MODEL USES: FOUNDATIONS FOR A MODULAR REQUIREMENTS CLARIFICATION LANGUAGE

B. Succar[1], *N. Saleeb*[2], *W. Sher*[3]

[1]Director, ChangeAgents pty ltd, Member of the Centre for Interdisciplinary Built Environment Research (CIBER), University of Newcastle, Australia

[2]Associate Professor, Middlesex University, United Kingdom

[3]Associate Professor, University of Newcastle, Australia

bsuccar@changeagents.com.au

ABSTRACT

Building Information Modelling (BIM) tools and workflows can increase design productivity, reduce construction waste, and improve connectivity of facility operations. To achieve such benefits, model-based deliverables (e.g. model-based cost estimation, construction planning, or asset tracking) first need to be clearly specified by owners/clients and, second, be delivered by supply chain players according to these specifications. While there are many guides, protocols, and standards for defining information content within models, there is little guidance for specifying the uses to be derived from this modelled information. To bridge the gap between what is expected from BIM, and what will actually be delivered, there is a need for a clear and modular 'requirements clarification' language. Based on published research – including a framework, conceptual ontology, and competency model – as well as on-going practical applications, this paper introduces the Model Uses concept, comprising a Model Uses Taxonomy and a Model Uses List. Model Uses are the intended, planned, or expected project deliverables resulting from generating, collaborating, or linking models to external databases. This paper explores the conceptual foundations of Model Uses and then provides practical examples – an implementation task list and an assessment module - of how this modular language assists in identifying BIM project requirements and facilitating project delivery.

Keywords: Building Information Modelling, Model Uses, Knowledge Blocks, Modular Language.

INTRODUCTION

There is a growing disparity between the different types of BIM guides, protocols and standards covering information exchanges throughout a project's lifecycle. On one hand, there is a variety of competing schemas for defining information content at object/element scale – e.g. Levels of Development, Levels of Detail, and Levels of Information (USACE, 2007) (BIMforum, 2016) (DBW, 2016) – and information management specifications for design, construction and post-construction activities - e.g. PAS1192-2:2013 (BSI, 2013) and COBie (East, 2013). On the other, there are only a few guides covering the pre-definition and post-measurement of project outcomes. To help address this imbalance, this paper builds upon available literature and earlier research to introduce the Model Uses *concept*, *taxonomy* and *list*. Model Uses are the "intended or expected project deliverables from generating, collaborating-on and linking models to external databases" (BIM Dictionary, 2016). Acting as a *knowledge block*, each Model Use represents a set of predefined requirements, specialised activities and specific project outcomes, grouped together under a single heading so they can be easily specified, measured and learned. In combination with other knowledge blocks (e.g. Competency Items and Defined Roles), Model Uses provide a foundation for the development of a Modular Requirements Clarification Language, a performance-centric approach to services' procurement and project delivery.

Definition

As a concept, Model Uses is a major reinvestigation and a practical expansion of the 'BIM Uses' taxonomy, a "method of applying Building Information Modeling during a facility's lifecycle to achieve one or more specific objectives" (Kreider & Messner, 2013, p.6) (NBIMS, 2013), and of 'BIM Outcomes', "the possible desired results to be obtained from the application of BIM" (ISO/TS 12911:2012, p.11). While the two terms Model Use and BIM Use are applied interchangeably across industry, Model Uses – as defined in this study – represent a *conceptual departure* from BIM Uses and an *umbrella term* covering multiple industries and their varied model-based use cases. This adoption of the Model Use term arises because:

- The acronym 'BIM' in the United States often refers to the Building Information *Model* while – in Australia, the United Kingdom and many other countries - it consistently refers to Building Information *Modelling*. Since the term is intended to describe the relationship between the *user* and the *product* (the model), *Model Use* is less ambiguous;
- Unlike BIM Use, the term *Model Use* is not exclusive to the construction industry and can be applied to Geographic Information Systems (GIS - e.g. Urban Modelling), Product Lifecycle Management (PLM - e.g. Sheet Metal Cutting) and similar information systems;
- The term *Model Use* is semantically connected to *Model View* and *Model View Definition* (ISO 29481-1:2010, p.32); and
- The term *Model Use* has recently been adopted by the same research colleagues who popularised the term BIM Use (Kreider and Messner, 2015).

It is also important to differentiate between *Model Uses* (what is planned or requested) and *Model-based Deliverables* (what is actually delivered). That is, "deliverables and BIM uses [Model Uses] are two sides of one coin – BIM uses represent the tool or process – deliverables represent the output" (NATSPEC, 2014, p.6). In essence, Model Uses translate quantifiable project requirements (input) into measureable project outputs.

To avoid confusing Model Uses (e.g. Clash Detection, Thermal Analysis, and Relocation Management) with Model-based deliverables, the latter will be suffixed with a *Delivery Format* (e.g. Clash Detection *Report*, Thermal Analysis *Chart*, and Relocation Management *Animation*).

Benefits sought from defining Model Uses

This study is intended to set the scene for the introduction of a *Modular Requirements Clarification Language*. Such a language would facilitate communication between industry stakeholders and contribute to the reduction of project complexity by:

- Identifying project requirements and deliverables to be included in Requests for Proposals (RFP), Employer's Information Requirements (EIR) and similar;
- Assessing individual competency and organisational capability against predefined performance targets;
- Defining Learning Outcomes by identifying the competency sets embedded within each Model Use, Document Use, and Data Use; and
- Bridging the semantic gap between interdependent industries and information systems - Construction (BIM), Geospatial (GIS) and Manufacturing (PLM).

Available Model Use lists

There are a number of Model Use lists currently available. Below is a partial list of *Noteworthy BIM Publications* (Kassem, Succar and Dawood, 2015) reviewed as part of this study – in chronological order:

(1) **PENN State BIM Project Execution Planning Guide** (2010): 25 well-defined BIM Uses mapped to four phases. This classification was adopted by the **US National BIM Standards v3** (2015). Also in 2015, Kreider and Messner published the **Model Use Ontology** with *Model Use* replacing the *BIM Use* term without providing a conceptual justification;
(2) **VA BIM Guide** (2010): 19 Requirements for using BIM, only 10 defined;
(3) **PD ISO/TS 12911-2012** Framework for building information modelling (BIM): a list of generic Outputs (e.g. drawings, reports, animation);
(4) **New York City BIM Guide** (2012): 15 well-defined BIM Uses;
(5) **Finland COBIM Standards** (2012): 12 loosely defined 'common BIM requirements' across phases;
(6) **Massport Authority BIM Guide** (2014): 51 well defined BIM Uses; and
(7) **The Port Authority of NY & NJ** (2015): 38 BIM Uses – none defined.

These publications are significant contributions to this topic, and collectively provide a solid basis for this study. However, to enable the development of a flexible Model Uses Taxonomy and a comprehensive Model Uses List, a number of identified limitations must be first addressed - including:

- The *small number* of identified BIM Uses / Outputs in these collective efforts cannot represent all model-based deliverables across design, construction, and operation. For Model Uses to support a Modular Requirements Clarification Language, they need to address all possible activities and outcomes;
- The *similar names* of BIM Uses which may cause confusion. For example, 'Phase Planning (4D Modeling)', '3D Control and Planning', and 'Programming' – as in NBIMS (2015) – will need to be further differentiated;
- The *inflexible association* of BIM Uses with specific asset lifecycle phases. Model Uses can apply across multiple phases – especially within high BIM capability organisations and project teams (Succar, 2010);
- The *lost opportunity* to link BIM Uses / Project Outputs to roles, learning outcomes, performance metrics, and individual competencies; and
- The *conceptual ambiguity* and *isolation* of these efforts. Few of these noteworthy publications have clear conceptual origins or from part of a larger conceptual structure. The conceptual ambiguity inhibits the expansion of available lists and the conceptual isolation prevents the generation of relations between Model Uses and other concepts (e.g. with Competency Items).

The above limitations are significant and have thus been addressed during the development of a new Model Use concept.

DEVELOPING A NEW MODEL USE CONCEPT

The process of developing a new Model Use concept was completed in three steps: first, the Model Use term was *conceptually grounded*; second, information represented by Model Uses was *differentiated* from other types of information; and, third, Model Uses were organised into a taxonomy.

Conceptual Grounding of the Model Use concept

Model Uses are a *product of* and an *extension to* the expansive BIM Framework (Succar, 2009). As illustrated in Fig. 1, Model Uses are derived by overlaying three existing conceptual structures:

- The **Tri-Axial Framework** which identifies Model Uses as the *intended* or *expected* model-based *deliverables* [Tri-axial Framework>Fields>Field Components>Deliverables (Model-based Deliverables)];
- The **Competency Framework** which defines Model Use classes according to the nine topics within the Operation Competency Set [Competency Framework>Competency Hierarchy>Competency Tiers (Domain Tier)>Competency Set (Operation Set)>Competency Topics]; and
- The **BIM Ontology** which identifies the Model Use *concept* as a *knowledge block* [BIM Ontology>Knowledge Objects>Knowledge Set (Knowledge Blocks> Information Uses>Model Uses].

The introduction of Model Uses as a *new conceptual construct* is based on the BIM Framework Conceptual Reactor, a cumulative theory-building approach discussed in Succar and Kassem (2015). The Reactor explains how – by passing through an iterative, three-stage theory-building process (Meredith, 1993) (Meredith, Raturi, Amoako-Gyampah, & Kaplan, 1989) – the BIM Framework can be continuously extended according to evolved research objectives.

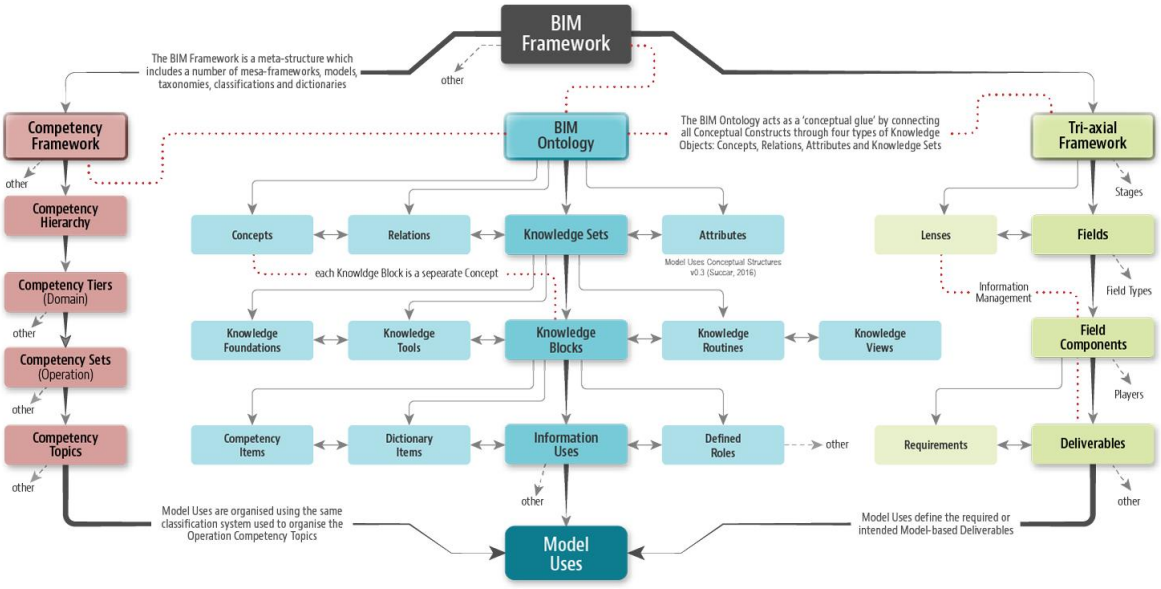

Fig. 1. Conceptual structures underlying the Model Uses concept, taxonomy and list (larger image)

Identifying the Information Represented by Model Uses

For Model Uses to enable the development of a Modular Requirements Clarification Language, it is important to establish what differentiates Model Uses from other types of information generated or captured throughout a project's lifecycle. Using an *Information Management Lens* (Succar, 2009), three main *Project information Types* were identified:

- **Documented Project Information**: project information collated within documents for functional purposes. Documented Project Information are captured and exchanged either manually or through digital means, and are intended for use by the human actor (e.g. drawings, maps and reports);
- **Modelled Project Information**: project information collated within models for functional purposes. Modelled Project Information are generated by the human actor or driven by machine-captured data (e.g. structural analysis and asset tracking); and
- **Structured Project Data**: granular project information *collated within* or *driving the generation of* documents and models. Structured Project Data are inputted by the human actor (e.g. Fabrication Scripting); captured through sensors and scanners; derived from connected data sources; or generated through machine learning.

These Project Information Types clarify what information is *embedded in* or *exchanged as* **models** (and thus can be represented by *Model Uses*); *embedded in* **documents** (represented by *Document Uses*); or *stored/exchanged as* **data** (represented by *Data Uses*). The remainder of this paper focuses exclusively on Modelled Project Information and introduces a Model Uses Taxonomy for organising this information type.

Organising Model Uses into a taxonomy

To properly represent Modelled Project Information, Model Uses are organised into a conceptual structure that follows six guiding principles:

Principle 1: accuracy of representation, the taxonomy carefully delimits the definitions and thus overall number of Model Uses: if the number is too small, definitions would be wide and imprecise; and, if the number is too large, definitions would overlap and cause confusion.
Principle 2: flexibility of use, Model Uses are defined for applicability across varied contexts so they can be:

- Equally applied across markets;
- Equally applied at any/all project lifecycle phases;
- Equally used for service' procurement, capability development, organizational implementation, project assessment and personal learning;
- Flexibly prioritised to suit the varied requirements of each project; and
- Easily assigned to any/all project participants based – not only their traditional roles but - on their proven experience and assessed capability.

Principles 3-6: **clarity**, **coherence**, **extensibility** and **minimal encoding bias**, Noy & McGuinness' criteria (2001) for developing ontologies.

THE MODEL USES TAXONOMY AND MODEL USES LIST

Based on the aforementioned six principles, the Model Uses Taxonomy was developed. It include *three Categories* and *nine Series* (Fig. 2):

Category I: General Model Uses represent Modelled Project Information applicable across varied knowledge domains, industries, and information systems. General Model Uses are collated within a single Series, General Modelling (1000-1990) and are affixed with the term 'modelling' as a differentiator from other categories - examples [synonyms]:

- 1020 Audio-visual Systems Modelling [Sound Systems Modelling; Video-network Modelling]
- 1420 Temporary Structures Modelling [Scaffolding Systems Modelling; Fence Modelling]
- 1490 Urban Modelling [City Modelling; Precinct Modelling]

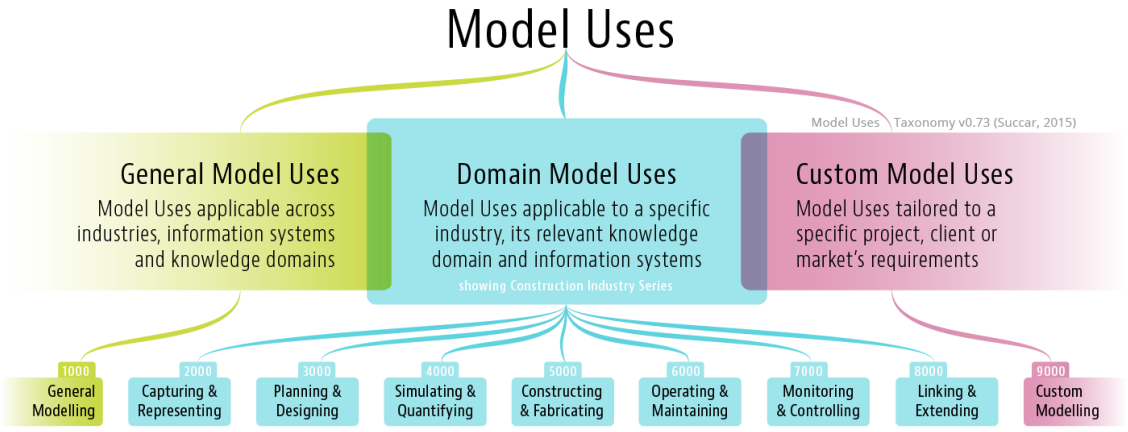

Fig. 2. Model Uses Taxonomy (larger image)

Category II: Domain Model Uses represent industry-specific Modelled Project Information. Table 1 below collates all *Construction Domain* Model Uses into seven Series:

Table 1. Partial Model Uses List (Domain Model Uses - v0.73, Sep 8, 2015)

CODE	MODEL USES	CODE	MODEL USES
Series 2: Capturing and Representing (2000-2990), *synonyms not listed*			
2010	2D Documentation	**2060**	Photogrammetry
2020	3D Detailing	**2070**	Record Keeping
2030	As-constructed Representation	**2080**	Surveying
2040	Generative Design	**2090**	Visual Communication
2050	Laser Scanning		
Series 3: Planning and Designing (3000-3990), *synonyms not listed*			
3010	Conceptualization	**3070**	Lift Planning
3020	Construction Planning	**3080**	Operations Planning
3030	Demolition Planning	**3090**	Selection and Specification
3040	Design Authoring	**3100**	Space Programming
3050	Disaster Planning	**3120**	Urban Planning
3060	Lean Process Analysis	**3130**	Value Analysis
Series 4: Simulating and Quantifying (4000-4990), *synonyms not listed*			
4010	Accessibility Analysis	**4140**	Reflectivity Analysis
4020	Acoustic Analysis	**4150**	Risk and Hazard Assessment
4030	Augmented Reality Simulation	**4160**	Safety Analysis
4040	Clash Detection	**4170**	Security Analysis
4050	Code Checking & Validation	**4180**	Site Analysis
4060	Constructability Analysis	**4190**	Solar Analysis
4070	Cost Estimation	**4200**	Spatial Analysis
4080	Egress and Ingress Analysis	**4210**	Structural Analysis
4090	Energy Use	**4220**	Sustainability Analysis
4100	Finite Element Analysis	**4230**	Thermal Analysis
4110	Fire and Smoke Simulation	**4240**	Virtual Reality Simulation
4120	Lighting Analysis	**4250**	Whole modular Analysis
4130	Quantity Take-off	**4260**	Wind Studies
Series 5: Constructing and Fabricating (5000-5990), *synonyms not listed*			
5010	3D Printing	**5050**	Construction Logistics
5020	Architectural Modules Prefabrication	**5060**	Mechanical Assemblies Prefabrication
5030	Casework Prefabrication	**5070**	Sheet Metal Forming
5040	Concrete Precasting	**5080**	Site Set-outs
Series 6: Operating and Maintaining (6000-6990), *synonyms not listed*			
6010	Asset Maintenance	**6050**	Handover and Commissioning
6020	Asset Procurement	**6060**	Relocation Management
6030	Asset Tracking	**6070**	Space Management
6040	Building Inspection		
Series 7: Monitoring and Controlling (7000-7990), *synonyms not listed*			
7010	Building Automation	**7030**	Performance Monitoring
7020	Field BIM	**7040**	Real-time Utilization
Series 8: Linking and Extending (8000-8990), *synonyms not listed*			
8010	BIM/Spec Linking	**8050**	BIM/IOT Interfacing
8020	BIM/ERP Linking	**8060**	BIM/PLM Overlapping
8030	BIM/FM Integration	**8070**	BIM/Web-services Extension
8040	BIM/GIS Overlappping		

CATEGORY III: Custom Model Uses represents a mixture of *General* and *Domain* Model Uses to reflect any custom project requirements. Custom Model Uses are collated within a single Series, Custom Modelling (9000-9990) - examples:

- 9XXX Modelling of floating sculpture with wave-powered signal beacon
- 9YYY Modelling security systems for a correctional facility
- 9ZZZ Modelling ventilation systems for an astronaut staging station

The current Model Uses List includes 125 items (download full list from BIMexcellence.org/model-uses) reflecting current abilities of software solutions. Future iterations may incorporate additional items and/or updated descriptions following the relevant advances in technology and the evolving expectations of industry stakeholders.

A Note on Model Use Validation

The Model Uses List was developed by collating BIM Use definitions from publicly available sources and then organising them through the Taxonomy. Nine international subject matter experts were invited to review the model; eight offered their written commentary. The List was refined based on this commentary which was then anonymised and redistributed to the experts. To test usability, Model Uses were collated into online assessment modules (BIM Excellence, 2016) and embedded within an Employer's Information Requirement (EIR) document. Additional comments were sought and addressed before the Model Uses Taxonomy and List were published as a peer-reviewed blog-post (BIM ThinkSpace, 2015). While this validation process is both lengthy and laborious, the feedback received proved instrumental in improving Model Use definitions and the Model Uses List. Continuous testing and calibrations are being conducted with Model Use definitions subjected to public scrutiny through the BIM Dictionary (2016) which provides an opportunity to place commentary on each term.

PRACTICAL APPLICATIONS OF MODEL USES

After introducing the Model Uses concept, Taxonomy and List, the following sections demonstrate the practical applicability of Model Uses through a sample *Implementation Task List* and a *Performance Assessment Module*.

Model Use as an Implementation Task List

Each Model Use represents an *intended* set of project outputs from generating or exchanging Modelled Project Information. To deliver each output set, multiple activities need to be conducted. These activities are either unique to each Model Use or common across multiple Model Uses. Table 2 is a sample Model Use Implementation Task List collating a subset of common tasks. These tasks can be allocated to individuals, mapped against project milestones, or – as shown below – grouped according to organisational *Performance Improvement Phases* (Succar, 2016):

Table 2. Model Use as an Implementation Task List – Clash Detection used as an example

I	**SCOPING PHASE** - activities include:	
	a	Establish if [**Clash Detection**] is applicable for this {Project Type}
	d	Establish if [**Clash Detection**] is required for this project
	c	Establish the relative priority of [**Clash Detection**] for this project
	d	Establish who is the {Responsible Party} to conduct [**Clash Detection**]
II	**ASSESSMENT PHASE** - activities include:	
	a	Assess if the {Responsible Party} has the ability to conduct [**Clash Detection**]
	b	Assess the quality of the [**Clash Detection**] delivered by {Responsible Party}
III	**ANALYSIS PHASE** - activities include:	
	a	Analyse whether [**Clash Detection**] abilities match Clash Detection {Requirement}s
	b	Generate a *Proceed*, *Pause/Clarify*, *Stop/Modify* or *Abort* [**Clash Detection**] {Request}
IV	**PLANNING PHASE** – activities include (not in order):	
	a	Select the software application suited for conducting [**Clash Detection**]
	b	Gain access to model(s) in the format necessary for conducting [**Clash Detection**]
	c	Prepare model(s) or part model(s) for [**Clash Detection**] – sample tasks:
		c1 Delete/purge/turn-off non-mission critical parts; and
		c2 Open/import/collate model(s) into [**Clash Detection**]{Software Application}
	d	Define target components/systems for [**Clash Detection**] (select set, load filter…)
	e	Identify target results for [**Clash Detection**] – examples:
		e1 Spatial, geometrical or semantic; or
		e2 Drawings, Details, Quantities, Specifications or Analytical Data
V	**ACTING PHASE** - activities include (in chronological order):	
	a	Execute the [**Clash Detection**] {Program} {Script} {Extension}
		a1 Check for redundancy and errors; and
		a2 Remove/isolate redundancy and errors
	b	Generate [**Clash Detection**]{Report}
	c	Communicate [**Clash Detection**] results
VI	**MEASURING PHASE** - activities include (not in order):	
	a	Confirm workflow for next round of [**Clash Detection**]; or
	b	Refine process for next round of [**Clash Detection**]
Note: [Clash Detection] can be replaced with other Domain Model Uses		

Model Use as a Performance Assessment Module

A comprehensive Model Uses List provides an expanded opportunity to assess the performance of organisations against specific Model Uses (Alaghbandrad, April, Forgues, and Leonard, 2015). An assessor can use this List to: **First**, identify one or more *target* Model Uses, each representing a set of expected project deliverables. **Second**, an assessor can evaluate the ability or performance of project participants – organisations, individuals or teams - against each Model Use. For example, below are six sample assessment questions (BIM Excellence, 2016) using Cost Estimation as a sample Model Use:

- Are you experienced in conducting [**Cost Estimation**] on {Project Type}?
- How many Cost Estimates have you completed over the past {Period}?
- What BIM Software Tool(s) were used to conduct [**Cost Estimation**]?
- Do you have documented processes for performing [**Cost Estimation**]?
- What are the Standards, Protocols and Classification Systems followed when performing [**Cost Estimation**]s?
- What [**Cost Estimation**] {Document Types} do you deliver at {Phase X}?

Third, the assessor generates a report identifying/comparing the abilities or performance of projects participants; as exemplified in Fig. 3:

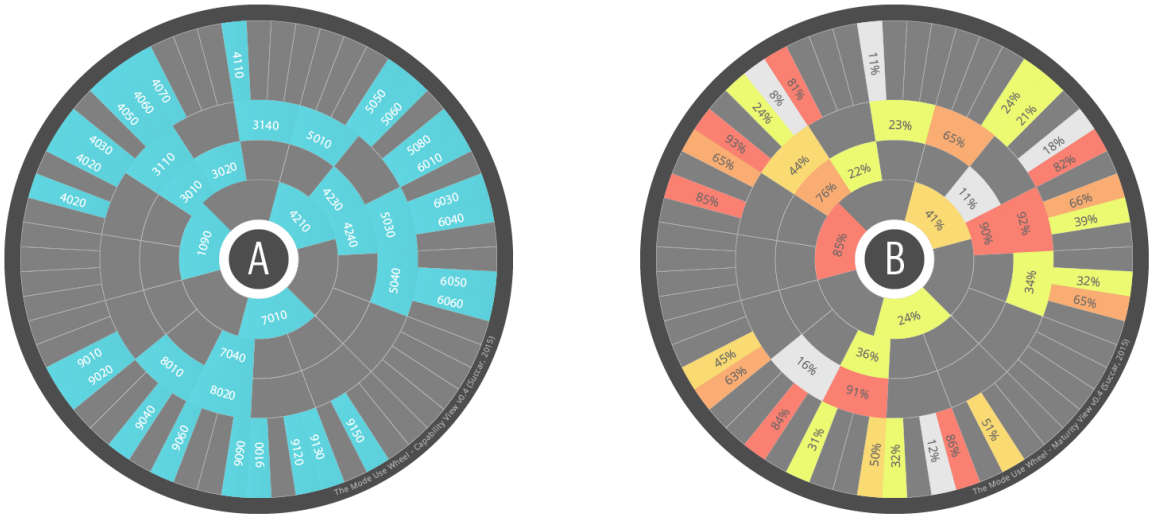

Fig. 3. Model Uses Wheel – target requirements (A) verses assessment results (B) – larger image

The Model Uses Wheel (Fig. 3) is a visual summary of assessment results:

- The cells in **Wheel A** identify *target* Model Uses selected by the assessor
- The cells in **Wheel B** provide a visual summary of *assessment results*
- Assessment results vary from *Low* (0-20%); *Medium-Low* (21-40%); *Medium* (41-60%); *Medium-High* (61-80%); to *High* (81-100%)
- Depending on the assessment type, the results may reflect either the *Maturity Level* of an organisations or project teams (Succar, 2010); the richness of Modelled Project Information; or the *Competency Level* of an individual or group (Succar et. al, 2013).

The partial questions list and sample chart exemplify how the Model Uses List - when combined with target-specific metrics – enable a wide range of assessments and - by extension - the development of learning programmes and certification regimes.

CONCLUSION

This paper introduced the Model Use concept and Model Uses Taxonomy as a *product of* and an *extension to* the expansive BIM Framework. A Model Uses List was provided and two sample practical applications were demonstrated: Model Use as an Implementation Task List and Model Use as a Performance Assessment Module. Model Uses – in conjunction with other *knowledge blocks* (e.g. Competency Items and Defined Roles) - lay the foundations for a Modular Requirements Clarification Language that enables the translation of project goals into granular requirements; comparison of project requirements with actual deliverables; and conducting multiple types of interconnected performance assessments. Current research and future publications will expand this Language by formulating *knowledge routines* (e.g. project workflows) that connects varied knowledge blocks into a performance-centric - as opposed to compliance-centric - approach to BIM services' procurement, information management and project delivery.

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