HOW BIM IS ASSESSED USING ARUP'S BIM MATURITY MEASURE?

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Since 2007, seventeen Building Information Modelling Assessment Methods (BIM-AMs) have been developed globally. Most previous studies on BIM maturity, however, tended to focus on promoting and introducing new assessments - but they rarely documented how these assessments are applied in the Architecture, Engineering and Construction (AEC) industry. It is this gap that this paper seeks to address. To do so, the Arup's BIM Maturity Measure, one of the current BIM-AMs, is applied to 1291 live projects. Through this application, the paper aims to identify how the AEC industry could use BIM performance measurement systems to create knowledge and feedback loops. Two main concluding remarks are highlighted. Firstly, it is observed that 'mature' projects are influenced by multiple internal and external forces that impact on BIM's implementation including the application of efficient BIM Execution Plan and BIM Design Data Reviews. Secondly, through data mining, it is possible to identify best BIM practices which is important to learn lessons and use as examples. These findings contribute to the BIM maturity agenda and provide fresh perspectives and insights in BIM-AMs.

Keywords: BIM, BIM Maturity Measure, BIM assessment method, Arup

INTRODUCTION

Performance measurement has been the subject of various studies in the last couple of decades. The evolving nature of businesses, growing competition, specific improvement initiatives, the power of information technology and the changing business roles have all led to a significant interest in performance measurement in different research disciplines (Neely, 1999), e.g. education, business management and environmental buildings. The potential of performance measures has been widely acknowledged, as Behn (2003), notes:

> As part of their overall management strategy, public managers can use performance measures to evaluate, control, budget, motivate, promote, celebrate, learn and improve.

In the Building Information Modelling (BIM) research agenda, the emergence of Assessment Methods (AMs) has started in 2007 with the release of the National BIM Standard Capability Maturity Model (NBIMS-CMM) (NIBS, 2007). Since then seventeen assessments have emerged globally to assess BIM on the level of projects, organisations, teams or individuals (Azzouz, Copping and Shepherd, 2016).

Despite the high level of academic and construction industry interest in BIM maturity (BRE, 2015; Månsson and Lindahl, 2016; Kassem, Succar and Dawood, 2013), there has been limited studies on the application of BIM-AMs to live projects in companies. Past assessments, such as the BIM Proficiency Matrix (Indiana University Architect's Office,

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2009), the Building Research Establishment (BRE) BIM Level 2 Certification (BRE, 2015) and the Organisational BIM Assessment Profile (CICRP, 2013) have contributed to the research agenda of BIM-AMs. Yet, there are no available publications on the use of these assessments in the Architecture, Engineering and Construction (AEC) industry. Other assessments were applied only to two studies as with the Owner's BIMCAT (Giel, 2013) and the Goal Driven Method for evaluation of BIM project (Lee and Won, 2014). Applying BIM-AMs to case studies will help not only to test and validate these assessments, but also to demonstrate how BIM is implemented across different projects, companies and geographies that have different social and cultural contexts.

Researchers on BIM-AMs have acknowledged the need and benefits of BIM-AMs. They explained how AMs assist AEC companies to measure their own successes and or failures (Succar, Sher and Williams, 2012), identify areas for improvement, compare their BIM progression with other AEC companies (CICRP, 2013) and help 'to realise the promise of BIM' (Kam, 2013). But with the lack of case study projects, it has been a challenge to provide a robust and thorough evidence of these benefits. Therefore, the application of BIM-AMs in the AEC industry is important to unlock the full potential of assessments; their opportunities and challenges.

This gap in literature is addressed here by applying one of available BIM-AMs, the BIM Maturity Measure (BIM-MM), to a sample of 1291 projects in Arup - a global firm of designers, planners, engineers, consultants and technical specialists. Through this application, the paper aims to highlight how the use of BIM-MM could contribute towards creating feedback loops and identifying best BIM practices in the built environment. The paper expands what is currently known about BIM maturity and builds on the small number of limited previous studies that apply BIM-AMs in the AEC industry.

LITERATURE REVIEW: BIM MEASUREMENT

When released in 2007, the aim of the NBIMS-CMM, the first developed BIM-AM, was 'to help users gauge their current maturity level, as well as plan for future maturity attainment goals through commonly accepted, standardised approach' (NIBS, 2007). Today, there are seventeen AMs with different aims, perspectives and evaluation focus (these assessments have different levels of similarities and differences). They have individually and collectively reflected a wide range of criteria such as the methods of data exchange, the level of development of model elements and the processes involved when implementing BIM.

To shift the research field of BIM maturity from theory to practice and to help AEC professionals managing BIM projects, organisations and policies, there is a need to apply AMs to live projects. This is a challenge that has been addressed by very few researchers. Amongst these researchers are Kam *et al*., (2013) of Stanford University who apply the VDC Scorecard to 130 projects 'to validate and inform the evaluation measures while demonstrating the scalability and repeatability of the scorecard framework and the value of a global knowledge base of BIM and VDC maturity to benchmark project performance.' The collected data were then analysed according to measured criteria, project phase and countries.

Another study that documents the application of an AM in practice is carried out by Berlo and Sebastian (2012) of TNO Built Environment and Geosciences in the Netherlands. In their study, the 'BIM Quick Scan' was applied in 130 companies. The tool was developed in 2009 in a form of an online questionnaire with almost 50 questions grouped into four

main sections. After applying this tool in the AEC industry, collected data were analysed to compare BIM maturity levels across the four sections of the BIM Quick Scan. These sections are: Organisation and Management, Mentality and Culture, information Structure and Information Flow, and Tools and Applications. Together, these sections help to evaluate BIM on the level of 'organisations', not on the level of projects as in the BIM-MM and the VDC Scorecard.

This paper contributes to these studies. It focuses on the application the BIM Maturity Measure (BIM-MM) to 1291 projects. The BIM-MM is one of the seven available AMs that evaluate BIM in 'projects'. It is practical, fast to complete, user-friendly and available freely online for other professionals to use - some assessments as the one provided by the BRE requires fees (BRE, 2015). Furthermore, the BIM-MM offers a comprehensive and balanced platform to measure BIM and reflects its interdisciplinary approach - some of the current BIM-AMs reflect one side of BIM as in NBIMS-CMM. BIM-MM constitutes of different measurement criteria that address the internal and external forces influencing the implementation of BIM (Figure 1). Internal forces reflect Arup's key BIM criteria such as Virtual Design Reviews and Common Data Environment, whilst external forces refer to client's drivers when implementing BIM i.e. Employer Information Requirements, Projects Procurement Route and BIM Contract.

Figure 2: Internal and external forces of BIM in BIM-MM

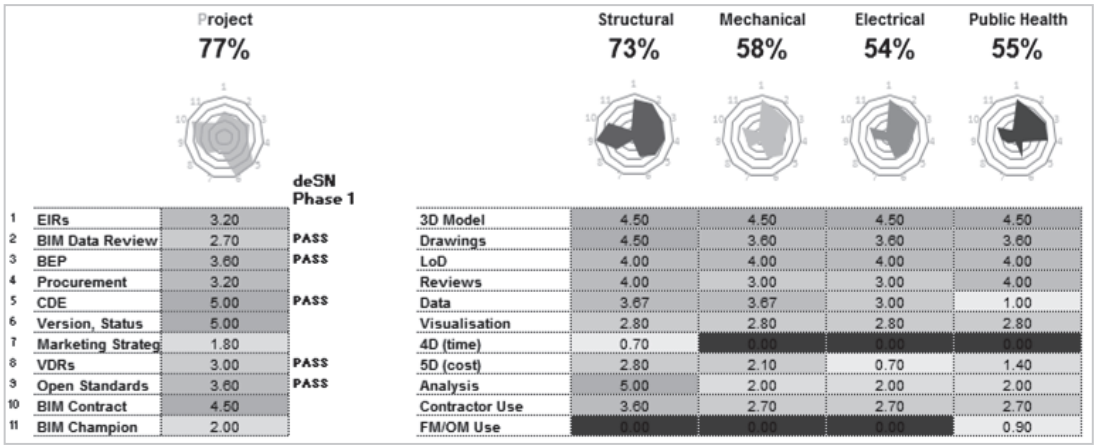
RESEARCH METHODS

This research relies on quantitative approach. It applies the BIM-MM to 1291 projects in Arup's five regions: Americas, Australasia, East Asia, Europe and UKMEA. These projects are widely varied with different types, size and phase. The BIM-MM was developed in Arup to assess the evolving nature of BIM and to create a common view of BIM best practice (Azzouz and Hill, 2017). It constitutes of over 20 critical criteria which covers two main parts:

1. Project: this first part of the BIM-MM assesses project wide processes and practices. It looks at the project from an overarching perspective rather than focusing on assessing BIM in a specific discipline involved in the project. Completion of this section results in the creation of Information Management Score (IM Score), left side of Figure 2.

2. Disciplines: this part assesses specific disciplines involved in the project such as architecture, mechanical and electrical disciplines, (right side of Figure 2). The assessment sheets of these disciplines are mostly similar, but each has a section for discipline specific criteria.

Together, the average scores of 'Project' and the assessed 'disciplines' gives a Primary Score of the project as a coherent whole.



Project 77%

1	EIRs	3.20		
2	BIM Data Review	2.70	PASS	
3	BEP	3.60	PASS	
4	Procurement	3.20		
5	CDE	5.00	PASS	
6	Version, Status	5.00		
7	Marketing Strateg	1.80		
8	VDRs	3.00	PASS	
9	Open Standards	3.60	PASS	
10	BIM Contract	4.50		
11	BIM Champion	2.00		

deSN Phase 1

	Structural 73%	Mechanical 58%	Electrical 54%	Public Health 55%
3D Model	4.50	4.50	4.50	4.50
Drawings	4.50	3.60	3.60	3.60
LoD	4.00	4.00	4.00	4.00
Reviews	4.00	3.00	3.00	4.00
Data	3.67	3.67	3.00	1.00
Visualisation	2.80	2.80	2.80	2.80
4D (time)	0.70	0.00	0.00	0.00
5D (cost)	2.80	2.10	0.70	1.40
Analysis	5.00	2.00	2.00	2.00
Contractor Use	3.60	2.70	2.70	2.70
FM/OM Use	0.00	0.00	0.00	0.90

Figure 2: A snapshot of the BIM-MM (two parts: project and disciplines)

Global BIM Maturity Initiative: Data Collection

As part of their BIM strategy, Arup has directed significant efforts towards BIM measurement. This has led to the development of the Global BIM Maturity Initiative to create a comprehensive overview of how BIM is implemented across projects, disciplines, groups and regions. Only between March and September 2016, the BIM-MM was applied to 1291 projects. Choosing projects to assess relies on a specific criteria and all projects that meet the criteria should be measured. Moreover, selecting which projects to measure is also influenced by projects' phase and status. Projects that are on hold, before concept, after site, or do not include any design services (such as consultancy and desktop research studies) are excluded.

To collect the data, the BIM Maturity Team (the authors) contacts project managers, BIM Champions and Group Leaders of all offices across Arup's regions - Arup has offices in more than 40 countries. Communication process is illustrated in Figure 3 that shows the two parallels of communication (A and B).

Managers of each project would then assess if the project should be measured or not. If yes, then they would submit the BIM-MM of the project, and if not, they identify the reason for exclusion. Once completed and submitted, the BIM-MM of each project will be sent automatically to one platform for analysis by the BIM Maturity team. Following the analysis, findings and reports are sent to all BIM Champions and Groups Leaders to use locally and get more insights on how BIM is applied in their group compared to other groups.

RESULTS: APPLYING THE BIM-MM IN PRACTICE

The collected data can be analysed and communicated differently according to the angle the analysis is considering. However, due to the scale of the dataset, only two points are addressed in this paper (1) the correlation between specific criteria and the overall score of projects, and (2) top ten BIM practices across the measured projects.

The Forces That Shape the Successful BIM Projects

There are different forces and influences that impact on the successful implementation of BIM in projects. These are both internal implemented by AEC businesses and external driven by the client. To explore these influences, the research investigates the correlation between different BIM criteria and the average overall score of projects. In particular, it focuses on the impact of the BIM Execution Plan (BEP) and the BIM Design Data Review (BDDR) on the overall scores.

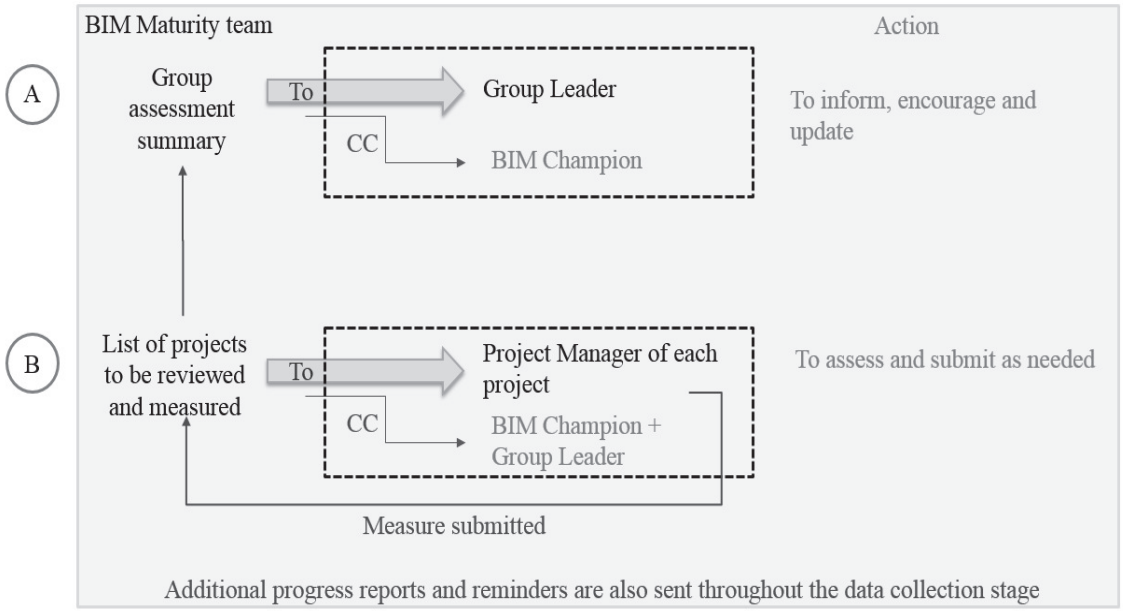


Figure 3: Communication process when collecting data

BEP refers to the formalisation of digital design goals and the specification of standards, roles, procedures and information exchange. BEP, as all the rest of criteria in BIM-MM, has six maturity levels which participants have to select one of them to define the current status of their projects. These levels evolve from level 0 where the criterion is not applied, to level 5 where the criterion is most optimised. BEP's maturity levels are:

- Level 0: No BEP.
- Level 1: Documented 'Traditional' Drawing / CAD Management Plan.
- Level 2: BEP created and used by Arup core disciplines.
- Level 3: BEP used by whole Arup design team.
- Level 4: Project-wide BEP driven by client information requirements and team collaboration needs.
- Level 5: Project-wide BEP based on defined information requirements cascaded through supply chain.

Observations of the findings show a juncture exists between efficient BEP and high overall scores of projects. As illustrated in Figure 4, average score of overall projects increases gradually when BEP maturity levels evolve. For instance, average overall IM Score with BEP Level 5 (68%) is over six times the average score of projects with no BEP (10%). Similar findings have been noted when looking at the correlation between BDDR and overall scores of projects.

Best BIM Practices

Through the application of the BIM-MM, best BIM practices can be identified. Across the 1291 assessed projects in this research, the Information Management (IM) Score of all top ten projects is above 80% (the highest is 93.4%). The IM Score focuses on the first part of the BIM-MM - 'Project' rather than concentrating on a specific discipline. IM Score reflects eleven criteria including (Table 1): 'Employer Information Requirements (EIRs)', 'BIM Design Data Review' (BDDR), 'BIM Execution Plan (BEP)', 'Project Procurement Route' (PPR), 'Common Data Environment' (CDE), 'Document/Model Referencing, Version Control and Status' (Doc Ref), 'Marketing Strategy' (knowledge sharing), 'Virtual Design Reviews' (VDR), 'Open Standard Deliverables' (OSD), 'BIM Contract' and 'BIM Champion'.

Each of the ten projects is a unique case study as projects are different in regards to scale, client, phase and type. However, despite these differences, the ten projects have relatively similar maturity levels for most of the evaluated criteria.

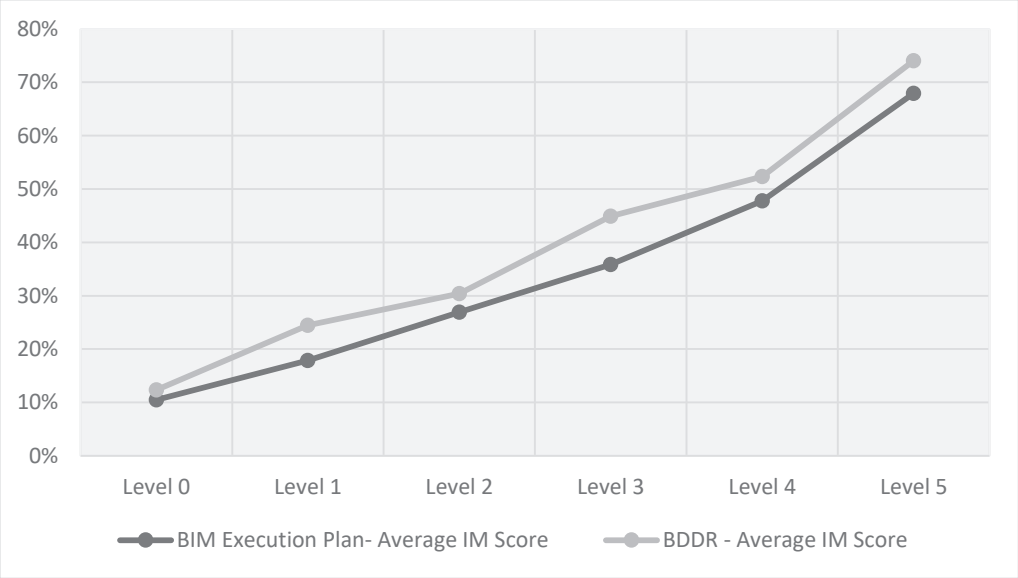


Figure 4: The correlation between BEP and the average overall score of projects

Table 1 shows the weights allocated to each measure in the ten projects. Common maturity levels are the highest in three criteria:

- Document, Model Referencing, Version and Status (Doc Ref), refers to good practice on projects and paramount when sharing models where the recipient needs to know what has changed and what it can be relied upon. Amongst the top ten projects, nine projects have Level 5. This means that these projects have 'project wide file naming, version control and status compliant with recognised BIM standard'. It is also important to note that this criterion has the highest average score when compared to the rest of the criteria across the ten projects (all ten projects are allocated to either Level 4 or 5 in this criteria).
- CDE, acts as a 'single source of truth' and facilitates the robust and controlled sharing and coordination of models, drawings, analyses, documents and data. Seven out of the ten projects have Leve 5 CDE, which means that 'client, designers and contractors are using a CDE to create and share work'.
- PPR, which refers to the consideration of BIM during procurement discussions with client, contractors and supply chain. In the top ten projects, seven have Level

5 PPR, which means that procurement strategy is developed to use BIM to create value through project optimisation.

- The top ten projects have high maturity levels. In each project, most evaluated BIM measures are allocated to Level 3 or higher (two exceptions are observed). All projects have BIM Champions who are guiding the teams to improve their BIM implementation and all projects have BIM contracts that define responsibilities across different engaged parties. So, the successful implementation of BIM in these projects is shaped by multiple integrated influences that reflect the internal forces of BIM within the organisation, and the external engagement of the client (all projects have BIM contracts and defined EIRs and PPRs). However, only two projects have low maturity levels in certain criteria (highlighted in blue in Table 1). These are in Projects 7, with BIM Contract Level 2 and Project 9 where there is no OSD in the project.

Table 1: Top ten projects and the weights of each measure

Project	EIRs	BDDR	BEP	PPR	CDE	Doc Ref	VDR	OSD	BIM Contract	BIM Champ	IM Score
1	4	4.5	4.5	4.0	4.0	5.0	5.0	3.6	4.5	5.0	92.4%
2	4	4.5	3.6	3.2	4.0	5.0	4.0	4.5	4.5	4.0	89.2%
3	3.2	2.7	3.6	4.0	5.0	5.0	5.0	4.5	3.6	5.0	87.3%
4	3.2	2.7	3.6	4.0	5.0	5.0	5.0	4.5	3.6	5.0	87.3%
5	4	4.5	4.5	4.0	5.0	4.0	4.0	3.6	4.5	4.0	85.9%
6	4	4.5	4.5	4.0	5.0	5.0	5.0	4.5	3.6	2.0	85.9%
7	4	4.5	4.5	4.0	4.0	5.0	4.0	3.6	1.8	4.0	85.3%
8	2.4	2.7	3.6	3.2	5.0	5.0	5.0	3.6	4.5	4.0	84.5%
9	4	4.5	4.5	3.2	5.0	5.0	5.0	0.0	3.6	5.0	82.4%
10	4	2.7	4.5	4.0	5.0	5.0	3.0	4.5	4.5	3.0	82.0%

DISCUSSION

'How to tell if the implementation of BIM is successful?' has been the subject of several research studies (Won and Lee, 2016; Arayici., 2011). In the last decade, seventeen AMs have emerged in academia and the AEC industry. Each of these assessments has different criteria to measure BIM (though some of them overlap with some common criteria); the BRE assessment, for instance, focuses on UK's Level 2 requirements and how BIM utilisation comply with the Government's strategy (including PAS 1192-2:2013) (BRE, 2015), the NBIMS-CMM focuses only on one facet of BIM, namely, information management (NIBS, 2007), whilst other methods, as the Virtual Design and Construction Scorecard (Kam *et al*., 2013), presents a more comprehensive approach when measuring BIM.

In the BIM-MM, multiple BIM perspectives are combined to reflect the internal and external influences influencing the BIM culture. However, it is crucial to investigate which the most critical criteria are contributing to the high overall score of projects. To address this point, this paper has focused on the correlation between BEP and BDDR and the overall score of projects. In addition, the correlation between the engagement of the BIM Champion and the overall score of projects was also investigated by the authors previously (Azzouz *et al*., 2016). What has been observed in this paper is that multiple

integrated elements lead to the successful implementation of BIM. Some of these elements, however, are more critical than the others.

It is difficult to compare the findings in this paper with previous studies as there is a shortage of publications on the application of BIM-AMs in the AEC industry. The study of Berlo and Sebastian (2012), mentioned in the literature review, evaluates BIM across 'organisations' not 'projects'. However, they conclude in their study that average BIM score is the highest in 'Information Structure and Information Flow' (one of the four main areas covered in the BIM Quick Scan). In our study, the highest average score amongst criteria is found in 'Document, Model Referencing, Version and Status' when looking at the top ten projects.

Due to the scale of the collected data, it is possible to compare BIM maturity levels between different countries (this has already been done by the authors and will be published in future work). Comparisons would help the business to better understand how BIM policies, technologies and processes are being utilised –similarly or differently- across different cultures and geographies. By doing so, areas of strengths and weaknesses can be identified in each region, and knowledge can be transferred between regions, groups, teams and disciplines. The findings would provide feedback for continual improvement when implementing BIM. Comparing maturity across geographies can be found in the work of Kam (2013) when applying the VDC Scorecard to 130 projects (one of the very few studies that focus on applying BIM-AMs in the AEC industry). In Kam's study, a comparison is made between different countries and finds 'Technology' to have the highest scores amongst the four main sections of the VDC Scorecard (Planning, Adoption, Technology and Performance).

CONCLUSION

One of the most obvious aims of AMs is to 'measure' BIM across projects, organisations, teams and individuals. However, it is important to note that BIM-AMs entail more than evaluation. AMs play a significant role in focusing people and resources on specific elements of BIM, they engender greater levels of communications across different levels of the business and help project managers and project teams to clarify what 'BIM' is and what 'good' looks like. With the uncertainty surrounding BIM definition, and the lack of guidance on how to implement it, it is seen that the BIM-MM can help to create a common understanding of BIM and its critical elements.

Since its release, the BIM-MM has attracted significant interest internally within Arup and externally. Internally, the BIM-MM has not only been helpful to the higher management level, but also at the operational level. It has been used by several projects managers as a method to communicate BIM strategies with different members of their teams including technicians. Furthermore, group leaders and BIM Champions have been using the overall outcomes to track their current BIM strategies and inform future directions. Externally, several researchers and professionals have expressed their interest in the BIM-MM and its findings. Some AEC companies are already using the tool in their businesses.

Arup is using the BIM-MM as a platform to drive innovation in their business. The wide implementation of the BIM-MM is in its second year. Further analysis has been carried out to compare BIM maturity levels across regions, groups, disciplines and teams. Data has been classified by project stage, client type, income, geography and project team. This analysis is of vital importance to illustrate the wider picture of BIM implementation

globally. It is also critical to learn lessons and transfer knowledge and skills between different teams and regions.

With the emergence of BIM-AMs, research across a range of areas will evolve; diverse measures will be added, further implementation of AMs in practice will be undertaken, more efforts will be directed towards transforming the outcomes into informative source of feedback and new optimised AMs will be created. This will require building bridges between professionals, academics and policy-makers.

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