BIM Standards Around The World

A Review of BIM Standards in the Global AEC Industry and BIM Roles of Project Stakeholders

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This paper investigates the nature of national BIM standards amoung various countries and examine the presence of standards that clarify the BIM roles of project stakeholders such as project management consultant (PMC) at the various stages of the construction project lifecycle, including inception, design and construction. A research has been conducted which case BIM studies from UK, Norway, Finland, US, Canada, Singapore and Australia were reviewed. The study indicates that current BIM standards have mainly focused on explaining the model standards and BIM requirements. There are only a few national standards, such as the case of Singapore, which highlight the BIM objectives at each stage of the construction process, the project stakeholders that should be involved, and the deliverables. The specific roles of the various project stakeholders for each objective are not adequately clarified and hence likely to vary from one project and organization to another.

Keywords- BIM, standards/guidelines, project stakeholders, roles

I. INTRODUCTION

The construction industry has in the recent times being characterised by resource scarcity, sustainability challenges, increasing complexity of designs and stricter regulation for sustainability and resource efficiency [1]. Such challenges have collectively enhanced the level of interest in new and innovative ways in which operations in the architecture, engineering and construction (AEC) industry can be enhanced. Within this context, Building Information Modelling (BIM) has increasingly been seen as a potentially effective way of dealing with these challenges. BIM as a process involves developing and using of computer software model for purposes of simulating the planning, designing, construction and operation of a facility. The resulting building information model is a data-rich, object-oriented and parametric digital representation of the construction project [2]. Data in the model can be extracted and analyzed in order to generate information that facilitate decision making as well as improved delivery of the complete project [3].

BIM constitutes a subset of computer-aided design software but makes use of processes that are significantly different from CAD. The advent of CAD in the late 1960s moved the manual pen and ink process to the computer thus making it possible to produce 2D drawings that were easier to manipulate, modify and retrieve [4]. In the late 1970s and early 1980s building information modeling based on 3D solid modelling was developed replacing 2D CAD for design development. Over the years BIM has seen further enhancements to include a time/schedule model (4D), cost model (5D) operation model (6D), sustainability model (7D) among others depending on the available information [5] [6].

From a design perspective BIM helps in presenting the elements of structure such as beams and columns as objects in digital models. Such representation significantly increases visualisation and hence the ability to improve design [7]. As BIM becomes increasingly implemented around the world, its applications have also gone beyond the improvement of design. BIM can be applied in the production, communication and analysis of building models; intelligent simulation of architecture; and improvement of the delivery process through provision of consistent and non-redundant data [8]. There is a general consensus in existing studies that the entire building life cycle, from conception to demolition, can be covered by BIM applications [9].

II. USES AND BENEFITS OF BIM

BIM offers a range of benefits to stakeholders in the AEC industry. It serves as an effective tool for data management during the entire project lifecycle by facilitating fast and easy access to information that is stored in a single centralised database [10]. The effective management of data further contributes positively to planning and scheduling of facilities through improved communication [12] [13]. Effective sharing of information through BIM also results into elimination of redundant efforts and hence more time is focused on the improvement of design and expedition of the construction process. Prior research has within this context indicated that 'waste and inefficiency' constitute a huge problem in the construction industry. For example, delays, errors and inefficiencies in the US construction industry have been found to account for $200 billion of the $650 billion that is spent on construction annually [14].

BIM also offers simulation benefits. It can not only simulate 3D, 4D and 5D building models but also a range of other operations, such as sunlight, emergency evacuation and heat transfer [15] [16]. BIM further provides a platform through which integrated management in aspects such as feasibility

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studies, objective design and planning and supply can be undertaken in an efficient way [17].

Statistically, the use of BIM in construction projects has been shown to lower costs by 33%; increase speed of delivery by 50%; contribute to sustainability by lowering green house gas emissions by 50%; and improve exports of construction products by 50%. A survey by McGrawhill Construction also identified benefits that key stakeholders in the AEC derive from the use of BIM (see figure 1).

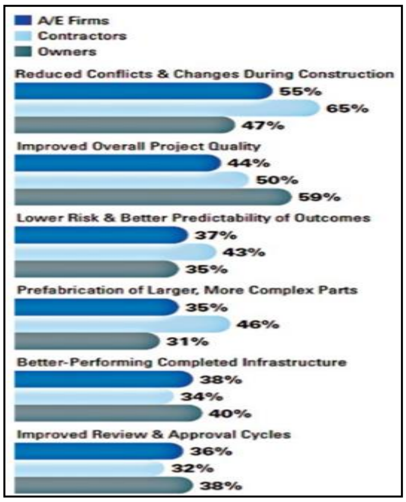


Figure 1: Benefits of BIM to stakeholders [18]

III. CURRENT CHALLENGES IN BIM ADOPTION AND EXECUTION

Adoption of BIM has been on an upward trend around the world. In developed countries such as UK and the USA the adoption rate by both the government and private sector has been high. A National BIM Report for 2016 in the UK by the National Building Specifications (NBS) for instance revealed that more than half of the professionals (54%) in the AEC industry were using BIM on at least some of their projects while another 42% were aware of it [12]. In developing countries such as Malaysia; BIM has been well received but the adoption rate has been relatively slow [13] [14]. Adoption of BIM at the global level is affected by the lack of standardisation of the BIM standards. In order to facilitate the collaboration between the stakeholders inside and outside of the BIM environment, it is important that standards for information exchange are agreed upon.

Standards are within the above context the guidelines, protocols and mandatory regulations that underlie the use of BIM. In the absence of standardised BIM guidelines it becomes difficult to agree on the quality of information to be used thus further affecting the use and reuse of the information among the partners. Furthermore, lack of standardised BIM guidelines negatively affects the extent to which building products and process are interchangeable. This in turn impacts the identification of products, processes and parameters that reduce inconsistency and the associated high costs [15].

Majority of existing studies on BIM have primarily focused on BIM deliverables and requirements [16][17]. In the process, an investigation of the extent to which BIM is sufficiently standardised has been not as much of coverage. Further, existing studies are yet to examine whether the roles of the different project stakeholders such as Project Management Consultants (PMC), contractors, architects, engineers and construction managers are clarified for each of the project lifecycle stages (i.e. plan, design and construction) in BIM.

This study seeks to fill these gaps through the following objectives:

- To explore the various BIM standards adopted around the world in the AEC industry
- To examine the clarity of roles of project stakeholders in each stages of project lifecycle in BIM standards

IV. REVIEW APPROCH: RESEARCH METHEDOLOGY

To garner the data required in achieving the objectives the study made of secondary data research. By definition, secondary research involves the collation and synthesis of already existing materials such as journals, textbooks, industry documents, periodicals and internet articles among others [18]. Several factors necessitated the use of secondary data. Firstly, the study required collection of BIM standards in several countries across regions such as North America, Europe, Middle East and Asia. Second, a significant amount of information on BIM standards has been comprehensively compiled in publicly available documents by relevant organisations such as the National BIM Standards (NBIMS-US) and British Standards Institute (BSI) in the UK. The availability of the BIM standards information makes the secondary research the optimal method to ensure a comprehensive data collection approach. Lastly, secondary research is appropriate for studies requiring national or international comparisons [19].

In order to ensure reliability of the data, only BMI standards from countries where the practice is well developed are included. Such countries include Canada, Finland, Australia, Norway, UK and USA. Content analysis was used to identify the key BMI standards as well as facilitate the comparison with relation to inclusion of roles of project stakeholders in each of the stages of the lifecycle.

V. FINDINGS

The following part of this paper will cover an overview of BIM standards around the world:

A. United Kingdom

BIM standards in the UK have been published by various organisations including the British Standards Institution (BSI), the BIM Task Group, AEC-UK and the Construction Industry Council [21]. BIM standards in the country are classified based on the maturity levels (see figure 1). At level 1, the BIM standards involve the collaborative production of 2D and 3D CAD information and provision of directions pertaining to the management of the design process. At level 2 the standards help in the achievement of BIM compliance on the use of file-based electronic information. Currently, the majority of stakeholders in the industry seek to achieve the second level BIM maturity. At Level 3 BIM maturity, the standards explain the integration of BIM and life cycle information. Attaining this level of maturity constitutes a long term objective for most stakeholders the AEC industry [22]. Table 1 provides a summary of the main standards in the UK.

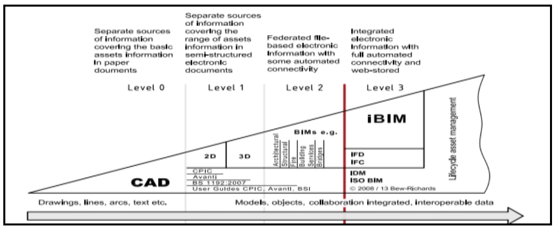


Figure 2: BIM Maturity Levels

- **PAS_1192_2_2013 Information management for capital/delivery phase using BIM:**

  This PAS constitutes an extension of BS 1192:2007 which provides information in regard to code of practice for the collaborative production of AEC information. It mainly focuses on project delivery phase which involves the accumulation of graphical and non-graphical data/documents for use in design and construction activities. Among the main stakeholders that find this PAS useful include individuals that are in charge of procuring, designing, construction, delivery and operating of building facilities.

  The contents in this PAS are in the form of requirements for the stakeholders. The requirements are specified based on four stages of information delivery including procurement, post contract-award, mobilisation and production. Specific roles of stakeholders based on project lifecycle stages are not included.

- **PAS_1192_3_2014 Information management for operational phase of assets using BIM:**

  This specification is similar to PAS 1192_2. The main difference is that it focuses on the operational phase of the facility as opposed to the capital/delivery phase. It is therefore relevant for project stakeholders responsible for operating and maintaining assets.

  The requirements of PAS 1192_3 revolve around the transfer of data from the project information model (PIM) to asset information model (AIM) in the operation phase.

  PAS 1192-3 broadly sets out roles by mentioning that the responsibility for information management should be set out in the contract between the asset owner and the operator/maintainer in the operation phase.

- **BS_1192_4_2014 Collaborative production of information – Employer's information exchange requirements using constructions operations building information exchange (COBie):**

This standard provides a schema in the form of a multi-page spreadsheet through which stakeholders such as suppliers and designers can create structured information and share it with the employer for purposes of assessing and using. One of the main benefits is that information in COBie can be reviewed and validated for compliance and completeness. The information covers aspects such as overall asset management, support for business questions and regulatory responsibilities.

BS_1192_4states in a general manner that during the briefing and operational phases it is the employer who should provide information while stakeholders on the supplier side should provide information in the design and construction phases.

- **BS_8536_1_2015 Code of practice for facilities management:**

The standard offers guidelines and recommendations regarding the information and data that project stakeholders need in order to enhance optimum operability and performance of the facility. As such, the standard is limited to the operational phase of the project life cycle. It can however be noted that information offered in this standard is still important in the design and construction phases where issues to operability are taken into consideration.

This standard articulates the roles of various project stakeholders although at the general level as opposed to roles at each phase of the project. The owner is required to determine the composition of the design and construction team and emphasise on collaborative working. The owner's representative (PMC) is on the other required to liaise with the design and construction team to ensure the required project outcomes and operational performance are taken into consideration. General roles for the operations team and facility manager are also described.

- **PAS_1192_5_2015 Specification for security-minded building information modelling:**

The specification recognition that BIM information may be subject to security threats. Accordingly, it offers and awareness of the security measures that project stakeholders making use of BIM should undertake in order to ensure that information pertaining to the project, system and asset remains well protected and managed. Only the role of the built asset security manager is specified and ranges from providing a holistic view of security issues to offering guidance on addressing the security issues. The roles of other project stakeholders at different phases of the project life cycle are not clearly articulated.

- **1192_2007_A2_2016 Collaborative production of AEC information- code of practice:**

This standard considers collaboration among stakeholders in construction projects as crucial to efficient delivery of facilities. The standard is mainly applicable in construction project documentation and allows for to work efficiently through standard data that solves problems of data reproduction.

B. Norway

Currently, Norway BIM standards are published by Statsbygg (A government department) and the Norway Association of Construction. The BIM manual offered by Statsbygg mainly focuses on defining the requirement that apply to the BIM deliverables. At the basic level two sets of requirements are identified: The open BIM deliverable and BIM objectives. In brief, the open BIM deliverable requires that a digital 3D BIM that is based on object-based design and makes use of open BIM standards be the main deliverable.

The BIM objective on the other hand specifies that the BIM shall be modelled for the specific BIM objectives that are specified in the project under consideration [23]. An additional 13 domain specific requirements are also issues as part of the BIM standards (See Table 2). Currently, all Statsbygg projects make use of open BIM principles. Attention while using BIM in the country is mainly given to the environmental impact of infrastructure and the lifecycle costs.

- **Architectural modelling**

This specification recognises that an effective architectural model should contain other domains in areas such as structural elements and electrical and mechanical equipment. Accordingly, it offers guidelines on components (e.g. generic and super structure) that should be included in order to ensure an interdisciplinary architectural model. No project stakeholder roles are specified.

- **Landscape architectural modelling**

In order to ensure ease of visualisation, this specification provides recommendations on landscaping elements. It explains the need for geometry elements of landscaping to be exported to IFC with the help of CAD systems and also recommends the use of open formats such as LandXML and CityGML for landscaping.

- **Interior design modelling**

This specification offers generic requirements for inclusion of information on interior design components such as furniture, fixtures and equipment (FF&E) into BIM. It emphasises the importance of the project team agreeing upon the information but does not highlight specific roles

- **Geotechnical engineering modelling**

Development of this specification is still ongoing. Nonetheless, the specification highlights to project stakeholders the risk of use of architectural tools that fail to support other geotechnical engineering processes. It thus supports the need for interoperability through use of a construction site BIM that corresponds with the structural BIM thus making the transfer of information easier.

- **Structural engineering modelling**

This specification covers the requirements for load-bearing elements such as concrete and steel structures and non-load-bearing concrete structures. It highlights the role of the structural designer as one that involves the production of both a design and analysis model that focuses on ease of coordination and improved costing.

- **Mechanical engineering modelling**

The specification provides details for modelling requirements in relation to mechanical engineering. It thus covers mechanical aspects of the building process such as plumbing, fire protection, heating and energy control. Besides an explanation of the modelling requirements the specification does not detail out the specific roles of the mechanical engineer and other stakeholders.

- **Electrical and communications engineering modelling**

This specification as the name suggests is limited to modelling aspects of electrical and communication aspects of the building process. It offers modelling requirements for the facility's electrical and communication support systems in aspects such as technical space and geometry. Roles and responsibilities of relevant project stakeholders are not defined.

- **Acoustical engineering modelling**

In this specification, the modelling requirements for acoustic properties for a range of building elements such as constructions and installations are explained. It also emphasises the importance of communicating acoustics conditions to the design team in the BIM. The acoustic engineering is recognised as playing an important role in providing relevant data but roles of other stakeholders are overlooked..

- **Fire safety engineering modelling**

This specification sets out the fire safety conditions that the safety engineer needs to include in the BIM. The overall goal is to ensure that building projects that utilise BIM have adequate protection to fire and have a layout and space planning that allow for efficient evacuation.

- **Other design and engineering modelling**

The specification recognises that the process of modelling entails a wide range of special disciplines that may differ from one project to another such as kitchen and laundry in hotels and hospitals. Accordingly, it emphasises the need to include such disciplines as part of the BIM information.

- **BIM construction and as built requirements**

BIM in Norway is currently limited with respect to the construction phase. However, this specification indicates that contractors are free to use the BIM as they choose. It also explains a few general roles of the contractors which include receiving and using the finalised generic design-BIM, reporting changes to client and design team and updating the native BIM.

- **BIM for facility management and operations**

This standard is also in the development process. It explains the need for transforming the “as built” BIM to the facilities management and operations (FM&O) BIM for the operations phase of the facility.

- **BIM for decommissioning and disposal**

Specific requirements for this standard are not stated. However, it mentions that BIM may be used in extracting relevant information at the decommissioning and disposal phase which can be relevant in handling of reuse and waste fractions.

C. Finland

Finland has a long tradition in the use of BIM. At present four maturity levels have been defined [24]. BIM level 1 and 2 are already in progress. At level 1 the main focus is on data management for document based structures, 2D and 3D documents while level 2 maturity involves visualising information in combined models. Level 3 and 4 are future maturities in which information is expected to support owner's processes and life cycle management and also be linked with the built environment.

The Finnish BIM standards have been put forward in the form of requirements that must be attained by stakeholders in the AEC industry. The current standards can be found in the publication series "Common BIM Requirements 2012" which articulates 12 areas that are relevant to procurement and construction [25] (see table 3). It can however be noted that there are relatively low levels of standardisation of BIM in Finland. A large number of construction firms have been writing their own detailed requirements and best and also the majority of large consulting firms have their own BIM groups [26].

- **General BIM requirements**

This general specification outlines the basic principles, requirements, concepts and targets for BIM in projects. It clarifies that it is the role of the BIM coordinator to apply the targets as well as supervise the use of the model.

- **Inventory models**

This specification provides a description of requirements for building site modelling. It covers inventory models and emphasises the need to use reliable and accurate sources of data that make implementation of plans easier.

- **Architectural design**

This specification explains that the architect BIM is mandatory in all the design phases and specifies the requirements in each of these phases. No specific roles of project stakeholders are included

- **HVAC + EA Design**

This part focuses on building services (BS) design task. It specifies the contents for the BS system model in terms of basic prerequisites for the use and maintenance in the life cycle of the building. Although it provides information content and geometry in each of the phases it fails to specify the roles of project stakeholders

- **Structural engineering**

The part breaks down the requirements for structural engineering process into a list of BIM tasks. In order to enhance collaboration this specification takes into account the needs of other design team parties. This in turn makes the requirements easier to adopt

- **Quality assessment**

The specification focuses mainly on information producers mainly designers. It explains that these information producers should ensure that the contents of information should be appropriate and reliable in order enhance viability of BIM. Checklists

- **Quantity takeoff**

In this part the essential BIM requirements and guidelines for use in quantity take-off are described. It highlights that the requirements are relevant for owners, designers, contractors and product fabricators. It advocates for a shift from manual drawings to computer-assisted measurements for quantity take-off

- **Visualisation**

In the visualisation part the documents highlights the importance of using technical illustration in BIM as opposed to the traditional photo-like rendering visualisation. It indicates that the technical illustrated is to be used by the design team, client and project manager to facilitate easier comparison between different design alternatives and improve communication. However, the roles of these stakeholders are not included.

- **HVAC analysis**

HVAC analysis provides graphical illustrations of lighting calculation and lighting analysis. In the process it also highlights the possibilities brought into BS analysis by modelling. Relevant stakeholders and their roles in HVAC analysis are not clearly highlighted

- **Energy analysis**

In a bid to contribute towards sustainable buildings and infrastructure this standard emphasises the importance of energy efficiency management. The requirements for ensuring energy efficiency in BIM are also provided

- **Management of BIM project**

This specification recognises the importance of using BIM from the client's point of view. Accordingly, it describes the general project management tasks that should be undertaken in order to meet client demands. Planning, implementation and control measures during the project process are also included but specific roles of project stakeholders are missing

- **Use and maintenance of building**

This part provides a description of the requirements for use of BIM in the use and maintenance phase of the lifecycle. The requirements are in the form of IFC based data transfer as well as other popular transfer methods such as COBie. The benefits of using BIM in facility services processes are also articulated but key roles of relevant stakeholders in the use phase are left out

- **Construction requirements**

BIM requirements for the construction phase are explained in this final part. The requirements are meant to be agreed between the project stakeholders on a project basis. The main roles of the contractor at this stage pertain to the delivery of information on adjustments for the as-built model to the client

D. USA

The US BIM Standard has been developed as an initiative of the BuildingSMART alliance which is a council of the National Institute of Building Sciences (NIBS). In 2012 NIBS released the Ntional Building Information Modelling Standard- version 2 (NBIMS-v2) which seeks to advance the art and science of the entire lifecycle of the built environment by providing a means through which electronic object data can be organised and classified. Among the groups that the standards are targeted include software developers and vendors, design, engineering, construction and operations professionals. The specific BIM standards in the US fall under four categories: construction operations building information exchange (COBie), design to spatial program validation, design to building energy analysis and design to quantity takeoff for cost estimating [27].

A focus on defining requirements is also evident in the US. For example, available BIM documents detail out the requirements for file sharing, quality planning, quality assurance and quality control. Unlike BIM standards in other countries, there is a separate BIM manual for owners in the United States. The manual also explains the various team roles and responsibilities that the owner should be aware of. Notably, the PMC role is included in which case it is recommended that for large and more complex projects there is need for the owner to designate an owner's BIM representative. Among the roles of this representative include representing the owner's requirement and communicating them effectively to other stakeholders [27]. A separate guide also exists for architects and engineers. Collectively, the manuals mainly focus on explaining the requirements and usage of the BIM guidelines and standards. Although the roles of some of the project stakeholders are highlighted they are not sufficiently clarified based on project life cycle stages

E. Canada

In Canada, BIM guidelines and standards are published by a variety of organisations with the main ones being buildingSMART Canada, Canada BIM Council and Institute for BIM in Canada (IBC).Unlike the UK and USA BIM in Canada is relatively young with key institutions such as IBC being established in 2014. Adoption rates are still relatively low with some provinces such as Canada being marked by 31% adoption rate. Barriers to adoption among non-adopters have been identified and include the lack of demand by clients and the supply chain and high cost of software, training and infrastructure [28].

A further evaluation of the standards indicated that little attention has been accorded to specific roles that project stakeholders should perform at the different stages of the project lifecycle. Only roles and responsibilities related to the BIM execution have been taken into account (see figure 2). The main areas of focus have been guidelines on the benefits of BIM for owners, project execution plan toolkits, contract language, practice manual for BIM, collaborative BIM working, interoperability and data segregation [28] [29].

	Strategic						Management				Production	
Role	Corporate Objectives	Research	Process + Workflow	Standards	Implementation	Training	Execution Plan	Model Audit	Model Co-ordination	Content Creation	Modelling	Drawings Production
BIM Manager	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N
Coordinator	N	N	N	N	N	Y	Y	Y	Y	Y	Y	N
Modeller	N	N	N	N	N	N	N	N	N	Y	Y	Y

Figure 2: Roles and responsibilities for BIM execution in Canada

Attempts to achieve interoperability at the international level are also evident in Canada. For example, BIM standards and protocols used in Canada were adapted from protocols used by AEC UK. The rationale behind adopted of the framework used in the UK is that BIM enabled technologies are consistently being used in the same way around the world (← What does it mean that BIM enabled technologies are consistently being used in the same way around the world? The reader may need a rationale for researching 'standards' then) and that it was prudent to make use of already existing standards as opposed to investing time to reinvent and create unique standards for Canada. Adapting of the BIM standards in Canada is also done with reference to US BIM standards published by NBIMS US V2 [28].

F. Australia

In Australia the development and use of BIM standards is largely coordinated by NATSPEC. The organisation has compiled a list of both local and international standards that players in the industry should use in the construction process [30].

- **Australia and New Zealand Revit Standards (ANZRS)**

The standard is designed for use by Autodesk Revit users. It allows them to define the project content and data and hence an enhanced ease of communication with consultants

- **AEC (UK) BIM Standard**

This standard is designed for use by clients in the design and construction stages. It is a generic document that is adapted from the UK BS1192:2007 BIM protocol. It seeks to provide information on techniques and concepts that architectural engineers can use at the design stage while utilising BIM technology. The roles of other professionals such as Quantity Surveyors, Contractors and Facility Managers are not specified

- **US National CAD standard, ISO 13567 and AS 1100**

This standard is adapted from the National CAD standard used in the United States. It provides a layering system for information used in the construction process. The classification of electronic building design data in this standard helps in streamlining and simplifying information and communication among key project stakeholders such as owners, designers and construction teams. Although the standard is applicable from project development stage to use of facility stage specific roles for various users are not defined

- **VA BIM Guide 'Trade colours for Clash detection**

This standard provides guidelines for clash detection as one of the BIM applications. The guidelines are meant to identify all clash processes so that they can be resolved before commencement of the construction process. Specific responsibilities of design/construction team and BIM manager are explained. However, the PMC role is not specified

- **National Guidelines for Digital Modelling**

This standard provides basic information for BIM users in relation to digital model creation and development. It also offers guidelines on how to engage in simulation and performance measurement. Although the PMC role is not articulated the standard emphasises that one of the reasons for models is to enhance information sharing between consultants and other stakeholders

- **Masterformat, Coordinated Building Information (CBI), Uniclass Table J**

The standards provide guidelines for developing a work results classification system. It recognises that the construction industry requires significant collaborative effort. The standard is therefore geared towards interoperability by ensuring that stakeholders can create, communicate and find relevant building information when needed.

G. Singapore

Spring Singapore is the country's national standards authority which coordinates the national standardisation program as well as Singapore's participation in international standardisation efforts. The Building and Construction Authority (BCA) have also been offering guidelines as such as the Singapore BIM Guide Version 1.0 published in 2012 and version 2 published in 2013. Currently, there are a total of seven main standards that explains the requirements for modelling and collaboration. They include individual discipline modelling, cross-disciplinary model coordination, model & documentation production, data security and saving and quality assurance and control, Workflow of design-build projects and [32]. Following is a summary of the key aspects of each standard/guideline.

- **Individual Discipline Modelling**

This standard provides information on procedures to be undertaken during modelling of BIM elements. It also provides guidelines for use in architectural and structural modelling for purposes of regulatory submission. It also emphasises the need for diving model into separate levels based on project size and phase as well as revising the model at the various project stages

- **Cross-disciplinary model coordination**

This standard provides guidelines on how the various stakeholders can achieve interoperability. It emphasises the need for sharing models and coordinating them with inter-disciplinary parties. Figure 3 provides an illustration of the collaboration required in the standard at various phases of the project

- **Model & Documentation Production**

This standard projects that conflicts may occur between 2D drawing contract documents and BIM model. In such a case contract documents take precedence but efforts should be made to reduce discrepancies through generation of 2D drawings from the BIM model and agreement on BIM exchange formats and documentation

- **Data security & saving**

The standard focuses on BIM security issues. It urges BIM users to establish a data security protocol for purposes of preventing data corruption, misuse or deliberate damage

- **Quality assurance and quality control**

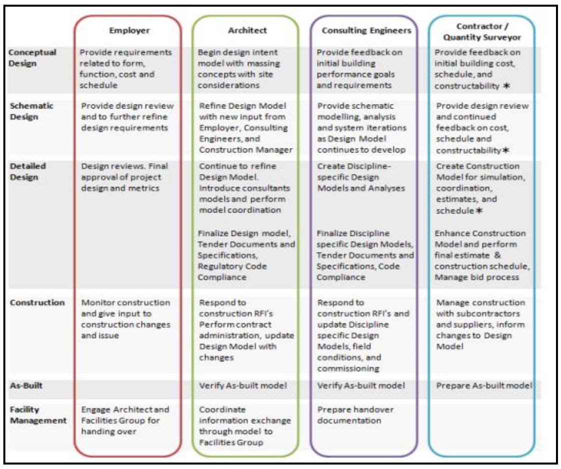
The standard recognises the need for a quality assurance plan as a way of maintaining accuracy of the BIM data. It indicates that an effective quality assurance plan should include modelling guidelines, dataset validation and inference checks

- **Workflow of design-build projects**

This standard outlines the various aspects that should be taken into consideration when producing a workflow of design-build projects. These include aspects such as establishing a BIM execution plan and incorporation of predefined project requirements

- **Workflow of design-bid build projects**

While taking into consideration the traditional design-bid-build delivery model, this standard describes generation of construction model by the main contractor. It includes activities for pre-tender stage and construction stage



	Employer	Architect	Consulting Engineers	Contractor / Quantity Surveyor
Conceptual Design	Provide requirements related to form, function, cost and schedule	Begin design intent model with massing concepts with site considerations	Provide feedback on initial building performance goals and requirements	Provide feedback on initial building cost, schedule, and constructability ✱
Schematic Design	Provide design review and to further refine design requirements	Refine Design Model with new input from Employer, Consulting Engineers, and Construction Manager	Provide schematic modelling, analysis and system iterations as Design Model continues to develop	Provide design review and continued feedback on cost, schedule and constructability✱
Detailed Design	Design reviews. Final approval of project design and metrics	Continue to refine Design Model. Introduce consultants models and perform model coordination Finalize Design model, Tender Documents and Specifications, Regulatory Code Compliance	Create Discipline-specific Design Models and Analyses Finalize Discipline specific Design Models, Tender Documents and Specifications, Code Compliance	Create Construction Model for simulation, coordination, estimates, and schedule ✱ Enhance Construction Model and perform final estimate & construction schedule, Manage bid process
Construction	Monitor construction and give input to construction changes and issue	Respond to construction RFI's Perform contract administration, update Design Model with changes	Respond to construction RFI's and update Discipline specific Design Models, field conditions, and commissioning	Manage construction with subcontractors and suppliers, inform changes to Design Model
As-Built		Verify As-built model	Verify As-built model	Prepare As-built model
Facility Management	Engage Architect and Facilities Group for handing over	Coordinate information exchange through model to Facilities Group	Prepare handover documentation	

Figure 4: Cross-disciplinary model coordination in BIM in Singapore

Unlike other country standards, the Singaporean BIM standards clarify the roles for consultants and contractors. The lead consultant is for instance tasked with the role of facilitating the definition and implementation of BIM execution plan, BIM goals and uses. The contractor is on the other hand required to study tender documents and coordinate with design contractors and sub-contractors among other roles [32]. It can however be noted that these roles are undertaken at the team level. Organizational level roles and responsibilities are yet to be clarified. In specific, the BIM guidelines identify a list of 28 BIM project objectives that should be completed from the conceptual to facility management stages of a construction project. It then provides an objective and responsibility matrix identifying the project members that should be involved in fulfilling the objective. Although a range of stakeholders such as architects, structural engineers, mechanical engineers, contractors and consultants are identified their specific roles are not clarified (see figure 5) [32].

BIM Project Objective	BIM Manager	Project members involved in fulfilling the objective A – model author; U – model users							
		Arc	Str	MEP	QS	Con	RS	FM	Others
Conceptual Design *Building massing studies or other forms of data representation with indicative dimensions, area, volume, location and orientation*									
1. All project members appointed at this stage to agree on needs, objectives, process and outcomes of the project. **Suggested Deliverable** • **BIM Execution Plan agreed and signed by related parties**									
2. Create site BIM models for master plan site study and feasibility analysis. - Site Analysis									

Figure 4: Extract of the Singapore BIM objective and responsibility matrix

VI. Discussion

The review of BIM standards from various world regions in the preceding section indicates considerable efforts towards developing the standards in order to respond to the evolving industry demands. For owners it is evident that current BIM standards around the world are drafted to minimise operation and maintenance costs and the renovation costs. BIM also takes into consideration the needs of contractors who have to manage larger and more complex projects while ensuring maximum efficiency and low costs. For designers, the various BIM have been developed to respond to increased pressure to produce innovative and cost effective designs. The standards are thus consistent with the BIM benefits that have been identified in research literature [6] [7].

The UK and the US have some of the most developed BIM standards, adopted by BIM organisations in other countries such as Canada and Australia as part of their BIM framework. Arguably, cross-country adoptations can help in the advancement of standardisation of BIM at the international level. In some countries standardisation of BIM at the national level is yet to be achieved. This is for instance evident in Finland where most of the large organisations have their own BIM guidelines. It should be noted that governments in the countries that have been reviewed have pioneered the use of BIM standards in the construction industry,whereby BIM standards have spread from governmental level to the private sector. However, barriers related to cost of implementation and lack of demand have slowed down the adoption of BIM [28, 33]. There is therefore need to educate stakeholders about the ability of BIM deliverables to offer benefits exceeding cost of implementation.

All the reviewed national standards have mainly focused on explaining the model standards and BIM requirements and deliverables. It is only in the case of Canada and Singapore where efforts have been made to explain the roles that different project stakeholders should perform in relation to project execution using BIM. Even in these two cases, a narrow approach has been used in which case only a few stakeholders (e.g. project manager, consultant and coordinator) have been taken into account. The roles identified are also at the team level as opposed to the organization level.

In the case of Singapore, which has identified BIM objectives at each stage of the construction process, a range of deliverables have been identified. However, it is the role of the BIM manager to identify which project stakeholders are supposed to be involved in such delivery [31]. The lack of clarity increases the chance that roles played by the various stakeholders are likely to differ from one organization to another. In order to ensure more efficient application of BIM in construction projects it is necessary that this area be addressed.

Despite the trend towards cross-country adoption of BIM standards, significant geographical differences are still evident. As industry stakeholders seek to achieve BIM standardization at the international level, BIM managers who seek to incorporate the role of PMC should carefully review the standards and establish areas where the PMC role is best suited. Some BIM functions can be incorporated directly into PMC roles while others require adjustment.

Some of the investigated BIM guidelines recognize the potential conflicts that arise during the transition from 2D drawing based contracts and BIM. In such case, it is required that the original contract structure remains. For AEC firms adopting BIM, the standards can still update the original work schedule and plans to better make use of the information model. Importantly, with the adoption of BIM new roles in the AEC industry are also emerging. Examples include data security managers, design coordination manager,BIM lead consultants and BIM directors.

VII. Conclusion

The use of BIM in the AEC industry is increasing in various parts of the world. Its effective use is likely to provide benefits in aspects such as planning and scheduling, ease of communication and coordination with the various stakeholders and elimination of redundant efforts. The overall outcome is reduction in waste and inefficiencies that have for long affected the performance of the construction sector. In developing countries high levels of adoption has however been hindered by the initial high costs, lack of skills in implementation and lack of enhanced standardisation of the guidelines at the national levels. In terms of roles and responsibilities, this analysis indicates that there has been inadequate focus in this area. The majority of BIM standards have mainly focused on explaining the model standards and BIM guidelines. The Singapore guidelines can be singled out for explaining the various project stakeholders that should be involved in delivering specific BIM objectives at various construction stages. New roles related to BIM such as data security managers and BIM coordinators and consultants are also identified. However, the actual roles of these stakeholders are not well clarified. It is suggested that there is need to for AEC industry to clarify roles of the project stakeholders a BIM environment in order to ensure smooth implementation.

Conclusion needs a bit more way forward analysis results based on your above discussions. Conclusion here is rather general and without any valuable addition in terms of added knowledge. You should come up with some conclusive remarks and recommendations based on benchmarking each (discussions).

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