The Five Components of BIM Performance Measurement

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Abstract

Building Information Modelling (BIM) is an expansive knowledge domain within the Design, Construction and Operation (DCO) industry[1]. The voluminous possibilities attributed to BIM represent an array of challenges that can be met through a systematic research and delivery framework spawning a set of performance assessment and improvement metrics. This paper identifies five complementary components specifically developed to enable such assessment: [1] BIM Capability Stages representing transformational milestones along the implementation continuum [2] BIM Maturity Levels representing the quality, predictability and variability within BIM Stages, [3] BIM Competencies representing incremental progressions towards and improvements within BIM Stages, [4] Organisational Scales representing the diversity of markets, disciplines and company sizes and [5] Granularity Levels enabling highly-targeted yet flexible performance analyses ranging from informal self-assessment to high-detail, formal organisational audits. This paper explores these complementary components and positions them as a systematic method to understand BIM performance and to enable its assessment and improvement.

Keywords: Building Information Modelling, Performance Assessment and Improvement, Capability and Maturity Models

[1] There is no widely used term-definition which is equally representative of all planning-to-demolition activities within the construction industry. The author opted – after experimenting with many available acronyms like AEC, AECO, AECOO and AEC/FM - to adopt DCO as a preferred acronym as it builds upon the three major project lifecycle phases (Succar, 2009a).

1. Building Information Modelling: a brief introduction

Building Information Modelling (BIM) is a set of interacting policies, processes and technologies (Succar, 2009a) generating a "methodology to manage the essential building design and project data in digital format throughout the building's life-cycle" (Penttilä, 2006). This definition is one of tens of attempts to delimit the BIM domain which continues to expand in coverage and connotation. It is important – if we acknowledge BIM's value to the DCO industry and are inclined to favour its systemic adoption - to identify the domain's knowledge structures, internal dynamics and implementation requirements.

Some signs of the proliferation of BIM

There are many signs that the use of Building Information Modelling tools and processes is reaching a tipping point in some markets[2]. An increasing number of large institutional clients[3] - within the US for example - now stipulate object-based 3D models as the medium for accepting project submissions. Other signs include the abundance of BIM-specific software tools, books[4], blogs[5], tweets[6], tags[7] and reports from trusted market watchers[8].

Issues arising from the proliferation of BIM

The abundance of industry discussions and academic literature professing the ability of BIM methodologies to increase productivity has not yet been coupled with the availability of metrics and knowledge tools to reliably measure this productivity. Also, organisations attempting to *generate new* or *enhance existing* BIM deliverables can find little guidance towards identifying and prioritizing their respective requirements. This mismatch between *expected BIM deliverables* and *unforeseen BIM requirement*s increases the risks, costs and difficulties associated with BIM implementation, allows the proliferation of 'BIM wash' – falsely professing the ability to deliver BIM services or products - and prevents industry players from achieving their BIM potential.

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[2] Refer to "Interoperability in the Construction Industry SmartMarket Report", a review of the research conducted by McGraw-Hill Construction Analytics during late-Spring 2007 (http://bit.ly/SMarket07) and McGraw-Hill's 2009 report "The Business Value of BIM: Getting Building Information Modeling to the Bottom Line" (http://bit.ly/SMarket09 - PDF 4MBs)

[3] Refer to relevant announcements by the US State of Wisconsin – Department of Administration (http://bit.ly/WisconsinBIM) and Texas Facilities Commission (http://bit.ly/TexasBIM) among others.

[4] Refer to basic search results like http://bit.ly/GoogleBooks_BIM or http://bit.ly/AmazonBooks_BIM

[5] Refer to blog search engine results similar to http://bit.ly/GoogleBlogs_BIM

[6] Refer to Tweet searches for the term BIM and/or IPD http://twitter.com/#search?q=bim%20ipd

[7] Refer to searches on Delicious http://bit.ly/Delicious_BIM and Digg http://digg.com/search?s=BIM

[8] Examples include the Building Design + Construction's Top 170 BIM Adopters ranking; part of the 2009 Giants 300 survey (http://bit.ly/Giants09).

2. The need for BIM performance metrics

The development of BIM performance metrics is a pre-requisite for BIM performance improvement. On one hand and without metrics, teams and organisations are unable to consistently measure their own successes or failures. Without measurement, no meaningful performance improvements may be achieved, financial investments may be misplaced and much efficiency may be lost. On the other hand and with the availability of measurement metrics, teams and organisations will be able to assess their own BIM competencies or compare them against an industry benchmark. Also, a valid set of BIM metrics will lay the foundations for a formal certification system which can be employed by industry leaders, governmental authorities and large facility owners/procurers to pre-select BIM service providers and attest to the quality of their deliverables.

2.1 Developing metrics and benchmarks

While it is important to develop metrics and benchmarks for BIM performance assessment, it is equally important for those metrics to be consistently accurate and adaptable to different industry sectors and organisational sizes. Much insight can be gained from performance measurement tools developed for other industries (Succar, 2009b); however, it is impractical to rely on any tool which is not specifically designed to measure key BIM deliverables/requirements or is not equally applicable across the construction supply chain.

This paper discusses a set of metrics purposefully developed to measure the specifics of BIM performance. To increase their reliability, adoptability and usability by different stakeholders, the metrics have been tailored to conform to a set of guiding principles partially discussed below:

Accurate: metrics are clear, falsifiable and allow accurate, repeatable assessment.

Applicable: metrics can be utilised by all stakeholders across Project Lifecycle Phases.

Attainable: benchmarks can be achieved through progressive accumulation of defined actions.

Consistent: when conducted by different assessors, measurements still yield the same results.

Cumulative: benchmarks are set as logical progressions; deliverables from one benchmark act as prerequisites for another.

Flexible: assessments can be performed across markets, organisational scales and their subdivisions.

Informative: measurements provide “feedback for improvement” and “guidance for next steps” (Nightingale and Mize, 2002).

Neutral: measurements do not prejudice proprietary, non-proprietary, closed, open, free or commercial solutions or schemata.

Specific: metrics are well defined and serve industry-specific assessment purposes.

Usable: metrics are intuitive and can be easily employed to assess BIM performance.

Based on the above guiding principles, the sections below introduce a set of complementary knowledge components which enable BIM performance assessment and facilitate its improvement:

3. Assessment components

There are five BIM Framework components (Succar, 2009a, Succar, 2009b) required to enable accurate and consistent BIM performance measurement:

3.1 BIM Capability Stages

BIM Capability is the basic ability to perform a task or deliver a BIM service/product. BIM Capability Stages (or BIM Stages) define the *minimum BIM requirements* - the major milestones that need to be reached by teams or organisations as they implement BIM technologies and concepts. Three BIM Stages separate 'pre-BIM', a fixed starting point representing *industry status before* BIM implementation, from 'post-BIM', a variable ending point representing the *ever evolving goal*[9] of employing *virtually integrated* Design, Construction and Operation (*vi*DCO) tools and concepts:

BIM Stage 1: object-based modelling

BIM Stage 2: model-based collaboration

BIM Stage 3: network-based integration

BIM Stages are defined by their *minimum* requirements. As an example, for an organisation to be considered at BIM Capability Stage 1, it needs to have deployed an object-based modelling software tool similar to ArchiCAD, Revit, Tekla or Constructor. Similarly for BIM Capability Stage 2, an organisation needs to be part of a multidisciplinary 'model-based' collaborative project. To be considered at BIM Capability Stage 3, an organisation needs to be using a network-based solution (like model servers or BIMSaaS[10]) to share object-based models with at least two other disciplines. Each of the three Capability Stages is further subdivided into Competency Steps. What differentiates stages from steps is that stages are *transformational* or *radical* changes while steps are *incremental* ones (Henderson and Clark, 1990) (Taylor and Levitt, 2005). The collection of steps required when working towards or within a BIM Stage - across the continuum from pre-BIM to post-BIM - is driven by different *perquisites for*, *challenges within* and *deliverables of* each BIM Stage. In addition to their type (the Competency Set they belong to – refer Section 3.3 below), BIM Steps can be also identified according to their location on the continuum (Fig. 1):

A Steps: from pre-BIM Status leading to BIM Stage 1

B Steps: from BIM Stage 1 leading towards BIM Stage 2

C Steps from BIM Stage 2 leading towards BIM Stage 3

D Steps from BIM Stage 3 leading towards post-BIM

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[9] The author has stopped using the term Integrated Project Delivery (IPD) to represent the *ultimate goal of* implementing BIM (AIA, 2007) to prevent any confusion with the term's evolving contractual connotations.

[10] Building Information Modelling Software As A Service, refer to http://bit.ly/BIMbits & http://bit.ly/BIMaaS

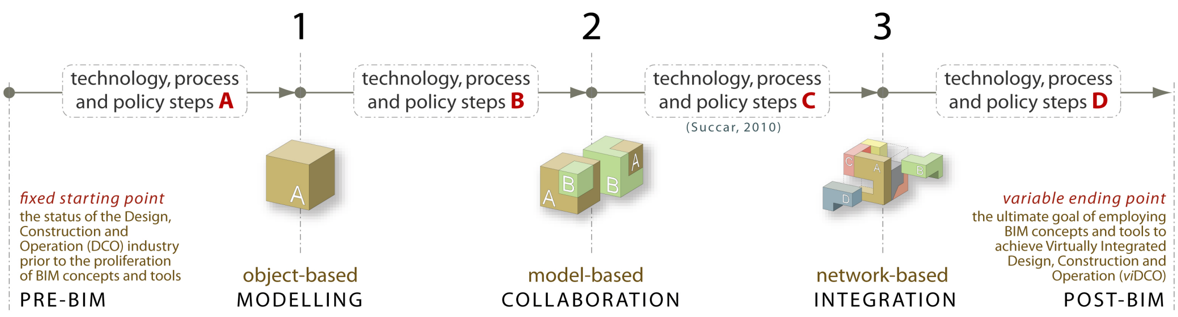

Fig. 1. Step Sets leading to or separating BIM Stages – v1.1

3.2 BIM Maturity Levels

The term 'BIM Maturity' refers to the quality, repeatability and degree of excellence within a BIM Capability. That is, as opposed to 'capability' which denotes a *minimum ability* (refer to Section 3.1), 'maturity' denotes *the extent of that ability* in performing a task or delivering a BIM service/product. BIM Maturity's benchmarks are performance improvement milestones (or levels) that teams and organisations aspire to or work towards. In general, the progression from low to higher levels of maturity indicate (i) better control through minimising variations between performance targets and actual results, (ii) better predictability and forecasting by lowering variability in competency, performance and costs, and (iii) greater effectiveness in reaching defined goals and setting new more ambitious ones (Lockamy III and McCormack, 2004) (McCormack, Ladeira and Oliveira, 2008).

The concept of BIM Maturity has been adopted from SEI's Capability Maturity Model (SEI, 2008), a process improvement framework initially intended as a tool to evaluate the ability of government contractors to deliver a software project. CMM originated in the field of quality management (Crosby, 1979) and was later developed in 1980s for the benefit of the US Department of Defence (Hutchinson and Finnemore, 1999). It's successor, the more comprehensive Capability Maturity Model Integration (CMMI), continues to be developed and extended by the Software Engineering Institute, Carnegie Mellon University. There are also other varieties of CMMs across many industries (Succar, 2009b) but they are all - in essence – specialised frameworks to assist stakeholders in improving their capability (Jaco, 2004) and achieving process improvement benefits. These include increased productivity and Return On Investment (ROI) as well as reduced costs and post-delivery defects (Hutchinson and Finnemore, 1999).

Maturity models are typically composed of multiple maturity *levels* - process improvement 'building blocks' or 'components' (Paulk, Weber, Garcia, Chrissis and Bush, 1993). When the requirements of each level are satisfied, implementers can then build on top of established components to attempt 'higher' maturity. Although CMMs are not without their detractors (Weinberg, 1993) (Jones, 1994) (Bach, 1994), research conducted within other industries have already identified the correlation between improving process maturity and business performance (Lockamy III and McCormack, 2004).

The ‘original’ software industry CMM, however, is not applicable to the construction industry as it does not address supply chain issues, and its maturity levels do not account for the different phases of a project lifecycle (Sarshar, Haigh, Finnemore, Aouad, Barrett, Baldry and Sexton, 2000). Although there are other efforts – derived from CMM - which focus on the construction industry (Succar, 2009b), there is no comprehensive maturity model/index that can be applied to BIM, its implementation stages, players, deliverables or its effect on project lifecycle phases.

To address this shortfall, the BIM Maturity Index (BIMMI) has been developed by analysing and then integrating several maturity models used across different industries (Succar, 2009b). It has been customised to reflect the specifics of BIM capability, implementation requirements, performance targets and quality management. The BIM Maturity Index has five distinct levels: (**a**) **Initial/ Ad-hoc**, (**b**) **Defined**, (**c**) **Managed**, (**d**) **Integrated** and (**e**) **Optimised** (Fig. 2). Level names have been chosen through comparing terminology used by many maturity models followed by selecting those easily understandable by DCO stakeholders and able to reflect increasing BIM maturity from ad-hoc to continuous improvement (Succar, 2009b).

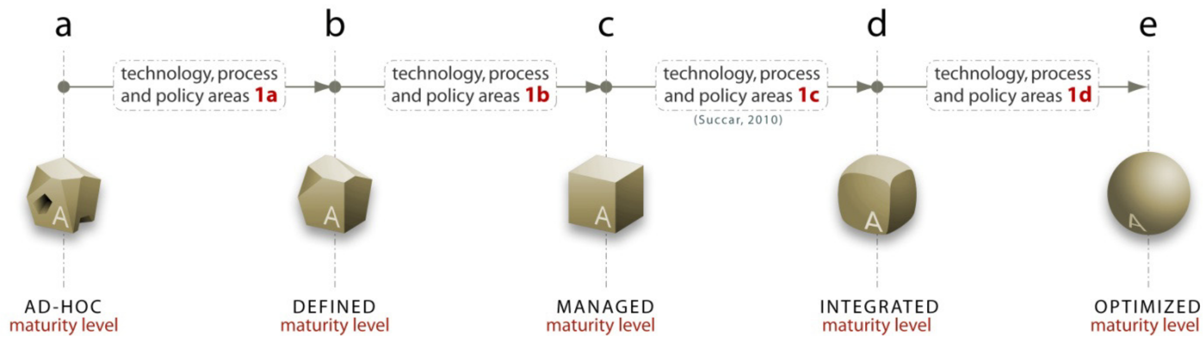

Fig. 2. Building Information Modelling Maturity Levels at BIM Stage 1

3.3 BIM Competency Sets

A BIM Competency Set is a hierarchical collection of individual competencies identified for the purposes of BIM implementation and assessment. The term Competency – as used by the author - does not necessarily reflect human abilities but a generic set of abilities suitable for implementing as well as assessing BIM Capability and/or Maturity. If a BIM Competency Set is used for active implementation, they are referred to as BIM Implementation Steps. However, if used for assessing existing implementations, they are referred to as BIM Assessment Areas. The below diagram (Fig. 3) reflects how the BIM Framework (Succar, 2009a) generates BIM Competency Sets out of multiple Fields[11], Stages and Lenses[12]:

[11] BIM Fields are conceptual clusters of domain players interacting and overlapping within the DCO industry (Succar, 2009a). There are three BIM Field Types (Technology, Process and Policy) and three Field Components (Players, Requirements and Deliverables).

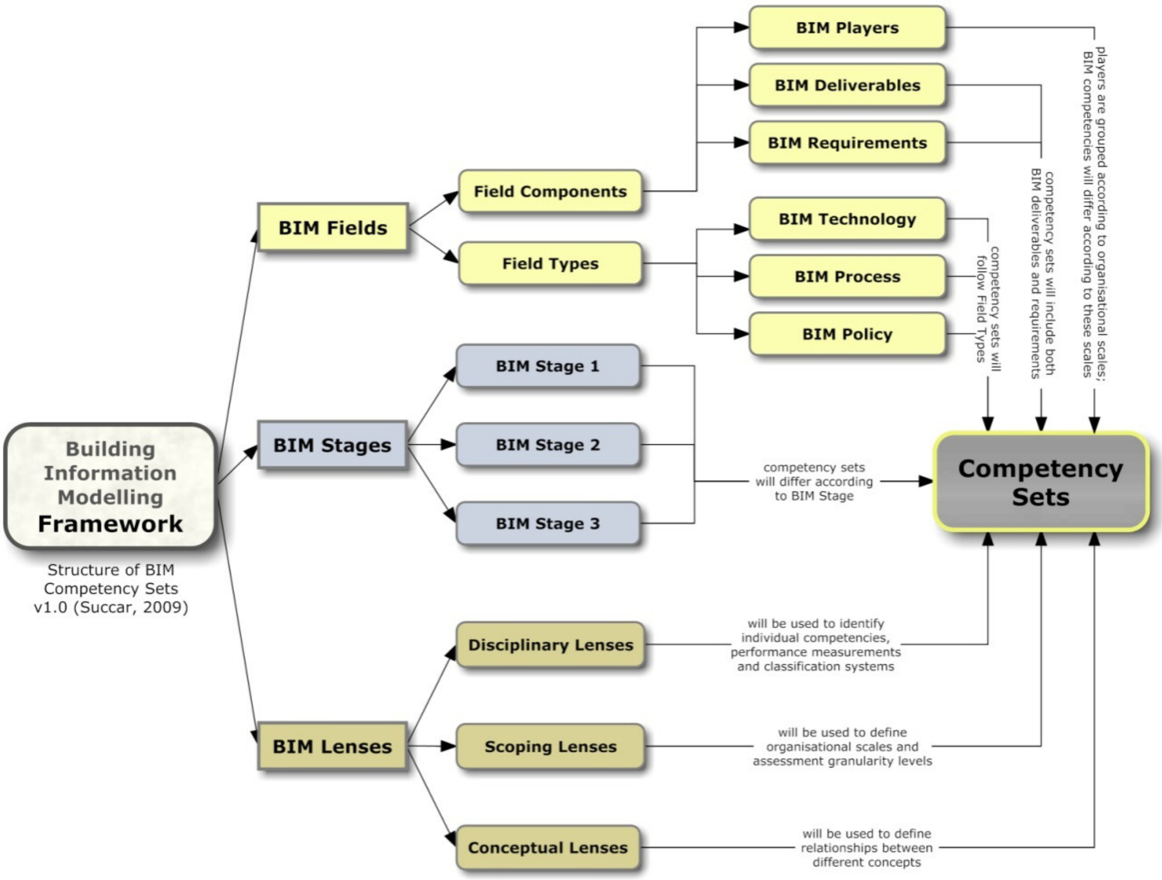

Fig. 3. Structure of BIM Competency Sets v1.0

BIM Competencies are a direct reflection of BIM Requirements and Deliverables and can be grouped into three sets – Technology, Process and Policy:

Technology sets in *software, hardware* and *networks*. For example, the availability of a BIM tool allows the migration from drafting-based to object-based workflow (a requirement of BIM Stage 1)

Process sets in *leadership, infrastructure, human Resources* and *products/services*. For example, collaboration processes and database-sharing skills are necessary to allow model-based collaboration (BIM Stage 2).

Policy sets in *contracts, regulations* and *research/education*. For example, alliance-based or risk-sharing contractual agreements are pre-requisites to network-based integration (BIM Stage 3).

Below (Fig. 4) is a partial mind map of BIM Competency Sets shown at Granularity Level 2 (to understand Granularity Levels, please refer to Section 3.5):

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[12] BIM Lenses are distinctive layers of analysis which allow domain researchers to selectively focus on any aspect of the DCO industry and generate knowledge views that either (a) highlight observables which meet the research criteria or (b) filter out those which do not (Succar, 2009a).

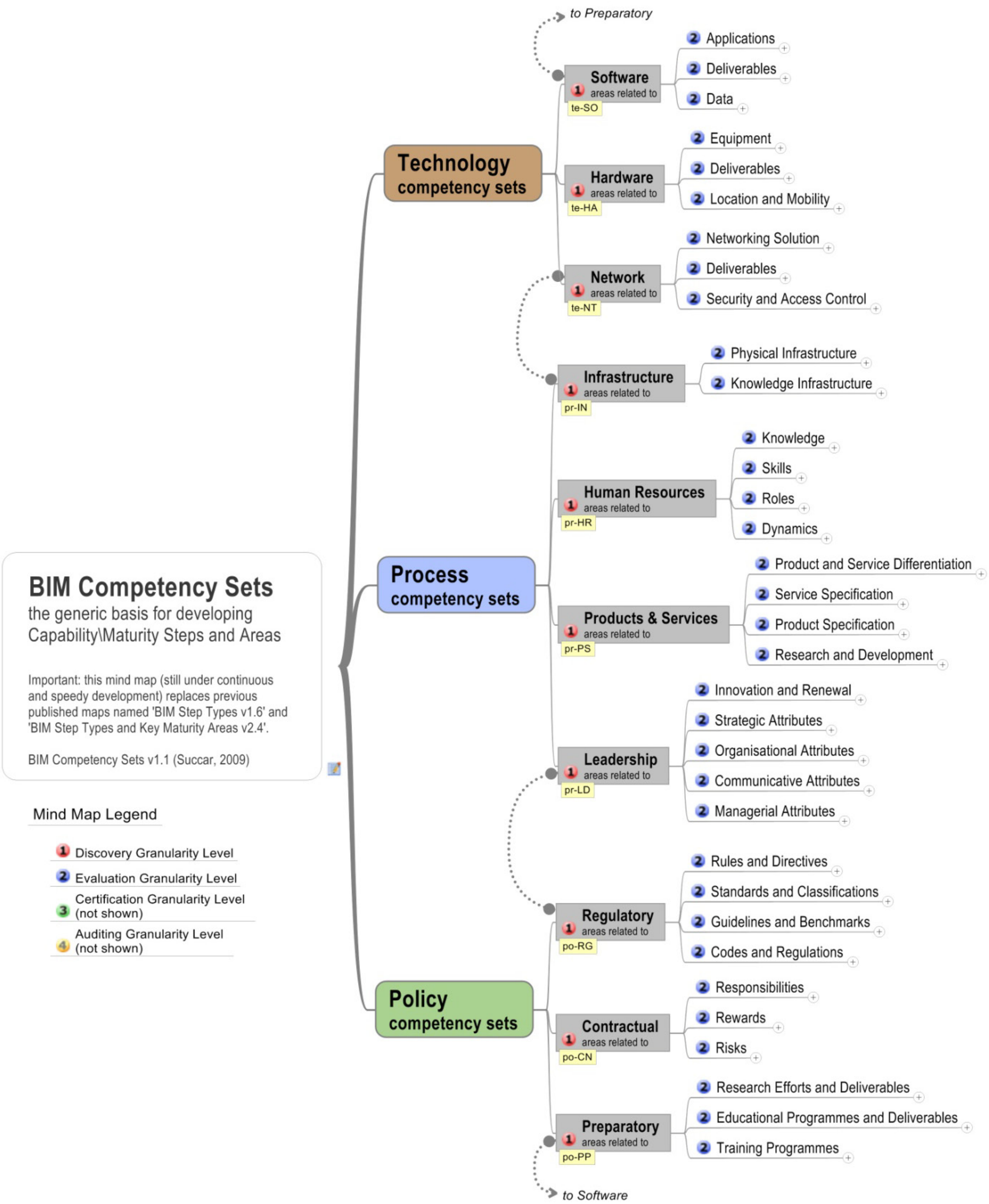

Fig. 4. BIM Competency Sets v1.1 – shown at Granularity Level 2

3.4 BIM Organisational Scales

To allow BIM performance assessments to respect the diversity of markets, disciplines and company sizes, an Organisational Scale (OScale) has been developed. The Scale can be used to customise assessment efforts and is depicted in Table 1 below:

Table 1. Organisational Scale

Low Detail			**High Detail**			
Name	**Sym**	**Granularity**	**Name**	**Sym**	**Granularity**	**Short Definition**
MACRO Markets and Industries	**M**	Markets 1	(Macro M)	**M**	Market 1	Markets are the “world of commercial activity where goods and services are bought and sold” http://bit.ly/pjB3c
			(Meso M)	**Md**	Defined Market 2	Defined Markets can be geographical, geopolitical or resultant from multi-party agreements similar to NAFTA or ASIAN.
			(Micro M)	**Ms**	Sub-Market 3	Sub-markets can be local or regional.
	I	Industries 4	(Macro I)	**I**	Industry 4	Industries are 'the organised action of making of goods and services for sale'. Industries can traverse markets and may be service, product or project-based. The AEC industry is mostly Project-Based. http://bit.ly/ielY3
			(Meso I)	**Is**	Sector 5	A sector is a "distinct subset of a market, society, industry, or economy whose components share similar characteristics" http://bit.ly/15UkZD
			(Micro I)	**Id**	Discipline 6	Disciplines are industry sectors, “branches of knowledge, systems of rules of conduct or methods of practice”. http://bit.ly/7jT82
				Isp	Specialty 7	Specialty is a focus area of knowledge, expertise, production or service within a sub-discipline.
MESO Projects and their teams	**P**	Project Teams 8	n/a	**P**	Project Team 8	Project Teams are temporary groupings of organisations with the aim of fulfilling predefined objectives of a project - a planned endeavour, usually with a specific goal and accomplished in several steps or stages. http://bit.ly/dqMYg
MICRO Organisations Units, their Teams & Members	**O**	Organisations 9	(Macro O)	**O**	Organisation 9	An organisation is a 'social arrangement which pursues collective goals, which controls its own performance, and which has a boundary separating it from its environment. http://bit.ly/v7p9N
			(Meso O)	**Ou**	Organisational Unit 10	Departments and Units are specialised divisions of an organisation. These can be co-located or distributed geographically.
				Ot	Organisational Team 11	Organisational Teams consist of a group of individuals (human resources) assigned to perform an activity or deliver a set of assigned objectives. Teams can be physically co-located or formed across geographical or departmental lines.
			(Micro O)	**Om**	Organisational Member 12	Organisational members can be part of multiple Organisational Teams.

3.5 BIM Granularity Levels

Competency Sets include a large number of individual competencies grouped under numerous competency headings (refer to Fig. 4). To enhance BIM Capability and Maturity assessments and to increase their flexibility, a Granularity ‘filter’ with four Granularity Levels (GLevels) has been developed. Progression from lower to higher levels of granularity indicates an increase in (i) assessment breadth, (ii) scoring detail, (iv) formality and (iv) assessor specialisation.

Using higher-granularity levels (GLevels 3 or 4) exposes more detailed Competency Areas than lower-granularity levels (GLevels 1 or 2). This variability in breadth, detail, formality and specialisation enables the preparation of several BIM performance measurement tools ranging from low-detail, informal and self-administered assessments to high-detail, formal and specialist-led appraisals. Table 2 below provides more information about the four Granularity Levels:

Table 2. BIM Competency Granularity Levels v2.1

GLevel Number, GLevel Name, Description and Scoring System (Numerical and/or Named)			OScale applicability	Assessment By, Report Type and *Guide Name*	
1	**Discovery**	A low detail assessment used for basic and semi-formal discovery of BIM Capability and Maturity. Discovery assessments yield a basic numerical score.	All Scales	Self	Discovery Notes *BIMC&M Discovery Guide*
2	**Evaluation**	A more detailed assessment of BIM Capability and Maturity. Evaluation assessments yield a detailed numerical score.	All Scales	Self and Peer	Evaluation Sheets *BIMC&M Evaluation Guide*
3	**Certification**	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.	8 and 9	External Consultant	Certificate *BIMC&M Certification Guide*
4	**Auditing**	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 Non-structured (Continuous) Capability and Maturity and yield a Named Maturity Level plus a Numerical Maturity Score for each Competency Area audited.	8, 9, 10 & 11	Self, Peer and External Consultant	Audit Report *BIMC&M Auditing Guide*

Granularity Levels thus increase or decrease the number of Competency Areas used for performance assessment. For example, the mind map provided in Fig. 4 reveals **ten Competency Areas** at GLevel 1 and **thirty-four Competency Areas** at GLevel 2. Also, at GLevels 3 and 4, the number of Competency Areas available for performance assessment increase dramatically as depicted in Fig. 5:

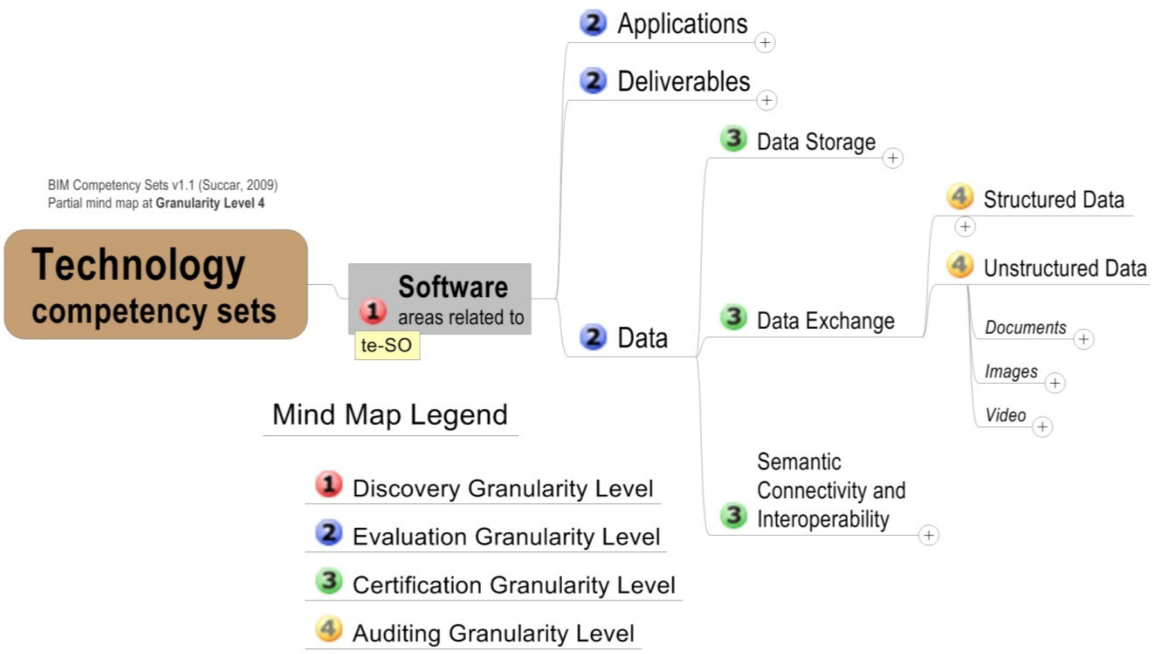

Fig. 5. Technology Competency Areas at Granularity Level 4 – partial mind map v1.1

The partial mind map depicted in Fig. 5 unveils many additional Competency Areas under GLevel 3 like Data Storage and Date Exchange. At GLevel 4, the map unveils even more-detailed Competency Areas like Structured and Unstructured Data which in-turn branch into computable and non-computable components (Kong, Li, Liang, Hung, Anumba and Chen, 2005) (Mathes, 2004) (Fallon and Palmer, 2007).

4. Applying the five assessment components

Using the above five complementary Framework components, BIM performance assessments can be conducted - in conformance with the guiding principles discussed in Section 2.1 - at multiple combinations of Capability, Maturity, Competency, Organisational Scale and Granularity. To manage all possible configurations, a simple assessment and reporting workflow has been developed (Fig. 6):

Fig. 6. BIM Capability and Maturity Assessment and Reporting Workflow Diagram - v2.0

Expanding on the above diagram, a total of five workflow steps are needed to conduct a BIM performance assessment. Starting with an extensive pool of generic BIM Competencies - applicable across DCO disciplines and organisational sizes – assessors can first filter-out non-applicable Competency Sets, conduct a series of assessments based on remaining Competencies and then generate a suitable Assessment Report.

5. In Summary

The five BIM Framework components, briefly discussed in this paper, enable an array of assessment possibilities for DCO stakeholders to measure and improve their BIM performance. These components complement each other and enable highly-targeted yet flexible performance analyses ranging from informal self-assessment to high-detail and formal organisational audits. Such a system of assessment can be utilised to standardize BIM implementation and assessment efforts, enable a structured approach to BIM education and training as well as establish a solid base for a formal BIM certification process. The five components and other related assessment, scoring and reporting tools are currently being extended, tested and validated. A mechanism for identifying and continuously updating BIM Competencies by subject matter experts is actively being developed. Also, a sample online tool (focusing on a sample discipline, at a sample granularity) is currently being formulated. Once conceptual validation, field testing and tool calibration are successfully conducted, the five components may be well-placed to consistently assess, and by extension improve, BIM performance.

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