A PROPOSED APPROACH TO COMPARING THE BIM MATURITY OF COUNTRIES

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ABSTRACT

BIM concepts and tools have now proliferated across the construction industry. This is evidenced by the comparative results of BIM adoption rates reported through a number of industry surveys. However these surveys typically cover a small number of industry stakeholders; are intended to establish adoption rates by organizations rather than markets; and are unsupported by theoretical frameworks to guide data collection and analysis. Based on a published theoretical framework, this paper proposes three metrics to augment survey data and help establish the overall BIM maturity of countries. These metrics apply to noteworthy BIM publications (NBP)s and assess their BIM knowledge content (BKC). NBPs are publically-available industry *documents* intended to facilitate BIM adoption; while BKCs are specialized *labels* (e.g. report, manual, and contract) used to describe NBP contents. The three metrics – *NBP availability*, *NBP content distribution,* and *NBP relevance* - are applied in assessing the knowledge deliverables of three countries – United States, United Kingdom and Australia - chosen for their similar construction culture and active BIM scene. The paper then discusses how these complementary metrics can inform policy development and identify market-wide knowledge gaps.

Keywords: Building Information Modeling (BIM), Country-scale BIM maturity, Noteworthy BIM Publications, BIM Knowledge Content taxonomy.

1. INTRODUCTION

This paper adopts a wide-angle approach to BIM maturity as applicable to countries rather than organizations. Assessing maturity at this large scale is conceptually supported by a published framework used as a basis for proposing new qualitative metrics to complement quantitative surveys conducted in three countries. For the purposes of simplification and targeted exploration, we propose three - out of many possible - qualitative metrics; focus on three countries with similar construction cultures; and steer away from differentiating between BIM readiness, adoption, diffusion, infusion and maturity. These self-imposed limitations are intended to facilitate this exploration of country-wide BIM maturity and will be removed in future more detailed studies.

1.1 COUNTRY-SCALE BIM MATURITY

BIM maturity refers to the quality, repeatability and degrees of excellence in delivering a BIM-enabled service or product (Succar, 2010). There are an increasing number of BIM-specific maturity frameworks (Giel and Issa, 2012) (Chen, Dib and Cox, 2012) (Mom and Hsieh, 2012). Many of these frameworks are intended to measure the performance of organizations and teams but are not applicable across all *organizational scales* (Succar, 2010). For example, there are several maturity models available for assessing *organizational BIM capability/maturity* (TNO, 2010) (NIST, 2007) (BIMe, 2013) (Succar, 2010), *BIM project performance* (IU, 2009) (Suermann, Issa and McCuen, 2008) (BIMScore, 2013) (BIMe, 2013), and *individual BIM competency* (Succar 2013) (BIMe,

2013). However, metrics suitable for assessing macro organizational scales – e.g. market, industry or country scales - are nearly absent in the construction industry.

Country-scale maturity studies are however available across a number of disciplines, yet are nearly absent in the construction industry, in general, and the BIM domain in particular. For example, there are both qualitative and quantitative metrics for assessing e-Government maturity, and have been applied in measuring the online presence of governments across 22 different countries (Accenture Consulting, 2004). Country-scale e-Commerce maturity models are also available and identify three distinct stages - experimentation, ad-hoc implementation and integration – for establishing maturity (KPMG, 1997 and Zandi, 2013).

With the absence of specialized maturity metrics, analyzing quantitative survey data collected by prominent industry associations (e.g. McGraw-Hill Construction, 2012; NBS, 2013 and BuildingSMART, 2012) has been the only readily available option. This paper introduces additional metrics to augment survey data in establishing country-scale maturity.

1.2 Underlying conceptual framework

Assessing and comparing country-scale BIM maturity is conceptually based on the theoretical framework developed by Succar (2009, 2010). The framework's components – those applicable to this paper - are briefly described below:

- **Organizational Scales:** the framework identifies three scales: **Macro** - markets and industries; **Meso** - projects and their teams; **Micro** - organizations, units, their teams and members. Each of these scales is further divided into more granular organizational scales. There is a total of 12 organizational scales with the *organizational member* as the smallest scale, to the *international market* as the largest scale. This paper applies one of the macro scales - *Defined Markets* - to focus on country-level maturity.
- **BIM Maturity:** the framework identifies five distinct levels of maturity (Initial, Defined, Managed, Integrated and Optimized) that can be applied at all organizational scales. Levels represent the progression from lower to higher levels of maturity and indicate (i) improved control resulting from fewer variations between performance targets and actual results, (ii) enhanced predictability and forecasting of reaching cost, time and performance objectives, and (iii) greater effectiveness in reaching defined goals and setting new more ambitious ones (Lockamy III & McCormack, 2004) (McCormack, Ladeira, & Oliveira, 2008). *This paper adopts the BIM maturity definition as introduced in the framework.*
- **BIM Fields** and **BIM Lenses** and their delimitations: these are discussed in some detail in section 1.3.

1.3 Noteworthy BIM Publications

Noteworthy BIM publications (NBP)s are publically-available documents developed by various industry and academic entities; aimed at a wide audience; and intended to promote BIM understanding, regulate BIM implementation or mandate BIM requirements. These publications encapsulate extensive BIM-focused knowledge; collate significant domain expertise; and represent a substantial effort within the BIM domain. To assist in identifying NBPs, the authors employed explicit ontological structures from the BIM Framework (Succar, 2009) as represented in Figure 1 below:
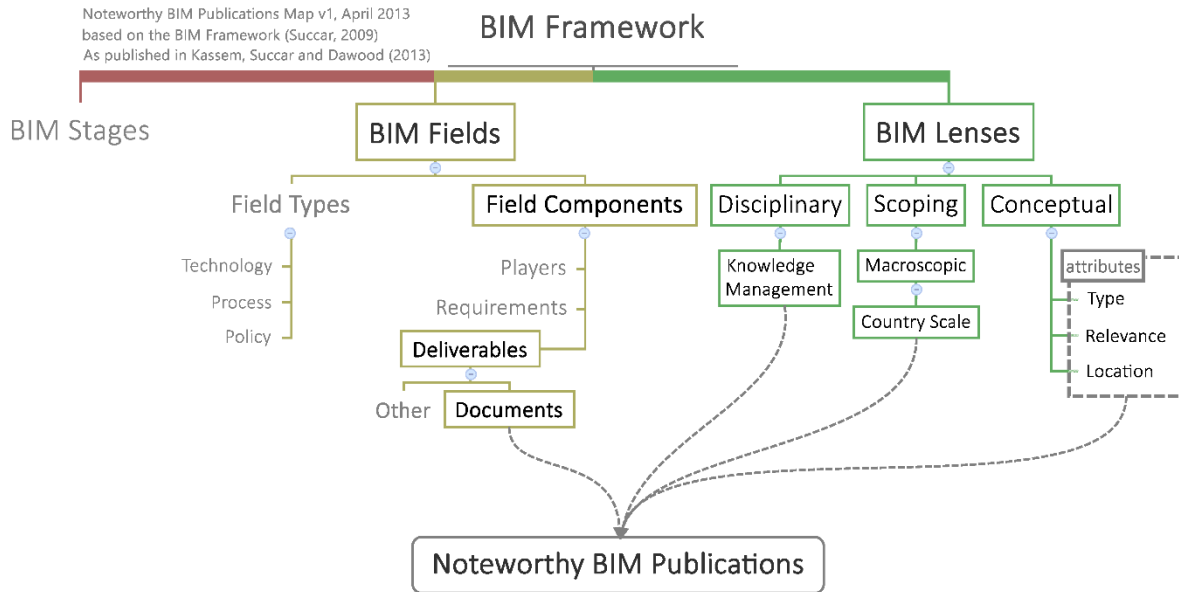
Figure 1: Conceptual derivation of Noteworthy BIM Publications using the BIM Framework

The BIM Framework and its ontological structures are intended to organize domain knowledge and facilitate its understanding. Figure 1 explores how noteworthy BIM publications are derived from the interaction of BIM fields and BIM lenses:

- NBPs are documents (i.e. not websites, blogs or similar);
- NBPs reflect BIM knowledge (i.e. publications focused on BIM skill are excluded);
- NBPs are the deliverables of BIM players (i.e. publications delivered by players from other industries are excluded);
- NBPs cover relevant BIM topics (i.e. publications covering pre-BIM topics are excluded);
- NBPs are macroscopic (i.e. documents aimed at small groups of practitioners or students are excluded); and
- NBPs are selected and organized by country of origin (i.e. NBPs developed across several countries are excluded - e.g. Inpro-EU[1], IDDS[2] or bSI[3]).

Using these framework-based delimitations, NBPs represent numerous types of published documents spanning industry initiatives, peer-reviewed journals, self-published books and other noteworthy publications. However, for the purposes of targeted analysis, this paper focuses exclusively on publications developed by governmental bodies, industry associations, research institutions and communities of practice.

1.4 Country Selection

Australia (AU), the United Kingdom (UK) and the United States (US) are selected as sample countries to test BIM maturity metrics. This selection is a reflection of three main criteria: (a) the similarity between their construction markets in terms of applicable technologies and terminology, (b) the availability of reasonably wide BIM adoption surveys (BEIIC, 2010 in Australia, NBS, 2013 in the U.K. and McGraw-Hill Construction, 2012 in the U.S.) and (c) the availability of noteworthy BIM publications. Below are the surveys from across the three countries:

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[1] Open Information Environment for Knowledge-Based Collaborative Processes throughout the Lifecycle of a Building, please refer to http://www.inpro-project.eu/main.asp

[2] Integrated Design and Delivery Solutions, please refer to http://www.cibworld.nl/site/programme/priority_themes/integrated_design_solutions.html

[3] buildingSMART International and their varied noteworthy publications, please refer to http://www.buildingsmart.org/

Australia – BIM Adoption Surveys

In 2010, a nationwide survey of architects, engineers, builders, owners and facility managers has been conducted (BEIIC, 2010). Data collected reflected industry's perception of BIM benefits and measured their BIM adoption. The adoption rates reported from a sample of 255 Architects, 44 engineers, 12 contractors, 39 owners, 8 manufacturers and 'other' (facility managers, software vendors, project management) are summarized in Figure 2. The report (BEIIC, 2010) highlighted the widespread adoption of BIM and estimated its impact on the Australian economy to reach $4.8 billion by 2025 (BEIIC, 2010, p. 11).
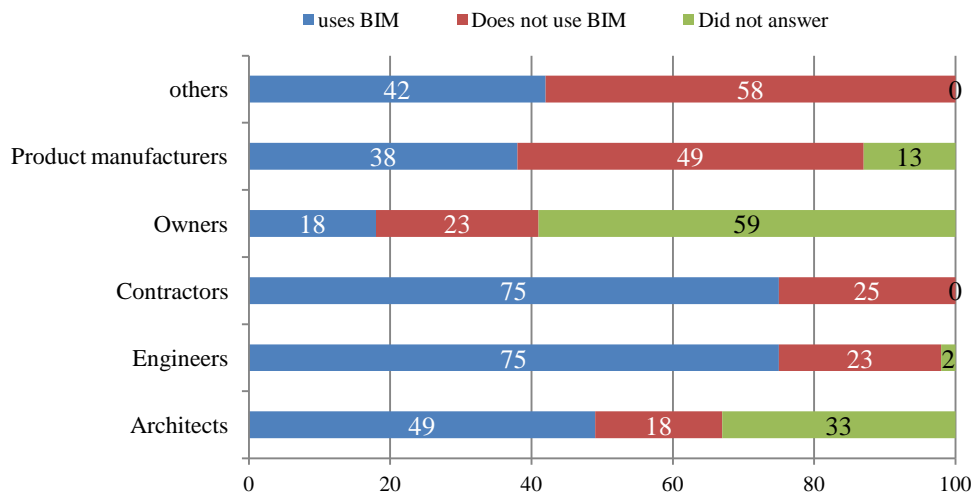

Figure 2: BIM adoption rates in Australia (adapted from BEIIC, 2010)

United Kingdom – BIM Adoption Surveys

In 2013, NBS (2013) conducted a survey including a 1000 professionals across the UK. As shown in Figure 3, the survey did not report its results by discipline but grouped all results as one:

Figure 3: BIM adoption rates in the UK (adapted from NBS, 2013)

United States – BIM Adoption Surveys

In 2012, McGraw-Hill Construction published a survey covering BIM adoption rates across North America (95% of the 582 respondents were from the U.S.) (McGraw-Hill Construction, 2012). Survey results - excluding 10% of sample size (i.e. owners and others) - is reported in Figure 4 below:
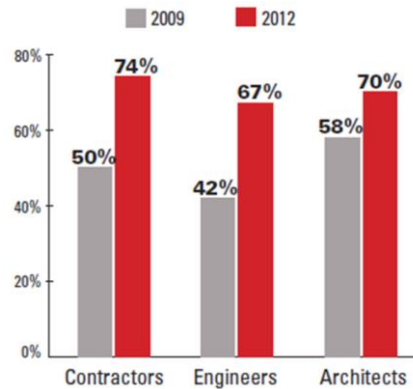
Figure 4: BIM adoption rates in the U.S. (adapted from McGraw-Hill Construction, 2012)

2. THE THREE METRICS

The survey data collated by industry associations provide valuable input into BIM adoption rates across different markets. To augment survey data, this paper proposes three qualitative metrics for measuring country-scale BIM adoption, and by extension, BIM maturity:

Metric 1: the availability of noteworthy BIM publications (NBP)s;
Metric 2: the distribution of NBPs across BIM Knowledge Content (BKC) labels and clusters; and
Metric 3: the relevance of each NBP across markets.

2.1 Metric 1: availability of NBPs

Noteworthy BIM publications (NBP)s are publically-available industry documents incorporating guidelines, protocols and requirements focusing on BIM deliverables and workflows. These publications are the product of various governmental bodies, industry associations, communities of practice and research institutions, intended to facilitate BIM adoption, and realize BIM's value-adding potential. The 'availability' of noteworthy BIM publications is proposed here as an indicator of a country's BIM maturity, a concept derived from other disciplines. For example, in e-Government research, the lowest level of maturity is 'availability' – the online presence - of government documents (Accenture, 2004). Similarly, the World Bank uses availability and number of online documentation as an indicator of a country's e-Government maturity (APEC, 2004). Another example, e-Commerce maturity identifies documentation availability as a maturity indicator (KPMG, 1997). Based on these two examples, this paper adopts a similar approach and identifies the *availability of country-specific NBPs as an indicator of that country's BIM maturity*. In this respect, Table 1 below collates several NBPs that can be used as BIM maturity indicators:

Table 1: Availability of NBPs – Metric 1

Code	Document title	Issuer Type[4]	Issuer, Year
AU 01	CRC-CI National Guidelines for Digital Modelling + Case Studies (2 documents)	RB	CRC-CI, 2009
AU 02	Digital modelling and the built environment, department of Innovation Industry, Science and Research	GD	DIISR, 2010
AU 03	Productivity in the buildings network: assessing the impacts of Building Information Models, report to the Built Environment Innovation and Industry Council	IB	BEIIC, 2010
AU 04	NATSPEC National BIM Guide and Project BIM Brief template	IB	NATSPEC, 2011
AU 05	BuildingSMART Australasia, National Building Information Modelling Initiative	IB	buildingSMART, 2012

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[4] RB: Research body, GD: Governmental department, CP: Community of Practice, PI: Private industry, IB: Industry body, LA: Local authority

Code	Document title	Issuer Type[4]	Issuer, Year
AU 06	BIM in Practice, an initiative by the Australian Institute of Architects and Consult Australia	IB	AIA-CA, 2012
AU 07	BIM-MEP AUS initiative by the Air Conditioning and Mechanical Contractors' Association of Australia (AMCA)	IB	AMCA, 2012a
UK 01	Building Information Model (BIM) Protocol - Standard Protocol for use in projects using Building Information Models, CIC/BIM ProFirst Edition 2013	IB	CIC, 2013
UK 02	AEC (UK) BIM Protocol Implementing UK BIM Standards for the Architectural, Engineering and Construction industry - Updated to unify protocols outlined in AEC (UK) BIM Standard for Revit and Bentley Building Version 2.0 September 2012	CP	AEC, 2012
UK 03	Soft Landing Strategy	GD	Cabinet Office, 2012
UK 04	Government Construction Strategy	GD	Cabinet, 2011
UK 05	BIM Management for value, cost & carbon improvement, report number URN 11/948 - A report for the Government Construction Client	GD	DBIS, 2011
UK 06	CPIx BIM assessment form	IB	CPC, 2011
UK 07	Building Information Modelling - an introduction for house builders	IB	NHBC Foundation, 2013
UK 08	Refurbishment resource efficiency case study: Manchester Central Library	IB	WRAP, 2010
UK 09	National BIM Report 2013	PI	NBS, 2013
UK 10	First Steps to BIM March 2013 Competence A Guide for Specialist Contractors	GD	NSCC, 2013
US 01	GSA BIM guides series	GD	GSA, 2007
US 02	Integrated project delivery: a guide	IB	AIA, 2007
US 03	Contractor's Guide to BIM	IB	AGC, 2006b
US 04	National building information modeling standard - version 1.0 - part 1: overview, principles and methodologies	GD	NIST, 2007
US 05	BIM user guides	GD	USCG, 2005
US 06	BIM guidelines	LA	NYCDDC, 2012
US 07	State of Ohio Building Information Modeling protocol	LA	OHIO DAS, 2010
US 08	Planning Guide for Facility Owners– Version 1.0	RB	PennState, 2012
US 09	E203: Building Information Modeling and Data Exhibit	IB	AIA, 2012a
US 10	G Document 201: Project Digital Data Protocol Form	IB	AIA, 2012b
US 11	G Document 202: Building Information Modeling Form	IB	AIA, 2012c
US 12	Consensus Docs 301 BIM Addendum	IB	ACGA, 2006
US 13	Building Information Modeling: A Road Map for Implementation To Support MILCON Transformation and Civil Works Projects within the U.S. Army Corps of Engineers	GD	USACE, 2006
US 14	Building Information Modeling (BIM) Roadmap Supplement 2 – BIM Implementation Plan for Military Construction Projects, Bentley Platform	GD	USACE, 2011
US 15	BIM Project Execution Planning Guide and Templates – Version 2.0 BIM Project Execution Planning	RB	Penn State, 2010
US 16	Construction Operations Building Information Exchange (COBIE): Requirements Definition and Pilot Implementation Standard	GD	USACE, 2007
US 17	USACE BIM Minimum Modeling Matrix (M3) V1.0	GD	USACE, 2012
US 18	The Business value of BIM in North America: Multi-Year Trend Analysis and User Ratings (2007-2012)	PI	McGraw-Hill Construction, 2012
US 19	NISTIR 7417 General Buildings Information Handover Guide: Principles, Methodology and Case Studies	GD/CP	NIST and FIATECH, 2007
US 20	IPD Case Studies	IB / RB	AIA & University of Minnesota, 2012

2.2 Metric 2: distribution

This metric reports BIM maturity in terms BIM Knowledge Content (BKC) distribution across noteworthy BIM publications. BKC is a specialized taxonomy with several classifications. The main classification identifies three *knowledge content clusters* (guides, protocols and mandates) which are subdivided into eighteen *knowledge content labels* (e.g. report, manual, and contract). As described in Figure 5, the BKC taxonomy and its classifications are derived from the explicit ontological structures of the BIM Framework (Succar, 2009) (Succar,

2013). BKC labels and clusters classify NBPs according to their *actual knowledge content* rather than according to each publication's title or its specific – and sometime conflicting - use of terminology. A succinct definition of the three BKC clusters is provided below:

- **Guides**: documents which are *descriptive* <u>and</u> *optional*. Guides clarify goals, report on surveys/accomplishments or simplify complex topics. Guides do not provide detailed steps to follow to attain a goal or complete an activity;
- **Protocols**: documents which are *prescriptive* <u>and</u> *optional*. Protocols provide detailed steps or conditions to reach a goal or deliver a measureable outcome. While documents within this cluster are prescriptive, they are optional to follow unless dictated within a Mandate (see next cluster); and
- **Mandates**: documents which are *prescriptive* <u>and</u> *dictated* by an authority. Mandates identify *what* should be delivered and – in some cases – *how, when* and *by whom* it should be delivered.

When used to assess NBPs, the three BKC clusters would inform country-scale BIM maturity assessment. For example, a country, with all its NBPs pertaining to a single cluster (e.g. guides – descriptive and optional), would arguably face different implementation challenges to those faced by a country with its NBPs distributed across guides, protocols and mandates.
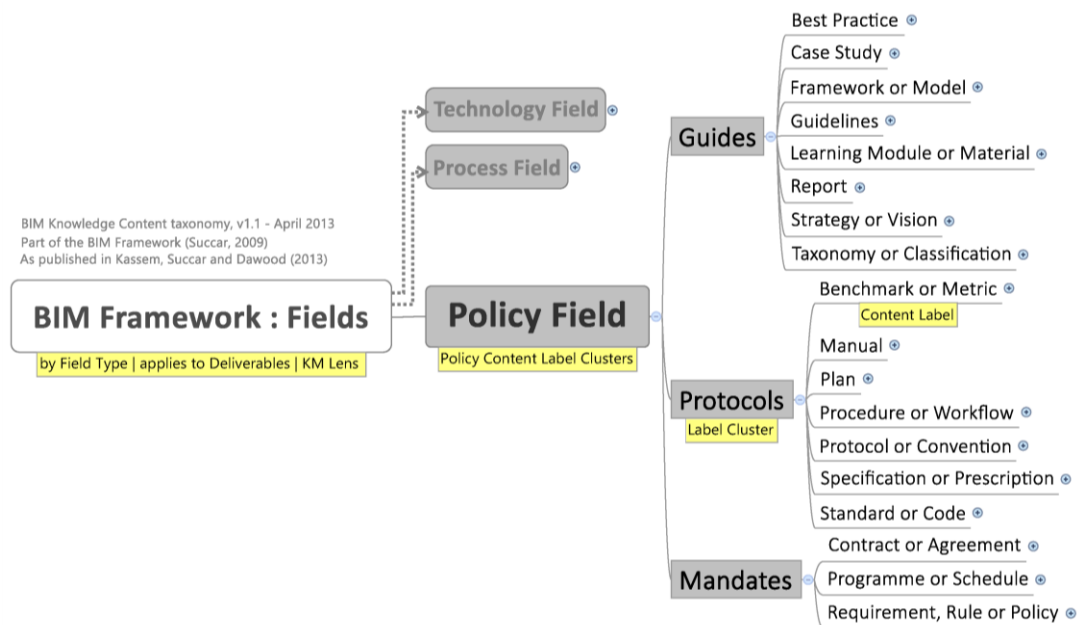

Figure 5: The BIM Knowledge Content taxonomy – Mind Map (Succar, 2013)

BKC clusters and labels (Figure 5) are applied in Table 2 below to classify sample NBPs (refer back to Table 1). Figure 6 also clarifies the distribution of NBPs across clusters:

Table 2: Mapping of NBPs using the BKC taxonomy

		Guides				Protocols				Mandates	
		Case Study	Guideline	Report	Strategy or…	Metric or…	Manual	Procedures or…	Specifications …	Contract or…	Requirement…
		G2	G4	G8	G9	P1	P2	P4	P6	M1	M3
Australia	AU 01	●	●				●				
	AU 02			●							
	AU 03			●							

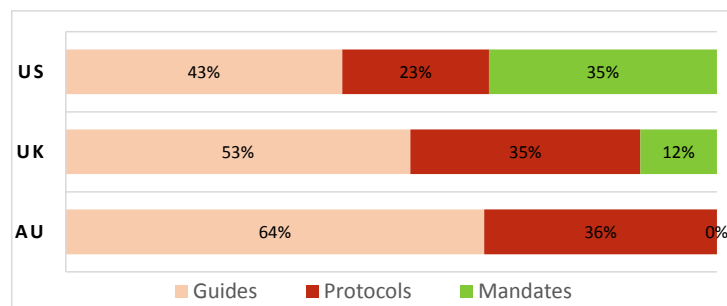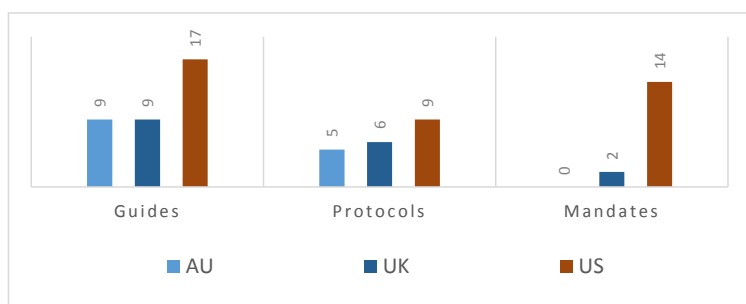|		Guides				Protocols				Mandates	
		Case Study	Guideline	Report	Strategy or…	Metric or…	Manual	Procedures or…	Specifications …	Contract or…	Requirement…
		G2	G4	G8	G9	P1	P2	P4	P6	M1	M3
	AU 04		●					●			
	AU 05			●	●						
	AU 06		●								
	AU 07		●				●	●	●		
United Kingdom	UK 01		●			●				●	
	UK 02		●			●					
	UK 03				●						●
	UK 04				●						
	UK 05			●	●	●		●			
	UK 06					●					
	UK 07						●				
	UK 08	●									
	UK 09			●							
	UK 10		●								
United States	US 01		●							●	
	US 02		●							●	
	US 03		●							●	
	US 04		●		●	●					
	US 05		●								
	US 06					●				●	●
	US 07					●				●	●
	US 08		●								●
	US 09					●				●	
	US 10									●	
	US 11									●	
	US 12									●	
	US 13		●		●						●
	US 14						●	●			
	US 15		●					●			
	US 16								●		●
	US 17					●					
	US 18	●		●							
	US 19	●	●		●						
	US 20	●		●							

Figure 6: Comparison of labels distribution among countries

2.3 Metric 3: Relevance

Using another classification developed as part of the BIM Knowledge Content taxonomy, NBPs can be assessed according to their level of relevance in comparison to other NBPs across markets. Using this metric, an NBP – noteworthy in its own right - can be measured using a five Relevance (R) index:

R0 - Redundant: the NBP includes out-dated information which is no longer usable or useful
R1 - Relevant: the NBP is relevant, current and contains actionable information
R2 - Regarded: the NBP is highly-relevant, well-cited and well-used in comparison to other similar-topic NBPs
R3 - Recommended: the NBP is authoritative and impactful and considered a reference (among other references)
R4 - Requisite: the NBP is the most authoritative document covering a specific topic

The relevance index is used below (Table 3) to compare different NBPs introduced earlier in Table 1:

Table 3: Relevance Metric as applicable to NBPs

	AU							UK										US																			
	AU 01	AU 02	AU 03	AU 04	AU 05	AU 06	AU 07	UK 01	UK 02	UK 03	UK 04	UK 05	UK 06	UK 07	UK 08	UK 09	UK 10	US 01	US 02	US 03	US 04	US 05	US 06	US 07	US 08	US 09	US 10	US 11	US 12	US 13	US 14	US 15	US 16	US 17	US 18	US 19	US 20
R0																																					
R1		●	●							●	●		●	●	●	●	●	●		●		●	●	●	●					●	●				●	●	●
R2	●				●	●			●			●							●								●	●	●					●			
R3				●			●	●													●					●						●	●				
R4																																					

The Relevance Metric as applied in Table 3 above is based on the authors evaluation through initial desktop research and their own experiences as researchers and BIM consultants. These evaluations will need to be tested, confirmed, or modified as discussed in the next section.

3. METRIC VALIDATION

This paper proposes a wider-angle approach to assessing the BIM maturity of countries by augmenting data collected through surveys with qualitative assessment of the knowledge deliverables of each country. These metrics are still in the early stages of development and are proposed here to instigate discussion and invite collaboration. The next step the authors will take is to separate between BIM adoption, readiness, capability and maturity metrics. This will be then followed by data collection from subject matter experts as to either confirm, modify or update our initial evaluation of NBPs. Based on feedback received, additional metrics may be proposed and a weighted scoring system devised and applied to compiled metrics.

4. CONCLUSIONS

There is an increasing number of BIM maturity metrics to assess the performance of individuals, organizations and projects. Of these, only a few metrics can be applied to measure and compare the BIM maturity of countries. This paper proposed a new approach to augment data collected through surveys. The three metrics are supported by a published framework and measure the availability of noteworthy BIM publications (NBP)s, evaluate NBP distribution across BIM knowledge content (BKC) clusters, and establish the relevance of individual NBPs. In addition to assessing country-scale BIM maturity, researchers and policy makers may find benefit in this proposed approach to evaluate NBPs, identify gaps in BIM knowledge content, and highlight areas requiring further research and development.

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