THE EMERGENCE OF BUILDING INFORMATION MODELLING ASSESSMENT METHODS (BIM-AMs)

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ABSTRACT: Building Information Modelling Assessment Methods (BIM-AMs) are used to evaluate the implementation of BIM and improve its adoption in practice. Over the past nine years there have been at least 16 BIM-AMs developed in academia and industry, each offering a unique perspective on BIM performance. Despite the continual growth of BIM-AMs, the field as a whole is still under-examined. Most previous studies tend to focus only on introducing new methods, rather than comparing and contrasting the diverse range of existing models. This paper addresses this gap, by analysing the similarities and differences between these assessments. A critical evaluation of the current AMs covers several features, including their simplicity and complexity, the most evaluated measures, whether the AM assesses projects, organisations, teams or individuals and the forms of communication of the results. This is followed by a representation of limitations and roles of BIM-AMs. This comprehensive comparison enriches the current research agenda of BIM-AMs. It helps to collectively reflect the extensive body of knowledge on BIM-AMs and recommends directions for future research.

Keywords – BIM, Assessment Methods, performance measurement, maturity models, comparative method.

1. INTRODUCTION

In the last decade, the need for Building Information Modelling Assessment Methods (BIM-AMs) has rapidly increased. With the government BIM Level 2 target for all publicly-funded projects by 2016, and the enormous challenges in measuring the 'maturity' of BIM performance, it is of vital importance that professionals adopt BIM-AMs. Assessments help organisations to track their progression (CIC, 2013), create 'healthy feedback loop' of BIM capacity (Kam *et al.*, 2013b) and develop a roadmap for stakeholders to assist them identifying goals for their future plans (NIBS, 2007). These benefits have been highlighted by Neely *et al.* (1997), who work explicitly on the broader field of performance measurement:

> Businesses choose to measure performance for various reasons- to know where they are, to know how rapidly they are improving, to enable comparison with other businesses, even to influence individuals' behaviours (Neely *et al.*, 1997, p. 1141).

Since 2007, the research field of BIM performance measurement has witnessed a gradual growth with at least sixteen Assessment Methods (AMs) which evaluate projects, organisations, individuals and teams. Several universities and commercial companies in the Architecture, Engineering and Construction (AEC) domain have contributed to the field of BIM-AMs. Amongst the most recognisable assessments are the National BIM Standard Capability Maturity Model (NBIMS-CMM) (NIBS, 2007), which was the first AM developed, the BIM Maturity Matrix (Succar, 2010) and the Virtual Design and Construction (VDC) Scorecard (Kam, 2015). Each has a unique perspective on BIM performance.

Despite this increasing interest, there are many cultural and practical barriers to adopt BIM-AMs, which have prevented them becoming wide-spread. Such challenges include the shortage of frameworks that are ready for use in industry, the lack of case study projects for validation (Kam *et al.*, 2013b) and the absence of an overarching research agenda for BIM-AMs. Most existing academic literature has focused on individual AMs, rather than analysing the range of available AMs as a whole (CPI, 2011; VICO, 2011; CIC, 2013), which is crucial to understanding the full picture of BIM performance measurement. Neither common properties and shared characterisations, nor contrasting aspects of these AMs, have been considered previously (Indiana University Architect's Office, 2009; BRE, 2015). Only a handful of past studies, e.g. (Giel, 2013; NIBS, 2015), have consistently explored and examined the synthesis of multiple AMs. In particular, they focused on comparing the measures included in only six AMs by classifying them into five groups: planning, technical, personnel, managerial and process measures. What is needed to effectively understand the domain is to propose a research agenda for BIM-AMs by comprehensively presenting their current roles and future development. This paper, therefore, maps the landscape of BIM-AMs by exploring the literature in order to simplify the complexity of this research field.

1.1 Definitions of BIM-AMs

The literature on BIM-AMs presents a lack of consensus as to their definition and demonstrates the diversity of the subject. The earliest definition of BIM-AMs is reported by the National Institute of Building Sciences (NIBS), whose early AM, the Capability Maturity Model (CMM), is a tool targeted at the architecture, engineering, construction and operation industry for an immediate evaluation of current BIM processes in projects (NIBS, 2007). This evaluation is used by professionals to identify their current performance and create robust goals for future operations. BIM-AMs are also defined as 'instruments' that benchmark the *organisation's* BIM level of performance in the construction industry (Sebastian and Berlo, 2010). Each of the numerous definitions available in the literature is different, according to the authors' aim and perspective. Seemingly, the main difference between them is the assessment focus. In other words, some of the AMs assess projects others assess organisations, individuals or teams.

2. COMPARISON OF CURRENT BIM-AMS

The number of BIM performance measurement tools has gradually increased over the last decade (BRE, 2015; Nepal *et al.*, 2014; Succar, 2010). BIM-AMs have been developed in different countries, such as, the U.S. (7 AMs), the UK (3 AMs) and Australia (3 AMs). Table 1 presents the current AMs with main references according to their chronological progression. Development reached a peak in 2009 with four new assessments, and currently there are sixteen known BIM-AMs. Each of them, however, has different strengths, weaknesses, roles and emphasis. Some of the AMs, for instance, are user-friendly (Arup, 2014), provide guidelines for usage, are available free on-line (CIC, 2013) and offer case study projects (Berlo *et al.*, 2012). Others are less practical, lack instructions or require an external examiner and fees to implement the assessment (BRE, 2015), or suffer from a shortage of case study projects (VICO, 2011).

To support an understanding of the generic development of BIM-AMs, critical analysis of the literature has been carried out to compare their diverse properties. This comparison plays a central role in concept-formation, as it examines similar and contrasting features among different cases (Collier, 1993). Some of the distinguishing properties addressed in this paper are the origins of AMs, year of development, the simplicity and complexity, the most evaluated measures, whether the AM assesses projects, organisations, teams or individuals and the forms of results' communication.

Table 1 Existing BIM-AMs

Order	BIM-AM	Year	Main Reference
1	NBIMS-CMM	2007	(NIBS, 2007)
2	BIM Excellence	2009	(Change Agents AEC, 2013)
3	BIM Proficiency Matrix	2009	(Indiana University Architect's Office, 2009)
4	BIM Maturity Matrix	2009	(Succar, 2010)
5	BIM Quick Scan	2009	(Sebastian and Berlo, 2010)
6	VICO BIM Score	2011	(VICO, 2011)
7	Characterisation Framework	2011	(Gao, 2011)
8	CPIx BIM Assessment Form	2011	(CPI, 2011)
9	Organisational BIM Assessment Profile	2012	(CIC, 2013)
10	VDC Scorecard	2012	(Kam *et al.*, 2013b, a; Kam, 2015)
11	bim Score	2013	(bimSCORE, 2013)
12	The Owner's BIMCAT	2013	(Giel, 2013)
13	BIM Maturity Measure	2014	(Arup, 2014)
14	Goal-driven method for evaluation of BIM project	2014	(Lee and Won, 2014)
15	The TOPC evaluation criteria	2014	(Nepal *et al.*, 2014)
16	BIM Level 2 BRE Certification	2015	(BRE, 2015)

2.1 Simplicity versus complexity

AMs are generally designed to reflect either a model simplicity or a complex reality. Each has its own advantages and disadvantages (De Bruin *et al.*, 2005). The level of simplicity and complexity is dependent on the numbers and type of evaluated measures. Oversimplified AMs tend to be short, attracting more interest as they require less time to complete. However, they may not represent the complexity of the domain if they are limited to specific areas of BIM. Half of the current AMs evaluate fewer than thirty measures (sometimes called indicators, variables or areas of interest), as illustrated in Figure 1. The NBIMS-CMM is an example of a simplified AM (NIBS, 2007), with only 11 measures. Participants completing the NBIMS-CMM are required to answer 11 questions, which takes 15-30 minutes to complete. Critics of NBIMS-CMM contend that this

AM is limited to specific measures and does not benchmark diverse areas of BIM (Kam *et al.*, 2013b). In contrast, complex AMs are always more detailed and comprehensive than the simplified models. The largest number of measures can be found in the 'Characterisation Framework' with 74 measures, over six times the number evaluated in NBIMS-CMM (Gao, 2011). This is followed by the 'Owner's BIMCAT', which includes 66 measures (Giel, 2013). However, one criticism in much of the literature on complex AMs is that they limit interest, (De Bruin *et al.*, 2005), because of their extensive detail and the time needed to complete the assessment. Difficulties arise when an attempt is made to complete the full detailed assessment and respondents might leave many questions unanswered. For instance, when the Centre of Integrated Facility Engineering (CIFE) researchers evaluated 108 pilot projects using the VDC Scorecard, the average proportion of questions answered was 72% (Kam *et al.*, 2013b). The link between simplicity and complexity is dynamic. Thereby, simplicity might be found in 'complex' AMs when a detailed method employs clear language, description of the measures and a structured framework with direct guidelines on how to use this AM. It is also found that simplified and short tools might be difficult to apply if they lack clear structure.

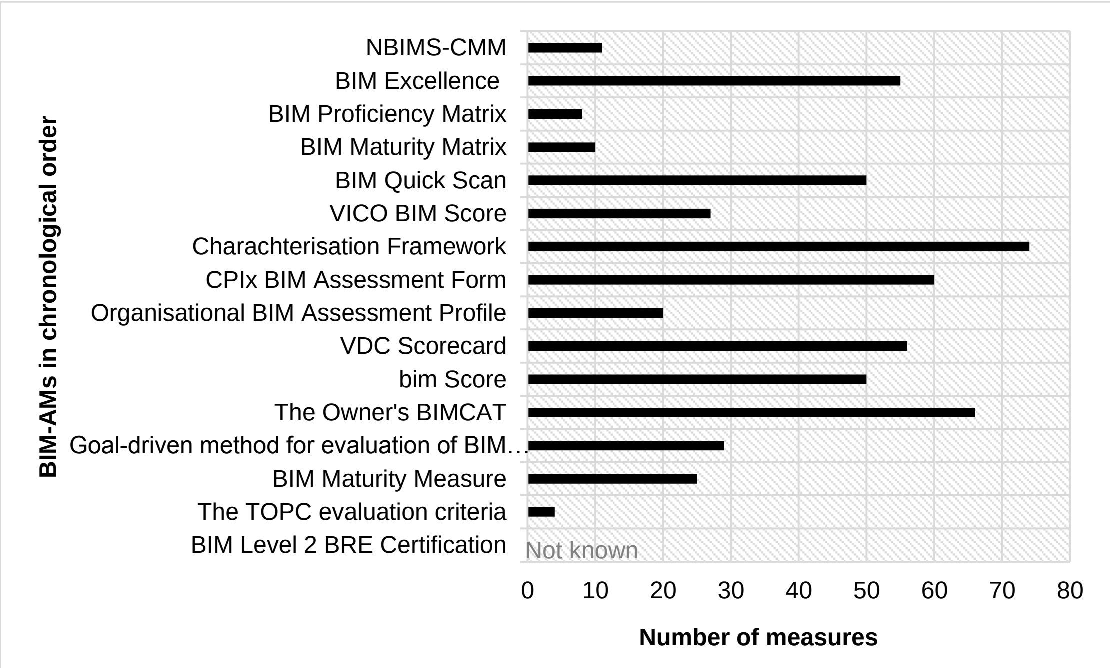

Figure 1 Simplicity versus complexity of the current BIM-AMs (from older, NBIMS-CMM, to most recent BRE Certification)

2.3 Assessment focus

BIM-AMs can be classified into four different groups according to their evaluation focus. AMs can evaluate BIM across either projects, organisations, teams or individuals. Currently, ten of the sixteen AMs evaluate organisations compared to six evaluate BIM in projects, three across individuals and one across teams. Some of the existing AMs, however, have multiple versions in which each has a different evaluation focus. The most recent BIM-AM, for instance, the 'BIM Level2 BRE Certification' has two versions (BRE, 2015): 'BIM Level 2 Business Systems Certification', evaluates organisations, and 'BIM Level 2 Certificated Practitioner Scheme', which assesses individuals.

Each of the four groups has its main focus. AMs of ‘organisations’ help the AEC industry to assess their readiness practices when implementing BIM (CIC, 2013). AMs that evaluate ‘projects’ help companies to manage their BIM utilisation. They assist managers in minimising uncertainty and concentrating financial and human resources on critical issues (Kam, 2015). Assessing ‘projects’ was first suggested in 2007 when NBIMS-CMM was created (NIBS, 2007). Whilst wider efforts have been given to evaluating organisations and projects, far less attention has been directed at assessing teams and individuals. In fact, it might be a challenge to evaluate individuals and teams in terms of BIM. One of the main concerns is the continuity of the BIM experience. If recognition was given to individuals at a certain time, would there be an expiry date of this credit, or would they need to be assessed again to check that their BIM knowledge and expertise has been maintained? Future direction of individual assessments might therefore suggest a continuous evaluation to ensure those certified professionals still meet the appropriate requirements.

The AMs of organisations and projects are different in their objectives and therefore they define different areas of measurement. The former tend to focus on assessing visions, plans, culture change, collaboration and strategies of BIM in organisations. Thus, AMs of organisations provide feedback on the organisation scale, without necessarily assessing any of its individual projects. Project assessment, however, is more concerned with evaluating how BIM has been implemented in terms of, for instance, data richness, data exchange and model use. Each project is unique, and therefore, levels of BIM implementation will vary within the same organisation according to certain circumstances, such as project size, complexity and client requirement.

2.2 Range of BIM-AMs’ measures

Choosing specific measures to benchmark is a fundamental part of the development of a performance measurement system in any discipline (Hatry, 2006). Each of the current BIM-AMs has its unique list of measures based on its objectives and priorities. Some of these measure are qualitative, and others are quantitative. The array of evaluated criteria is vast with over 200 different measures across the 16 AMs. To further complicate the situation, several developers evaluated the same measure, but used different terminologies. Therefore, in order to investigate the most popular evaluated measures, all have been extracted and classified into groups which evaluate the same BIM area. The most popular five measures, in order, are data richness, visions and goals, technology, data exchange and model use (Table 2).

Data richness is the highest examined measure and is therefore particularly important to scholars in the field of BIM performance measurement. It refers to ‘the maximum amount of information and geometry authorised for use by others’ (Harvard UCMC, 2013, p. 12). Eight of the AMs evaluate it, but they use different terms such as ‘Level of Detail’ (LOD) and ‘level of development’ (see Table 2). This includes the geometrical and non-geometrical information which an organisation needs to complete a specific BIM task at a certain timeframe. One of the big questions is how to measure LOD accurately without relying on subjective evaluation. Even with the five LODs defined by American Institute of Architects (AIA, 2008), it is still challenging to define sharp boundaries between these levels.

Table 2 Most commonly evaluated measures across the 16 BIM-AMs, with exact terminology

BIM-AM	Data richness	Visions and goals	Technology	Data exchange	Model use
NBIMS-CMM	Data richness	-	-	Interoperability + Delivery Method	-
BIM Excellence	-	-	Technical	-	-
BIM Proficiency Matrix	Data richness	-	-	-	-
BIM Maturity Matrix	-	Leaderships' BIM visions	Technology	Network	Software usage
BIM Quick Scan	-	Vision &strategy	Tools and applications	Internal and external information flow	Use of modelling
VICO BIM Score	-	-	-	-	-
Characterisation Framework	Level of detail	Vision into Implementing BIM		Data Exchange	Model Uses
CPIx BIM Assessment Form	-	-	-	-	-
Organisational BIM Assessment Profile	Level of development	BIM vision & Objectives/ goals	Software and hardware	-	-
VDC Scorecard	Level of detail/ development	Management Objectives	Technology	Data Sharing Method	Model uses
bim Score	Level of detail/ development	Management Objectives	Technology	Data Sharing Method	Model uses
The Owner's BIMCAT	Data richness/ LOD	Goals/ Objectives	Technology	-	-
BIM Maturity Measure	Level of development	-	-	Common data environment	Drawings
Goal-driven method for evaluation of BIM project	-	-	-	-	-
The TOPC evaluation criteria	-	-	-	-	-
BIM Level 2 BRE Certification	Not known				
Total number of AMs measuring this	8	7	7	7	6

The second joint most common measures are 'visions and goals', 'technology' and 'data exchange' examined in seven AMs. Similar to LOD, these measures are interpreted differently as seen in Table 2. On the practical side, the measures will be evaluated against various levels of maturity. For instance, in the 'Organisational BIM Assessment Profile', participants have to select one out of six maturity measures ranging from *0 Non-Existent* (no BIM vision of objectives defined) to *5 Optimising (CIC, 2013)*.

One of the main challenges when investigating the range of measures is to classify them into useful and structured categories. Past researchers have differently categorised measures into main BIM areas and sub-areas. Defining key common measures across the 16 AMs is still problematic. Many scholars have not clearly defined or explained their measures, making it difficult to explore similarities and differences. Another unresolved problem is deciding what type of performance information should be tracked. Several developers of the existing AMs have extensively discussed the methodological criteria behind selecting their measures. This includes explanations of employed methods in the development of AMs such as Delphi method, focus groups and surveys. In contrast, it is not clear in many other AMs how the measures have been chosen (CPI, 2011; VICO, 2011).

2.4 Reporting results

Clearly communicating the results of an AM is crucial to understanding the meaning of the outcomes. In the current BIM-AMs, results are presented in several forms including radar charts (Sebastian and Berlo, 2010; Arup, 2014), tables (Indiana University Architect's Office, 2009), reports (Change Agents AEC, 2013) and certifications (BRE, 2015), see Figure 2. A final overall score is usually provided either as a percentage or as points. In several AMs, once the overall score of the assessment is calculated, it will be then allocated to one of multiple ‘BIM Maturity Levels’. For example, in the VDC Scorecard, an overall score will be allocated to one out of five maturity levels ranging from Conventional Practice (0-25%) to Innovative Practice (90-100%) as seen in Figure 2. Other AMs similarly calculate the overall score, but without allocating the project to a certain level of maturity. This is exemplified in the BIM Maturity Measure (BIM-MM) developed by Arup (Arup, 2014) where, once the assessment is completed, a primary score is provided as a percentage, but without being directed to a particular maturity level.

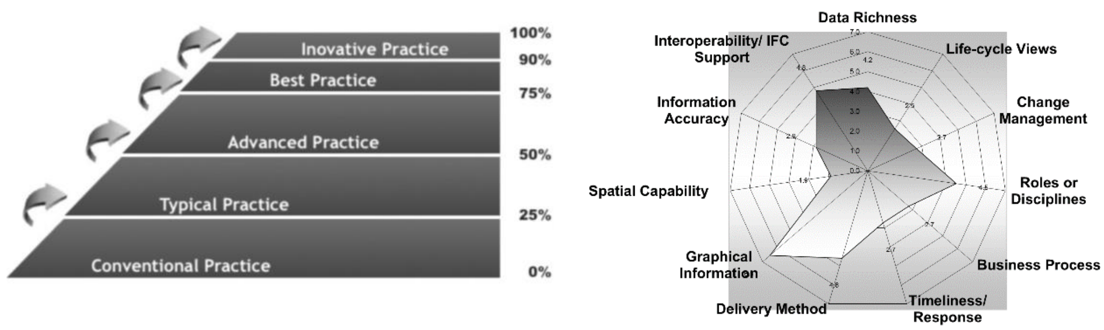

Figure 2 Communicating results in VDC Scorecard (Left), (Kam et al., 2013b), and NBIMS-CMM (right), (NIBS, 2007)

3. BIM-AMs: limitations and roles

Having discussed the different properties of BIM-AMs, it is beneficial to collectively provide a snapshot of their evolution and the emerging trends. This snapshot is portrayed in Figure 3 which demonstrates the development of AMs between 2007 and 2016. It also presents their diverse features, explained previously, which include year of development, origin, whether they are research or industry based, their complexity and whether they evaluate projects, organisations, teams or individuals. Previous advances in AMs have contributed significantly to the field of BIM performance measurement. This contribution varies, however, according to the limitations and roles of each assessment.

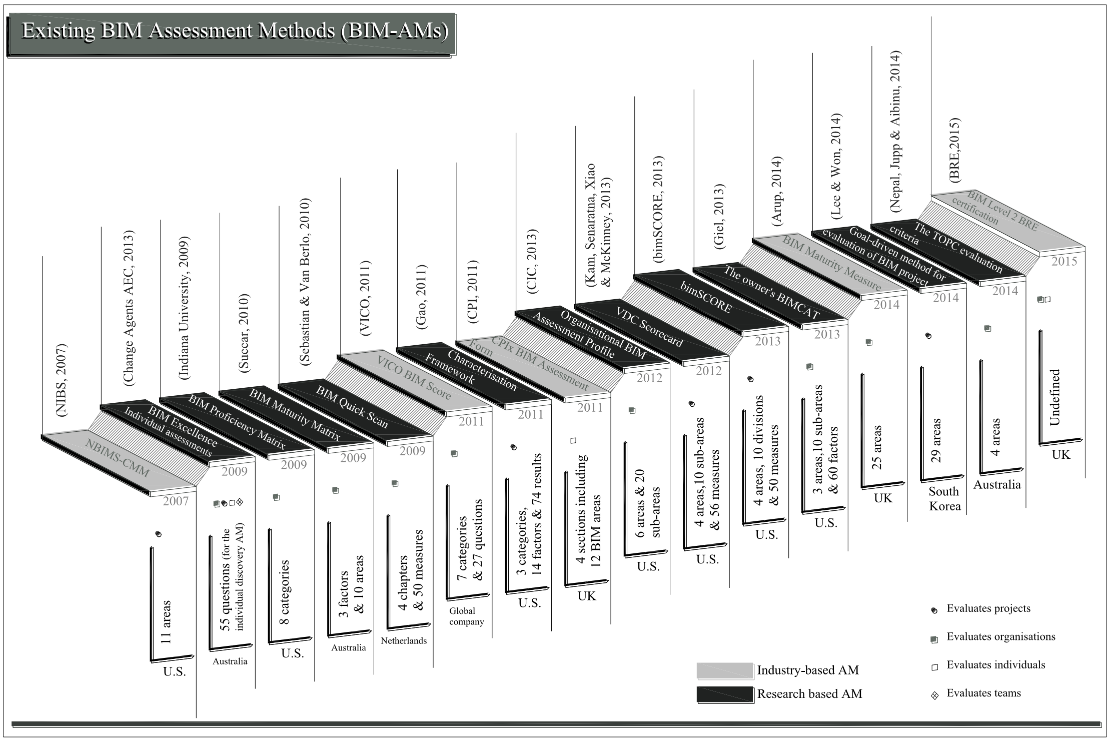

Figure 3 The evolution of BIM-AMs

3.1 Limitations of current BIM-AMs

There are many limitations facing the existing BIM-AMs, and the most important four are presented here. Firstly, most current AMs lack quantitative and objective measures when evaluating BIM. This makes subjectivity one of the most pressing challenges in BIM performance measurement (Kam, 2013). For example, some of the evaluated measures in NBIMS-CMM, business process and data richness, are subjective and open to interpretation. Consequently, it is likely that scores might be different when the AM is completed by two participants evaluating the same project (NIBS, 2007). Secondly, there are limited case study projects supporting the validation process of AMs (Kam *et al.*, 2013b). Thirdly, none of the current AMs have been widely acknowledged and commonly applied in the AEC industry (Sebastian and Berlo, 2010). In contrast, many AMs in different disciplines are well recognised, such as BREEAM and LEED. Fourthly, the criteria for selecting and weighting the measures in some of the AMs is not clear. For instance, the release of 'BIM Level 2 Business Systems Certifications' and 'VICO BIM Score' have not been supported by any explanation of their development process. In order to overcome these limitations, future AMs should build on the previous work to learn lessons and avoid current problems. AMs have to have more quantitative measures because subjectivity is one of the most inherent challenges. In addition, more case study projects should be provided which would assist in exploring the validation, practicality and reliability of tested AMs.

3.2 Role of current BIM-AMs

Despite their various limitations, AMs have become wide-spread in different fields such as environmental sciences, computer science, business and management. This significance can be linked to their roles and the impact on these disciplines. Neely (1999) identifies seven reasons for the 'revolution' of performance measurement, including the changing nature of work, increasing competition, changing organisational roles, changing external demands and the power of information technology. These reasons can equally be applied to the AEC industry and might explain the growth in the field of BIM-AMs. According to previous researchers, BIM-AMs have numerous roles, including the ability to:

- Help academia and industry to distinguish a 'healthy feedback loop' of BIM capacity in practice. This feedback may assist professionals to optimise their BIM adoption and increase their return on investment (Kam *et al.*, 2013b, p. 4)
- Assist companies to evaluate their level of BIM integration and improve their current adoption by defining advancement strategies and objectives (CIC, 2013)
- Document BIM implementation of previous projects as an internal source of information. This documentation may help BIM managers to compare projects to each other and increase BIM benefits (Gao, 2011)
- Help companies to compare projects, both internally and externally, in order to optimise their performance. This would provide an overall review of the industry's performance when trends in industry surveys are observed (McCuen *et al.*, 2012)
- Develop a roadmap for stakeholders to help them identify goals for future plans (NIBS, 2007)
- Help companies gain market recognition for their BIM services when high levels of maturity are achieved (Succar, 2010)

BIM-AMs offer opportunities for improvement by identifying areas of strengths and weaknesses. At the decision makers' level, the results of BIM-AMs provide governments and local authorities with a better understanding of the current position of BIM implementation. At the company level, professionals can use the results to compare capabilities between different projects and teams internally. Finally, for individual and team assessments, the results help companies to optimise their staff performance and influence individuals to improve their implementation of BIM (including training and education).

4. CONCLUSION

This paper has explored the current state-of-the-art in the field of BIM-AMs. The main focus has been to provide a comparative analysis of the AMs by contrasting a number of their distinguishing characteristics. From this comparison, a number of conclusions can be drawn. Firstly, over the past decade, the number of BIM-AMs has seen a gradual growth, both in academia and in the AEC industry. This growing interest reflects the need for AMs to help professionals achieve sharper and more efficient businesses by identifying areas of limitations and potential optimisations. Secondly, it is clear that each AM has its unique properties, aims and evaluation criteria, with widely varied number and type of measures. Thirdly, in order to shift BIM-AMs from theory into a broader practical context, their roles, contributions and significance should be acknowledged. Indeed, one of their indirect contributions is the ability to encourage a dialogue and a greater level of communication between different individuals and teams. If applied at the early stages of a project, BIM-AMs have the potential to introduce an array of BIM-related measures. Such measures will create a common language and set shared goals for individuals to achieve by the end of the project. This particular benefit of AMs has not yet been debated in the BIM literature, but has been highlighted in other fields, such as the environmental AMs.

The next steps for BIM-AMs should focus on both awareness and improvement. Awareness should be raised of the importance of measurement as a source of power and innovation. This should be done at three levels: academia (for more research to be carried out), AEC industry (to apply AMs in practical context) and Government (to benchmark the implementation of BIM on a national level). Improving on the current shortcomings of BIM-AMs, especially the subjectivity of its measures, is also of great importance. AMs offer opportunities for the future, but the research field of BIM-AMs is in its infancy and much more work needs to be done.

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