USING A BIM MATURITY MATRIX TO INFORM THE DEVELOPMENT OF AEC INTEGRATED CURRICULA

Shan-Ying Shih[1*], Willy Sher[2] and Anthony Williams[3]

1. University of Newcastle, shan-ying.shih@uon.edu.au* Corresponding author
2. University of Newcastle, willy.sher@newcastle.edu.au
3. University of Newcastle, tony.williams@newcastle.edu.au

ABSTRACT

This paper draws on two case studies - an architecture practice transiting from 2D to BIM (Arayici et al. 2011) and a concert and congress centre (Anita 2010) - to highlight the benefits that BIM provides to architecture, engineering and construction (AEC) disciplines. It evaluates these case studies against the criteria provided in Succar's (2010a) BIM maturity matrix (MM), which offers a means for organisations to assess and benchmark the BIM preparedness of their teams and organizations. Our analyses indicate that the interdisciplinary use of BIM supports activities from design to construction and improves knowledge-sharing for collaboration within each discipline. Furthermore, Succar's (2010a) MM provides support for future studies in establishing AEC integrated curricula to advance students' collaborative abilities using BIM to meet the requirements of industry.

Keywords: BIM, BIM maturity matrix, Collaboration, AEC integrated Curricula

INTRODUCTION

Several studies of traditional design and construction processes have indicated that these are inefficient (McCuen et al. 2011). Accordingly, interest in Building Information Models (BIM) has increasingly gained weight over the past 30 years (Wong et al. 2011). This trend not only encourages employers to consider candidates with BIM abilities over those who lack BIM knowledge (Azhar et al. 2008) but encourages BIM to be integrated into academic curricula (Taylor et al. 2008).

BIM is emerging as an innovative evolution rather than an improvement revolution within the Architecture, Engineering and Construction (AEC) industries (Pollock 2010). As such, it represents a combination of interactive policies, communicative processes and technological implementations, and provides a platform supporting project data from different disciplines in digital format (Babič et al. 2010; Grilo & Jardim-Goncalves 2010; Succar 2009). However, a misconception held by some practitioners is that implementing BIM is similar to implementing 2D CAD (Babič et al. 2010; Azhar et al. 2008). Succar (2010a) argues that this is not the case and proposes a comprehensive framework that allows those involved to gauge how well prepared they are for progressing from single, stand-alone users of BIM, to members of multi-disciplinary teams, collaborating with colleagues located in different parts of the world.

This paper draws on two case studies to highlight the benefits that BIM provides to AEC disciplines. It evaluates these case studies against the criteria provided in Succar's (2010a)

BIM maturity matrix (MM). It first of all briefly describes Succar's MM followed by the case studies, which are then evaluated against the MM. Finally, the paper identifies the commonalities between the cases and explores how these findings may be used to inform the development of BIM courses in relevant university degrees.

SUCCAR'S BIM MATURITY MATRIX (MM)

The functions of available Capability Maturity Models are specific to either information technology industries or procedures of an implementation (Succar 2010a). There are few comprehensive maturity models that can be applied to BIM except for Succar's MM. This MM provides a means for organisations to assess and benchmark the BIM preparedness of AEC teams and organizations. It offers a measurement tool that tracks their progress and assesses staff competencies and productivity improvements. The content of Succar's MM is a multi-functional assessment system which integrates theoretical and time-tested maturity models. Space does not permit a detailed description of the MM. For a fuller explanation, please see Succar (2010a) and Succar, Sher and Williams (2012 in press). The five main components of the MM and its fundamental concepts are described as follows.

Component#1 BIM organisational scales: To allow BIM performance assessments to respect the diversity of markets, disciplines and company sizes, Succar (2010b) developed an organisational scale (OScale) as shown Figure 1.
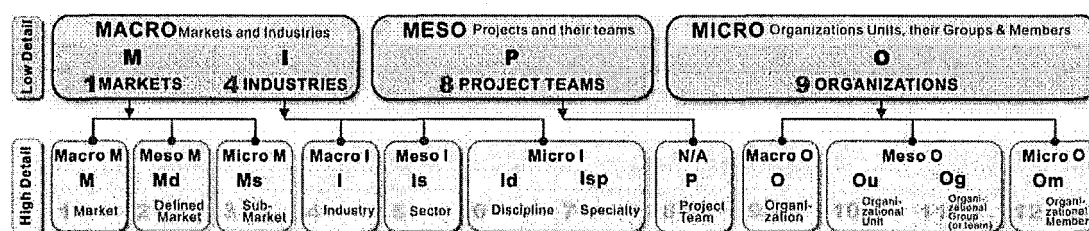

Figure 1: Part of Organisational Scale
(Adapted from: Succar et al. 2010b; 2012)

Component#2 BIM competency sets: According to Succar (2010b), a BIM Competency Set is not only a hierarchical cluster of respective competencies identified for the purposes of BIM implementation and assessment but also a direct reflection of BIM requirements and deliverables. These can be grouped into three sets – Technology, Process and Policy as shown in Figure 2.
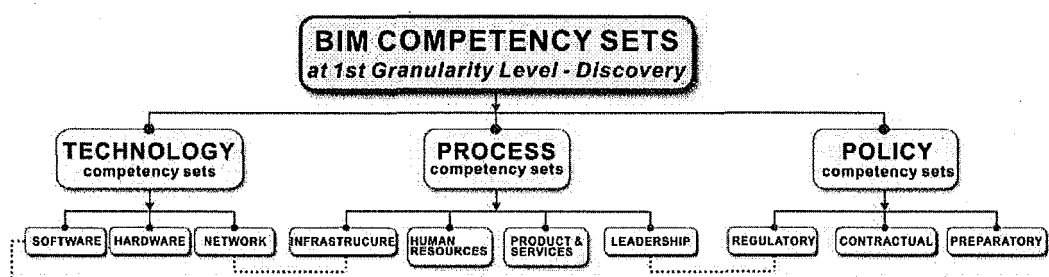

Figure 2. Part of BIM Competency Sets
(Adapted from: Succar et al. (2010b; 2012)

Component#3 BIM granularity levels: To strengthen BIM Capability and Maturity assessments and to increase their flexibility, Succar (2010b) developed a Granularity "filter" with four Granularity Levels (GLevels) as illustrated in Table 1. Progression from lower to higher levels of granularity indicates an increase in (i) assessment breadth, (ii) scoring details, (iii) formality and (iv) assessor specialisation.

Table 1: part of BIM Competency Granularity Levels

Glevel Num	1	2	3	4
Glevel Name	Discovery	Evaluation	Certification	Auditing
Description	A low detail assessment used for basic and semi-formal discovery of BIM Capability and Maturity. Discovery assessments yield a basic numerical score.	A more detailed assessment of BIM Capability and Maturity. Evaluation assessments yield a detailed numerical score.	A highly-detailed appraisal of those Competency Areas applicable across disciplines, markets and sectors. Certification appraisal is used for Structured (Staged) Capability and Maturity and yields a formal, Named Maturity Level.	The most comprehensive appraisal...In addition to competencies covered under Certification, Auditing appraises detailed Competency Areas including those specific to a market, discipline or a sector. Audits are highly customisable, suitable for Nonstructured (Continuous) Capability and Maturity and yield a Named Maturity Level plus a Numerical Maturity Score for each Competency Area audited.

(Adapted from: Succar et al. (2010b; 2012)

Component#4 BIM capability stages: BIM Capability Stages describe how practitioners progress from first time naïve users of BIM to members of multi-disciplinary collaborative design teams. These stages describe the steps of BIM implementation and technology that need to be traversed to progress to succeeding levels. They describe the minimum requirements of each stage and also define the major milestones that need to be reached by practitioners. BIM stages include three stages and four steps (Figure 3).
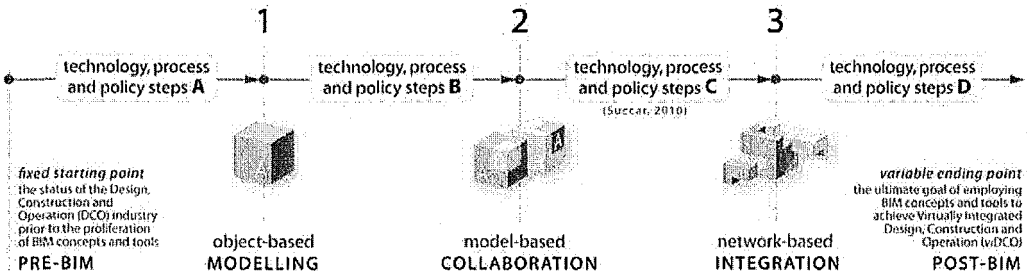

Figure. 3 Step Sets leading to or separating BIM Stages.
(Adapted from: Succar et al. (2010b; 2012)

Component#5 BIM maturity levels: BIM Maturity is chiefly concerned with the quality, repeatability and degree of value within a BIM Capability Stage and is divided into five levels: (a) Initial/Ad-hoc (b) Defined (c) Managed (d) Integrated and (e) Optimised .
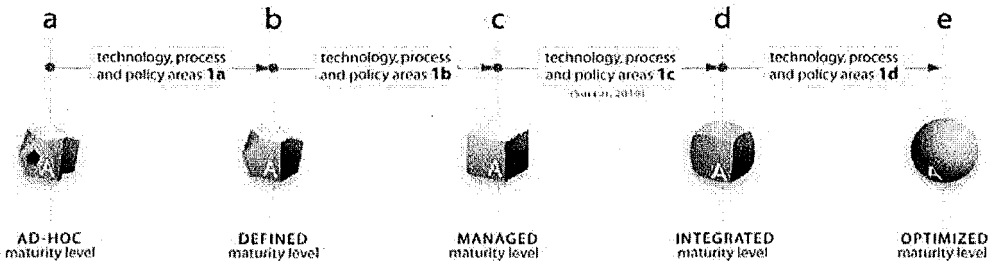

Figure 4. Building Information Modelling Maturity Levels at BIM Stage 1
(Adapted from: Succar et al. (2010b; 2012)

Applying the five assessment components

Assessment of the five BIM MM components can be conducted in multiple combinations of Capability, Maturity, Competency, Organisational Scale and Granularity. To manage all possible configurations, Succar (2010a) developed a workflow (Fig. 5). This workflow is useful for evaluating the functional and organizational capacity of BIM implementation against a theoretical and empirical complete BIM MM. In addition to being an effective indicator of the state of BIM implementation, Succar's MM provides AEC senior stakeholders with a strategic view of the developments of BIM and trends of entire building industries.
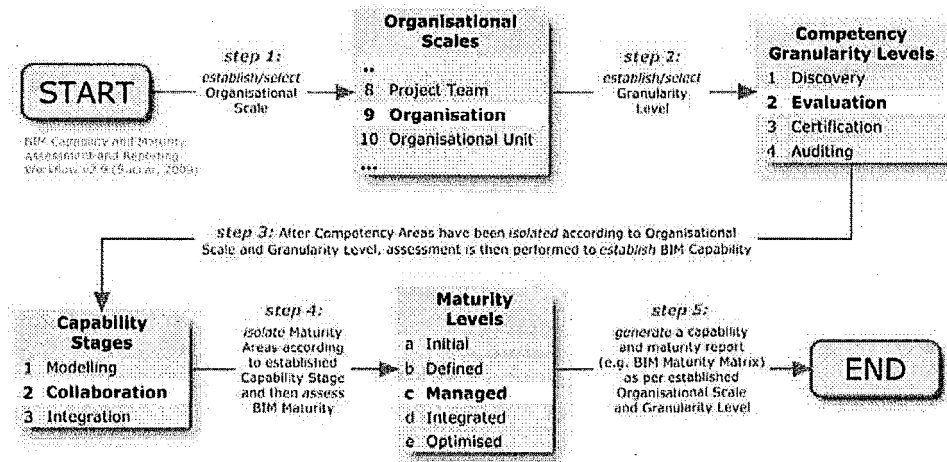
Figure. 5 BIM Capability and Maturity Assessment and Reporting Workflow Diagram (Adapted from: Succar et al. (2010b; 2012)

INDUSTRIAL CASE STUDIES

The remainder of this paper maps and discusses two BIM implementations (presented in published case studies) against Succar's (2010a) MM. Analysis of the case studies allows commonalities to be identified, and has enabled us to offer some preliminary generalisations about the manner in which AEC professionals collaborate when using BIM. It should be noted that the focus and emphasis of the case studies varied, and that some did not provide all the information called for in Succar's (2010a) MM. In light of the scarcity of studies about BIM implementations, we argue that our observations contribute to the body of knowledge about this topic.

Case study#1 – Knowledge Transfer Partnership (KTP) Project (Arayici et al. 2011)

This BIM implementation was executed through a Knowledge Transfer Partnership (KTP) project between the University of Salford (US) and John McCall's Architects (JMA), investigating the manner in which JMA transited from traditional 2D CAD to BIM. This transition comprised BIM explorations, decision-making as well as the promotion of BIM

awareness and abilities. The whole process can be categorized and highlighted in the following three topics:

BIM Introduction: Instead of adopting a top-down approach, a bottom-up approach was used to increase JMA's awareness of BIM in the introduction process. In this context, bottom-up learning implies the progression of implicit knowledge to explicit knowledge, while top-down learning implies the reverse (Sun et al. 2001)

BIM Database: A Project Support Information (PSI) database was developed by integrating all information from each project as well as for all current and future projects. It was improved in response to the feedback and requirements of JMA staff.

BIM Regulations: A guidance document was developed to describe the processes and procedures for using BIM libraries. It helped users to understand the concept of BIM, the availability of libraries and resources, and the expectation about how different types of building should be modelled at JMA. Furthermore, it informed the processes and procedures to be adopted when tasks changed and / or when new staff were appointed.

Case Study#2 – Concert and Congress Centre (CCC) Project (Anita 2010)

The Concert and Congress Centre (CCC) project was undertaken in Reykjavik, Iceland between 2005 and 2010. This study helped understand the deficiencies of 2D tools and the advantages of BIM within the design process. Moreover, it identified correlations between factors that encouraged and those which hindered individuals, teams and organizations, as well as those which influenced interdisciplinary use of BIM. These may be classified and described as follows:

Individual: 2D design work is argued to be intuitive for architects and engineers (AE) but BIM requires AE to have BIM skills and building-related knowledge. This results in solutions that integrate information-aided simulation and calculation models. However, individuals' lack of awareness of and ability in BIM leads to inefficient design activities (e.g. repetition of activities by engineers and draftspeople).

Team: AEC designers need to agree on a collaborative IT platform. Use of different tools by teams and disciplines will result time-consuming and purposeless communication in group meetings. Moreover, improper accesses can lead to fragmented information sharing and low productivity during design processes.

Organization: Collaborative activities in dynamic design environments are "cyclic" rather than linear. This means that individuals/teams may refer to and / or be referred to incorrect information unless this cyclical collaboration is effectively facilitated. Hence, a regulative document plays a decisive role in assuring accuracy and quality. The results of inadequate regulation include chains of incorrect decisions as well as a wasting of time and money, as well as depletion of morale.

Assessment against Succar's MM

The two case studies described above provide information about introducing BIM, BIM adoption, as well as individual and team challenges between different disciplines. Selected data from these studies is presented in the matrix shown in Table 2. This shows the level of granularity with which each competency set was evaluated.

Table 2. Maturity Discovery

BIM Maturity Matrix		KTP-Project					CCC-Project				
Assessment at Granularity Level 1		A	B	C	D	E	A	B	C	D	E
Technology	Software			●				●			
	Hardware	–	–	–	–	–	–	–	–	–	–
	Network			●			●				
Process	Leadership		●				●				
	Human Resources		●					●			
	Infrastructure		●				●				
	Products & Services	–	–	–	–	–	–	–	–	–	–
Policy	Contractual		●					●			
	Regulatory		●					●			
	Preparatory	–	–	–	–	–	–	–	–	–	–
Stage	Collaboration	●(2)					●(1)				
Scale	Organisation			●(9)				●(8)			

A=Initial, B=Defined, C=Managed, D=Integrated, E=Optimised
—=Information Unavailable
Collaboration (1)=Object-based Modelling, (2)=Modelling-based Collaboration
Organization (8)=Project teams, (9)=Organizations

Technology: The KTP-project indicated that the BIM tools selected by JMA aligned with their requirements. Comparably, the collaborative methods of the CCC-project were separate within the project teams/organization. In both the KTP and the CCC projects, designers upgraded from 2D drawings to 3D visualization. This also improved their ability to discover design errors before construction and enhanced the manner in which multiple disciplines could work together simultaneously.

Process: The BIM roles adopted in the KTP and CCC-projects were informally defined and teams were formed accordingly. However, BIM knowledge is typically shared informally. On the CCC-project BIM was implemented without guiding strategies, whereas JMA staff shared and recognised BIM knowledge. In the KTP-project, BIM knowledge was seen as an asset, and senior leaders held a common vision about BIM implementation.

Policy: The PSI system of the KTP-project evolved by integrating all information for all current and future projects, and facilitated lean improvements by eliminating waste. Additionally, a guidance manual explaining the libraries and resources was available. In contrast to the KTP-project, the CCC-project provided no BIM guidelines, regulations or modelling standards.

Stage: Modelling-based collaboration of the KTP-project and objected-based modelling of the CCC-project were both in the initial stage. The interaction, trust and respect inherent in BIM collaboration still needed time to develop in both cases.

Scale: BIM leadership of the KTP-project was established and different roles within the implementation process were defined. On the other hand, stakeholders of the CCC-project thought beyond a single project. Collaboration protocols between project members were sparsely defined and documented.

CHALLENGES AND FUTURE WORK

This paper has explored the challenges of implementing BIM in multi-disciplinary environments through the use of Succar's MM. Our intention is to draw of these and other findings to inform the development of undergraduate curricula so that students are better prepared for their future workplace experiences in the AEC professions. Succar's MM has been used to identify the requirements of AEC disciplines and how these might be embedded within AEC curricula. If students are to be equipped to operate in mature BIM environments, they need to experience curricula that replicate collaborative real-world practices. This implies that BIM courses need to be delivered to multi-disciplinary cohorts (including, for example, students in architecture, engineering and construction management). Securing individual discipline's commitment to such an approach is likely to be challenging. However, industry is already engaging in these integrated work practices and it is incumbent on universities to prepare students for the challenges they will face.

A finding from the two case studies is that the role of education or of a profession in introducing BIM is important. The introduction of BIM needs to be implemented more systematically and gradually because it strongly affects the later stages such as awareness and abilities training, knowledge sharing and source collecting. In other words, the level of educators' BIM ability and knowledge must be able to meet the industrial requirements Succar's MM identifies. It significantly impacts students' perceptions and applications of collaboration using BIM. Not only is this an issue for educators, there are challenges regarding the size of group, time and location, equipment and materials for future study.

CONCLUSION

The purpose of this paper is to evaluate two case studies of the manner in which BIM has been implemented against Succar's (2010a) MM. The MM set up criteria to not only help evaluate the level of BIM implemented for each AEC individual, team and organisation, but also to provide clear directions and suggestions for improving capabilities of using BIM. Furthermore, it highlights the potential for future studies in establishing AEC integrated curricula and advancing students' collaborative abilities and competencies using BIM for their future workplaces (Kalin 2012).

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