasional Application											Significant (Strong) 3
level 2 BIM	ISO19650	Consistency	Cost	Time	Quality	Satisfaction	Health and Safety	Performance	Profitability	Productivity	Sustainability	Collaborative Culture	Current KPI relationship total
Level 2 Education and Training		There is internal training undertaken (i.e. intermediate bim training or system training) CDE, FM, software based training	2										2.00
Information Requirements (EIR)	Exchange Information Requirement (EIR)												
Uses													
Supplier assessment forms													
Execution Plan (BEP)	Information Delivery Plan												
Master Information and Task Team Information (MIDP and (TIDP)													
Model production Delivery Table (MPDT)													
Responsibility Matrix (RM)	Assignment Matrix												
Document management stage- Common Data Environment (CDE)													
Information Exchange													
COBie data	<CDE> State												
Currrent Maturity level (Total)			2.00										

The Evidence = Relationship of BIM and KPIs													Legend
Operational Level			(Operating BIM across the organisation / project, and how the management of information being collected is achieved.)										No Relationship (None) 0
Sub Metrics		Maturity level and descriptor	Relationship with KPIs										Not Significant (Weak) 1
Secondary metrics associated with the main BIM metrics that is expected to be measured to achieve BIM		Awareness											Moderate (Medium) 2
		Occasional Application											Significant (Strong) 3
level 2 BIM	ISO19650	Consistency	Cost	Time	Quality	Satisfaction	Health and Safety	Performance	Profitability	Productivity	Sustainability	Collaborative Culture	Current KPI relationship total
Information Requirements (EIR)	Exchange Information Requirement (EIR)	Fully developed EIR in the provided documents (AIR)	3										3.00
Document management stage- Common Data Environment (CDE)	<CDE> State												
3D – 6D inputs													
Level of Development (LoD)	Level of Information need												
Project reviews													
Lifecycle Analysis													
As built model													
Project Information Model (PIM) exchanges													
Information Delivery (AIM)													
COBie data													
Handover requirements (GSL)													
Post Occupancy Evaluation (POE)													
Currrent Maturity level (Total)			3.00										

BIM assessment across all organisational levels

Strategic level
Interviews (Left) vs Questionnaire (Right)

Maturity level		Maturity level descriptor	Sub Metrics		Maturity level		Maturity level descriptor
Frequency	Total		Level 2 BIM	ISO19650	Frequency	Total	
3	2.45	Systems that are able to integrate the BIM models (CDE) that are compliant with Level 2 BIM standards into operations.	Collaboration process		3	2.45	Systems that are able to integrate the BIM models (CDE) that are compliant with Level 2 BIM standards into operations.
3	2.55	Understanding and fully implementing the UK BIM Level 2 standards. Fully understanding and application of the CAPEX and OPEX	Processes and Standards		2	2.09	Understanding and partially implementing the UK BIM Level 2 standards. Partial understanding of the CAPEX and OPEX
3	2.36	Partial understanding of roles defined in PAS 1192-2:2013 and have limited internal resources	Roles and Responsibilities	Function	2	2.18	Partial understanding of roles defined in PAS 1192-2:2013 and have limited internal resources
2	2.27	Good understanding of how form of contracts are and alignment of standards with Level 2 BIM projects (i.e. 1 to 2 project).	Contractual agreements		2	1.82	Good understanding of how form of contracts are and alignment of standards with Level 2 BIM projects (i.e. 1 to 2 project).
3	2.36	Awareness training required and producing a roadmap, and some staff training in the basics.	Level 2 Education and Training		3	2.36	Awareness training required and producing a roadmap, and some staff training in the basics.
2	2.27	Some confidence in a particular procurement route and how Level 2 BIM is being implemented from stage 1.	Procurement route		2	2.09	Some confidence in a particular procurement route and how Level 2 BIM is being implemented from stage 1.
3	2.45	Full understanding and inclusion of a standardised matrix table that covers all contractor design portions (2D and 3D).	Design elements		2 3	2.09	Some understanding of the main packages (i.e groundworks, structure, MEP and architecture, external works) covered.
3	2.45	Ability to Complete EIRs specific identifies which the clients need for their facilities.	Information Requirements (EIR)	Exchange Information Requirement (EIR)	3	2.20	There is a basic understanding of the quality and what should be an EIR, and the ability to develop an EIR with or without the help from a consultant.
3	2.27	Understanding of the Asset requirements and basic outline of them and some understanding of COBie.	Asset Information Requirement (AIR)		1	1.80	Understanding of the Asset requirements and basic outline of them and some understanding of COBie.
2	2.09	Able to use model data but not integrated with FM systems and procedures.	GSL champion engagement		1 2	1.80	Able to use model data but not integrated with FM systems and procedures.
2	2.00	Awareness training required, and relevant employees training on the basics.	Facilities Management Education and Training		2	1.82	Awareness training required, and relevant employees training on the basics.
Consistency	2.32		BIM Maturity level Totals		Occasional Application	2.07	

Implementation level

Interviews (Left) vs Questionnaire (Right)

Maturity level		Maturity level descriptor	Sub Metrics		Maturity level		Maturity level descriptor
Frequency	Total		Level 2 BIM	ISO19650	Frequency	Total	
2	2.16	There is internal training undertaken (i.e. intermediate BIM training or system training) CDE, FM, software based training	Level 2 Education and Training		2	1.90	There is internal training undertaken (i.e. intermediate BIM training or system training) CDE, FM, software based training
2	2.16	Basic template and external procured EIR	Information Requirements (EIR)	Exchange Information Requirement (EIR)	2 3	2.33	Basic template and external procured EIR
2	2.47	BIM uses are outlined but not tailored for specific projects	Uses		2	2.20	BIM uses are outlined but not tailored for specific projects
3	2.37	BIM uses are outlined but not tailored for specific projects	Supplier assessment forms		2	1.89	BIM uses are outlined but not tailored for specific projects
3	2.47	Clients are able to review the BEP	Execution Plan (BEP)	Information Delivery Plan	3	2.40	Clients are able to review the BEP
2	2.21	Consultant reviews of MIDP and TIDP.	Master Information and Task Team Information (MIDP and (TIDP)		2	2.00	Consultant reviews of MIDP and TIDP.
2	1.95	Basic MPDT Template	Model production Delivery Table (MPDT)		2	2.00	Basic MPDT Template
3	2.32	Basic RM template developed but not completed.	Responsibility Matrix (RM)	Assignment Matrix	3	2.10	Basic RM template developed but not completed.
3	2.68	CDE supplied by you or supplied by others - CDE is fully compliant to BIM Level 2 and security requirements	Document management stage- Common Data Environment (CDE)	<CDE> State	3	2.56	CDE supplied by you or supplied by others - CDE is fully compliant to BIM Level 2 and security requirements
2	2.47	Information exchange is defined with basic requirements.	Information Exchange		2 3	2.20	Information exchange is defined with basic requirements.
2	1.89	Understanding the use of COBie but not incorporated on the FM.	COBie data		2	2.00	Understanding the use of COBie but not incorporated on the FM.
Occasional Application	2.29		BIM Maturity level Totals		Occasional Application	2.13	

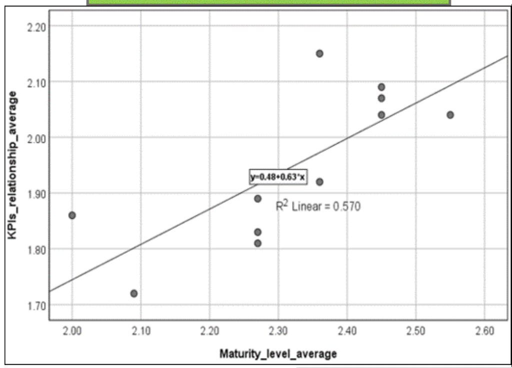
Operational level

Interviews (Left) vs Questionnaire (Right)

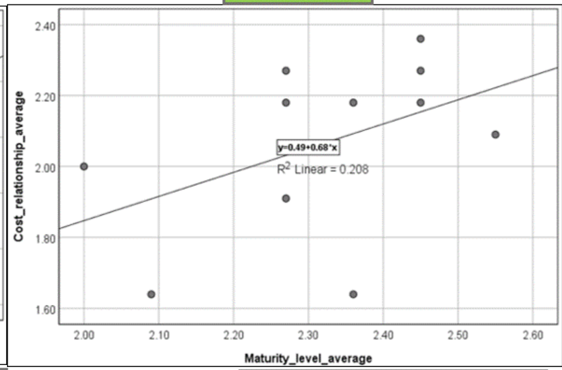
Maturity level: Frequency	Maturity level: Total	Maturity level descriptor	Sub Metrics: Level 2 BIM	Sub Metrics: ISO19650	Maturity level: Frequency	Maturity level: Total	Maturity level descriptor
2	2.00	Basic template and external procured EIR	Information Requirements (EIR)	Exchange Information Requirement (EIR)	2 3	2.20	Basic template and external procured EIR
2	2.33	CDE supplied by you or supplied by others - CDE implemented but not Level 2 BIM compliant / PAS1192-5 compliant	Document management stage- Common Data Environment (CDE)	<CDE> State	3	2.40	CDE supplied by you or supplied by others - CDE is fully compliant to Level 2 BIM and security requirements
1 2	1.50	Simply Identified 3D-6D elements, but not fully followed	3D – 6D inputs		1 3	2.00	Identified but not used in a certain degree over projects
2	2.00	Good understanding of the LoD and basic ability to check (Visual checks) the models	Level of Development (LoD)	Level of Information need	3	2.40	Full understanding of the LoD and capability to use the models (Visualise and check the information)
2	1.83	Good understanding of the roles and responsibility and acknowledging the clients on the gateway reviews to be applied	Project reviews		1	1.90	Good understanding of the roles and responsibility and acknowledging the clients on the gateway reviews to be applied
1 2	1.50	No capability to operate on the lifecycle.	Lifecycle Analysis		2	2.00	Basic Usage of the Lifecycle but not fully managed
2	2.00	As built model is acknowledged by project team members in line with BIM level 2, and ready to be used.	As built model		3	2.10	As built model is acknowledged by project team members in line with BIM level 2, and ready to be used.
1 2 3	2.00	Information model is acknowledged by project team members in line with BIM level 2, and ready to be used.	Project Information Model (PIM) exchanges		2	2.00	Information model is acknowledged by project team members in line with BIM level 2, and ready to be used.
1	1.67	Good Understanding of AIM and using it in the basic level but is not fully level 2 BIM compliant	Information Delivery (AIM)		1	1.80	Good Understanding of AIM and using it in the basic level but is not fully level 2 BIM compliant
2	1.83	Good Understanding and using it in the basic level but not fully integrated in the system	COBie data		1	1.90	Good Understanding and using it in the basic level but not fully integrated in the system
1	1.50	Basic understanding of Hand-overs and its requirements for the GSL, but is not presented	Handover requirements (GSL)		1 3	2.00	Good understanding of the Hand-overs required for the GSL, and is being used but not fully Level 2 BIM compliant
1	1.50	Basic understanding of Post Occupancy Evaluation, but is not presented	Post Occupancy Evaluation (POE)		1	1.60	Good understanding of the Post Occupancy Evaluation, and is being used but not fully Level 2 BIM compliant
Occasional Application	1.80		BIM Maturity level Totals		Consistency	2.03	

Regression analysis scatter plot diagrams for all organisational levels

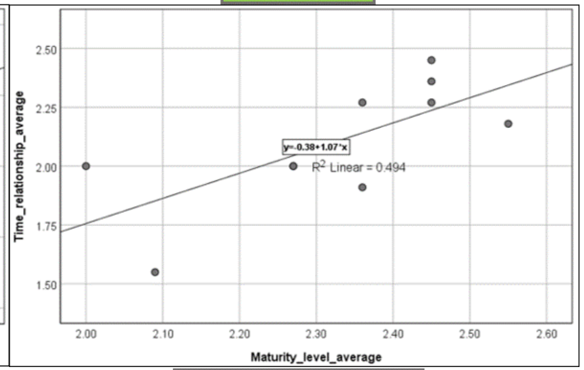
STRATEGIC



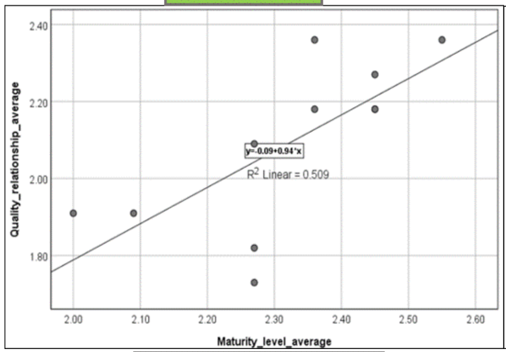
COST



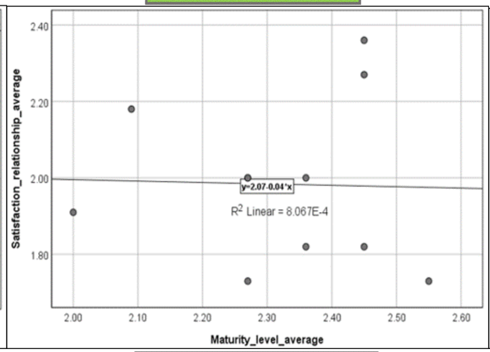
TIME



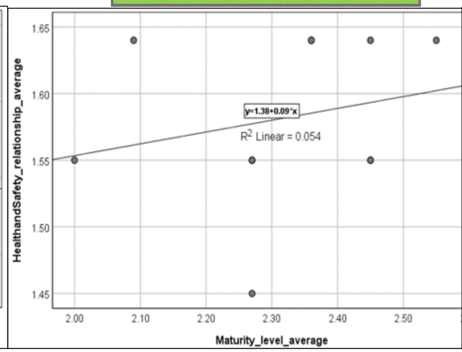
QUALITY



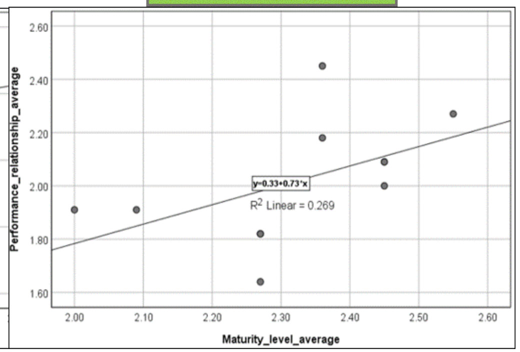
SATISFACTION



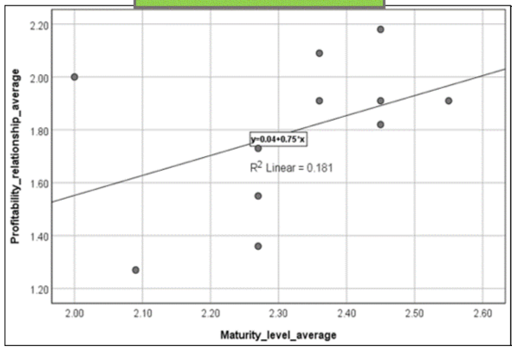
HEALTH AND SAFETY



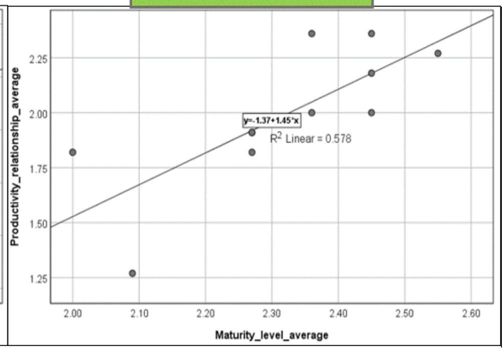
PERFORMANCE



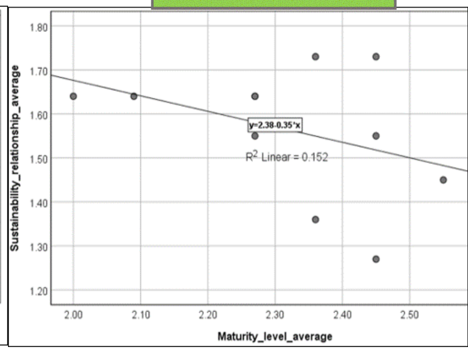
PROFITABILITY



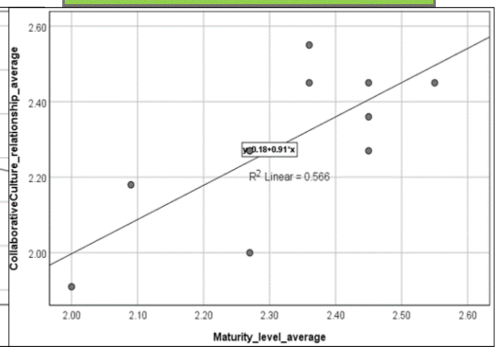
PRODUCTIVITY



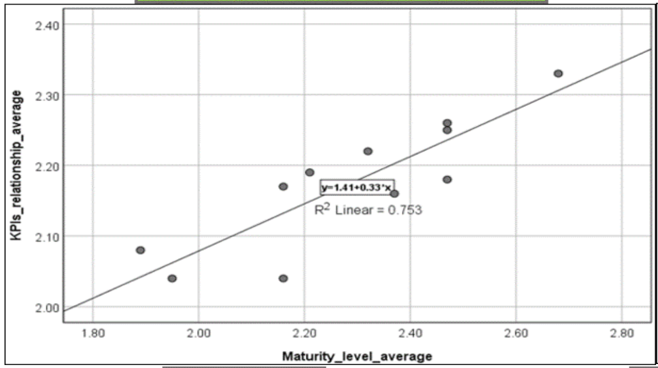
SUSTAINABILITY



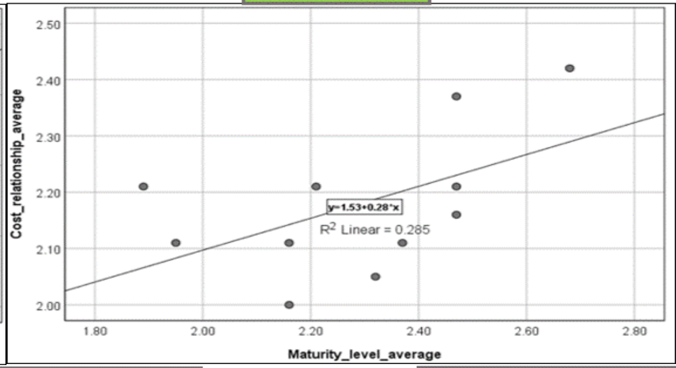
COLLABORATIVE CULTURE



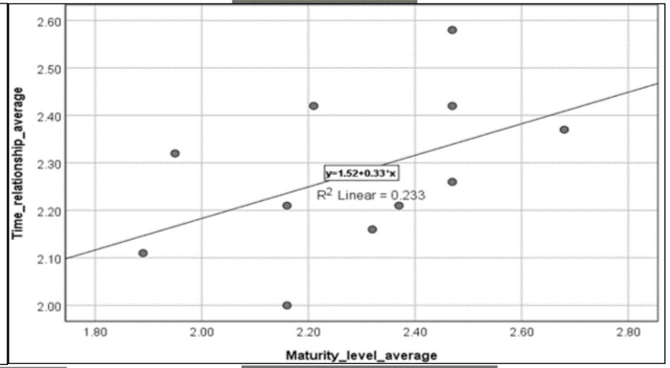
IMPLEMENTATION



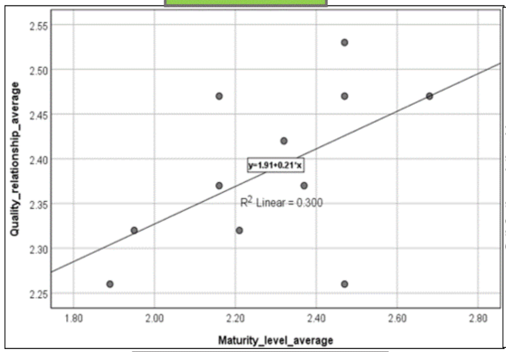
COST



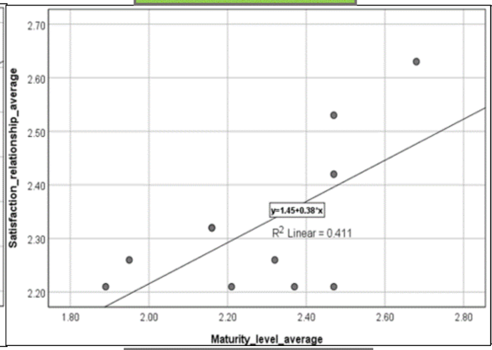
TIME



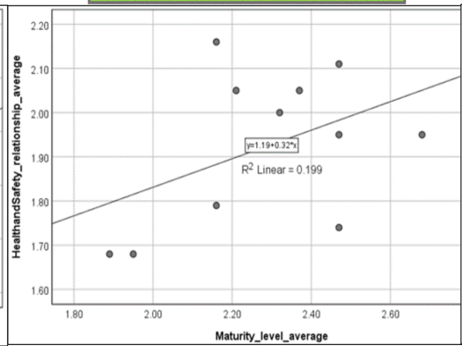
QUALITY



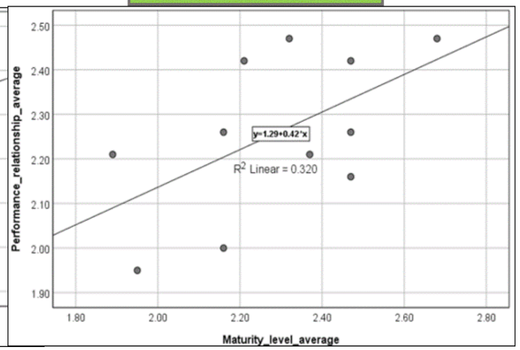
SATISFACTION



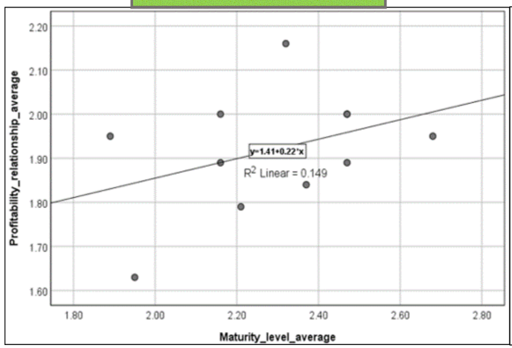
HEALTH AND SAFETY



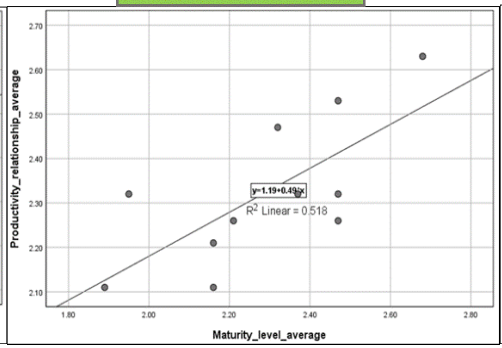
PERFORMANCE



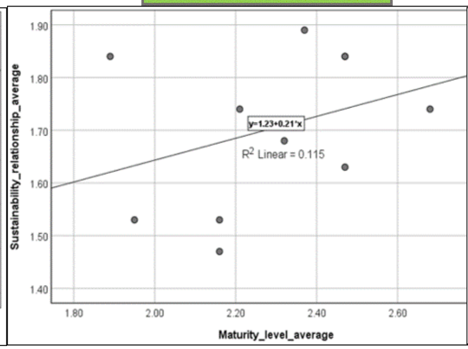
PROFITABILITY



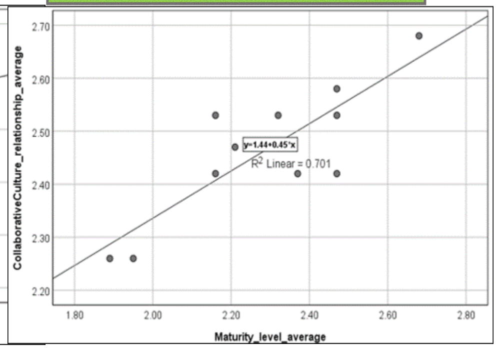
PRODUCTIVITY

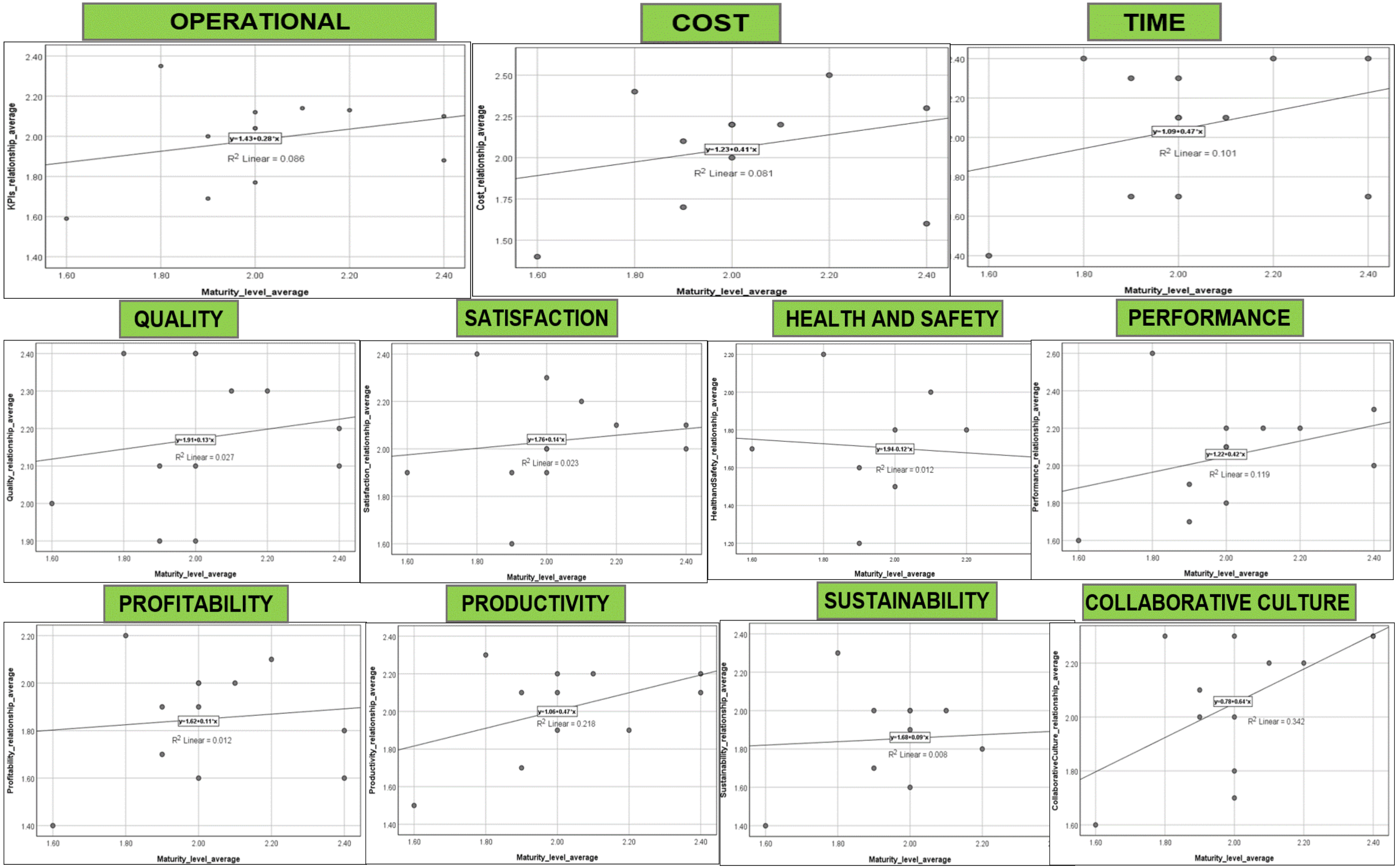


SUSTAINABILITY



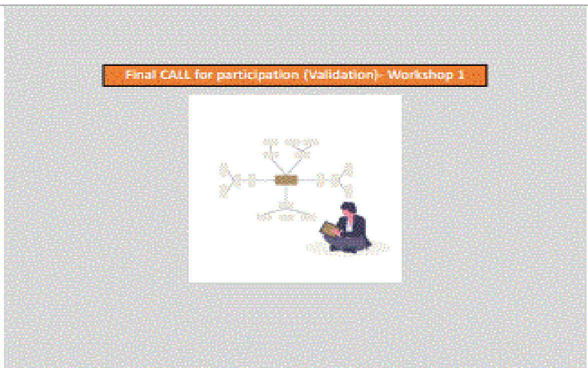
COLLABORATIVE CULTURE



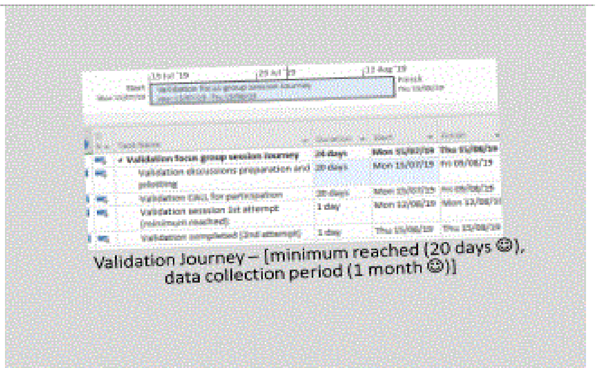

OPERATIONAL
KPIs_relationship_average
Maturity_level_average
y=1.43+0.28*x
R2 Linear = 0.086
COST
Cost_relationship_average
Maturity_level_average
y=1.23+0.41*x
R2 Linear = 0.081
TIME
Maturity_level_average
y=1.09+0.47*x
R2 Linear = 0.101
QUALITY
Quality_relationship_average
Maturity_level_average
y=1.91+0.13*x
R2 Linear = 0.027
SATISFACTION
Satisfaction_relationship_average
Maturity_level_average
y=1.76+0.14*x
R2 Linear = 0.023
HEALTH AND SAFETY
HealthandSafety_relationship_average
Maturity_level_average
y=1.94-0.12*x
R2 Linear = 0.012
PERFORMANCE
Performance_relationship_average
Maturity_level_average
y=1.22+0.42*x
R2 Linear = 0.119
PROFITABILITY
Profitability_relationship_average
Maturity_level_average
y=1.62+0.11*x
R2 Linear = 0.012
PRODUCTIVITY
Productivity_relationship_average
Maturity_level_average
y=1.06+0.47*x
R2 Linear = 0.218
SUSTAINABILITY
Sustainability_relationship_average
Maturity_level_average
y=1.68+0.09*x
R2 Linear = 0.008
COLLABORATIVE CULTURE
CollaborativeCulture_relationship_average
Maturity_level_average
y=0.78+0.64*x
R2 Linear = 0.342

Appendix H: Chapter 9 Additional information on Validation sessions

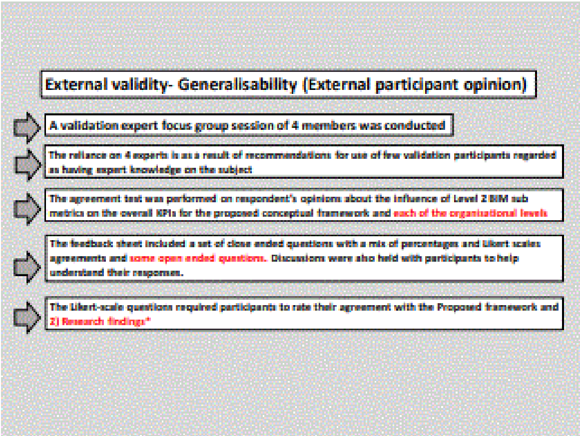
Validation Workshop



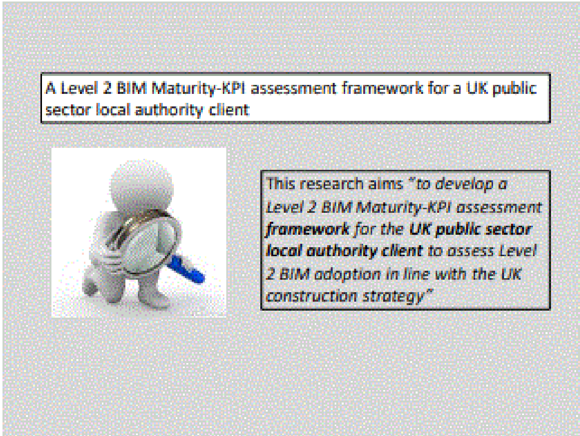
1



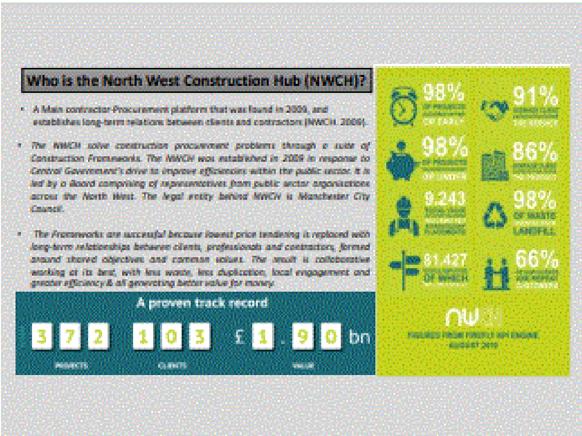
2



3

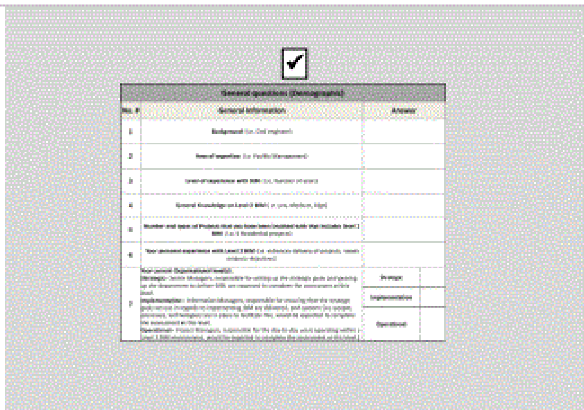


4

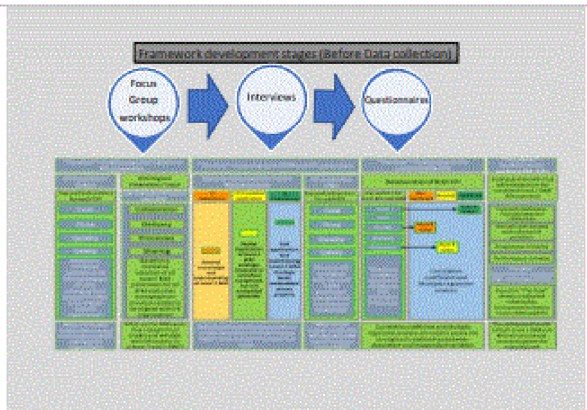


5

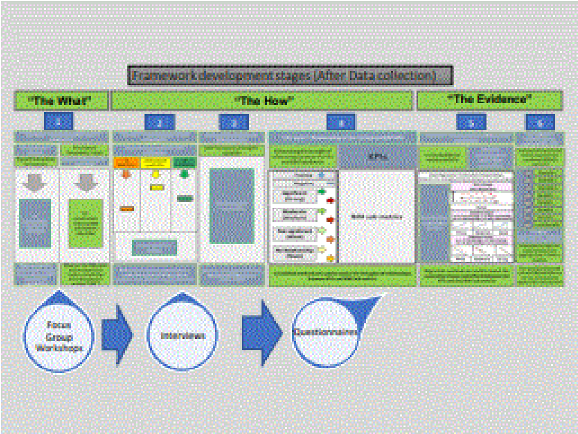
6



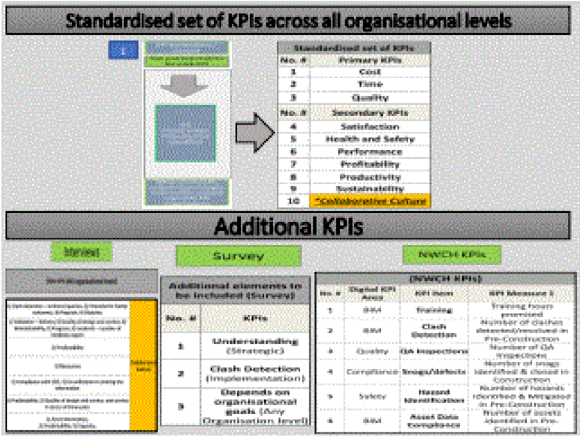
7



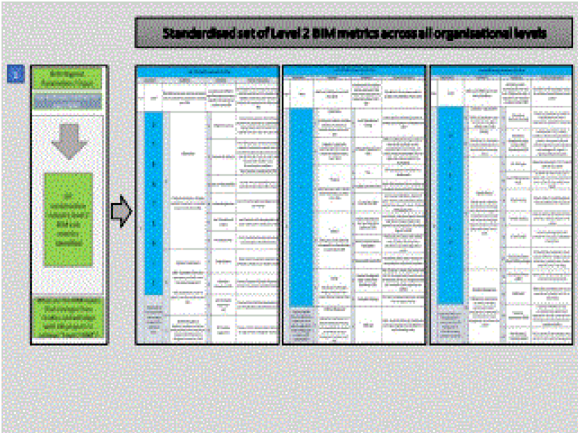
8



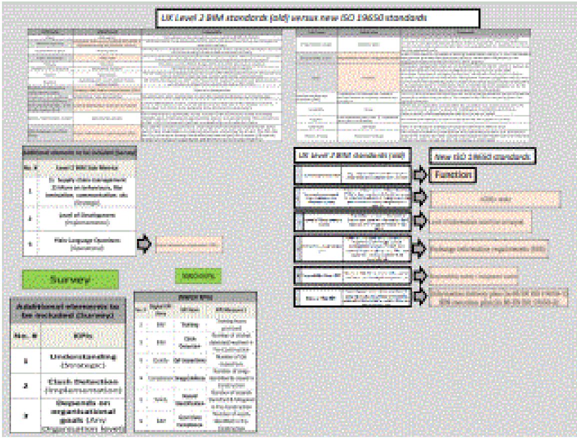
9



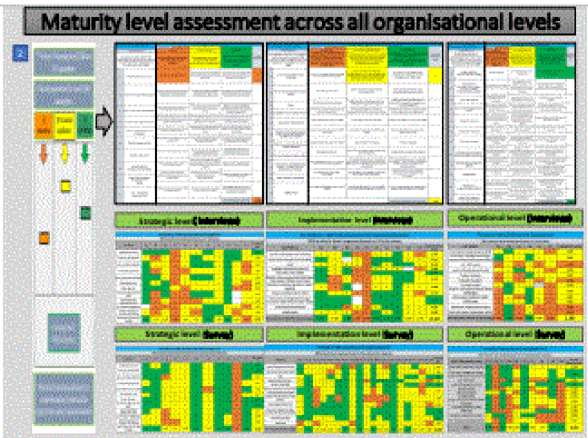
10



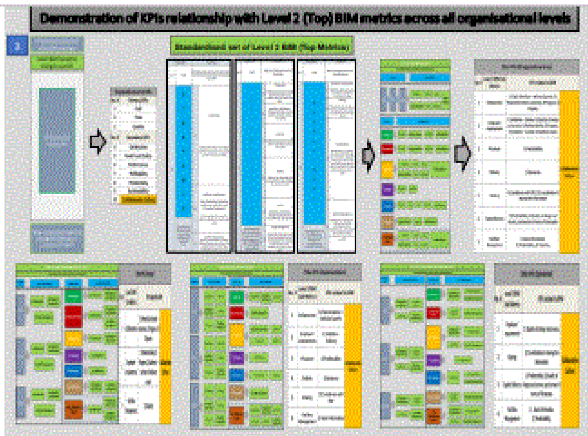
11



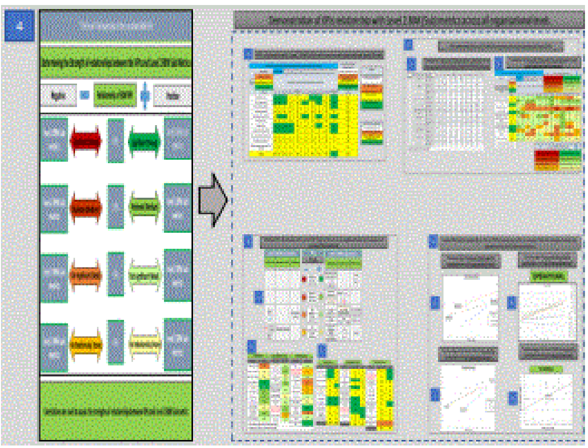
12



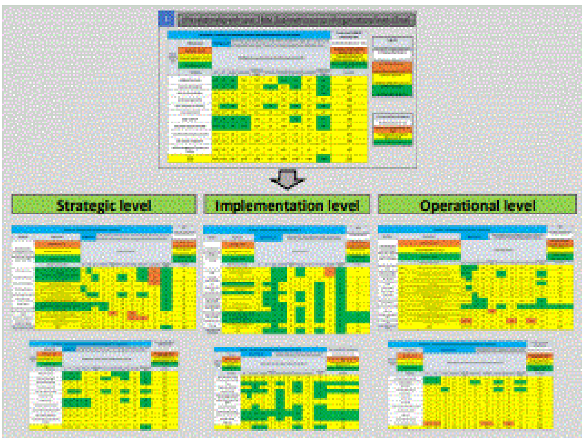
13



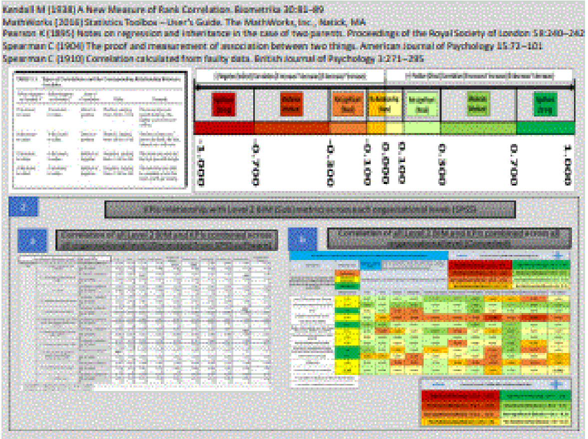
14

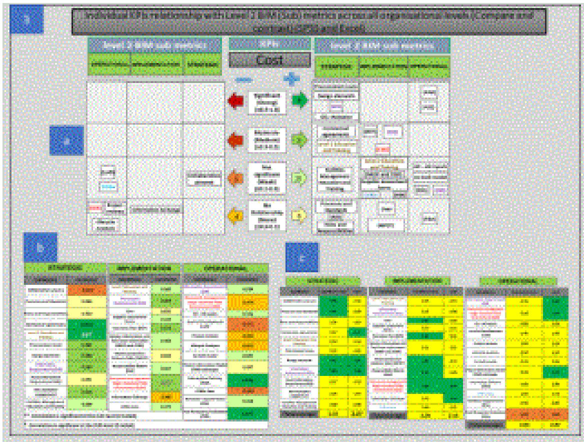


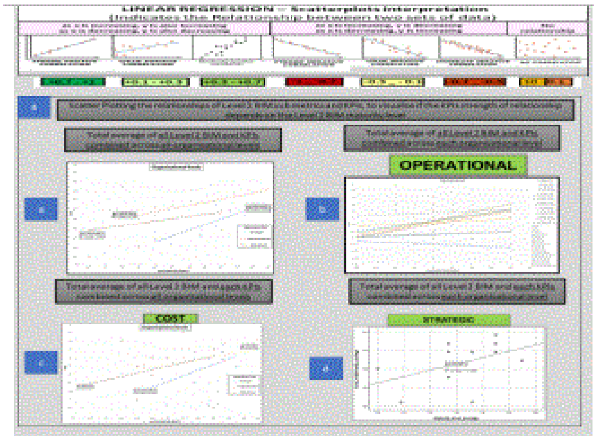
15

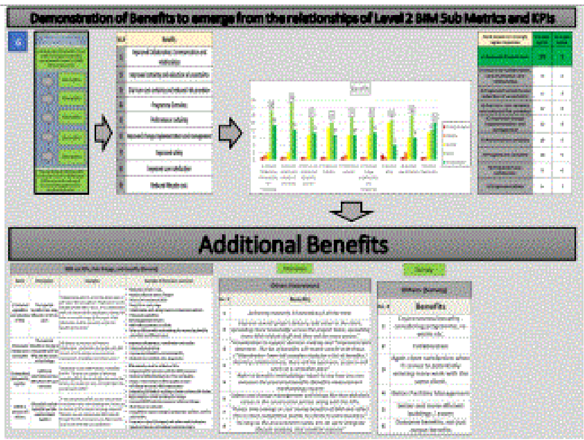


16


Kendall M (1938) A New Measure of Rank Correlation. Biometrika 30:81–89
MathWorks (2016) Statistics Toolbox – User's Guide. The MathWorks, Inc., Natick, MA
Pearson K (1895) Notes on regression and inheritance in the case of two parents. Proceedings of the Royal Society of London 58:240–242
Spearman C (1904) The proof and measurement of association between two things. American Journal of Psychology 15:72–101
Spearman C (1910) Correlation calculated from faulty data. British Journal of Psychology 3:271–295
-1.000
-0.700
-0.300
-0.100
0.000
0.100
0.300
0.700
1.000

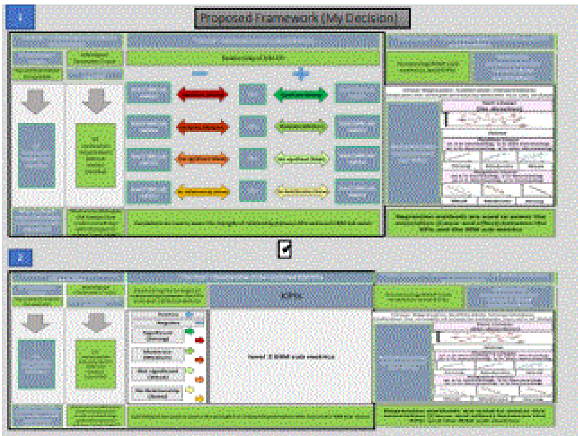

Cost

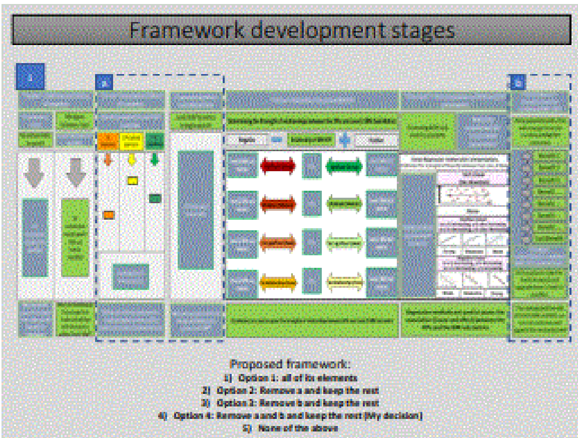

LINEAR REGRESSION – Scatterplots interpretation
OPERATIONAL
COST
STRATEGIC


Demonstration of Benefits to emerge from the relationships of Level 2 BIM Sub Metrics and KPIs
Additional Benefits

19

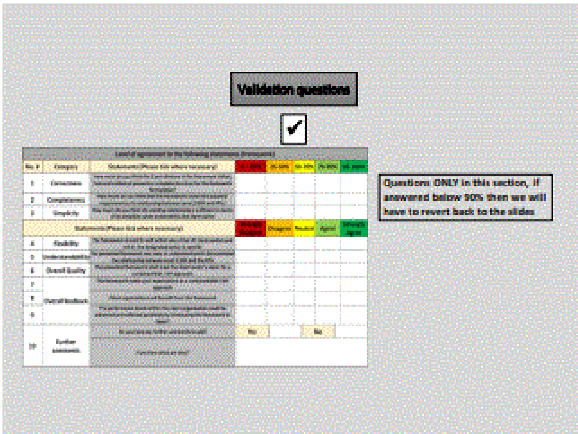
20

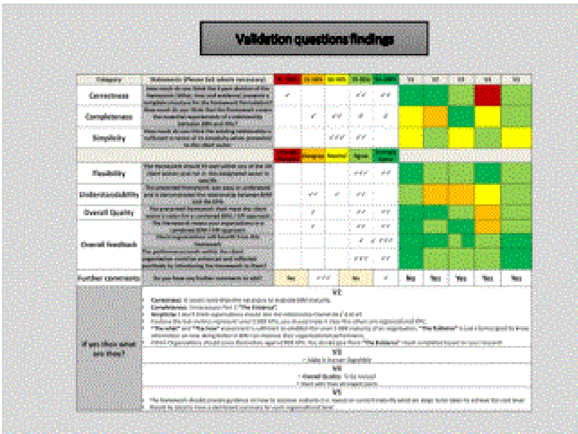

Proposed Framework (My Decision)

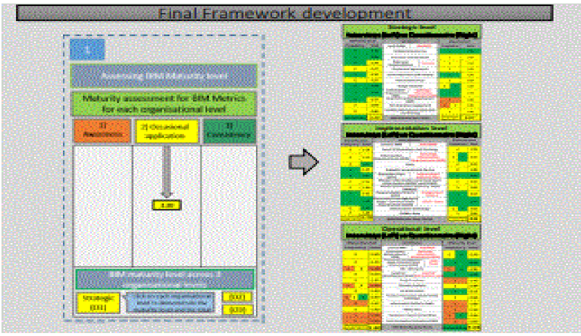

Framework development stages
Proposed framework:
1) Option 1: all of its elements
2) Option 2: Remove a and keep the rest
3) Option 3: Remove b and keep the rest
4) Option 4: Remove a and b and keep the rest (My decision)
5) None of the above

21

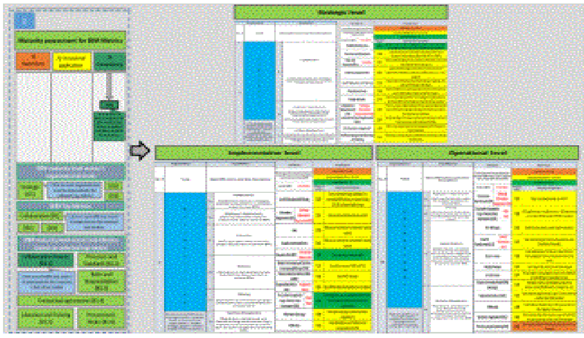
22


Validation questions
Question: ONLY in this section, if answered below 90% then we will have to revert back to the slides

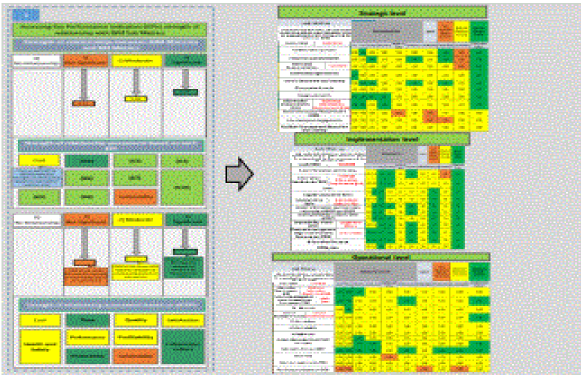

Validation questions findings



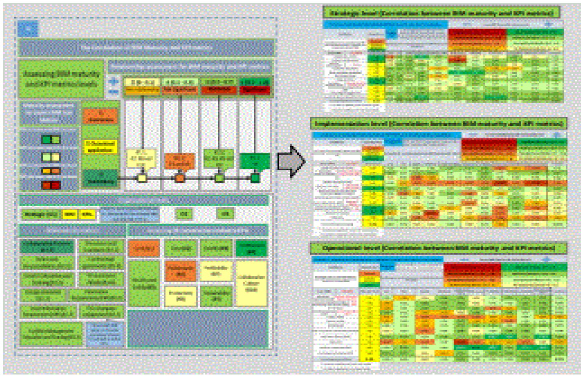
27



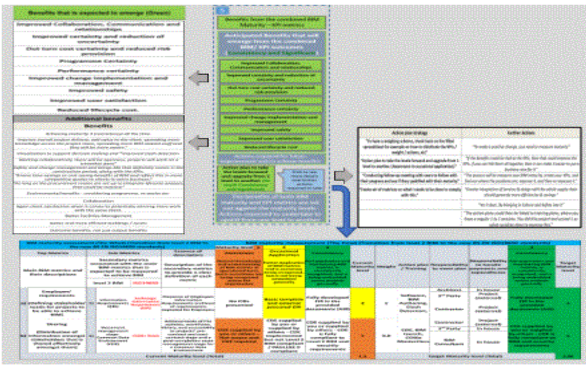
28



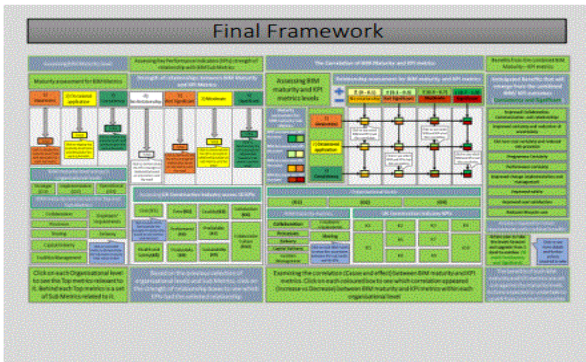
29



30



31



32

Appendix I: Publications to date

Aboumoemen, A. & Underwood, J. (2017) *A Level 2 BIM Maturity-KPI Assessment: Literature Review.* 13th International Postgraduate Research Conference (IPGRC 2017), 14-15 September 2017, Salford, UK.

Aboumoemen, A. & Underwood, J. (2019) *A Level 2 BIM Maturity-KPI Relationship Assessment.* 14th International Postgraduate Research Conference (IPGRC 2019), 16-17 December 2019, Salford, UK.

Mollasalehi, S., Rathnayake, A., Abou Moemen, A., Underwood, J., Fleming, A. J., Kulatunga, U., & Coates, S. P. (2017). How BIM-lean integration enhances the information management process in the construction design. In *Proceedings, 25th Annual Conference of the International Group for Lean Construction (IGLC)* (pp. 531-538). International Group for Lean Construction (IGLC).

Mollasalehi, S., Aboumoemen, A. A., Rathnayake, A., Fleming, A. J., & Underwood, J. (2018). Development of an integrated BIM and lean maturity model. *Proceedings IGLC 26-Chennai, India 2018*, 1217-1228.

Rathnayake, A., Mollasalehi, S., Aboumoemen, A., Kulatunga, U., & Samir, H. H. (2018) Building Information Modelling Adoption for better cost estimation: Sri Lankan perspective. *The Tenth International Conference on Construction in the 21st Century (CITC-10)* Colombo, Sri Lanka