A Global Analysis of BIM Standards across the Globe: A Critical Review

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Building Information Modelling (BIM) represents a paradigm shift in the Architectural, Engineering and Construction (AEC) industry as companies reposition themselves from a people, technology and process perspective to improve efficiency and quality. Different countries worldwide have made considerable effort to produce different standards in isolation for successfully delivering projects using BIM. This has highlighted the lack of and the need for a review of these efforts for BIM implantation and adoption. Thus, aim of this paper is to identify and compare BIM standards, guidelines and templates from around the globe in order to provide an indicative central resource for BIM documentation and gaps in BIM standards. To achieve this aim, a qualitative research methodological approach was utilised, underpinned by document analysis of BIM standards developed in different countries across six continents. These findings are presented in tabular format along with illustrations to highlight documentation gaps, which form the basis of discussion. This research evaluates 13 countries' BIM standards, guidelines and templates; the correlation of which presents relationships and synergy, including recommendations for the development of standards based on the gaps presented. Research findings provide a pivotal appreciation of the different levels of maturity – the discourse of which can act as a signpost for each countries reflection, viz: government, industry bodies or academic institution to help develop BIM standards to fill the gaps in contract, Employers Information Requirement (EIR), BIM Execution Plan (BEP) and design documentation.

Keywords*:* BIM, Adoption, Analysis, Design, Standard

1.0 INTRODUCTION

Given the unique nature of construction projects, paper-based drawings and fragmented working relationships with different stakeholders; the Architectural, Engineering and Construction (AEC) industry suffers with problems not often encountered by other industries. The governments push to tackle these issues led to a technical and process revolution termed 'Building Information Modelling' (BIM) which is being embraced by the AEC industry (Rahman and Suwal, 2013). United States National Building Information Modeling Standard (NBIMS) describes BIM as "a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle; defined as existing from earliest conception to demolition" (NBIMS, 2007).

The transition to Computer-Aided Design (CAD) did not radically alter the way professionals worked; it simply fast tracked the delivery process. The emphasis with CAD was on format and output, whereas BIM focuses on open information and workflows (Livingston, 2007). BIM adoption is rapidly becoming a matter of importance for the global construction industry that has faced barriers and challenges to increase productivity, efficiency and quality.

There are currently six countries with national BIM mandates (UK, Singapore, Norway, Finland, South Korea and Denmark). However, many other countries are set to follow suit as BIM adoption gains momentum (Carr, 2015). McGraw Hill Construction (2015) research higIhlighted that BIM use across several countries is forecast to greatly increase over the next 2 years with the UK at 136%, South Korea at 126%, Australia at 115%, China at 108% and Germany at 95%, and with the global average anticipated at 95%. A recent study by Jung and Lee (2015) suggests that North America have been using BIM the longest with an average of 8.5 years, compared with Oceania at 7.7, The Middle East/Africa at 5.9, Europe at 5.3, Asia at 4.9 and South America at 3.4.

This radical shift in people, process and technology needs to be underpinned by standards and guidance, and instigated via a 'top down' approach. Succar (2009) stipulates that the majority of AEC firms would benefit from a clear set of guidelines and standards which present a measurable and repeatable methodology to implement BIM at national and organizational level. In addition to understanding of the processes and workflows required for BIM, standards for BIM are also key elements for effective BIM implementation (Obi et al 2021). Godager et al (2021) highlighted the need for to improve the existing standards to allow for integrating BIM and other technologies for handling structured and unstructured data. This investigation seeks to identify BIM standards, guidelines and templates, compare their relationships and highlight gaps in BIM documentation across six continents (Australasia, Asia, Europe, North America, South America and The Middle East) where there were efforts to produce BIM standards, to promote best practice and further development of BIM standards around the globe.

2.0 MATERIALS AND METHODS

As part of an ongoing research study, a desk-based research has been adopted for this stage as the main method of research to achieve the purpose of this study. Document analysis has been carefully selected to form the basis for this research study to provide a systematic procedure for reviewing and evaluating documents. Some advantages of document analysis include efficiency, availability of documents, cost-effectiveness, lack of obtrusiveness and reactivity, stability, exactness of data and wide coverage (Bowen, 2009). Given the recent advancements in BIM technology and standardisation measures, literature has been confined to industry standards, guidelines and templates.

2.1 Qualitative approach

As this research looked at the developed BIM standards in countries with high usage of BIM in AEC industry. There were many countries requested for BIM usage in the delivery of construction projects but did not develop BIM standards. Thus, this study focused on those

countries which developed BIM standards to aid practitioners in sharing information without ambiguity and misunderstanding of information. The key research question was how the current BIM standards would help in collaboration between the different participants in a construction project. To answer this question, qualitative research approach was found to be the most appropriate one as purpose of this research was not to measure or amenable to count data about BIM Standards in different countries. The technique adopted for data collection was analysis of government reports, documents, websites about BIM standards in the countries of the study (Hammarberg et al., 2016). Content analysis method was used in collecting the primary data (Hennink et al. 2020). Documents that have been used for systematic evaluation as part of this study include BIM standards, guidelines and templates. Data has been collated through a comprehensive review of global BIM standards, guidelines and template publications. Research has been limited to thirteen countries (See Table 1) which have a large share of construction market value or a reputation for BIM use/research (Roberts, 2019). BIM documentation developed by the governments, Local Authorities, States, academic institutions and industry bodies are recorded, analysed and discussed.

3.0 PREVIOUS RELATED WORK

A detailed investigation by Xu et al. (2014) identified that BIM standards have the strongest effect on whether companies and individuals adopt BIM. Chan et al. (2019) stated that one of the key barriers to BIM adoption by AEC industry was the lack of BIM standards. Becerik-Gerber, et al. (2011) identified that 71% of the BIM companies questioned, utilise BIM standards, of which only 35% adopted industry standards, the remaining 65% developed their own company standards. Whilst the push appears to stem from industry, it is important to understand global trends in BIM Standardisation. More recent study conducted by Panteli et al. (2020) discussed the recent advancements in the field of BIM standardisation in the European Union member countries. This study found that the existing regulations have focused on the improvement of general BIM concept, classification, processes, methodologies, information exchange among various participants in the design and construction of a facility and information management during its use.

A study by Smith (2014) into global strategies highlighted trends in BIM implementation in North America, Scandinavia, UK, Singapore, China, Hong Kong and Australia. Findings showed that North America, UK and Scandinavia are leading the way with critical factors being government support and coordinated BIM standards, legal protocols and education. Jung and Lee (2015) explored the status of BIM adoption across six continents and transcontinental, North America, Europe, Oceania, Asia, Middle East and North Africa and South America. Overall, North America was the most advanced continent, closely followed by Oceania and Europe. These three continents, along with Asia are advancing rapidly towards a high maturity level, whereas the Africa and South America are still in the early phase. A review of noteworthy BIM publications was undertaken by Kassem, et al. (2013) which only documents BIM publications from the U.S., UK and Australia, whilst failing to highlight standards from successful BIM adopters such as Singapore, Finland and Norway to name a few. Additionally, the majority of publications are now date due to BIM developing at a rapid rate.

Many other studies, similar to that of Howard and Bjork (2008) concentrate more on BIM and industry standardisation from an Information Technology (IT) perspective, with particular emphasis on Industry Foundation Classes (IFC).

Azzran et al. (2019) argued that using open BIM standards such as COBie and IFC during the operational stage might solve many problem facing facilities management systems. The use of open BIM standards will help in making sure that the exchanged information can be used by the stakeholders for different purposes and for as long as needed (Oldfield et al., 2017). Demenev et al. (2019) pointed out that analysis of the trends of modern construction industry revealed the need for using standards for BIM, which might help in executing certain tasks during the whole life cycle of a facility.

However, the one commonality between all previous research studies is that no attention has been focused on not only creating a global BIM standards resource, but also categorizing and analyzing BIM standards per country to gauge maturity.

4.0 STANDARDS

Several leading standardization bodies regarding BIM (e.g. British Standards Institute, International Organisation for Standardisation, European Committee for Standardisation) have been established to develop standards specifically for BIM implementation in a bid to make sharing and exchanging information between different participants in delivery and use of a facility smooth and trouble free.

Substantial effort has been made by some countries to help define standardised BIM methodologies and tools for documenting the information requirements of design, construction and operational processes (See Table 1). This push aims to resolve inefficient working practices which have plagued the AEC industry over the years. Demystifying processes enables all project stakeholders to work in the same way, collaborate efficiently, and share compatible models and information for the good of the project. This section seeks to highlight those countries that are at the forefront of standardising BIM and those that are trailing in their wake. Standards are highlighted to serve as a useful reference point and aligned to BIM work stages.

New Zealand and Australia have several industry bodies in common, with the National Building Specifications (NATSPEC) and the Australian and New Zealand Revit Standards (ANZRS) publishing BIM guidance documentation in both countries. Relationships between New Zealand's BIM documentation refers only to their sister documents published by the same issuer. That being said, there are a broad range of guidance documentation relating to several project phases but with the exception of an EIR and BIM contract.

Although many government projects in China possess the resources to capitalise on the benefits of BIM, the Chinese government has yet to issue any nationwide regulations to mandate BIM use on public projects. Therefore, the progression of BIM use in China over the last decade has been driven purely from the marketplace. China's 'National 12th Five Year Plan (2011-2015)' makes no specific reference to BIM, although it does state China's commitment to creating more energy efficient buildings. It would be difficult to see how this could be achieved without a mandate for BIM implementation. Findings demonstrate that standards aren't being used comprehensively as they have not been tailored to the needs of Chinese culture and conditions (Xu, et al., 2014) and that existing Chinese construction laws and regulations lack the relevant provisions for a collaborative BIM process (Su, 2013).

Table 1: BIM Standards Adoption in Different Countries

		Countries Adopting and Implementing BIM with Developed Standards												
		USA	**UK**	**Demark**	**Finland**	**Sweden**	**Netherlands**	**Spain**	**Norway**	**New Zealand**	**Australia**	**China**	**South Korea**	**Hong Kong**
Assessment Criteria	BIM Standards may have impact on Building Programme	√	√			√		√	√	√	√			√
	BIM Standards relate to Building Codes/Regulations	√	√	√	√	√	√	√	√			√		

	BIM Standards, Guidelines and Templates are clear and easy to follow	√	√		√	√	√			√	√		√	√
	BIM Standards may influence the Project Cycle	√	√	√	√		√	√	√				√	√
	BIM Standards support for 3D Working Methods			√						√	√	√		√
	BIM Standards support for BIM adoption in an Organization	√	√					√	√			√	√	
	BIM Standards support for digital compliance checking					√		√		√	√			
	Standards for BIM Execution Plan	√	√			√				√				√
	Information Support for Facilities Management	√	√		√			√	√				√	
	BIM Standards for Digital Information Security		√											
	Support for Co-ordinating Building Information system	√	√	√	√	√	√		√	√		√		
	BIM Standards Discipline Specific	√			√		√	√	√			√	√	√
	Collaborative development (Standards developed by different disciplines and Academia)	√	√		√			√						
	BIM standards may impact Manufacturers				√					√	√	√		
	BIM Standards for Energy Simulation							√	√					

Although Hong Kongs government has yet to mandate the use of BIM, The Hong Kong Construction Industry Council (CIC), a statutory body responsible for coordinating Hong Kong's construction industry, are making progressive steps to increase BIM use. A key part was assisting in the development of the *Hong Kong* Institute of *Building Information Modelling* (*HKIBIM*), 2014 report 'Roadmap for Building Information Modelling Strategic Implementation in Hong Kong's Construction Industry' which identified the need to devise a set of standards to facilitate the wider use of BIM on AEC projects. It is recommended that standards should include, but not limited to; Project Execution Plan, Modelling Methodology, Level of Detail, and Component Presentation Style and Data Organisation, with the scope involving all disciplines and building lifecycle stages.

The European Union's recently amended directives on public procurement to encourage Member States to adopt BIM by 2016, is favourable for its roll out in France, but the government must act quickly or face slipping behind competitors in the international market (Delcambre, 2014). However, BIM Crunch (2014) suggests that a realistic target mandate for BIM use on public sector projects is 2017. Although, there are no BIM standards or guidelines currently available, France is taking steps to develop standards which will support the roll out of BIM. These include the establishment of "Le Plan Transition Numérique dans le Bâtiment" task group to develop a BIM mandate which will see 500,000 houses designed and built using BIM over a three year period from 2014 to 2017 (Knutt, 2015); MINnD exploring and developing open BIM standards for infrastructure projects within France with research centered around four key issues, the structure of information, improvements in contract conditions, specifying collaborative platforms

and defining tools to be developed (MINnD, 2014); and the Minister for Housing, Equality territories and Rural Affairs announcing its commitment to the three year digital transition plan with €20m investment to promote digital tools, increase competence, develop digital tools and set a digital governance to be visible internationally and locally (Ministry of Housing, Equality territories and Rural Policy, 2015). A 'digital portal', to share BIM knowledge and best practice amongst AEC professionals was launched in 2015.

The U.S. has many project planning standards and guidelines, including both contract and BEP documents, published by numerous states and industry bodies. Whilst on the face of it, this may appear a good thing, it presents BIM users with the dilemma of which guideline to adopt. Analysing U.S. BIM standards highlights the fragmented nature of relationships between the documentation, with the majority having been developed by state departments in isolation. NBIMS (NBIMS, 2007) presentation makes difficult reading and is far too lengthy at 183 pages. However, alternative standards such as University of Southern California (UCS, 2012), Ohio Department of Administrative Services (Ohio DAS, 2010), and Indiana University (IU, 2012) are well presented but lack the detail of NBIMS (NBIMS, 2007) or equivalent UK standards.

5.0 FINDINGS

Whilst the BIM standard tables presented in the previous section provide an invaluable source of reference to individual countries standards and for international comparison, they also serve as a rich source of information surrounding BIM adoption, maturity and main focus areas. The key findings related to BIM standards, for both country and continent are highlighted below.

- The US and the UK have been a head of other countries in developing BIM standards which other countries such as Australia and Canada adopted some these developed standards in their BIM framework.

- The average number of BIM standards and guidelines per country is 13.2. While this figure suggests a respectable number of BIM standards given the recent uptake of BIM, the majority of these BIM standards have been authored by only 48% of those countries investigated in this study. Although, industry design standards and project planning measures are critical for the widespread adoption and delivery of BIM, many countries such as China, India, Pakistan, France, Germany, Netherlands, Norway, Spain, Brazil, Dubai and Qatar (52%) fail to offer project stakeholders any form of project planning guidelines.

- Design and information standards outweigh project planning standards by 4 to 1. This statistic further expresses the need for more focus targeted at developing pre-project strategic documents such as contracts, Organizational Information Requirements (OIR), Asset Information Requirements (AIR), EIRs and BEPs. Without a strong and interrelated suite of pre-project standards to underpin the project, the chances of successful project outcomes diminish.

- Europe has more standards, guidelines, templates and shared parameter files than all other continents combined along with 5.2 times as many BIM standards and document relationships as the next nearest continent, Asia. Not only that, Europe has over three times more relationships between standards than all other continents combined. It is these relationships between standards which create a consistent workflow throughout any project.

- The UK is the only country to have a complete set of BIM standards for all areas measured (contract (1), EIR (2), BEP (3) and design and information (19)). Having a complete set of BIM standards gives practitioners the confidence to successfully plan, design and deliver BIM to the required maturity levels. The focus of the reviewed national standards has mainly been on explaining the model standards and BIM requirements and deliverables except in Singapore and Canada, the roles of different project stakeholders should be carried out in relation to project execution using BIM.

- The U.S. has developed the most standards (36), excluding relationships, followed by the UK (25), Finland (23), Norway (14) and Singapore, Spain, Australia and New Zealand (13). However, U.S. BIM standards are state led, leading to a fragmented approach to standardization and duplication of effort. The key to a successful rollout of BIM is the availability and application of a common set of BIM standards.

Generally, BIM standards are still under development and not yet reached full implementation and adoption in most of the countries. A considerable number of countries have not yet started adopting BIM and others have not developed their own standards for BIM but adopted standards from other countries. Globalization may require international BIM standards which can be adopted in any country. To achieve this, an international organisation should take the initiative and lead this process. Yes, it can be argued that each country has its own characteristics, but commonality is more than incongruity within the AEC industries.

6.0 CONCLUSION

The global AEC industry is still trying to 'find its feet' with standardising processes and documentation in order to reap the inherent benefits of BIM. However, countries such as the UK, Singapore, Norway, Finland, South Korea, and Denmark have already started to issue national mandates, which set high benchmarks for other countries to follow. Given this, the push for BIM adoption varies between countries, with governments being the predominant driving force for achieving national mandates; and AEC companies and industry bodies promoting BIM use where these governments fail to be proactive.

Generally, most countries that have started to develop BIM standards and initiatives, have placed more emphasis on design and information with seemingly little emphasis or consideration of project planning measures such as contracts, EIR and BEP documentation. This is set to change, with countries such as the UK providing a holistic set of BIM standards and guidelines over a project lifecycle. This paper also highlighted the fragmented nature of BIM standards and guidelines, in particular the U.S. where standards are developed by each state with no overarching framework. The main challenge moving forward is to develop BIM standards for use at both national and international levels to enhance overseas collaboration in the global market. Those countries which are behind the BIM adoption curve are encouraged to evaluate more mature standards created by other countries, in order to maximize transition and minimize tailoring to meet country-specific legislative requirements.

The research presented in this paper may help researchers and practitioners to investigate issues raised from the findings discussed above such as improving the current BIM standards. Practitioners may also work with academics and researchers internationally to develop standards that can globally be adopted.

Despite this research analysed government documentations BIM standards in thirteen countries, it was not possible to conduct focus groups in these countries to discuss the implementation of these standards to gain more understanding of their limitations and any issues occur during usage for collaboration at different stages of a project due to time and funding constraints.

Further research work will be conducted including carrying out focus groups and interviews in the thirteen countries used in this investigation to support the findings presented in this paper. A questionnaire survey will also be conducted in other countries adopting BIM but there is no BIM standards developed by their governments to gauge how designers, contractors and others involved in the delivery of a construction project collaborate in these countries using BIM and the need for BIM standards to be developed for their countries.

7.0 ACKNOWLEDGEMENT

This work was supported by the Innovate UK [grant number KTPR9597]

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