Comparative Analysis of International and National Level BIM Standardization Efforts and BIM adoption

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Abstract
Use of digital engineering such as BIM in construction projects reveals social and economic benefits through productivity improvement, better visualizing and collaboration, and ease of communication. However, BIM standardization efforts and policy initiatives that ultimately influence the adoption varies significantly from country to country.

This paper presents the international and national BIM standardization efforts. National standardization efforts and policy initiatives are discussed with the emphasis on pre and post policy BIM adoption. Policies of countries leading in BIM adoption such as the USA, the UK, Singapore, Finland and Norway are discussed. The USA and the UK BIM adoption were specifically analyzed in terms of contractors' BIM adoption and the proposition of BIM use by owners. The analysis suggests that the national governance and institutional frameworks influence BIM adoption. Hence, we recommend that the governments in the countries where BIM is becoming established should consider proliferation of national standards and compliance for a wider spread of BIM adoption.

Keywords: BIM, standardization, policy initiatives

1 Introduction
Building information modeling (BIM) appears to be established now as one of the most promising recent developments in digital engineering in the Architectural, Engineering and Construction (AEC) industry. Studies (Talebi, 2014) conducted have revealed the benefits and challenges of BIM adoption in real construction projects.

Both social and economic driving forces for BIM adoption and value propositions were studied globally among contractors (McGraw Hill, 2014), designers, engineers and clients (Eastman et al., 2011; McGraw Hill, 2014 b). A global survey (McGraw Hill, 2014) found that 75% of highly BIM engaged contractors perceive that BIM has the ability to capture most detailed comprehensive information of a building project while 41% of contractors perceive that the reduction of design errors using clash detection as the top ranking benefit of BIM adoption. 21-23% of contractors value efficiency in quantity take-off and cost estimating (reduced construction cost) while 19% of contractors value 4D models to support construction analysis and planning (reduced overall project duration).

Studies (Taylor and London, 2011; Shan et al, 2012) reported productivity improvements gained though BIM adoption on case study projects. For example, a case study project, City of Dreams Casino Macau (Taylor and London, 2011) reported a significant productivity improvement in time (of re-work) and cost of Heating, Ventilating, and Air Conditioning (HVAC) through BIM adoption. There was only 43 hours of rework on the entire project compared to an anticipated 25,000 hours and this has been attributed to the use of BIM. The HVAC contractor projected over 4.5% (US$400K) of labor savings on the $HKD 9.04 Million guaranteed maximum price (GMP) contract through BIM adoption. Supportively, Shan et al (2012) reported a 38% reduction of work hours through the

implementation of a BIM model based steel connection system compared to a conventional steel connection construction methodology.

Even though the driving forces for digital engineering and building information modeling for construction are revealing globally, national level standardization and policy initiatives vary significantly in different countries. This can result a variation in BIM adoption because national policy initiatives as well as standardization of the regulatory environment have a significant influence. For example, countries such as Singapore, the UK, the USA and Finland are leading in BIM policy regulations and adoption, while policy initiatives and adoption in countries such as Australia are still slow. Policy initiatives can range from exclusive mandatory requirements to more market driven laissez-faire approaches.

This study conducts a comprehensive literature review on international and national regulations and policy initiatives and analyzes the BIM adoption globally. The countries are selected to represent various geographic regions according to the availability of data. The aim of this piece of work is ultimately to drive towards a deeper analysis of the concept of the "internationalization of BIM". This study is useful for high level built environment/infrastructure policy makers, large government agencies exploring BIM implementation at project and program level and also the international construction companies who work across country boundaries and grapple with the complexity of different regulatory frameworks and practices.

2 BIM Standardization

2.1 International Standards

As BIM evolved with CAD, various CAD vendors promoted BIM as their own solutions. These proprietary applications use vendor specific data formats, non-standard/non compatible methods and interfaces. The absence of a publicly available open standard resulted inter-operability issues between various applications, which hindered the collaboration between stakeholders in design, procurement and operation. For example, the software packages architects use were not compatible with the packages the structural engineer uses. Hence, the need for an established norm or requirement about technical systems arose.

Early efforts to standardize CAD include Initial Graphics Exchange Specification (IGES) in the USA and VDA-FS in Germany. ISO Standard for the Exchange of Product model data (STEP) 10303 which is a 3D CAD standard and VDA-FS was superseded by ISO standard (STEP). Construction specific standardization efforts within STEP include AP 241 and Generic Model for Life Cycle Support of AEC Facilities.

A step change in BIM standardization occurred in 1990's with the formation of buildingSMART, formerly called the International Alliance for Interoperability (IAI), with a number of chapters around the world. The aims of buildingSMART were to improve the exchange of information between software applications used in the construction industry. As a result, Industry Foundation Classes (IFCs) were developed in 1994 as a neutral and open data format for open BIM. IFC Data model is registered with ISO as ISO16739.

Other international standards worth noting include ISO 13567, which is used to standardize the CAD layers, and ISO 12006 Building construction standards for modeling structures (Part 2: Framework for classification of information and Part 3: Framework for object-oriented information). In addition to IFC data model, BuildingSMART defines two other families of corresponding standards (1) ISO 12006 part 3 for International Framework for Dictionaries (IFD) and (2) ISO 29481 Process Definition Standard - Information Delivery Manual (IDM).

2.1.1 IFC Data model

The IFC data model is now in its fourth release (2013) and it incorporates several extensions of the original model specifically in relation to building, building service and structural areas, enhancements of geometry and other resource components. Release 4 also includes numerous quality improvements, a fully integrated simple ifcXML specification and a new documentation format. The IFC specification is written using the EXPRESS data definition language based entity-relationship model consisting of entities organized into an object-based inheritance hierarchy.

Following are the main file formats that IFC specification supports to exchange file structures between different applications.

- ASCII file format (IFC data file with suffix ".ifc").
  This is the most widely used IFC format due to the compact size yet readable text.
- IFC-XML as an XML format(IFC data file with suffix ".ifcXML")
  The ifcXML exchange file structure is the XML document structure and suitable for interoperability with XML. ifcXML spec is provided as defined by W3C.
  The XML schema is automatically created from the IFC-EXPRESS source using the "XML representation of EXPRESS schemas and data". This ensures that both IFC-EXPRESS and ifcXML handle the same data consistently and that the *.ifc and *.ifcXML data files can be converted bi-directionally.
  Due to the large size of typical building models, this format is less common in practice.
- The property set and base quantity library

2.2 National Standards

This section discusses the BIM policy initiatives and standardization efforts by selected countries. The countries were selected based primarily on BIM leadership and to cover various geographic regions globally. Table 1 summarizes BIM standardization and policy initiatives by each country together with the administration organization/regulatory body.

2.2.1 USA

U.S. General Administration (GSA) commissions federal buildings. In 2003 the General Services Administration (GSA), through its Public Buildings Service (PBS) Office of Chief Architect (OCA), established the National 3D-4D-BIM Program. For all major projects, (prospectus-level) receiving design funding in Fiscal Year 2007 and beyond, GSA requires spatial program BIMs be the minimum requirements for submission to OCA for final concept approvals by the PBS Commissioner and the Chief Architect. At the same time, all GSA projects are encouraged to deploy mature 3D, 4D, and BIM technologies (spatial program validation and beyond, at strategic project phases in support of specific project challenges. (GSA, 2014) In addition, GSA published a series of (eight) BIM guides: 3D-4D-BIM overview, spatial program validation, 3D laser scanning, 4D phasing, energy performance and operations, circulation and security validation, building elements and facility management.

National Institute of Building Sciences (NIBS) is an authoritative source of innovative solutions for the built environment and was established to act as the interface between government and private sector. The National BIM Standard-United States (NBIMS-US) which is currently in its version 2, was developed as an initiative of NIBS's buildingSMART alliance. NBIMS-US provides consensus based standards through referencing existing standards, documenting information exchange and delivering best business practices for the entire built environment. With open BIM standards, detailed models can be built which then deliver accurate products that can be used during commissioning and operation to ensure facility functionality throughout the life of the facility and to deliver high performance, carbon neutral, and net zero energy based facilities (NIBS, 2014).

Industry wide BIM adoption in North America surged from 28% in 2007 to 71% in 2012 (49% in 2009). In 2012, 71% of architects, engineers, contractors and owners report that they have become engaged with BIM on their projects, showing a 75% growth over five years (McGraw Hill, 2012). The same study reported the percentages of BIM stakeholder groups (architects, engineers, contractors and owners) who were using BIM in 2009 and 2012 and who were projecting to use BIM in 2014 in more than 60% of their project. Table 2 shows the BIM policy initiatives in the USA and BIM adoption in North America.

Table 1 BIM standardization and/or policy initiatives by country

Country	Organization	Standardization and/or Policy Initiative
USA	U.S. General Administration (GSA)	• National 3D-4D BIM Program in 2003 • BIM required in all final concept approval for all major projects since 2007

		• 3D, 4D, and BIM technology deployment encouraged in all GSA projects • GSA BIM Guide Series
	National Institute for Building Science (NIBS)	• National Building Information Modelling Standard (NBIMS) on Building Energy Performance(BEP)
UK	UK government	• Model-based BIM (level 2) mandated on all public sector projects by 2016. • Commitment to BIM in Government projects over a 5-year time frame
	BIM Task Group	• Support and assistance in transitioning to BIM and electronic delivery • Information sharing environment (Operations Building Exchange COBie)
	AEC (UK) committee	• Unified standard for the Architectural, Engineering and Construction industry CAD & BIM in the UK
	British Standards Institute (BSI)	• Information sharing standards created (PAS 1192:2)
Finland	Senate Properties	• Models meeting IFC standards in its projects mandated since 1 October 2007 • BIM Guide called Common BIM Requirement 2012, COBIM
Norway	Civil State Client Statbygg	• BIM mandated for the lifecycle of their buildings. • All Statbygg project using IFC/IFD based BIM by 2010 • Statsbygg Building Information Modelling Manual released in 2007
	Norwegian Homebuilders Association	• Norwegian Homebuilders Association BIM Manual
Singapore	Building and Construction Authority (BCA)	• BIM e-submission system mandated for regulatory submissions in 2015 • Singapore BIM Guide
Hong Kong	Hong Kong Housing Authority	• Full implementation of BIM on all its housing development projects by 2014 • BIM standards, user guide, library component design guide and references.
South Korea	Korean Ministry of Land Infrastructure and Transportation (MLIT)	• BIM mandated for all projects over S$50 million and for all public sector projects by 2016
Australia	BEIIC (the Built Environment Industry Innovation Council)	• National Building Information Modelling Working Party reporting to BEIIC • NATSPEC National BIM Guide developed in 2011

Table 2 BIM policy in the USA and adoption in North America (data source: McGraw Hill, 2012; McGraw Hill, 2014)

Year	Policy	Industry	Percentage of stakeholders[1]

[1] Percentage of stakeholders using BIM on more than 60% of their projects

		wide adoption	Architects	Engineers	Contractors	Owners
2003	National 3D- 4D BIM program					
2007	BIM mandated	28%				
2009		49%	37%	21%	21%	18%
2012		71%	60%	26%	31%	30%
2014			75%	43%	55%	44%

A recent survey done with contractors (McGraw Hill, 2014), reported that BIM has established traction among contractors in the USA. McGraw Hill, (2014) developed a BIM engagement index to measure the level of engagement of contractors. The US has both the fewest low-level users (21%) and the largest number at high and very high levels (22%) compared to other countries (McGraw Hill, 2014). These can be due to: (i) policy in place for seven years; (ii) post-policy active adoption of BIM; and (iii) wide spread use and rapid growth. Also McGraw Hill (2014, p.44) reports that the contractors in North America are far more advanced at BIM use compared with those in other parts of the world, and they are planning to invest to increase the depth of use. Of particular importance is the collaboration of owners as well as use of BIM for improving process outcomes and reducing error and omissions. 82% US based contractors also consider multi-trade coordination of BIM to be a top pre-construction activity. This demonstrates the penetration of BIM use in other stakeholder groups beyond the designers.

The survey indicated that 11% of US owners reported that they were at a very high BIM involvement level (over 75% of their projects involve BIM) in 2012 (McGraw Hill, 2014b) and furthermore, 40% forecast they would be at that level in 2016.

Tables 3 and 4 show the BIM adoption data among contractors and proposition of BIM use among owners in the USA together with BIM policy initiatives. BIM Policy initiatives and the adoption data discussed above over the years are shown in Figure 1.

Table 3 BIM engagement of contractors in the USA (data source: McGraw Hill (2014))

Year	BIM engagement Index in the USA(BIM engagement Index globally)			
	Low	Medium	High	Very High
2003	National 3D- 4D BIM program			
2007	BIM mandated			
2014	21%(36%)	36%(36%)	22%(17%)	22%(11%)

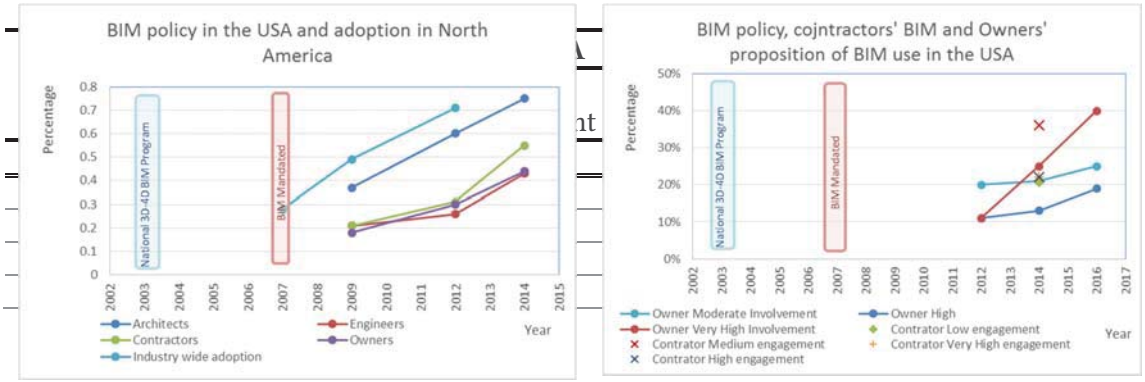

Table 4 Proposition of BIM Usage by owners in the USA (data source: McGraw Hill (2014b))

2.2.2 UK

BIM maturity model in the UK specifies different levels. Level 2 BIM is a series of domain specific models (e.g. architectural, structural, services, etc.) with a single environment where structured data can be shared using an information sharing environment called COBie UK 2012 (Construction-

Figure 1 Policy Initiatives and BIM adoption in North America and the USA

Operations Building information exchange). CoBie format was created by Bill East of the US Army Corps of Engineers. Level 2 BIM is defined as "file based collaboration and library management. Level 3 in BIM maturity model in the UK is an integrated and interoperable version of BIM (iBIM).

By 2016, level 2 BIM will be mandatory on all public sector projects, including delivery of all project and asset information, documentation and data. The overarching goal of the government's BIM strategy is to reduce capital costs and carbon dioxide creation from the construction and operation of the built environment by 20%. The UK government also developed a BIM Task Group to support and assist both government and non-government contractors in transitioning to BIM and electronic delivery. In addition, British Standards Institute (BSI) created information sharing standards called PAS 1192:2 that delivers the workable definition of Level 2 technology compliance. UK Government's commitment to embrace BIM in government projects over a 5-year period includes a roadmap.

McGraw Hill (2014) reports that 12% of the UK contractors have been using BIM for six or more years, while 19% BIM general contractors in the UK claim more than 10 years' experience. The highest percentage of BIM beginners are in the UK (37%) likely reflecting the increase of BIM users in response to the government policy to mandate BIM in 2016. Table 5 shows the BIM engagement data among contractors where there is a significant percentage (54%) of low engagement users.

Table 5 BIM engagement of contractors in the UK (data source: McGraw Hill (2014))

Year	BIM engagement Index in the UK(BIM engagement Index globally)			
	Low	Medium	High	Very High
2014	54%(36%)	19%(36%)	17%(17%)	11%(11%)
2016	level 2 BIM mandated			

A recently conducted survey on BIM adoption by product manufacturers as a health-check, reports that many (40%) are ready for April 2016 and most of the rest (50%) intend to be (BIM4M2, 2014).

McGraw Hill (2014 b) survey of owners reported that the UK owners are generally more enthusiastic about their BIM involvement, triggered by the impending government mandate for 2016. The very high involvement level shows a consistent growth from 22% in 2012 to a forecast of 38% in 2016. Almost all (92%) report being at least moderate users in 2012, as shown in Table 6.

Table 6 Proposition of BIM Usage of owners in UK (data source: McGraw Hill (2014b))

Year	Proposition of BIM use in UK		
	Moderate Involvement (25-50%)	High Involvement (51-75%)	Very High Involvement (more than 75%)
2012	42%	28%	22%
2014	12%	58%	28%
2016	22%	35%	38%
2016	level 2 BIM mandated		

2.2.3 Finland

Senate Properties is a government owned enterprise under the Finnish Ministry of Finance and acts as the government's expert on the working environment and working premises. Senate Properties has mandated the use of models meeting IFC standards in its projects since 1st October 2007. In addition, Senate Properties published series of project requirements detailing guidelines for modelling requirements. This series of BIM requirements is called Common BIM Requirement (COBIM, 2012). There has been a series of 13 releases to date include : general part, modelling of the starting situation, architectural design, MEP design, structural design, quality assurance, quantity take-off, use of models for visualization, use of models in MEP analyses, energy analysis, management of a BIM project, use of models in facility management and use of models in construction.

2.2.4 Norway

The civil state client Statsbygg in Norway mandated BIM use for the lifecycle of their buildings. By 2010, all of Statsbygg project were using BIM models based on IFC and IFD. The BIM guideline in Norway is called "BIM Manual". Statsbygg Building Information Modelling Manual's first version was released in 2007 and its current version is 1.2.1.9 (BIM Manual, 2013) Norwegian Homebuilders Association BIM Manual is among other industry guidelines and its latest version is 2.0 (Norwegian Homebuilders Association BIM Manual, 2012). It aims to give a practical aid to use BIM for project planning for residential dwellings.

2.2.5 Singapore

The Building and Construction Authority (BCA) in Singapore led a multi-agency effort in 2007/2008 to implement the world's first BIM electronic submission (e-submission). This initiative called Construction and Real Estate Network (CORENET) was established in 2011 (BCA, 2011). Project teams only need to submit one building model, which contains all of the information needed to meet the requirements of a regulatory agency. The CORENET is the central repository for building codes, regulations and circulars published by various building and construction regulatory agencies in Singapore. The agencies involved are BCA, IDA, JTC, LTA, MOM, NEA, NParks, PowerGas Ltd, PUB, SPRING Singapore, SCDF and URA. The milestones of the regulatory requirements and BIM roadmap in Singapore are as follows (Fat, 2012).

- In 2012 BIM was mandatory as part of public sector building project procurement
- In 2013 architectural BIM e-submission was mandated for all new building projects greater than 20,000 sqm.
- In 2014 engineering BIM e-submission was mandated for all new building projects greater than 20,000 sqm.
- In 2015 architectural and engineering BIM e-submission was mandated for all new building projects greater than 5,000 sqm

The Singapore BIM Guide is the reference guide that outlines the roles and responsibilities of project members when using BIM at different stages of a project (Singapore BIM Guide, 2013). It consists of both BIM Specifications and BIM Modelling and Collaboration Procedures. The Singapore BIM Guide was first launched in 2012.

2.2.6 Hong Kong

The Hong Kong Housing Authority (HKHA) started piloting BIM since 2006. Hong Kong was aiming for full implementation of BIM on all its high-rise housing development projects by 2014. BIM standards, user and design guides and reference material were prepared to facilitate the process. These include BIM standards manual, BIM user guide (Part I), BIM user guide (Part II), BIM library components design guide, BIM library components reference and standard approach of modelling (SAM) for creating building information structural model.

Wong et al. (2011) discusses the Hong Kong public sector initiatives on BIM adoption. They highlight the implementation of BIM in Hong Kong and the USA and further recommend strategies for BIM implementation in Hong Kong.

2.2.7 South Korea

The Public Procurement Service in South Korea made BIM compulsory for all projects over S$50 million and for all public sector projects by 2016[2]. McGraw Hill(2014) reports that while BIM is reaching maturity among contractors in Europe and north America, it is becoming established with contractors in other regions that represents the next tier of BIM maturity where the majority of their contractors' BIM use falling in the three to five years' experience tier.

2.2.8 Australia

National Building Information Modelling initiative was taken by the Built Environment Industry Innovation Council (BEIIC) in Australia. buildingSMART Australasia, commissioned by BEIIC conducted stakeholder consultation workshops in early 2012 in Adelaide, Brisbane, Canberra, Hobart, Melbourne, Perth and Sydney with 160 participants representing a broad cross section of the Australian building and construction industry - including clients, consultants, contractors,

[2] http://www.buildingsmart.org/wp-content/uploads/2014/07/October-2014-Richard-Petrie-Toronto-Plenary-Standards-Overview.pdf

educators and government representatives. The workshop participants unanimously endorsed the need for national action in six areas: procurement and legal issues; BIM guidelines; multi-disciplinary BIM education; product information libraries; business process change; and compliance and certification issues as a matter of priority (builidngSMART Australasia, 2012). Milestones of Australian initiatives include the NATSPEC National BIM Guide developed in 2011 and ACIF-APPC BIM Framework released late 2014.

McGraw Hill (2014) reports that the Australia and New Zealand region shows unique leadership in external collaborative processes (50%) and upgrade desktop hardware (50%) and contractors in Australia show above-average (67%) commitment to building models. However, compared with those with other regions, contractors in Australia and New Zealand are slightly newer BIM users, which resulted in their relatively lower engagement levels.

McGraw Hill (2014) further reports that majority of the contractors' BIM use fall in the three to five years' in Australia. The recent contractors' BIM adoption represents that BIM is becoming established in the regions including Australia.

3 Discussion and Conclusions

This paper studied the international and national level BIM standard and policy initiatives globally. BIM policy initiatives in selected countries/regions were analysed together with BIM adoption where the data is available.

Does mandating influence the BIM adoption?

In the USA, the National BIM policy program was introduced in 2003. Four years later BIM was mandated in the USA. Even though, there was 28% industry wide BIM adoption in North America when the legislation mandated BIM for architectural drawings, two-year later the industry adoption reached almost half. Five years from the legislation, industry adoption reached 71%. It is also, notable from North American data that the architects were the leading stakeholder group in post-policy BIM adoption, while owners lag behind in BIM adoption compared to other stakeholder groups. Despite, seven years from the legislation three quarter of architects were using BIM while almost half of other stakeholder groups including engineers, contractors and owners were using BIM. It is notable that there is a significant influence of the legislation for the architects' quick adoption growth. Supportively, USA wide adoption data reported that only about one fifth of contractors had low level of BIM engagement after seven years from legislation. Only 40% of owners were willing to highly involve with BIM even after nine years from the legislation. The USA as a country where BIM is well-established, shows that the national governance and institutional framework influences the wide spread of BIM adoption.

UK government policy is in place to mandate level 2 BIM in 2016 with a five-year government commitment to encourage industry to participate. The BIM engagement among more than half of contactors in UK is low in 2014. Interestingly, in the same year 58% owners reported high BIM involvement with a 35% proposition to use BIM with a high involvement in 2016. This might be due to the announcement of the strategy that mandates the use of level 2 BIM by 2016 but also due to the presence of a comprehensive BIM maturity model. The BIM maturity model requires level 3 BIM as the next stage where BIM is fully integrated to enable collaborative process between all the parties.

Despite the limited adoption data, policy initiatives of other leading countries, such as Finland, Norway, Singapore and HongKong were also discussed. The adoption data evidence that BIM is becoming established in South Korea and Australia.

Hence, through preliminary analysis, we argue that there is an influential link between national policy initiatives and the adoption data. Supportively, Gu et al. (2014) mention in their BIM Ecosystem that government regulations are critical to promote BIM usage and adoption in strategic and significant projects. However, a strong causal relationship cannot be claimed without a robust data collection. In addition, as Gu et al. (2014) argue, compliance and proliferation of national standards can be one of the instruments that governments can use among the others including incentives, rewards and code of practice to promote BIM adoption.

Future work

Future studies of this work include exploring the influence of policy on BIM adoption based on cases selected from a country where BIM is well established and a country where BIM is becoming established such as Australia. The Australian NATSPEC National BIM Guide will be revisited to compare with leading counties to investigate the strengths and weaknesses.
In addition, the aspects of international code of practice for multi-national projects will be studies. This will attempt to address the questions of which code to be used?; the country of origin; the consultants country; the contractors country; or an independent international code.

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