Formalising UK Building Information Modelling Standards to Aid Collaboration

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Abstract

The United Kingdom (UK) government's ambitious plans to meet Building Information Modelling (BIM) Maturity Level 2 by 2016 places significant pressure on construction companies to not only meet the mandated requirements, but also ensure their existing BIM capability delivers these requirements. This poses a significant challenge to some organisations, as BIM requires a radical repositioning in the way buildings are designed and managed, with collaboration playing a pivotal role in this process. For example, many construction companies still use traditional 2D CAD files, bespoke data, and drawing standards that are company-specific (and often non-compliant). These types of organisations have therefore struggled to appreciate the importance of BIM, especially where professionals continue to use 'bad habits', or engage parochial standards that are difficult to share or replicate. Conversely however, there is a real opportunity for companies to proactively embrace this transition to BIM through a number of conduits, not least: the installation of industry standard best practices; embedding improved collaborative approaches; improving data veracity, flow and coordination throughout the design, construction and operations and maintenance phases. In addition, there is an abundance of BIM standards such as PAS 1192-2:2013, PAS 1192-3:2014, BS 1192:2007, BS 1192-4:2014, AEC (UK) BIM Protocol, COBie Data Drops-Structures, etc, which add confusion rather than facilitate the process. Acknowledging these challenges, BIM standards from both the UK and United States (U.S.) will be analysed to address the industries need. It is postulated that one 'uniform' methodology is adopted throughout the industry, to promote best practice and avoid conflicts during collaboration.

Keywords: BIM, adoption, ICT, collaboration, construction, design, standards

1 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 often not encountered by other industries. The governments push to tackle these issues led to a technical and process revolution termed 'BIM' which is being embraced by the AEC industry [1]. NIBS [2] describe 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 life-cycle; defined as existing from earliest conception to demolition".

The transition to computer-aided design (CAD) did not radically alter the way professionals worked, it simply fast tracked the delivery. The emphasis with CAD was on format and output, whereas BIM focuses on open information and workflows [3]. BIM adoption is rapidly becoming a matter of importance for the UK construction industry that has faced barriers and challenges to increase productivity, efficiency and quality.

The UK Government Construction Clients Board appointed the BIS/industry working group to develop the 2011 'Building Information Modelling (BIM) Working Party Strategy Paper' [4] which outlines how government clients can make progressive use of BIM on public sector schemes. The report presents a framework which incorporates seven key education and support areas (contract and legal, delivery standards, training and support systems, Construction Operations Building Information Exchange (COBie) definitions, data management server, cost-benefit analysis, and communications). However, Kassem *et al.* [5] review of existing studies and initiatives revealed that BIM protocols are mainly proposed at industry-wide level, thus require substantial modification before being applied at project level. The majority of UK construction firms would benefit from a clear set of guidelines and standards which present an effective strategy and methodology to implement BIM at organisational level. The possibilities and challenges BIM presents need to be understood and tackled through the adoption of an industry wide, measurable and repeatable approach [6].

2 Technical

Substantial effort has been made to help define standardised methodologies and tools for documenting the information requirements of design, construction and operational processes. However, Ganah and John [7] argue that task groups formed by various UK institutions such as the RICS, CIB, CIOB, RIBA, etc, are not yet fully integrated to provide a holistic, long-term approach to integrated and collaborative processes. Findings suggest that there were systematic approaches to BIM implementation, but these weren't adopted by the UK construction

industry prior to the development of PAS 1192-2:2013 [8], and the BIM overlay to the RIBA Outline Plan of Work 2012 [9]. Becerik-Gerber *et al.* [10] identified that 71% of the BIM users questioned, utilise BIM standards within their organisations, of which only 35% adopted industry standards, whilst the remaining 65% developed their own company standards.

The United States (U.S.) are at an advanced Maturity Level through the development of major initiatives including the U.S. National Building Information Modeling Standard (NBIMS) and IAI buildingSMART [2], but the question remains; could the UK develop standards from lessons learnt in the U.S.? Or do existing standards published by UK institutions facilitate collaborative BIM?

2.1 Process

2.1.1 Employer's Information Requirements

BSI [11] define the Employer's Information Requirements (EIR) as a "pre-tender document setting out the information to be delivered, and the standards and processes to be adopted by the supplier as part of the project delivery process". Successful procurement is reliant on a good EIR, which should contain information exchange and collaborative working requirements, and then incorporated into a suppliers Project Execution Plan (PEP). The EIR must only contain enough information to answer the 'plain language questions' required at that particular stage, at an appropriate level of detail [8]. The BIM Task Group [12] EIR guidance document includes standard responses which, in many cases, can be adopted without amendment. However, some aspects of the EIR will require editing based on project specific requirements. An alternative EIR guidance document has been produced by CLAW [13] which also provides an example format; guides the user through the EIR process; and refers heavily to PAS 1192-2 [8], PAS 1192-3 [14], and BS 1192:2007 [15].

2.1.2 BIM Execution Plan (BEP)

BSI [8] describe the 'Pre-Contract Building Information Modelling (BIM) Execution Plan (BEP)' [16] as facilitating the procurement process, and the 'Post Contract-Award Building Information Modelling (BIM) Execution Plan (BEP)' [17] as assisting in the management of delivery on the project, including the contractual information exchange requirements set out in the BIM Protocol and wider project deliverables established by the contract. The requirements and differences between the production of the Pre-Contract BEP and Post Contract BEP are highlighted in Table 1.

CPIx [16] [17] are the only BEP standards within the UK and U.S. which incorporate 'pre' and 'post' contract project planning, whilst providing a 'user friendly' BEP template. Other guides and templates are readily available from both countries which facilitate the BEP process (see Table 2). However, templates such as AEC [18], GSFIC [19], Princeton University (PU) [20], and USAF [21] are clear and logically structured, but lack the detail of CPIx [16] [17].

Table 1: Pre-Contract and Post Contract BEP Requirements

Category	Requirements	Pre-Contract BEP	Post Contract BEP
	Everything requested in the Employer's Information Requirements (EIR)	•	•
Management	Project goals for collaboration and information modelling	•	
	Major project milestones consistent with the project programme	•	•
	Project Information Model (PIM) deliverable strategy (e.g. the CIC Schedule)	•	•
	Roles, responsibilities and authorities		•
	Survey strategy including the use of point clouds, Light Detecting and Ranging (LIDAR) or Global Navigation Satellite Systems (GNSS)		•
	Existing legacy data use		•
	Approval of information		•
	PIM authorisation process		•
Planning and Documentation	Revised PIP confirming the capability of the supply chain		•
	Agreed project processes for collaboration and information modelling		•
	Agreed matrix of responsibilities across the supply chain		•
	Task Information Delivery Plan (TIDP)		•
	Master Information Delivery Plan (MIDP)		•
Standard Method	The volume strategy		•
	PIM origin and orientation (which may also be geo-references to the earth's surface using specified projection)		•
	File naming convention		•
	Layer naming convention, where used		•
	Agreed construction tolerances for all disciplines		•
	Drawing sheet templates		•
	Annotation, dimensions, abbreviations and symbols		•
	Attribute data		•
The IT Solutions	Software versions		•
	Exchange formats		•
	Process and data management systems		•

Table 2: BEP Standards, Guidelines, and Templates

Code	Document Title	Issuer, Year	Doc. Type[1]
UK01	AEC (UK) BIM Protocol: Project BIM Execution Plan	AEC, 2012	G
UK02	Pre-Contract BIM Execution Plan (BEP)	CPIx, 2013	S, T
UK03	Post Contract-Award BIM Execution Plan (BEP)	CPIx, 2013	S, T
US01	BIM Project Execution Planning Guide	CICRG, 2010	G
US02	GSFIC BIM Execution Plan - Series 1:Template	GSFIC, 2012	T
US03	Princeton University BIM Execution Plan Template	PU, 2012	T
US04	US Air Force BIM Project Execution Plan (USAF PxP)	USAF, 2010	T
US05	BIM Project Execution and Standards Guide	WMU, 2011	G
US06	Building Information Modeling (BIM) Guidelines	USC 2012	T
US07	State of Ohio Building Information Modeling Protocol	ODAS, 2010	T

[1]S – Standard, G – Guide, T – Template

2.1.3 Design Standards UK

The development of BIM standards in the UK is gaining increased support from industry bodies, regulators, and construction professionals through shared knowledge and understanding. One industry body at the forefront of BIM standardisation is The British Standards Institution (BSI) [22] (see Table 3). Although the development was facilitated by the BSI, Publically Available Specification (PAS) is not to be regarded as a British Standard. Its publication enables a specification to be rapidly developed to fulfil an immediate industry need. PAS may be considered for further development as a British Standard, or constitute part of the UK input into the development of a European or International Standard [8] [14].

Previous versions of BS 1192 which date back to 1998 only provided guidance for the structuring and exchange of CAD data. The 2007 version places more emphasis on collaborative processes and has been upgraded to a Code of Practice, thus design teams will need a very good reason not to implement it. This standard also offers definitive guidance on technicalities such as how to use well-structured names for the directories, files and layers [23]. BSI recently published BS 1192-4:2014 [11] which aligns closely with BS 1192:2007 [15], PAS 1192-2:2013 [8], PAS 1192-3:2014 [14], all of which document best practice for the management of collaborative projects using Facilities and Asset Information Modelling based design, construction and use. BS 1192-4:2014 [11] on the other hand deals specifically with the UK usage of COBie facility information exchange schema between the employer and the supply chain [11].

Alternative BIM guidelines have been developed by The AEC (UK) Initiative. Turco [24] describes the AEC [25] ‘AEC (UK) BIM Protocol for Autodesk Revit’ as a workable implementation of the AEC [26] ‘AEC (UK) BIM Protocol’. Both standards are closely aligned with BS 1192:2007 [15], however, these standards

have no legislative backing but are still written in the context of rules to be followed rather than points to cover. AEC's publications are intended to support all BIM work undertaken within a practice to enable a unified, practical, and coordinated approach to BIM in a design environment.

Standards in the UK are relatively straightforward, logical and clearly identify how each document relates to other standards (see Table 3). The only difficulty lies in deciding which standard to adopt and whether standards developed outside the UK offer a more comprehensive solution.

2.1.4 Design Standards U.S.

The U.S. has published many long standing BIM publications thanks to the work of industry bodies, government departments, academic institutions, and local authorities. The National Building Information Modeling Standard (NBIMS) claim to be a key element in the building industry transformation and establish standard definitions for building information exchanges to support critical business scenarios using standard semantics and ontologies. NBIMS is made up of a committee of the National Institute of Building Services (NIBS), and the Facility Information Council (FIC). The vision for NBIMS is "an improved planning, design, construction, operation, and maintenance process using a standardised machine-readable information model for each facility, new or old, which contains all appropriate information created or gathered about that facility in a format useable by all throughout its lifecycle" [2] P.6. NBIMS are likely to be the catalyst in changing the current AECO industry processes by introducing much needed order and standardisation to the definition and use of building data, along with the development of the first Capability Maturity Model (ICMM) [27].

The American Institute of Architects (AIA) issued 'Integrated Project Delivery: A Guide' [28] which focuses more on the principles of Integrated Project Delivery (IPD) but doesn't refer to BIM. The AIA published its first contract in 2008 which specifically refer to BIM [29]. The AIA [30] defined Levels of Detail (LOD) through a sliding scale of LOD 100-500 (LOD 100: Conceptual, LOD 200: Approximate geometry, LOD 300: Precise geometry, LOD 400: Fabrication, and LOD 500: As-built) [31]. Statsbygg [32] claim the AIA [30] LOD concept, established through the E202 Protocol is now starting to be adopted throughout the world. The AIA developed further standards to meet the rapid uptake of BIM, these include AIA [33], which establishes protocols for the development, use, transmission, and exchange of digital BIM data; and AIA [34], which is a digital data protocol form to be used in conjunction with [33].

Analysing U.S. BIM standards in Table 3 highlights the fragmented nature, with the majority having been developed in isolation. NIBS [2] presentation makes difficult reading and is far too lengthy at 183 pages. However, alternative standards such as UCS [35], Ohio DAS [36], and IU [37] are well presented but lack the detail of NIBS [2] or equivalent UK standards.

Table 3: UK and U.S. BIM Standards

	Code	Document Title	Issuer, Year	Relationship
UNITED KINGDOM	1	BS 1192 Collaborative production of architectural, engineering and construction information - Code of practice	BSI, 2007	
	2	BS 1192-4 Collaborative production of information: Part 4 – Code of practice	BSI 2014	1, 3, 4
	3	PAS 1192-2 Specification for information management for the capital/delivery phase of construction projects using BIM	BSI 2013	1, 4
	4	PAS 1192-3 Specification for information management for the operational phase of assets using BIM	BSI 2014	1, 3, 12, 13, 14, 15, 16
	5	AEC (UK) BIM Protocol Implementing UK BIM Standards for the Architectural, Engineering and Construction industry	AEC, 2012	1, 3, 7, 8
	6	BIM Overlay to the RIBA Outline Plan of Work	RIBA, 2012	1
	7	BS 8541-1 Library objects for AEC – Part 1: Identification and classification – Code of practice	BSI, 2012	1, 8, 9, 10
	8	BS 8541-2 Library objects for AEC – Part 2: Recommended 2d symbols of building elements for use in BIM	BSI, 2011	7, 9, 10
	9	BS 8541-3 Library objects for AEC – Part 3: Shape and measurement – Code of practice	BSI, 2012	7, 8, 10
	10	BS 8541-4 Library objects for AEC – Part 4: Attributes for specification and assessment – Code of practice	BSI, 2012	7, 8, 9
	11	BS 7000-4 Design management systems: Guide to managing design in construction	BSI, 2013	1, 3
	12	BS ISO 55000 Series: Asset management	BSI, 2014	
	13	BS 8210 Guide to facilities maintenance management	BSI, 2012	12, 14, 15, 16
	14	BS 8587 Guide for facilities information management	BSI, 2012	1, 3, 15, 16
	15	BS 8572 Procurement of facility–related services - Guide	BSI, 2011	16
	16	BS 8536 Facilities management briefing – Code of practice	BSI, 2010	11
UNITED STATES	1	National Building Information Modeling Standard - Version 1.0 - Part 1: Overview, Principles and Methodologies	NIBS, 2007	2, 3, 4, 5, 6
	2	Document E202: Building Information Modeling Protocol Exhibit	AIA, 2008	
	3	Document E203: Building Information Modeling and Data Exhibit	AIA, 2013	4, 5
	4	Document G201: Project Digital Data Protocol Form	AIA, 2013	3
	5	Document G202: Project Building Information Modeling Protocol Form	AIA, 2013	3, 4
	6	GSA BIM Guide Series: BIM Guide For Spatial Program Validation	GSA, 2007	
	7	Integrated Project Delivery: A Guide	AIA, 2007	
	8	Building Information Modeling (BIM) Guidelines – For Design Bid Build Contracts	USC 2012	1
	9	State of Ohio Building Information Modeling Protocol	ODAS, 2010	2
	10	Building Information Modeling (BIM) Planning Guide for Facility Owners – Version 2.0	PState, 2013	
	11	BIM Guidelines 7 Standards for Architects, Engineers, and Contractors	IU, 2012	1, 12
	12	Triton College BIM Standards Manual – Architecture, Interior Design, Construction Management	TC, 2009	

2.2 Information Standards

2.2.1 Information Classification

A large percentage of project documentation is produced in text format, thus methods for organising and improving the management of building data is essential in a collaborative BIM process.

UniFormat is a standard for classifying building elements and related sitework, ensuring consistent economic evaluation of construction projects and enhanced project management during all project stages, whilst MasterFormat provides a master list of numbers and titles classified by work results or construction practices, used to organise project manuals, detailed cost information, and relate drawing notations to specifications. OmniClass is a newly developed AEC industry-wide initiative led by the Construction Specifications Institute (CSI) and endorsed by The Information Architecture Institute (IAI) which is intended to be the most comprehensive classification format, which encapsulates all project phases (see Figure 1).

2.2.2 Information Exchange

BIM presents many interoperability issues given the reliance on embedded information. The first step towards resolving these issues and developing a computerised process for information interoperability within the AEC industry was the Industry Foundation Classes (IFC), 1999. IFC's are defined by the buildingSMART alliance and represent the accepted industry standard for design models and information exchange. IFC's include object specifications, classes, and provide a useful structure for data transfer between applications. However, IFC's still require further development, especially relating to the exporting of non-geographical data, complex geometries, parametrically modelled components, complexity of language, and large file sizes [38]. International Framework for Dictionaries (IFD) is an open terminology standard, where concepts and terms are given a unique identification number and tagged with a Globally Unique ID (GUID). Information Delivery Manual (IDM) is then used to specify exactly what information is exchanged, whilst relating it to the IFC model. IDM can be utilised from the 'Preparation and Brief' phase right through to assisting the facilities manager manage the buildings data during the 'In Use' phase (see Figure 1).

NBIMS initiated project COBie in December 2006 to support the handover of projects between builders and operators. The primary objectives of COBie was to identify the data and information exchange needs of facilities managers, operators, and asset managers upstream of the facility life cycle [39] (see Figure 1); and provide a robust framework for information organisation. The COBie standard is a key requirement stipulated in the BIM Task Group [4] report [40]. All public sector projects in the UK will require COBie data at designated data drops in the project lifecycle, thus it will be a key industry requirement to generate, validate, and share COBie data in a collaborative BIM process. Standards and guidance

documentation to facilitate this process include BS 1192-4 [11], BIM Task Group [41], and PAS 1192 [8] [14] 'Information Delivery Cycle' diagram.

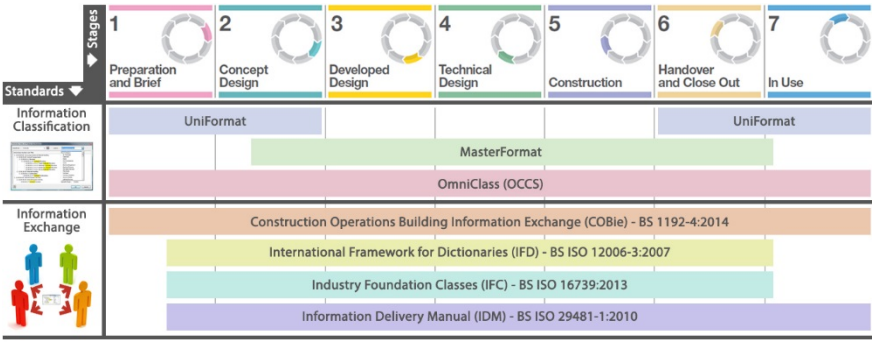

Figure 1: Information Standards by Project Phase

3 Conclusion

Findings clearly indicate that the construction industry is still trying to find its feet with standardising processes and documentation to reap the inherent benefits of BIM. Although, the adoption of industry standards and the introduction of project planning measures was identified as essential for the successful delivery of BIM, few companies have adopted them to date. The key to successful delivery of BIM is to closely follow industry standards, along with the production of a good EIR, BEP, and PEP specific to the project and company's requirements.

There appears to be several UK BIM standards and initiatives such as PAS 1192-2:2013 [8], PAS 1192-3:2014 [14], BS 1192:2007 [15], and BS 1192-4:2014 [11] which seem to be clear, logical and heavily promoted by industry bodies. Alternative guidance documents developed by the AEC [25] [26]; although lacking legislative powers, are closely aligned to BS 1192:2007 [15] and enable a practical, and coordinated approach to BIM in a design environment. Aside from BS 1192:2007 [15], the other documents have only recently been published, thus have not been the subject of research to determine which standards the industry is using, and whether there are alternative publications which offer a more holistic delivery of BIM.

BIM standards within the U.S. seem to be more widely implemented than the UK. The most commonly used standards include NIBS [2], AIA [30], AIA [33], and AIA [34]. However, this paper highlights the fragmentation between U.S. standards and guidance documentation. U.S. publications are either poorly presented, too complex or lack detail. Although, it is noted that some of the U.S. content could be utilised to improve existing UK BIM standards. Further investigation to critically compare U.S. and UK standards to highlight improvement areas and identify the best placed publications to develop a

measurable and repeatable approach to successfully achieve collaborative BIM, would be a natural progression from this paper.

In a collaborative BIM process, it is crucial to adopt a standard classification model such as UniFormat, MasterFormat, or OmniClass. Although, research has identified that OmniClass provides the complete built environment solution. COBie data and information exchange standards are commonly overlooked by industry, but a key requirement stipulated in the governments BIM Task Groups [4] report. IFC proves to be a useful tool in data and model exchange, however more research and development needs to be undertaken to tackle large file sizes, non-geographical data, complex geometries, and parametrically modelled components. IFC standards should be used in conjunction with IFD and IDM frameworks to enable the complete information exchange solution.

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