AN ANALYSIS OF THE CURRENT BUILDING INFORMATION MODELLING ASSESSMENT METHODS

Author: Youssef Bougroum
Supervisor: Dr. Alexander Copping

AR30315- Research Dissertation

APRIL 1, 2016

DEPARTMENT OF ARCHITECTURE & CIVIL ENGINEERING
University of Bath

Abstract

Building Information Modelling (BIM) is gaining increased attention and importance in the Architecture, Engineering, and Construction (AEC) Industry. With this increased relevance, it becomes crucial to evaluate the implementation of BIM, or what is referred to as "BIM Maturity". The development of BIM Assessment Methods (AMs) has been sporadic and inconsistent compared to the proliferation of BIM itself. This paper will assesses a selection of BIM Assessment Methods (AMs) in order to understand the shortcomings of the current BIM-AM landscape.

Much of the existing work surrounding BIM-AMs has been centred on suggesting new potential assessment frameworks. Although this paper does not suggest a new framework for the assessment of BIM, it uses a thematic analysis to arrive at measures of "best practice" which should be included in a new framework. This paper adds value to the current research through its detailed analysis of 5 assessment methods and through the interviews carried out with industry experts.

This dissertation has many key findings. Results of this analysis show that the current BIM-AMs vary greatly in terms of design, structure, length of assessment, metrics, and outputs. At the heart of these inconsistencies is the difference in the nature of development of assessment methods.
Most of the current BIM-AMs are limited to assessing the technology surrounding BIM itself (i.e. the BIM models). A comprehensive assessment of BIM maturity has to include an assessment of the social aspects of BIM (e.g. the communication channels put in place). Secondly, assessment tools should aim to be consistent to allow for greater "repeatability". Finally, any new potential framework should incorporate a "confidence level", to account for inaccuracies which arise due to uncertainties in data collection.

The interviews conducted provided some valuable insight into the state of BIM in the architecture, engineering, and construction (AEC) sector. From a main contractor's perspective, BIM is adopted despite significant knowledge gaps regarding its potential benefits and how BIM assessment should be carried out. From a sub-contractor standpoint, BIM adoption is regarded as a contractual obligation that companies have to fulfil. In summary, the current knowledge of BIM is centred on the BIM software employed, and there is very little knowledge of the processes or policies which have to support BIM adoption.

Acknowledgements

Many people were behind the completion of this dissertation. I owe much gratidute to my supervisor, Dr. Alex Copping for his invaluable time, effort and insights throughout the whole project. I also want to thank Mr. Ben White and Mr. Sam Cooke, for providing valuable insights into the contracting industry, providing more relevance and credibility to this research. On a more personal note, I would like to dedicate this work to my grandfather, may his soul rest in peace.

Table of Contents

Key terms and definitions

Below is a definition of terms used in this paper. Whilst not exhaustive, this list does provide the reader with definitions of key terms which will be used throughout this paper.

Performance Measurement System: A framework which is put in place to assess performance. A performance measurement system usually incorporates various individual performance metrics.

Effectiveness: A measure of how economically a firm's resources are utilized (Neely, et al., 2005).

Coverage: The extent of BIM competencies or aspects that an assessment tool aims to evaluate.

Repeatability: A measure of the consistency of the results when an assessment tool is assessed by different assessors.

BIM maturity: A measure which denotes the quality, repeatability and degree of excellence within a capability

BIM Processes: The processes or operational channels put in place to aid BIM adoption and implementation.

BIM Capability: The minimum ability in performing a task or delivering a measureable outcome (Succar, 2013).

BIM Champion/Leader: An individual who is the most knowledgeable about BIM, and who drives BIM adoption within their organisation.

Virtual Design and Construction: Virtual Design and Construction (VDC) can be defined as the use of multidisciplinary performance models of construction projects, including their product, organisation, and process (POP) models, for business objectives (Kunz & Fischer, 2012). Therefore, VDC encompasses a broader set of considerations when compared to BIM.

BIM Model: The 3D model created by software such as Tekla which is used as the basis for BIM data storage and exchange.

BIM Competencies: An individual's ability to perform a specific task or deliver a measureable outcome (Succar, 2013).

BIM Maturity: BIM maturity is the gradual and continual improvement in quality, repeatability and predictability within available BIM Capability (Succar, 2013).

Project Deliverables: A general term referring to BIM Models, Model Components, Model-based Deliverables and all other project/process deliverables expected out of using BIM tools and workflows. (ChangeAgents, 2016)

1. Introduction

1.1 Rationale

For as long as they have existed, organisations have been interested in ways to improve their performance. Performance measurement is a topic of relevance across a variety of sectors and industries. The architecture, engineering and construction (AEC) sector is no exception to this trend. With the recent proliferation of BIM as the new face of innovation and technology in the AEC sector it becomes necessary to assess BIM implementation. Before the implementation of BIM can be measured, it is necessary to define the scope of BIM as a term. For the purpose of this paper, Succar's definition of BIM is used as, "Building Information Modelling is a combination of processes, technologies, and policies which allow for digital and greater control of the design process, and project data, throughout a building's entire life cycle."(Succar, 2013).

Domestically, the UK government has stated that all publicly funded projects will require "collaborative 3D BIM" starting in 2016 (Azouz, et al., 2015). As BIM becomes more prevalent across the ACE sector, greater measures have to be taken to fully understand its scope in order to monitor and measure its implementation. It is worth noting that the development of Assessment Methods (AMs) to evaluate the implementation of BIM has been sporadic and inconsistent in comparison with the growth of BIM itself.

BIM Assessment Methods (AMs) are tools developed to evaluate the BIM Maturity (i.e. utilisation) across individuals, projects, or organisations. Since the establishment of the first Assessment method in 2007, there have been several other attempts at measuring the implementation and maturity of BIM through a series of **assessment methods (AMs)**. These AMs have been developed both by academia and the industry in an independent manner, resulting in a lack of consistency in the assessment methods followed. In addition, the independent nature of the development of these assessment tools has resulted in an apparent variability in the inputs and outputs of each. The available AMs vary in most aspects including the scale of evaluation (i.e. whether they evaluate individuals, projects or teams), the number of BIM measures, and the level of detail required (i.e. the number of measures). As a result of BIM's broad definition, most early AM's are too general and rely heavily on qualitative feedback, leading to inconsistencies to potential subjectivity in responses.

1.2 Aims & Objectives

This paper aims to provide a comprehensive analysis of a selection of BIM AM’s. The analysis will highlight the strengths and shortcomings of a selection of assessment methods, allowing for a greater understanding of the current AM landscape. The objectives of the research can be listed as follows:

- Classify the current AMs into distinct categories depending on their proposed scale of evaluation (i.e. whether they evaluate individuals, projects, or organisations).
- Use a selection of BIM-AMs to compare these different categories of AMs, determining the advantages and disadvantages of each
- Dissect, in great detail, a selection of 5 AMs. Present drawbacks of each AM individually, and identify a common trend across this range of AM’s.
- Carry out small-scale interviews with industry experts to provide legitimacy and verification to the analysis carried out
- Suggest “best-practice” guidelines which should be followed when creating a new assessment method

1.3 Methodology Overview

The methodology followed was key to achieving this paper’s aims and objectives. First, an extensive literature review provided a deeper understanding of performance measurement design systems and of the existing research carried out on BIM-AMs. A comparative and investigative analysis was employed in order to examine and compare a selected range of BIM-AMS. This analysis then resulted in certain key outputs in the form of pertaining thematics. Through two interviews, a verification of these thematics took place, giving the outputs of the analysis more credibility and relevance. Finally, based on these findings, recommendations as to what a “best practice” assessment method should entail were made.

1.4 Dissertation Structure

Chapter 1 of this dissertation serves an introductory section, where the rationale, aims & objectives behind the research are stated. Chapter 2 is an extensive Literature Review, which provides relevant background relating to performance measurement design, and the case of BIM specifically. Chapter 3 covers in great detail the research methodology followed throughout this dissertation. Chapter 4 is dedicated to the desktop analysis which was carried out in order to examine a select range of BIM AMs. Chapter 5 discusses the outputs which arose from this analysis. Chapter 6 serves as a discussion and verification of these outputs through the two interviews carried out with relevant industry professionals. Chapter 7 suggests recommendations of what a “best practice” framework should entail as a result of this discussion. Chapter 8 includes some conclusive remarks on the research and suggests what future research should aim to achieve.

2. Literature Review

2.1 Defining BIM

Over the past decade, the term BIM has grown to define a multitude of concepts and principles, perhaps losing its core definition in the process. As different disciplines within the AEC industry derive different benefits from BIM, definitions vary from one stakeholder to the next. For instance, contractors see the benefits of BIM as enhanced scheduling, estimation, and drawing exchanges (Barlish & Sullivan, 2012). Architects, on the other hand, tend to see the benefits of BIM during the upstream phases- and more specifically in terms of better coordination and productivity during the design process.

Therefore, before evaluating the current BIM assessment tools, it is critical to come to consensus on a clear definition of BIM.BIM is not a software, a hardware, or a modelling tool. In fact, BIM has been defined as "an intelligent 3D virtual building model that can be constructed digitally by containing all aspects of building information- into an intelligent format that can be used to develop optimized building solutions with reduced risk and increase value before committing to a design proposal" (J. Woo, 2010). This definition of BIM fails to address the processes and policies that surround BIM. In fact BIM's scope extends beyond the technology (i.e. model) mentioned in this definition. This definition focuses on the upstream phase of projects, where BIM provides designers with the opportunity to assess different design proposals in detail at no extra cost. BIM has also been defined as "The process of creating and using digital models for design, construction and/or operations of projects."(Hill, 2009). Here, the definition is more geared towards the construction and operation phases, where contractors aim to streamline operations in order to reduce costs. For the purpose of this paper, Succar's definition of BIM is used as, "Building Information Modelling is a combination of processes, technologies, and policies which allow for digital and greater control of the design process, and project data, throughout a building's entire life cycle."(Succar, 2013). This definition embodies a more holistic view of BIM as it is not limited to the technology itself (i.e. the BIM model).

Whilst it is true that the technology (i.e. the BIM model itself) is a main component of BIM, it is worth noting that the processes and policies surrounding the technology are equally important. For instance, having effective communication channels allows for efficient data exchange to take place. It becomes evident then that having an exceptional BIM model without the proper supporting processes and policies will inhibit BIM implementation. It is therefore important to consider *all* aspects of BIM when evaluating the efficiency of BIM Assessment tools.

2.2 A push towards BIM adoption

The frequency and variation of BIM's definition contribute to the difficulty in measuring the extent of BIM's implementation. It is no secret, however, that to reap its full benefits, BIM should be adopted throughout the entirety of a building's life cycle including the design, construction and operation phases.

The recent proliferation of BIM comes a result of various efforts at different levels. At a project and organisational level, companies involved in the management of large scale projects are realizing the benefits of BIM such as efficient exchange of information. However, the greatest catalyst of BIM's growth has been the Government Construction Strategy, published in 2011. As part of the GCS, a client BIM Mobilisation Group was created to drive the adoption of BIM. As part of its strategy, the government will require fully collaborative 3D BIM (with all project and asset information, documentation and data being electronic) as a minimum for all publicly funded projects by 2016.

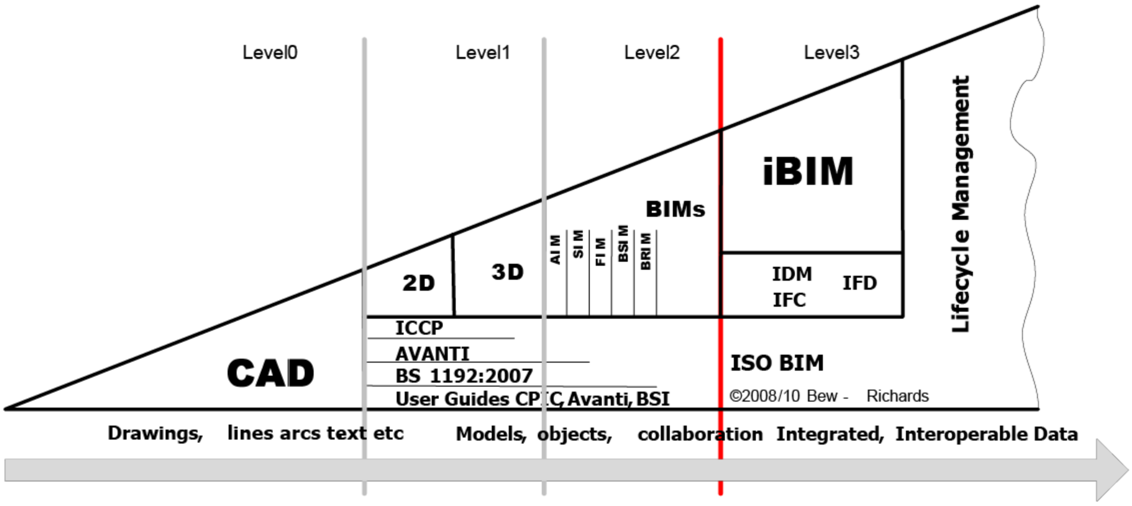


Figure 2.1. BIM Maturity Levels (HM Government, 2011)

In order to appreciate the requirements set by the Government Construction scheme in 2011, it is necessary to understand the scope of each level of maturity, as shown in Figure 2.1. Level 0, simply refers to a non-existent collaboration. Essentially, this is what the industry has been operating on as a whole after the computer revolution of the 90's. CAD platforms are used to create drawings, and excel spreadsheets used to calculate costs, and this is done on an organisational level (HM Government, 2011). The exchange of data is limited to the exchange of these different paper forms. Level 1 refers to a combination of 3D CAD models with complementary 2D drawings. This information is shared on a common platform at contractor level, and is not shared with other disciplines. Overall, the industry has been operating on 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 be able to combine data from different models to form a federated BIM model. A federated model is a combination of data from different models, allowing for a different analysis of the integrated aspect of the design. (i.e. clash detection)(Lymath, 2014). Level 3, or collaborative BIM, is taking a step further than the federated model approach. This requires the use of a single BIM model, allowing all stakeholders to use this model to input data. Human interpretation which is required in the federated BIM approach is automatically bypassed, and this allows for a greater control and ease of the manufacturing process at later stages (HM Government, 2011).

2.3 Performance Measurement Design

The recent proliferation of research on the subject of BIM-AMs from both academics and the industry is a product of both the government's initiative to promote BIM adoption and an organisational shift towards BIM. As BIM becomes more prevalent across the AEC sector, greater measures have to be taken to fully understand its scope in order to monitor and measure its implementation. Assessment Methods (AMs) are tools developed to evaluate the BIM Maturity (i.e. implementation) across individuals, projects, or organisations. The development of Assessment Methods to evaluate the implementation of BIM has been sporadic and inconsistent in comparison with the growth of BIM itself. In order to fully understand BIM AM’s it is necessary to take a step back and take a closer look at performance measurement design. Whilst little has been done in terms of performance measurement in the construction world, the same cannot be said about performance measurement as a whole. Performance measurement is a topic of relevance across various industries, and as such it will be examined broadly. Whilst some of the concepts discussed below will be particularly relevant to sectors such as manufacturing, the underlying principles which govern performance measurement system design are also applicable to the AEC sector.

At its heart, performance measurement can be seen as the process which leads the quantifying of action (Neely, et al., 2005). As Neely et. al (2005) stated, this adds value to organisations because action leads to performance. In order for such actions to be quantified effectively and consistently, a performance measurement system needs to be established or designed, as shown in Figure 2.2.

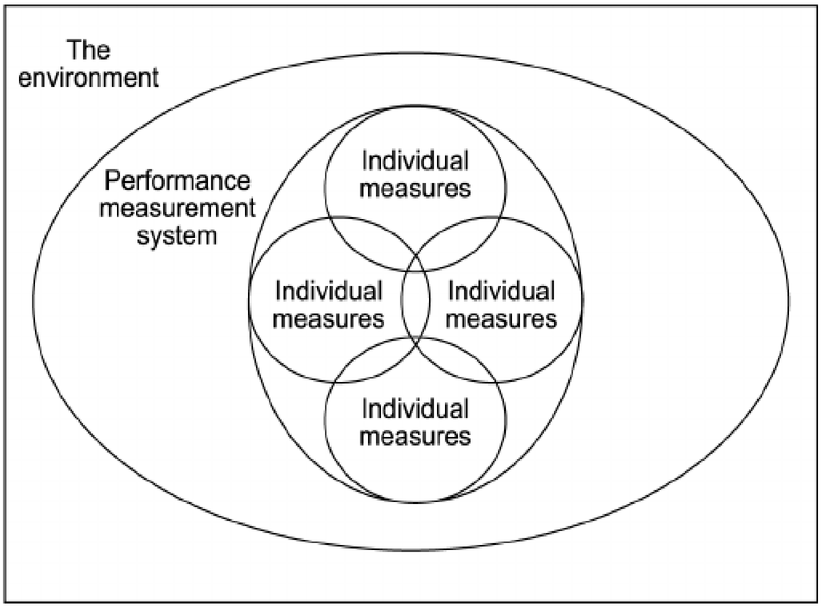


Figure 2.2. Performance measurement framework (Neely, et al., 2005)

2.3.1 Performance Measurement Measures

As shown in the figure above, a performance measurement system is comprised of various individual *measures*. A performance measure is a metric used to “quantify the efficiency and/or effectiveness of an action” (Neely, et al., 2005). In order to understand the definition of a performance measure, it is crucial to define and distinguish efficiency and effectiveness in the context of performance measurement design. As stated in the work of Neely et. al (2005), efficiency measures the allocation of a firm’s resources whilst effectiveness measures the degree to which costumer requirements are met. Having defined both of these terms, it is now possible to define a performance measurement system as a collection of individual measures which aim to quantify the efficiency and effectiveness of actions (Neely, 1994).
It is crucial to highlight the importance of the design of performance measures to the overall design performance measurement systems.
According to Neely et. al (2007), performance measures should aim to have the following characteristics. Whilst this list is not exhaustive, it gives an indication of what factors should be considered when designing performance measures.

1. Performance measures should be derived from strategy
2. Performance measures should be simple to understand

3. Performance measures should provide timely and accurate feedback
4. Performance measures should be based on quantities that can be influenced, or controlled, by the user alone or inco-operation with others
5. Performance measures should reflect the “business process”i.e. both the supplier and customer should be involved in the definition of the measure
6. Performance measures should relate to specific goals (targets)
7. Performance measures should be relevant
8. Performance measures should be part of a closed management loop
9. Performance measures should be clearly defined
10. Performance measures should have visual impact
11. Performance measures should focus on improvement
12. Performance measures should be consistent (in that they maintain their significance as time goes by)
13. Performance measures should provide fast feedback
14. Performance measures should have an explicit purpose
15. Performance measures should be based on an explicitly defined formula and source of data
16. Performance measures should employ ratios rather than absolute numbers
17. Performance measures should use data which are automatically collected as part of a process whenever possible
18. Performance measures should be reported in a simple consistent format
19. Performance measures should be based on trends rather than snapshots
20. Performance measures should provide information
21. Performance measures should be precise – be exact about what is being measured
22. Performance measures should be objective – not based on opinion

Source: Adopted from (Neely, et al., 1997)

2.3.2 Performance Measurement System Design

After defining what individual measures should aim to entail, it is crucial to then examine the performance measurement system as a whole. The “balance scorecard” framework is widely recognized as a prominent performance measurement framework. As stated in Kaplan and Norton’s (1992) work, this performance measurement system aims to address multiple perspectives of an organisation’s operations. These include:

1) **Financial perspective:** What is the shareholder’s perception of management?
2) **Internal business perspective:** What are the areas in which management must excel at?
3) **Customer perspective:** What is the customers’ perception of management?
4) **Innovation and learning perspective:** What are the ways in which management can continue to improve and create value?

Source: (Neely, et al., 2005)

Whilst the balanced scorecard is an elaborate attempt at providing a framework for performance measurement design, it does have various shortcomings. As Neely et. al (2005) suggested, the balanced scorecard fails to address the competitor perspective (i.e. what activities are competitors engaging in?). In fact, the development of the “balanced scorecard” has paved the way for various other attempts at establishing frameworks or guidelines for performance measurement system design. In his work, Maskell (1989) attempted to further clarify and establish the relationship between the performance **measures** and the performance measurement **system** through the following principles:

1) The measures should be directly related to the firm's manufacturing strategy
2) Non-financial measures should be adopted
3) It should recognized that measures vary between locations- one measure is not suitable for all departments or sites
4) It should be acknowledged that measures change as circumstances do
5) The measures should be simple and easy to use
6) The measures should provide fast feedback
7) The measures should be designed so that they stimulate continuous improvement rather than simply monitor.

Source: (Maskell, 1989)

Defining the individual measures and their relationship with the performance system within which they are implemented gives an indication of what a performance system should entail. The work of Wisner and Fawcett (1991) describes the process for developing a performance measurement system as the following:

1) Clearly define the firm's mission statement
2) Use the mission statement as a guide to identify the firm's strategic objectives
3) Develop an understanding of each function area's role in achieving the various strategic objectives
4) Develop global performance measures capable of defining the firm's overall competitive position to top management for each functional area
5) Communicate strategic objectives and performance goals to lower levels in the organisation in order to establish more specific performance criteria at each level.
6) Assure consistency with strategic objectives among the performance criteria used at each level
7) Use the performance measurement system to identify competitive position, locate problem areas, assist the firm in updating strategic objectives and making tactical decisions to achieve these objectives, and supply feedback after the decisions are implemented
8) Periodically re-evaluate the appropriateness of the established performance measurement system in relation to the current competitive environment.

Source: (Wisner & Fawcett, 1991)

Equally as important as the design of performance measurement systems is the way in which the system interacts with its surrounding environment. Internally, a performance measurement system can be part of a wider organisational strategy which can include assessment, implementation and procurement policies. Externally, the use of benchmarking allows the organisation to gain an appreciation of competitors' performance. The Lean Enterprise Benchmarking Project (1993) and Voss et al. (1992) have identified four dimensions to which firms should aim to benchmark themselves to:

1) Product innovation;
2) Product development;
3) Process innovation; and
4) Technology acquisition

Source: (Andersen Consulting, 1993) and (Voss, et al., 1993)

Camp (1989) defined benchmarking as the process of identifying industry best practices for the purpose of improving performance. Along those same lines, Camp (1989) suggested a comprehensive nine step benchmarking process which is detailed in Figure 2.3.

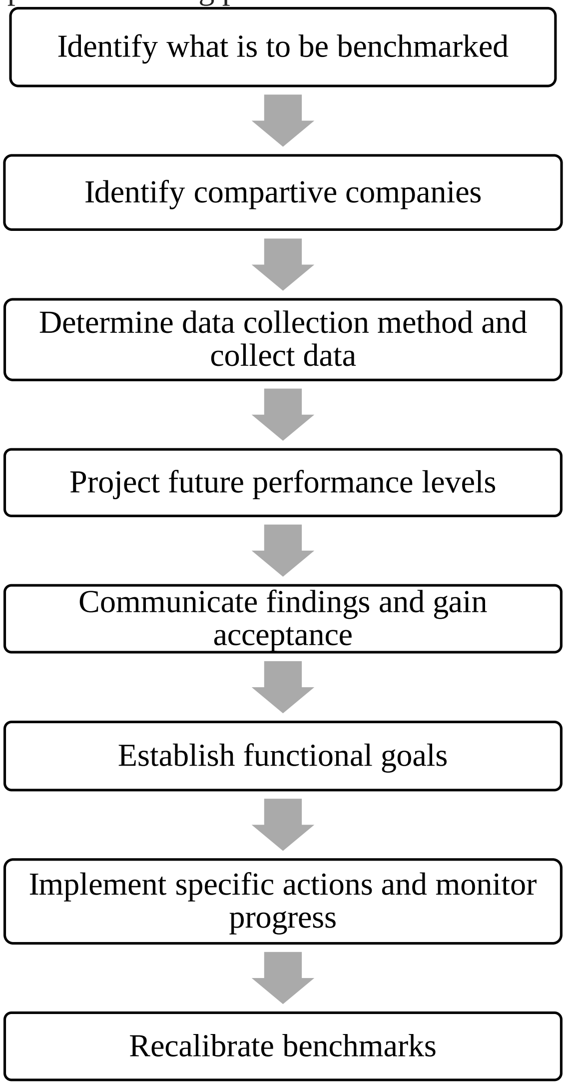


Figure 2.3. Camp's 9 step benchmarking process (Camp, 1989)

2.4 BREEAM: an established assessment method

In order to gain a greater understanding of how AMs are developed it is helpful to examine well established assessment tools. The Building Research Establishment Environmental Assessment Method (BREEAM), is aimed at evaluating an asset's environmental performance and was first published by the Building Research Establishment (BRE). With over 250,000 buildings in certification and widespread use in over 50 countries, it provides the ideal example of an established assessment method. Various BREAM schemes exist, and they can be tailored to any type of building:

- BREAM New Construction: dedicated for non-residential new build
- BREAM International New Construction: dedicated for residential and non-residential buildings for countries without a national BREAM scheme.
- BREAM In-use: dedicated to for existing buildings.
- BREAM Refurbishment: provides an assessment method for sustainable housing projects

- BREAM Communities: focuses on the sustainable urban planning of communities

As mentioned previously, the UK is characterized by a relatively mature built environment, one that is heavily populated with existing buildings when compared to new buildings. As such, the BREAM In-use scheme will be looked at in further detail. According to the BRE (2012), the BREAM In-use scheme has 4 outputs:

Part 1: Asset Rating: assesses the structure of the building, and fixtures and fittings (i.e. the building envelope)

Part 2: Building Management Rating: Assesses how the building is managed (facility management)

Part 3: Organisational Rating: Assesses the occupiers and the activities that are conducted within the building

Part 4: Key Performance Indicators (KPIs) based upon 4 environmental categories namely waste, energy, water and transport.

The BREAM In-use online system is an add-on which allows for the pre-assessment of assets by clients qualified by BRE Global. This allows clients to continually evaluate and improve the performance of their asset, prior to seeking formal certification. An overall "rating" results from pre-assessment questionnaire answers and ranges from Unclassified, Acceptable, Pass (1 star), Good, Very Good, Excellent, and Outstanding (6 stars). The pre-assessment assesses the following 9 categories:

1) *Management:* overall management policy, commissioning, site management and procedural issues
2) *Energy:* operational energy and carbon dioxide (CO2) issues plus DEC, EPC and EMS
3) *Health and Wellbeing:* indoor and external issues affecting health and wellbeing
4) *Materials:* environmental implications of building materials used, including life-cycle impacts.
5) *Transport:* transport-related CO2 and location-related factors
6) *Waste:* consumption and water efficiency
7) *Water:* maintenance programs intended to reduce potable water consumption
8) *Pollution:* air & water pollution issues
9) *Land Use:* ecological value conservation and enhancement of the site.

Source: (BRE Global, 2012)

Different weightings are used for the above categories in each of the four parts of the BREAM scheme, in order to adjust the relative value of credits scored in different categories, taking into account opportunity costs. The overall Asset, Building Management, and Organisational ratings are derived from answers to 197 questions, which can be broken into three main question types:

Tier 1- questions where one answer must be selected from a drop down list
Tier 2- questions with one or more present answer options
Tier 3- questions where users enter the answers into a text field, allowing for the answers to be used in the calculation of KPIs.

3. Methodology

At the core of most AM's is an underlying framework or performance measurement system. Therefore, it is logical to take a step back, and analyse performance measurement design organically. A deeper understanding of the underlying forces currently governing performance measurement design allows for a more holistic analysis to be carried out.

3.1 Literature Review: Context

At the onset of this research, a broad comprehensive literature review was carried out. The purpose of this literature review was twofold. Firstly, a review of performance measurement design was carried out in order to fully understand what is meant by performance, and why measuring performance is at the heart of improving efficiency. As mentioned previously, this was an ideal starting point for this research, as it clearly set out the shortcomings and advantages currently facing performance measurement design as a whole.
The second objective of the literature review was to outline both an established performance measurement framework and an established performance measurement tool: the Balanced Scorecard and BREEAM. The purpose of this was to gain an appreciation of the different components of these more established methods and tools, in the hope of establishing critical traits and characteristics.

3.2 Comparative Analyses: Determining the Key Themes

Following on from this introduction to the BIM AM landscape, a primary analysis of the current AMs was carried out. Currently, there are 14 available BIM assessment tools which have been developed over the past 9 years. The list below is an exhaustive list of the current BIM assessment methods developed to this date. This list served as the starting point of the research carried out on this project, and served as the basis of the primary analysis.

1. NBIMS-CMM (2007)
2. BIM Excellence (2009)
3. BIM Proficiency Matrix (2009)
4. BIM Maturity Matrix (2009)
5. BIM Quick Scan (2009)
6. VICO BIM Score (2011)
7. Characterisation Framework (2011)
8. CPIx BIM Assessment form (2011)
9. Organisational BIM Assessment Profile (2012)
10. VDC Scorecard (2012)
11. bimSCORE (2013)
12. The owner's BIMCAT (2013)
13. Arup BIM Maturity Measure (2014)
14. BRE BIM Certification Scheme (2015)

Source: (Azouz, et al., 2015)

This list of 14 assessment tools was reduced to a list of 9 assessment tools mainly due to difficulties in access. To adhere to the scope of the project, these Assessment Methods were categorized by their level of assessment- i.e. whether they assess individuals, projects, or organisations as shown in Table 3.1. Furthermore, this categorization served as the basis of the secondary analysis as it allowed for the comparison of tools which assess BIM competency at the same hierarchical level. It would have been a futile exercise to compare a tool which assesses individuals with another which assesses organisations.

Table 3.1. Categorisation of Assessment Methods

Name of AM	Evaluation Level	
VDC Scorecard (2012)	Project	1
NBIMS-CMM (2007)	Project	2
Arup BIM Maturity Measure (2014)	Project	
CPIx BIM Assessment Form (2011)	Project	3
BIM Proficiency Matrix (2009)	Organisation	
BIM Quick Scan (2009)	Organisation	
VICO BIM Score (2011)	Organisation	
Organisational BIM Assessment Profile (2012)	Organisation	4
BIM Excellence (2009)	Individual	5

Source: Original

The numbers on the right hand side of Table 3.1 indicate the representative selection of 5 Assessment Tools which was made for this analysis. It worth noting that initially the author aimed to select 6 AMs, two from each evaluation level. The “CPIx BIM Assessment Form” was initially thought to be aimed at assessing individuals. After contacting the CPI it was established that the CPIx Assessment Form assesses projects. Hence the only tool assessing individual which was available and accessible is the “BIM Excellence” tool. Where there was the possibility of more than one choice, various factors were taken into consideration. At the Project level of assessment, the choice was made in order to explore contrasting backgrounds, and to determine to what extent industry developed tools differ from those developed by academia. At the Organisation level, the choice was intended to explore the expected completion time, where one tool is evidently more elaborate than the other. This choice was made in order to investigate whether longer tools have any added value when compared to shorter, more concise ones. As the analysis evolved, more themes developed and were added to the thematic list. The table below is a brief summary of some of the themes which have arisen as a result of this analysis.

Table 3.2: Summary of Thematics

Thematic	Details
Qualitative vs Quantitative	Some tools are highly qualitative, resulting in highly subjective inputs. Others are completely qualitative. Where is the fine line?
Frameworks & Existing Literature	Some tools are based around existing performance measurement models, making them more credible and reliable, while others do not. What difference does this make?
Coverage	Coverage is the term used to define the scope or the extent of assessment of each tool. In other words, what aspects of BIM implementation does the tool seek to cover?
Academic vs Industry	Some tools have been developed by the industry whilst some have been developed by academia. What difference does this make?
Repeatability	Repeatability is the term used to define how easy it is for a reassessment to be carried out. How important is it to have a repeatable tool?

The analysis which then followed can best be described as two comparative analyses and one investigative analysis which formed the basis of an overall thematic analysis. In other words, two individual comparative analysis aimed to analyse 4 Assessment Methods, and one investigative analysis evaluated 1 Assessment Method, resulting in a total analysis of 5 assessment methods. To carry out these comparative analyses, three matrices were constructed, in which each assessment tool was evaluated and compared to its counterpart on various different criteria (see attached CD for full matrices). Finally, a link was then made between these overarching characteristics of performance measurement design discussed in the literature review and the findings of the individual comparative analyses. Figure 3.1 provides an overview of the overall process followed during the analysis.

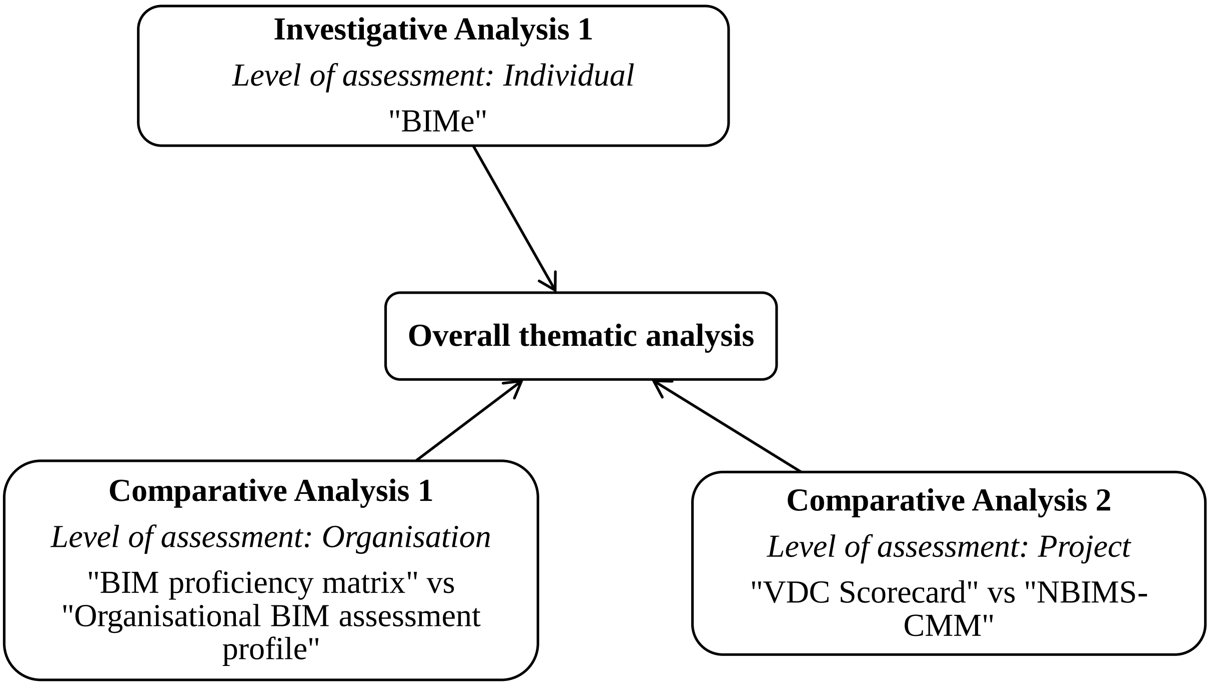


Figure 3.1: Overview of analysis process

3.3 Verification: A semi-structured Interview

Finally, two interviews were carried out with the Head of Engineering at Byrne Bros, a leading UK concrete contractor and with the BIM coordinator of one of Skanska's landmark projects. With over 20 years of experience in the contracting industry and a keen interest in BIM, Ben White has been at the heart of multi-disciplinary collaboration within the AEC industry. Sam Cooke, the second interviewee has been working with BIM for the past several years, and is now BIM coordinator for one of Skanska's major projects. The interviews were driven by the key themes and issues obtained from the comparative analysis, and served as a verification of the issues and thematic which resulted from the analysis.

Due to the open nature of the discussion, a semi-structured interview style was followed, and the entirety of the interview was recorded. A semi-structured interview aims to provide the interviewee with some guidance about the topics to be discussed through open-ended questions. The general aim is to encourage the interviewee to talk at some length and in their own way, regardless of whether what they say is "right" or not (Drever, 2003). Open-ended questions, allowed both myself and Ben the freedom to discuss the issues at hand unrestrictedly. The list of questions used in the interview can be found in the Appendix 1.

In addition to the questions listed above, two types of subordinate questions where used to fill in the structure of the interview. Prompts are questions designed to encourage the interviewee to say as much as they can or wish to. These include supplying or quoting further information which explain the rationale behind an idea. Probes are questions used to get the interview to expand in detail and explain further. These include asking further questions along the same line of thought- examples include “why?” or “how?”.

3.4 Overview

The final stage of the research consisted of making recommendations for a potential framework of BIM assessment. These recommendations were based on the findings of the analysis and the interviews. The recommendations were presented and formulated in a coherent yet autonomous manner in order to facilitate their understanding by the common reader. The figure below provides an overview of the overall methodology followed throughout the research paper.

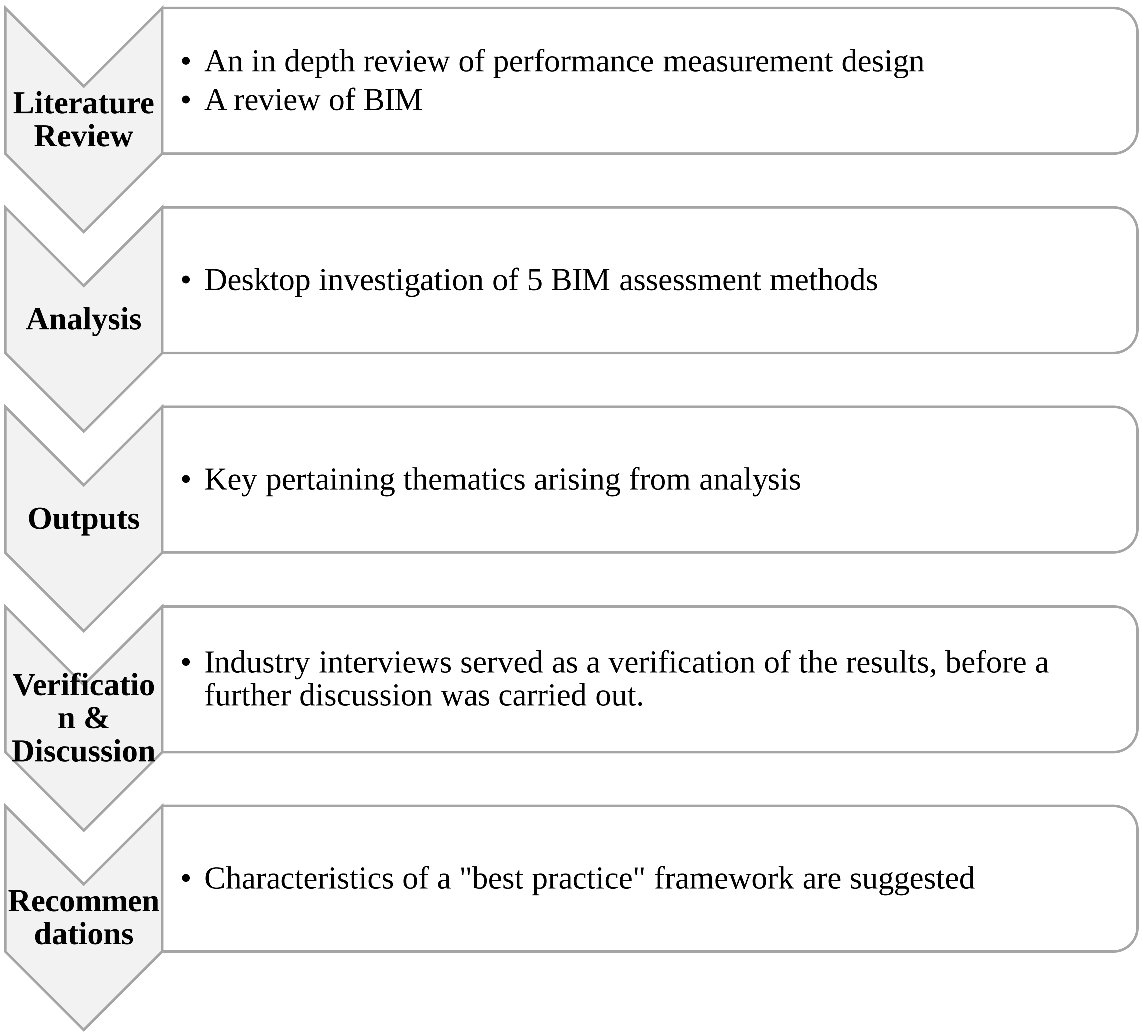


Figure 3.2: Methodology overview

4. Analysis

4.1 Comparative Analysis 1 : Assessing an organisation's BIM maturity

This section is dedicated to analysing two Assessment Tools aimed at assessing BIM maturity at the organisational level.

4.1.1 BIM Assessment Form

Overview

The first tool in question is the "BIM Assessment Form", designed in 2011 by the Construction Project Information Committee (CPIc) in consultation with the UK government's BIM task group. The CPIx is a committee of industry "experts" formed as a response to the lack of knowledge surrounding BIM and BIM maturity. As a result of this rushed process, this tool has failed in multiple aspects to deliver on its primary objective: evaluating an organisation's BIM maturity. At its heart, this tool is essentially a questionnaire with an estimated completion time of 1.5-2 hours comprising of 4 sections, as shown in the table below:

Table 4.1- Overview of assessment sections. (CPIx BIM Assessment Form, 2011)

Section	Description
Gateway Questions	Assesses the willingness of the individual filling this form on behalf of the organisation to exchange data and the quality of that data
12 Areas of BIM	Assesses the individual's understanding of 12 areas or functions that projects will benefit from after BIM adoption.
BIM Project Experience	The individual has to list up to 3 projects where BIM was used by his organisation.
BIM Capability Questionnaire	This is a broad questionnaire aimed at giving the assessor an idea of how much knowledge the organisation has regarding BIM.

Inputs

The "Gateway Questions" section serves as a confirmation section, where the person completing the form agrees to sharing information with the assessor. The purpose of this section is to ensure that the interviewee has the prerequisite knowledge and understanding of BIM processes in order for the evaluation to proceed. If the answer is "no" to any of the questions in this section, then the project team leader is to be contacted. Therefore, there is no clear indication that this section adds any value to the assessment of the organisation's BIM maturity More information is needed regarding the implications of answering "no" to any of the questions, and what this means in terms of assessment outcomes specifically.

The next section is of more relevant to assessing BIM maturity, as it is dedicated to assessing the organisation's team leader's understanding of 12 areas or functions that will benefit from BIM adoption according to the tool's creators. Table 4.2 is a sample of the areas or functions that are assessed. As can be seen from the list, this section focuses heavily on assessing the technical aspects of BIM. In other words, this section is geared towards evaluating the BIM models themselves, as opposed to other aspects of BIM adoption such the exchange of information. This limitation in terms of coverage can be attributed to the nature of the tool's development. Committees such as the CPIx are more concerned with the technology at the heart of BIM adoption, and as a result overlook the importance of other factors in determining BIM maturity.

Table 4.2- Sample areas of BIM assessed. (CPIx BIM Assessment Form, 2011)

Section	**Examples**
Facilities Management	Optimised handover Asset register Linked H&SF
Quantity take-off, costing	Schedules Material Lists Component List
Sales/Visualizations	Bid & Tender Marketing Client sign off
Safety Planning	Roof Access Confined spaces Improved method statements

The "BIM Project Experience" section prompts the assesse to provide details of a minimum of 3 recent projects in which their organisation has used BIM. This allows the assessor to gain an appreciation of the scope of BIM services that an organisation has been involved with and the benefits realised by BIM adoption. In doing so, there is an implication that previous experience with or exposure to BIM can lead to a greater understanding of BIM and its processes, and as such can be regarded as a key component to measuring an organisation's BIM maturity. In reality, there are other ways in which organisations can gain BIM competencies. Through relevant training and workshops, an organisation can gain exposure to the theoretical applications of BIM's processes without actually having any exposure to BIM in the industry. On the other hand, it is possible for an organisation to have been passively involved in 3 projects which have used BIM, without truly understanding the utility or drivers behind BIM implementation.

The final section of this assessment is the "BIM Capability Questionnaire" which gives the assessor an indication of which areas are in most need of training, coaching, and support. The questions that make up this questionnaire require subjective input from the person filling in the form. In addition, some of these questions require a lot of extra effort and research from the part of the interviewee, ultimately undermining their practicality. Whilst some questions are clear and concise others are highly subjective and vague. Figure 4.1 contains a sampling of some questions and the issues that arise with them.

Table 4.3. Sample BIM Capability Questionnaire (CPIx BIM Assessment Form, 2011)

Questions	**Issues**
Explain the discipline and rigour in the design process?	This question can be interpreted various ways by the interviewee. Terms such as "discipline" and "rigour" are left undefined.
What does BIM mean to your staff?	This answer highly depends on the interviewee's sense of judgement. It requires them to gauge individual opinions to form an overall sentiment of what value is given to BIM.

Outputs

The outputs of this tool are as ambiguous and subjective as its inputs. There is no clear scoring system but rather a “remark/comments” sections followed by a “recommendations” section. The outputs are therefore highly dependent on the assessor and their previous experience. This open-ended style of outputs has various disadvantages which will be discussed in greater detail in the discussion section. The tool’s coverage-or what competencies it aims to assess during assessment- is also very limited to assessing the technical aspects of BIM (e.g. the models being used).

4.1.2 Organisational BIM Assessment Profile

Overview

The other tool which aims to assess an organisation’s BIM maturity is the “Organisational BIM Assessment Profile” developed by Pennsylvania State University in 2012. The tool is a matrix that comes in the format of an Excel spreadsheet and takes approximately 2-2.5 hours to complete. This staged assessment is carried out through the assessment of six planning elements, listed in Table 4.4.

Table 4.4: Planning Elements (Organisational BIM Assessment Profile, 2012)

Element	Description	Max Maturity Level
Strategy	The overall support by management	25
BIM uses	The specific methods of implementing BIM	10
Process	The means by which the BIM Uses are accomplished	10
Information	The level of development of Models	15
Infrastructure	Technical & physical systems needed for the operation of BIM	15
Personnel	Human resources of the organisations	25

This tool aims to assess the overall BIM maturity of an organisation by determining the maturity levels of each planning element. The planning elements listed in Table 4.4 are composed of multiple sub-elements. Each of the sub-elements in turn is awarded a maturity level ranging from zero (0) to five (5). Note that a unique description of each maturity level is provided for each planning element being assessed. The list/figure/table below provides a general description of the Maturity Levels.

Level 0: “Non-existent”. Indicates that this element is not being used with the organisation
Level 1: “Initial”. Indicates the existence of an initial effort to implement this element.
Level 2: “Managed”. Indicates adequate (i.e. to the minimum level) adoption
Level 3: “Defined”. Indicates a clearly defined scope of adoption.
Level 4: “Quantitatively managed”. Indicates clear management of implementation.
Level 5: “Optimized”. Indicates an optimal use of the element.

Hence it can be seen that the “Strategy” planning element is comprised of five sub-elements, each with the possibility of gaining a maturity level up to (5), resulting in a maximum total possible score of 25.

Inputs

The first planning element is concerned with the overall strategy that supports BIM implementation in an organisation. The “Strategy” planning element is comprised of 5 different sub-elements, each aiming to assess different facets of the organisations overall BIM strategy. These sub-elements are listed in Table 4.3.

Table 4.5. “Strategy” Planning Element (Organisational BIM Assessment Profile, 2012)

Sub-Element	Description	
1. Organisational Mission and Goals	A mission is the fundamental purpose for existence of an organisation Goals are specific aims which the organisation wishes to accomplish	Maturity Level (1-5)
2. BIM Vision and Objectives	A vision is a picture of what an organisation is striving to become Objectives are specific tasks or steps that when accomplished move the organisation toward their goal	
3. Management Support	To what level does management support the BIM planning process	
4. BIM Champion	A BIM Champion is a person who is technically skilled and motivated to guide an organisation to improve their process by pushing adoption, managing resistance to change and ensuring implementation of BIM	
5. BIM Planning Committee	The BIM Planning committee is responsible for developing the BIM strategy of the organisation	

The second planning element comes under the name of “BIM Uses” and is dedicated to assessing the specific methods of implementing BIM. This is done through assessing two sub-elements: “Project Uses” and “Operational Uses”, which assess the specific methods of implementing BIM on projects and within the organisation, respectively. Therefore, the maximum contribution to the overall maturity level by this planning element is 10.

The third planning element, “Process”, evaluates the means by which the BIM Uses are accomplished. Through the two sub-elements “Project Processes” and “Organisational Processes”, an evaluation of both the external project BIM processes and the internal organisational BIM processes put in place. Again, each sub-element is attributed a score between zero (0) and five (5), resulting in a total maximum possible contribution of 10 for the “Process” planning element.

The fourth planning element is entitled “Information” and is mainly purposed with evaluating the BIM model in use. The Model Element Breakdown (MEB) sub- element identifies the different physical and functional elements that make up a model. Following that, the Level of development (LOD) sub-element assesses the level of completeness of the model. Therefore, similar to the previous planning element, a maximum possible contribution of 10 to the overall maturity level is possible.

The fifth planning element is dedicated to assessing the technological and physical systems needed for the operation of BIM within the organisation. This “Infrastructure” element is comprised of 3 sub-elements, namely: Software, Hardware, and Physical Spaces. The **“software”** sub-element evaluates the availability of adequate BIM software to the organisation’s personnel. The **“hardware”** sub-element assesses the advancement of the physical interconnections and devices which are required to run and store software. In other words, this section allows the assessor to gain an appreciation of the IT systems on which the organisation is running BIM software. The third sub-element of the “Infrastructure” planning element is the **“physical spaces”** sub-element. This element assesses a fundamental yet often overlooked aspect of BIM maturity: the dedicated BIM workspaces throughout the organisation. Each of the three elements (Software, Hardware, and Physical Spaces) can gain a maturity level between zero (0) and five (0) and so, the maximum level attributed to this section overall is 15.

The “Personnel” planning element is the sixth and final planning element of this assessment tool and is dedicated to assessing the organisations human resources. This is done through the individual assessment of 5 different criteria: **“roles & responsibilities”**, **“organisational hierarchy”**, **“education”**, **“training”**, and **“change readiness”**. The “roles & responsibilities” sub-element assesses the distribution of BIM responsibilities throughout the organisation. This gives an indication of whether BIM is limited to the BIM champion or whether BIM responsibilities are regularly reviewed to ensure they are properly distributed to other members of the organisation. The “organisational hierarchy” section determines the level to which the overall organisation’s structure accounts for BIM implementation. That is to say whether an organisation has a dedicated BIM implementation team or whether it has a BIM champion who sits outside the organisational hierarchy. The next sub-element is entitled “education” and assesses the availability and frequency of formal instruction about BIM. Following this is the “training” sub-element, which assesses the extent to which the organisation has adopted optimal training procedures. The lowest level of maturity is attributed to an organisation that lacks a training program altogether whilst the highest level of maturity indicates that the organisation has internalised an on-demand training offering. The fifth and last sub-element is dedicated to assessing “change readiness”, or the willingness and state preparedness of an organisation to integrate BIM.

Outputs

Equally as important as examining a tool’s inputs is examining a tool’s outputs. As mentioned previously, the tool’s output is an overall maturity level, with a maximum possible score of 90. In addition, to encourage continuous/staged assessment the organisation being assessed is encouraged to set target levels for each Planning Element. These target levels are determined following the same structure as described in the “Inputs” section previously, in order to ensure consistency and provide relatable maturity levels. This allows for the comparison of the current levels obtained through the assessment with those the organisation aims to achieve. As shown in the Figure 4.1, the tool’s output makes it easier to compare “target levels” to “current levels” and eventually identify areas of improvement.
In order for this benchmarking process to be effective, considerable time and effort has to be dedicated from the organisation’s BIM planning committee or BIM leader in determining adequate and appropriate target levels.

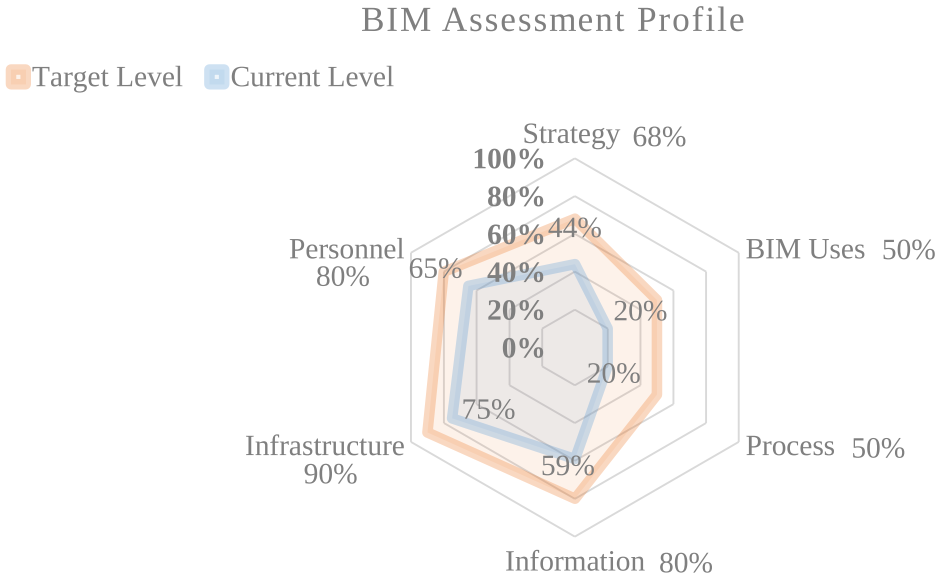


Figure 4.1: Sample BIM Assessment Profile (Organisational BIM Assessment Profile, 2012)

4.2 Comparative Analysis: Assessing a Project

This section will follow a similar structure to the previous one. A comparison of two assessment tools aimed at assessing projects will be made.

4.2.1 NBIMS-CMM

Overview

The first tool is was developed by the National BIM Standard (NBIMS) and uses the Capability Maturity Model to determine the BIM maturity levels of projects. This is achieved through the assessment of 11 "areas of interest" (AOIs), which are listed in Table 4.2.1. Each area of interest is given a maturity level ranging from one (1) to ten (10). Each maturity level corresponds to a level of maturity which is unique to that "area of interest". The completion time for this tool is estimated to be 1.5 hours.

Inputs

The first AOI, entitled "Data Richness", assesses the completeness of the Building Information Model from a data standpoint. In other words, this section determines the existence of a data rich environment along with the possibility of linking all authoritative information together. Entitled "Life-cycle views", the following AOI assesses how many phases of the project are going to be covered by the same Building Information Model. This provides an indication of the model's value to external stakeholders, especially at later stages of project's lifecycle. A good maturity level in this AOI indicates the potential for high cost savings, as it eliminates the need for repetitive data collection. The third AOI, under the name of "change management", assesses the efficiency of change management processes put in place. As a general guideline, change management processes typically include a root cause analysis and the implementation of a feedback loop (buildSMART alliance, 2007). A mature and robust change management process allows for the rapid implementation of change across a project. The highest maturity level in this AOI is attributed to a change management processes which allows for the implementation of change in under 48 hours. The fourth AOI is “Roles or Disciplines” and assesses the extent to which employees depend on the Building Information Model to accomplish their jobs. This, in turn, gives an indication of the value that the BIM is adding to a project. A higher maturity level indicates projects and individuals that rely almost entirely on the BIM to fulfil their tasks, hence implying that there is greater value derived from the use of the BIM. The fifth AOI, “Business Process”, assesses the extent to which a project’s business processes are designed to collect information in order to maintain the Building Information Model. A higher maturity level corresponds to seamless data collection across business processes, hence allowing for the maintenance of real time data in the model itself. In addition, if data is collected as part of business processes, then it comes at no extra cost and is more likely to be accurate(buildSMART alliance, 2007). The next AOI is “Delivery Method” and aims to assess the security and accessibility of the building information model. A high maturity level denotes that the BIM lies within a more net-centric web environment, where multiple parties can control and edit it. The next AOI is entitled “Graphical Information” and assesses the extent to which information from the BIM is recognized by the geographic information system (GIS). Integration with the GIS allows for the facility to be located spatially, and is of value to various stakeholders. For example, it allows services contractors to know water supplies and utilities cut-offs are in relation to the facility (buildSMART alliance, 2007). The penultimate AOI is “Information Accuracy” and assesses the accuracy of the information entered into the Building Information Model. In other words, this determines whether information (i.e. dimensions of internal spaces) is unverified and entered manually or whether information is calculated digitally. The final AOI is “Interoperability/IFC Support” and assesses the ability of the systems and products put in place to function with other products and systems. The use of Industry Foundation classes, allows for a platform neutral, open file specification to be implemented, resulting in complete interoperability.

Table 4.6: Summary of inputs(buildSMART alliance, 2007)

Area of Interest	Description
Data Richness	Assesses the completeness of the Building Information Model.
Life-cycle Views	Views refers to the phases of the projects which are being covered by BIM. In other words, this AOI aims to assess the extent of BIM's implementation throughout a project's different phases.
Change Management	Assesses the methodology used to change business processes that have been developed by an organisation.
Roles or Disciplines	Assesses the dependency of the various roles and disciplines involved in a project on BIM. That is to say how much the stakeholders involved in the project rely on BIM to accomplish their jobs.
Business Process	Assesses the ability of the business processes in place to collect real time data and incorporate it into the Building Information Model.
Timeliness/Response	Assesses the recentness and frequency of information updates. This in turn has an impact on the responsiveness and accuracy to questions and issues.
Delivery Method	Assesses the availability of data on a centralized structured network, allowing access for all stakeholders.
Graphical Information	Assesses the extent to which the Building Information Model includes 2-D, 3D, and object based drawings.
Spatial Capability	Assesses the compatibility of the different elements included in the model and their relative usability.
Information Accuracy	Assesses the accuracy of the information collected for the purpose of BIM is.
Interoperability/IFC Support	Assesses the ease of information sharing by multiple parties

Outputs

This tool has two main outputs. Firstly, an overall "AOI Chart" which provides an overview of the project's maturity levels in each of the eleven areas of interest. This allows for a quick visualisation of the strengths and weaknesses of BIM implementation across a project. As shown in Figure 4.2, this chart allows for the identification of potential areas of improvement.

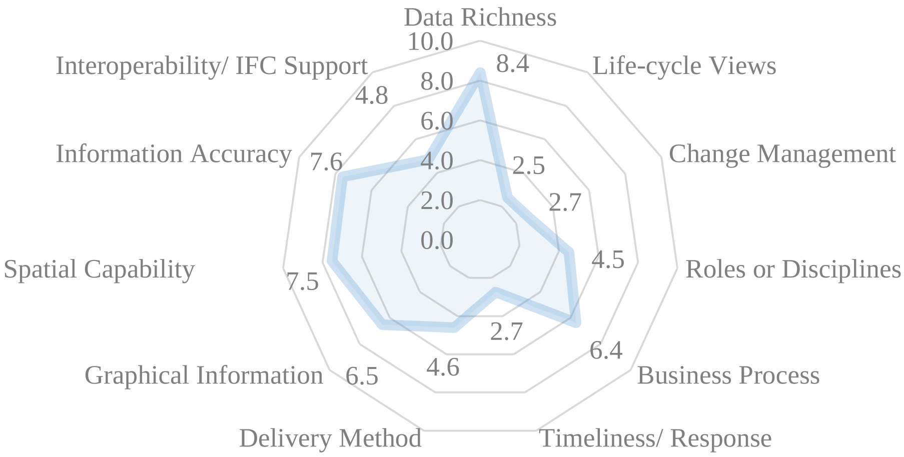


Figure 4.2- Sample Area of Interest Chart (buildSMART alliance, 2007)

The Capability Maturity Model (CMM), upon which this tool is based, provides a means for certification and a threshold for "minimum BIM".As mentioned previously, the 11 Areas of Interest which are being assessed are each attributed a maturity level ranging from one (1) to ten (10). In addition, each AOI is attributed a weighted importance, which is a relative weighting out of 100%. Therefore, when the individual scores are added, they amount to a maximum total of 100 points. As shown in the figure below, each score is equivalent to a corresponding Certification Level.

Table 4.1: The Capability Maturity Model (buildSMART alliance, 2007)

Area of Interest	Weighted Importance	Perceived Maturity Level	Credit
Data Richness	84%	Data Plus Expanded Information	4.2
Life-cycle Views	84%	Add Construction/ Supply	2.5
Change Management	90%	Limited Awareness	2.7
Roles or Disciplines	90%	Partial Plan, Design&Constr Supported	4.5
Business Process	91%	Some Bus Process Collect Info	2.7
Timeliness/ Response	91%	Data Calls Not In BIM But Most Other Data Is	2.7
Delivery Method	92%	Limited Web Enabled Services	4.6
Graphical Information	93%	3D - Intelligent Graphics	6.5
Spatial Capability	94%	Basic Spatial Location	1.9
Information Accuracy	95%	Limited Ground Truth - Int Spaces	2.9
Interoperability/ IFC Support	96%	Most Info Transfers Between COTS	4.8
		Credit Sum	**40.0**
		Maturity Level	Minimum BIM

Points Required for Certification Levels		
Low	High	
40	49.9	Minimum BIM
50	59.9	Minimum BIM
60	69.9	Certified
70	79.9	Silver
80	89.9	Gold
90	100	Platinum

4.2.2 VDC Scorecard

Overview

The VDC Scorecard was created by the Center for Integrated Facility Engineering (CIFE) at Stanford University in 2011. It aims to assess BIM maturity across projects through the assessment of 4 scorecard areas, namely**: planning**, **adoption, technology**, and **performance**. Each scorecard areas contains a set number divisions, totalling to 10 Divisions overall. Each division, in turn, comprises a number of measures, totalling to 56 total measures for the overall tool. The estimated completion time for this tool is around 2 hours. In this tool, the terms VDC and BIM are used interchangeably (refer to key definitions section).

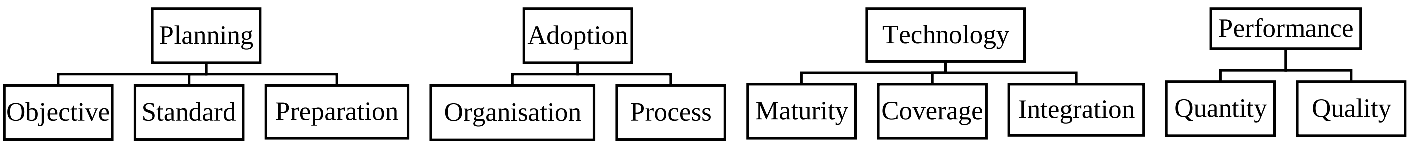


Figure 4.4: Overview of VDC Scorecard(Calvin Kam, 2014)

Inputs

Planning Area

3 Divisions make up the Planning Area: **Objective**, **Standard**, and **Preparation** with respective weightings of 40%, 30%, and 30%. With the greatest weighting in the Planning Areas, the objective division is crucial to the framework of the VDC scorecard, and evaluates projects on their inclusion of seven categories of VDC. It provides a set of tangible targets that the project aims to meet, and therefore allows the scorecard to be practical and quantitative. By setting mature targets and clear objectives, it becomes possible to identify inefficiencies and poor areas of performance. The 7 categories that comprise the objective division are as follows:

1. *Communication:* improvement in quality and frequency of communication
2. *Cost:* reduction in project costs
3. *Schedule:* reduce schedule uncertainty through interdisciplinary collaboration
4. *Facility:* enhance facility performance in areas such as energy use and thermal comfort through greater efforts during the design process.
5. *Safety:* reducing health and safety hazards and risks during the construction and operation of the building.
6. *Delivery:* improve owner satisfaction by optimizing the project delivery process

7. *Management:* improving project management through the use of VDC.

Performance Area

The Performance area is a measure of how well these targets have been met, and is divided into a Quantitative and Qualitative division, with respective weightings of 70% and 30 %. Quantitative metrics are weighed more heavily than qualitative ones to ensure objectivity of evaluation (Kam et al. 2013) and to create a more quantifiable evaluation that contributes to the final percentile scoring system. That being said, quantitative input might not be accurate due to various uncertainties or lack of evidence. Therefore, a "confidence level" is introduced to tackle this issue and is looked at in detail later.

Adoption Area

The adoption area consists of 2 divisions- **Organisation** and **Process**- both carrying an equal weighting. This area aims to measure how efficient a project team is in deploying its human capital to support the technology targets set in the Planning area. The Organisation Division measures the level of involvement and proficiency of the stakeholders in a project team (Kam et Al., 2013). The Process Division is concerned with measuring project performance through the assessment of the interactions and relationships between stakeholders (Kam et al., 2013). Whilst the Planning area sets aims and targets, the Adoption area determines the maturity of the necessary interactions and expertise to take full advantage of such technologies. In addition to having the necessary technology, a project has to have a workforce with right expertise and skillset to take full advantage of such technologies.

Technology Area

The Technology area consists of three divisions: Maturity, Coverage, and Integration with respective weightings of 40 %, 20 %, and 40%. Overall, this area is dedicated to assessing the product, organisation, process models used in a project. The Maturity division evaluates the level of implementation of the technologies and characterises them into 5 levels of implementation:

1) Visualisation
2) Documentation
3) Model-based Analysis
4) Integrated Analysis
5) Automation & Optimization

Outputs

This tool's output is a percentage score which is arrived to by calculating a weighted average of the 4 Planning Area scores. The planning area scores are created using a weighted average of their respective Scorecard Divisions. Each division's score, in turn, is calculated using a weighted average of its comprising measures.

More importantly, this overall percentage score is comparable and relatable to industry standards. These industry standards were initially set by Subject Matter Experts (SMEs) and were validated later on when empirical data from case studies became available. These benchmarks, allow the project being assessed to be directly compared with other projects. In addition, the percentage score were overlaid with tiers called "Maturity Levels of VDC Practice" which allowed for an industry wide certification. The tiers of the VDC Scorecard are as follows (Calvin Kam, 2014):

1) Conventional Practice (0%-25%)
2) Typical Practice (25%-50%)
3) Advanced Practice (50%-75%)
4) Best Practice (75%-90%)
5) Innovative Practice (90%-100%)

This tool accounts for the evolution of the industry and its norms by continually calibrating and updating these tiers. As such, each of the tiers is only valid for the corresponding version of VDC scorecard on which it was published.

4.3 Investigative Analysis: Assessing Individuals

4.3.1 BIM Excellence

BIM excellence, or BIMe, is a research-based tool developed in 2009 by ChangeAgents, a BIM performance assessment and improvement consultancy. BIMe was developed to measuring BIM maturity for (a) individuals, (b) organisations, (c) projects and (d) teams. For the purpose of this research paper, a closer look will be taken at the online tool which aims to assess individuals' BIM competency, entitled "BIMe Individual Discovery". The estimated time completion for this tool is 10 minutes.

Inputs

The tool comprises of the assessment of 8 sets of competencies, listed below. The BIMe Individual Discovery comprises of 55 total individual competencies, which can be split into 8 sets of competencies, as illustrated in the work of (Succar, 2013)

1. **Technical**
   Technical competencies measure the individual's ability to use the technology effectively to generate project deliverables. Technical competencies include modelling, drafting, model management etc..
2. **Operation**
   Operation competencies measure an individual's overall ability to complete project deliverables. Note that operation competencies are not limited to the technical use of models and can extend across the various daily tasks that are required of individuals.
3. **Functional**
   Functional competencies assess the non-technical abilities of individuals needed throughout a project. This include Collaboration, Project Management, and Facilitation etc.
4. **Implementation**
   Implementation competencies measure the availability and processes put in place in order to introduce BIM concepts and tools into an organisation. Example: "The ability to develop protocols specific to generating and maintain a Model Component Library".
5. **Administration**
   Administration competencies include tendering and procurement, contract management, and human resource management. In short, administration competencies

aims to assess an individual's knowledge and involvement in activities required to meet their respective organisation's strategic objectives.

6. **Supportive**
   Supportive competencies assess the supporting frameworks and process put in place to enable BIM implementation. Example: "the ability to assist others to troubleshoot basic software and hardware issues."
7. **Research & Development**
   Research and development competencies measure the individual's ability to evaluate existing processes, investigate new solutions and facilitate their adoption. Example: "the ability to assist others to troubleshoot basic software and hardware issues."
8. **Managerial**
   Managerial competencies measure an individual's understanding of and involvement with decision-making strategies and initiatives. Example: "the ability to understand the Business Benefits and Business Risks of model-based workflows".

Each competency is assessed through a question, which is answered based on the Individual Competency Index (ICI), developed by ChangeAgents. As shown in Figure 4.5, the ICI identifies 5 competency levels: (0) None, (1) Basic, (2) Intermediate, (3) Advanced and (4) Expert. Each of these competency levels measures both the conceptual knowledge (i.e. theoretical knowledge) and the applied knowledge (i.e. practical skills) required by the individual.

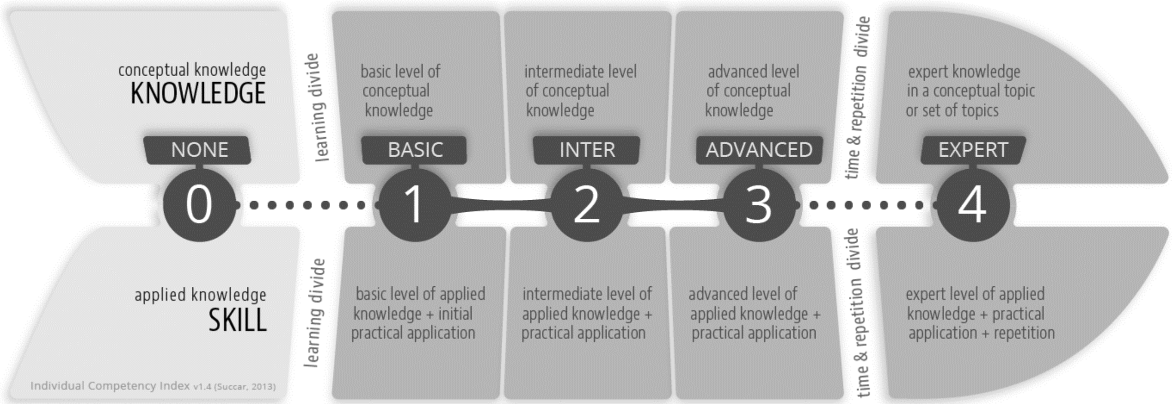
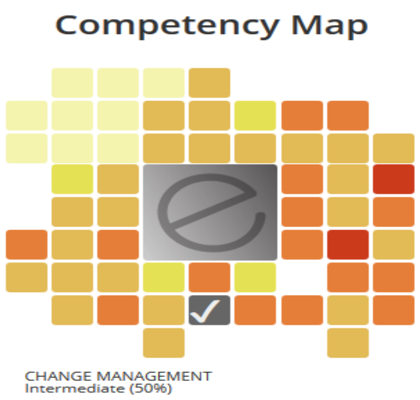


Figure 4.5: Individual Competency Index (Succar, 2009)

Outputs
After completion of the tool, 3 main outputs are available to the assessor. Firstly, a user unique BIM map gives an overview of the individual scores in each of the 55 individualcompetencies assessed, as shown in Figure 4.5.



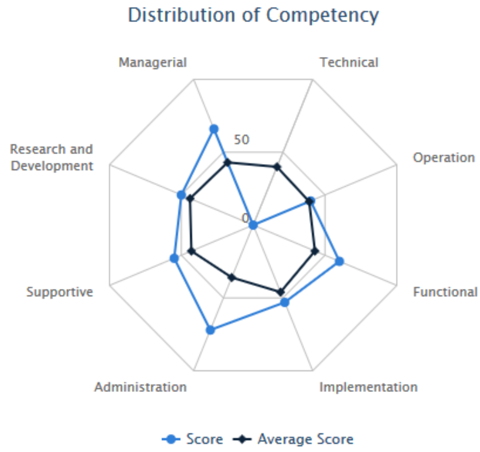


Figure 4.5: Competency Map and Comptency Distribution (ChangeAgents, 2016)

Secondly, a "Distribution of Competency" graph illustrates clearly relative areas of strength and indicates clearly potential areas for improvement, as shown in Figure 4.5.

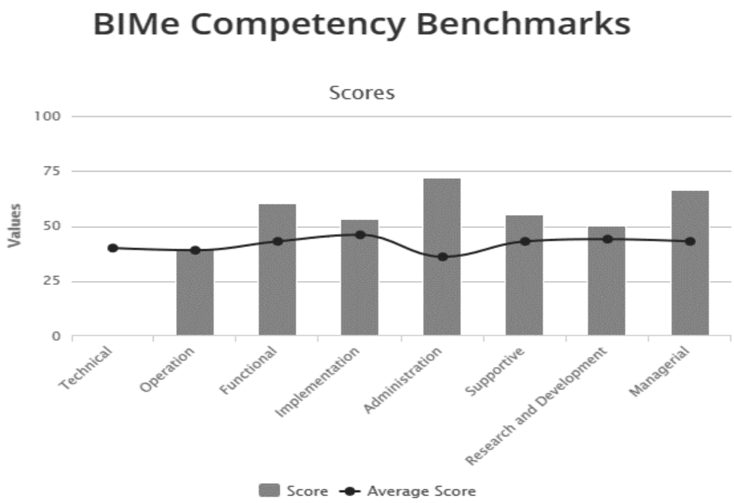


Figure 4.6: Sample BIMe Competency Results (ChangeAgents, 2016)

Finally, the percentage score achieved in each of the 8 sets of comptencies is compared to average scores, as shown in Figurre 4.6. Average scores are calculated from previously conducted assessments.

5. Outputs

Following this analysis, key thematics which highlight the inconsistencies across the BIM AM landscape were outlined. These key thematics are listed below and were later verified through interviews with industry experts.

Qualitative vs. Quantitative

The inconsistencies across the tools start here. Some tools are highly qualitative, such as the "CPIx BIM Assessment Form" (2011). This results in highly subjective inputs, greatly undermining the quality and value of the outputs. An over reliance on qualitative data results in a greater variability in the inputs, making it difficult to determine the value of every answer. On the other end of the spectrum, other tools such as BIM Excellence, developed by ChangeAgents in 2009, are completely quantitative.

Frameworks & Supporting Literature

Some tools are based around existing performance measurement models, and hence have an accompanying framework. One of such tools is the NBIMS-CMM (2007), which is based around the Capability Maturity Model (CMM), which has been used to measure performance in various industries such as banking, aerospace, and car manufacturing. On the other hand, The Construction Project Information Committee's "Assessment Form", developed in 2011, has no mention of a framework nor does it have any supporting literature.

Coverage

Coverage is the term used to define the scope of each tool. In other words, some tools assess certain aspects of BIM implementation that other tools simply do not. Coverage also refers to the varying amount of competencies each tool aims to evaluate, and their respectable weightings.

Confidence Level

Out of the five assessment methods included in this analysis, only one includes a "Confidence Level" metric. This measure is designed to account for the uncertainty of a given answer, and this is especially useful when evaluating projects in the downstream phases-where it becomes harder to remember details that have happened earlier on in the project. Interviewees may have uncertainties that arise in their answers due to a lack of available data or simply an inability to remember certain facts.

Nature of development: Academic vs Industry

The current BIM AM landscape is a product of joint efforts from the industry and academia alike. The issues that arise from this difference are many. Tools that have been developed by the industry entirely tend to be very commercial products, designed to gain as much adopters as possible. On the other hand of the spectrum, tools which have been developed entirely by academics, tend to be tedious, long and highly impractical to complete. There have been instances (Gao, 2011) where academics have published suggestions and recommendations of what future frameworks should entail without actually suggesting a tool or framework.

Repeatability

Repeatability is a term used to refer to the ability for another person to carry out the assessment. For instance, this is particularly relevant for tools which aim to assess individuals, as anyone should be able to use the tool. The analysis has found a great variety in terms of repeatability. Some assessments (such as BIMe) are conducted by experts whilst other are carried out by semi-experts.

6. Discussion& Verification

The aim of this section is twofold. Firstly, a discussion of the key thematics resulting from the analysis will take place to allow for the formulation of recommendations. Secondly, the responses from the interviews carried out will serve as a verification to these themes. The structure of this discussion will follow that of the analysis. As mentioned in the methodology, the interviewees were Mr. Ben White (Head of Engineering at Byrne Bros.) and Mr. Sam Cooke (BIM Coordinator at Skanska).

6.1 Assessing Organisations

The first comparative analysis compared two tools which assess organisations in two completely different manners. The first tool, CPIx's "BIM Assessment Form", is an example of a tool developed by industry experts. From analysing this tool's inputs, it is clear that there is a greater reliability on assessing an organisation's BIM maturity through their **understanding** of certain processes, such as those listed in Table 4.2. In order for this kind of assessment to be successful, clear definitions of terms such as "BIM Benefits" need to be provided to eliminate misinterpretations. As will be shown later, other tools focus instead on assessing individuals' **adoption** of these processes.
On the other hand, Penn State's Organisational BIM Assessment Profile, is an example of tool developed purely by academia. After carrying out the interviews with Mr. Ben White and Mr. Sam Cooke, they both had similar opinions on the debate surrounding the nature of the development of these tools. They both stipulated that an assessment tool which is to be used by the industry has to be designed by the industry. They both had concerns with using a tool developed by academia. Their primary concern was that tools designed by academia will aim to assess certain aspects of BIM which are simply not applicable or used in real life.

More importantly, and perhaps as a consequence of their differing natures of development, these tools also differ in the nature of their inputs. The "Organisational BIM Assessment Profile" relies on quantitative inputs while CPIx's"BIM Assessment Form", relies entirely on qualitative inputs. As demonstrated in the analysis, over reliance on qualitative data results in highly subjective inputs, ultimately compromising the quality and value of the tool's outputs.
When asked about this issue, both the interviewees agreed that whilst an over-reliance on qualitative inputs can be detrimental to the overall value of the outputs, some BIM capacities are still best assessed qualitatively.

Penn State's Organisational BIM Assessment Profile provides clear quantitative BIM maturity levels which can be compared to target levels. This user-friendly approach allows organisations to easily compare current maturity levels with target levels. Eventually, this leads to "continuous evaluation", or evaluation which is carried out repetitively to track the organisation's progress towards their BIM targets. On the other hand, CPIx's "BIM Assessment Form" makes no attempt at providing a quantitative output. Instead of providing the assesse with a score representing their maturity, the tool provides "comments" and "recommendations". This high dependency on subjective outputs has various disadvantages. Firstly, it greatly affects the repeatability of the assessment both from the assessor's and interviewee's end. If a different assessor carries out the assessment or a different BIM leader completes the form, then the answers will vary greatly. Secondly, it questions the long-term value of the assessment. When the organisation being assessed gets involved in another project, it will need to carry out another assessment

In terms of coverage, it is clear that Penn State's tool is not solely focused on evaluating the adoption of the technology alone. On the contrary, a greater emphasis is placed on organisations' overall BIM strategy and quality of staff. This comes in contrast to CPIx's BIM Assessment form, which is greatly focused on assessing the technical aspects of BIM (i.e. the models). When asked about this, both interviewees had similar views on the subject. They both suggested that a greater focus should be placed on the social aspects of BIM (i.e.

the communication interchange). According to Mr. Cooke, who is the BIM coordinator for one of Skanska's projects, having a robust BIM model without effective communication pathways in place leads to greater inefficiencies and loss of information.

6.2 Assessing Projects

It worth noting that there exists a great overlap between the assessment of projects and that of organisations. In fact, an argument could be made that assessing a project allows for an assessment of the organisations involved in that project as well. The two tools which were analysed in the analysis section are NBIMS-CMM, developed in 2007, and the VDC Scorecard, developed in 2011. The NBIMS-CMM is widely regarded as the first tool to attempt to assess BIM maturity. It is therefore interesting to see how the VDC Scorecard, developed some 4 years, later has improved upon the NBIMS-CMM.
These tools differ in the nature of their development. As mentioned previously, the VDC scorecard was developed at Stanford University while the NBIMS-CMM was developed by the National BIM Standard. As a result of this, the VDC scorecard is relatively lengthy and at times feels like an academic exercise. When asked about this subject, the interviewees were very adamant about the completion time of the assessments. In fact, they both claimed that the length of the assessment is the primary factor which determines whether or not the assessment will be completed or not.
Whilst the NBIMS-CMM relies exclusively on quantitative inputs, the VDC scorecard has a combination of qualitative and quantitative inputs. This is a clear improvement, and allows for the assessment of a variety of metrics which are best assessed qualitatively. The inclusion of a "confidence level" is also very critical, as it accounts for the uncertainties that arise when providing these inputs. Whilst both interviewees agreed that a variety of uncertainties arise when providing inputs, they didn't have any suggestions on how to tackle this issue. However, once the concept of a "confidence level" was introduced, they both agreed that it needed to be included in any future tool being developed.
In terms of outputs, both tools are similar in the sense that they include a quantitative output along with a corresponding "certifying scheme". In fact, the NBIMS-CMM is widely regarded as the first tool to incorporate the concept of "Minimum BIM", or an industry-recognized threshold level of BIM maturity that projects have to comply with. The VDC Scorecard goes a step further, and has an **evolving** "certification scheme". In other words, the data from the assessments carried out is used to calibrate the different ranges for each "certification level". Therefore, achieving a score of 40 % percent might be certified as minimum BIM for one year, but as more assessments are carried out, the new minimum score for "minimum BIM" might increase to 45%.
When asked about this, both interviewees agreed that having a certification scheme at the output of the tool adds more value and legitimacy to the assessment. With regards to repeatability, both tools were designed to be completed by BIM experts or semi-experts. In practice, this means that the assessment will be carried out by the project BIM leader or BIM champion, who is responsible for implementing BIM across all facets of the project. When asked about this, Mr. Cooke admitted that there have been many instances where assessment are carried out by individuals lacking the necessary background knowledge.

6.3 Assessing Individuals

The tool analysed for this section was the BIMe, developed in 2009, by ChangeAgents. When questioned about the evaluation of individuals, Sam Cooke responded that he did not see the benefit of assessing an individual’s BIM maturity externally. He also added that he has never come across an assessment tool dedicated to individuals, as he was more accustomed to assessing organisations. Ben White, on the other hand, stated that completion time is the primary factor to be considered. Getting people to complete an assessment during their working time, for something which they are not legally obliged is a challenge. Therefore, when assessing individuals, the assessments must be kept short and concise.

In addition, a greater emphasis has to be placed on defining the technical terms used throughout the assessment. This is seen throughout the BIMe, as all technical terms are included in an online glossary. As a result, this tool allows for the assessment of all individuals, regardless of prior knowledge.

As a result of its research-based nature, the BIMe tool is accompanied by a plethora of literature. This literature gives the tool a lot more context and adds to its credibility. When asked about this, the interviewees agreed that any new potential framework should come along with relevant literature. This allows the assessors to gain a deeper understanding of the tool, and the underlying framework upon which it is based.

7. Recommendations

Based on the analysis, results, and discussion presented above, this section will provide recommendations which should be included in a “best practice” assessment method. After carrying out the analysis, it became apparent that some characteristics were more pertaining and applicable to some tools more than others. Similar to the analysis, these recommendations will be made according to the level of assessment (i.e. whether the tool aims to assess individuals, projects, or organisations). Whilst this list is not exhaustive, it does provide a good indication of what measures a new framework should incorporate.

Repeatability

When assessing organisations, the assessment tool should aim to reduce the variability of results from different assessors. This can be achieved by putting a number of measures in place. As such, supporting literature allows all assessors to gain a better understanding of the tool and its objectives. Due to the advanced level of understanding of BIM and its processes, the assessment of organisations should be carried exclusively by BIM experts.

Supporting Literature

Having adequate supporting literature is critical not only to achieving ideal repeatability but also to giving the tool more legitimacy. This is crucial when assessing both individuals and organisations. When assessing individuals, supporting literature can help the assesse understand technical terms. When assessing organisations, the assessor can use the supporting literature to further understand the aims, and targets of the assessment and assessment surrounding it.

Qualitative & Quantitative Measures

A combination of both quantitative and qualitative measures should be used. This is to ensure that the tool measures metrics which are best measured quantitatively (such as the level of information included in the BIM model itself) and qualitatively (such as the communication levels associated with BIM adoption).

Coverage

A “best practice” tool should incorporate a complete assessment of all aspects of BIM evaluation. For instance, when assessing organisations, it is important to evaluate “change management” processes put in place by the organisation to support BIM implementation.

Confidence Level

In order to account for the various inaccuracies in data entry that arise to uncertainties, it is necessary to include a “confidence level” with every metric obtained. This can be in the form of a number between 0-1, which will serve as a multiplier to the scores entered by the assesse. This is relevant to all three levels of assessment.

Length of Assessment

In addition to incorporating all the measures suggested above, a tool assessing individuals should aim to be short and concise. As confirmed by the interviews, the issue faced by organisations is centred on getting their staff members to take the time and fill the assessment accurately and honestly.

Nature of Development

Ideally, a “best-practice” framework should be a joint effort of industry experts and academia alike. This is to ensure that any new tool is relevant to industry practices all whilst having

8. Conclusion

It is necessary to note that BIM assessment should only be considered as a component of the overall BIM implementation process. More often than not, BIM assessment is considered as an independent process, carried out for the sole purpose of fulfilling a contractual obligation. To derive more value from assessment, it becomes necessary to define assessment tools’ outputs in a manner that is aligned with the organisation’s overall BIM strategy. However useful it is to compare current levels with target levels, the organisation must have a BIM implementation strategy in place that makes use of the assessment’s outputs to implement BIM in order to reap the full benefits of BIM assessment.
The interviews conducted provided valuable insight into the current state of BIM implementation throughout the contracting industry. It offered two contrasting views into how organisations are implementing BIM. Skanska, the main contractor on the project, is **leading** BIM initiatives by encouraging and enforcing BIM implementation across the project. On the other hand, Byrne Bros., a concrete works sub-contractor, has adopted a reactive approach to BIM implementation. After conducting the interview with Ben White, it was made clear that his company is implementing BIM simply because of contractual obligations. In fact, Mr. White clearly stated that Byrne Bros. does not derive any direct value from the use of BIM. Unfortunately, BIM is still perceived as a contractual obligation which is imposed on contractors by virtue of their contracts. On the other hand, Mr. Cooke stated that as a main contractor, Skanska sees many benefits to BIM adoption. Many of these benefits are centred on the ability to coordinate efficiently and simultaneously the progress of the project.

8.1 Limitations

The methods employed in this research dissertation have several constraints. The selection of the five assessment methods used as the basis of the desktop analysis is not entirely representative of the current BIM-AM landscape. A large scale analysis, where all tools are examined thoroughly would have resulted in more comprehensive results. In addition, the two interviews conducted as a verification of the discussion and analysis only serve as "small-scale" verification. Ideally, interviews with BIM experts and assessors from a variety of organisations should be carried out. This, in turn, will allow for a better understanding of the challenges facing BIM assessment.

8.2 Further Research

In addition, due to the relatively *recent* proliferation of both BIM and BIM AMs, there is a lack of available case studies which explore the efficiency of BIM assessment methods. Most of the future research into BIM AM's has to be geared towards producing more case studies, where the use of Assessment Methods in real life projects is monitored closely in order to analyse their outputs.

Further work should also aim to combine the analysis of existing assessment tools with the findings of case studies in order to tailor the requirements of BIM evaluation by level of assessment. Furthermore, work should also be carried out to establish an industry-wide "evolving" benchmark system, for each of the three categories of assessment, namely individuals, projects, and organisations. This will in turn add more value, credibility, and purpose to all assessment tools adhering to these industry standards.

9. References

Andersen Consulting, 1993. *The Lean Enterprise Benchmarking Project,* London: s.n.

Azouz, A., Copping, A. & Shephard, P., 2015. *An investigation into Building Information Modelling Assessment Methods (BIM-AMs).* College Station, s.n.

buildSMART alliance, 2007. *Interactive BIM Capability Maturity Model.* s.l.:s.n.

Calvin Kam, D. S. B. M. Y. X. M. S., 2014. *The VDC Scorecard: Formulation and Validation,* Stanford: s.n.

Camp, R., 1989. *The search for industry best practices that lead to superior performance.* Milwaukee: ASQS Quality Press.

ChangeAgents, 2016. *BIM Excellence.* [Online]
Available at: http://bimexcellence.com/dictionary/
[Accessed 1 February 2016].

ChangeAgents, 2016. *BIMe Individual Discovery.* Melbourne: ChangeAgents.

Dassault Systems, 2014. *3ds.* [Online]
Available at: http://www.3ds.com/fileadmin/Industries/Architecture-Engineering-Construction/Pdf/Whitepapers/end-to-end-collaboration-enabled-by-bim-level-3-white-paper-aec.pdf
[Accessed 30 November 2015].

Drever, E., 2003. *Using Semi-Strucutred Interviews in Small-Scale Research.* 2nd ed. Glasgow: SCRE Centre.

Hill, M., 2009. *The business value of BIM: getting to the bottom line.* [Online]
Available at: http://www.bim.construction.com/research/2009
[Accessed 31 January 2016].

HM Government, 2011. *Government Construction Strategy.* [Online]
Available at:
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/61152/Government-Construction-Strategy_0.pdf
[Accessed 10 November 2015].

J. Woo, J. W. D., 2010. *Use of as-built building information modelling.* Alberta, s.n., pp. 538-548.

Kaplan, R. S. & Norton, D. P., 1992. The balanced scorecard- measures that drive performance. *Harvard Business Review,* pp. 71-79.

Kristen Barlish, K. S., 2012. How to measure the benefits of BIM- A case study approach. *Automation in Construction,* Volume 24, pp. 149-159.

Kunz, J. & Fischer, M., 2012. *Virtual Design and Construction: Themes, case studies and implementation suggestions ,* Stanford: s.n.

Maskell, B. H., 1989. Performance measures of world class manufacturing. *Management Accounting,* pp. 32-33.

Neely, A., 1994. Performance measurement system design-third phase. *Performance Measurment System Design Workbook.*

Neely, A., Hew, R., John, M. & Ken, P., 1997. Designing Performance measures: a structured approach. *International Journal of Operations & Production Management,* 17(11), pp. 1131-1152.

Neely, A., Mike, G. & Ken, P., 2005. Performance measurement system design. *International Journal of Operations & Product Management,* 25(12), pp. 1228-1263.

Program, C. I. C. R., 2013. *BIM Planning guide for facility owners,* Pennsylvania: The Pennsylvania State University.

Succar, B., 2013. An integrated approach to BIM compency assessment, acquisition and application. *Automation in Constuction,* Volume 35, pp. 174-189.

Succar, B., 2013. *Building Information Modelling: conceptual constructs and performance improvement tools,* Newcastle: s.n.

Voss, C., Coughlan, P., V., C. & Fairhead, J., 1993. *Developing and testing benchmarking and self assessment frameworks in manufacturing.* London, s.n.

Wisner, J. D. & Fawcett, S. E., 1991. Link firm strategy to operating decisions through performance measurement. *Production and inventory management journal,* pp. 5-11.

Gao, J., 2011. *A characterization framework to document and compare BIM implementations on construction projects*. Stanford.

9.1 Bibliography

B. Succar, 2010. The five components of BIM performance measurement, *CIB World Congress*, Salford.
B. Succar, 2009. Building information modelling framework: a research and delivery foundation for Industry stakeholders, *Automation in Construction*, pp. 357-375.

D.D Dubois, 1998, *The Competency Casebook: Twelve Studies in Competency-based Performance Improvement*, Human Resource Development Press.

Kaplan, R.S and Norton, D.P. (1993), " *Putting the balanced scorecard to work*", Harvard Business Review, September-October, pp. 134-47.

H. Abdirad (2015). *Advancing in Building Information Modelling (BIM) contracting: trends in the AEC/FM industry*.

10. Appendices

10.1 Appendix 1- Interview Questions

<u>Questions- Semi- structured interview</u>

1. While it is true that assessment tools that are quantitative are preferred to those that are qualitative, some metrics are better assessed qualitatively. The truth of the matter is that the ideal assessment tool would contain a combination of both. What are your thoughts on this?
2. Currently, there are 15 assessment tools available, developed by both the industry and academics, resulting in a great deal of variability in various aspects. One of such aspects is the length of the assessment. For Individual, Project, and Organisation assessments what are the ideal lengths of the assessment? What impact does a difference across this have on the reliability and usefulness of the tool?
3. The current AM's aim to assess a variety of competencies. In your opinion, what are the competencies that need to be evaluated when assessing BIM implementation? Do these need to include the social aspects of BIM implementation, or broader metrics such as "change management"?
4. How important is it to have a tool that is based around a model or framework? Does it affect its credibility and reliability? Is it more restrictive? Does it make it more challenging to adopt models which have been developed for other industries (i.e CMM) to the AEC industry?
5. The confidence level metric used in the "VDC Scorecard" tool is absolutely critical to the effectiveness of this tool. Do you think every tool should have a means of accounting for the uncertainties of the inputs?
6. The issue of repeatability is one which is especially relevant to assessment tools aimed at assessing projects or organisations. Who should be conducting these assessments within an organisation? (Experts/semi-experts/novice?) How repeatable are the assessments between assessors?