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A REVIEW OF THE EFFORTS AND ROLES OF THE PUBLIC SECTOR FOR BIM ADOPTION WORLDWIDE

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SUMMARY: *Building Information Modeling (BIM) adoption is spreading through the public sector (including government bodies and non-profit organizations) around the globe in the architecture, engineering and construction (AEC) industry. The public sector plays a key role in supporting and encouraging the adoption of BIM in the industry. Currently there is no comprehensive study on the efforts and roles of the public sector for BIM adoption. In this paper, different kinds of the efforts that the public sector has put for BIM adoption worldwide are reviewed to highlight the successful implementations of BIM and to identify the gaps in some countries. The countries covered in this paper are grouped into four regions – the United States, Europe, Asia, and Australasia. In each region, efforts of the public sector in different countries to BIM implementations including establishment of BIM programs and committees, organization of BIM activities and seminars, setting up of different BIM goals and promises, and preparation of BIM guidelines and standards are described and compared. This paper also identifies six major possible roles of the public sector for BIM adoption. The roles played by the public sector in each selected country are summarized and evaluated.*

KEYWORDS: *Building information modeling (BIM), BIM adoption, BIM standards, public sector*.

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1. INTRODUCTION

Building Information Modeling (BIM) is one of the most promising developments in the architecture, engineering, and construction (AEC) industry. It is defined as the digital representation of the physical and functional characteristics of a facility, and an approach to facilitate collaboration among various stakeholders at different phases of the life cycle of a facility (NIST, 2007b). Since its introduction in the 1970s, BIM has been developed for over three decades and is currently a key technology in the AEC industry to capture, store, share and manage building information over the whole life cycle of a building. There is a wide range of industry standards and file formats available for exchanging and managing BIM data. For example, Industry Foundation Classes (IFC) specification was developed by buildingSMART Alliance (formerly known as the International Alliance for Interoperability) as a neutral data format to describe, exchange, and share information typically used within the building and facility management industry sector (Häfele, 2013). For another example, Construction Operations Building information exchange (COBie) was developed as an information exchange specification for the lifecycle capture and delivery of information needed by facility managers (buildingSMART alliance, 2015).

BIM technology has been studied and applied to building design, construction, facility management, and even demolition (Yabuki and Li, 2006; Park et al., 2009; Huang et al., 2012; Cheng and Ma, 2013). Many countries around the world have adopted BIM technology. The United States is believed to be one of the pioneering countries for BIM adoption. Many public sector bodies at different levels in the United States have established BIM programs, set up BIM goals and implementation roadmaps, and published BIM standards. In 2007, for example, the United States National Institute for Building Sciences (NIBS) published the National Building Information Modeling Standard (NBIMS-USTM). Apart from the United States, many countries in Europe have embarked on significant BIM implementations. The United Kingdom government, for example, mandated that all UK government projects should use BIM by 2016. Although BIM adoption in the public sector came later in Asia, BIM has now developed rapidly in Asian regions. For instance, Singapore and Hong Kong have established their own BIM committees and published several BIM guidelines. The Mainland Chinese government also included BIM-related topics in the 12th National Five Year Plan in 2012.

The public sector plays a vital role in leading the industry towards BIM adoption. In recent years, BIM implementations continue to increase intensively as more and more government bodies and non-profit organizations of various countries worldwide implemented BIM in their projects and provided different BIM standards and solutions. Such divergence and coverage highlight the lack of and the necessity for a review of these efforts and the potential roles of the public sector for BIM adoption. However, currently there is no comprehensive study on the efforts and roles of the public sector for BIM adoption.

The existing reviews only cover a limited amount of countries and focus on some aspects of BIM implementations. For example, Succar (2009) listed the publicly-available guides, reports and visions related to BIM in Australia, Denmark, Finland, Netherlands, Norway, the United States and a consortium of organizations in Europe. Wong et al. (2009) discussed the roles of the public and private sectors as major stakeholders in promoting and providing support for BIM implementation in Singapore, Finland, Norway, and Denmark. Wong et al. (2011) conducted a comparative review of BIM initiatives taken in the United States and Hong Kong, including the government policy, guidelines, standards, and implementation status. In the first issue of Solibri Magazine 2011, Jauhiainen (2011) presents three public sector BIM adoptions in Statsbygg from Norway, Senate Properties from Finland, and the General Services Administration (GSA) from the United States. Martin (2012) compares the national BIM guidelines in the United States, Australia, UK, Finland, Norway, Sweden and Denmark. Although there have been some reviews of the BIM adoption efforts in various countries, most of them just focus on limited regions not worldwide. In addition, as the interest in BIM has grown dramatically in the AEC industry in recent few years, many countries have now started to investigate and implement BIM and the previous reviews become obsolete. For example, there has been almost no previous review covering the BIM

adoption efforts in UK, which has an overwhelming goal for national BIM adoption. Review covering the Asian countries is also lacking.

Therefore, this paper aims to provide a comprehensive review and comparison of the efforts and roles that the public sector has done in different countries worldwide for BIM adoption.

2. RESEARCH METHODOLOGY

Fig. 1 presents the methodology framework of this study. In order to perform this review study, all data (including BIM program, BIM pilot projects, BIM standards, annual BIM report, online training information, etc.) were collected from the official websites of each government body and non-profit organization of countries worldwide. Based on the data collection and review, this paper focuses on 14 countries/areas. These countries/areas are selected because the public sector has substantial efforts in BIM adoption and the information about these efforts is publicly available and in English.

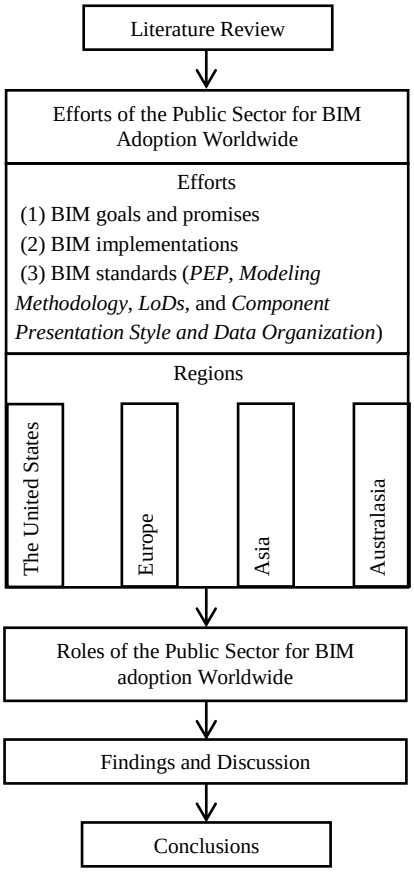

FIG. 1: The methodology framework of this study.

These countries were further grouped into four regions, which are the United States, Europe, Asia and Australasia. In each region, gap analysis of the public sector in different countries to BIM adoption was performed. Discussion and suggestions of their efforts were made based on the results of gap analysis. These efforts have been summarized and compared in these three main aspects – (1) the BIM goals and promises made by the public sector, (2) the BIM implementations such as establishment of BIM programs and committees, organization of BIM forums, and execution of pilot BIM projects, and (3) the BIM standards developed by the public sector. According to these BIM standards, four major types of contents contained in those BIM standards are identified. They are (1) Project Execution Plan (PEP), (2) Modeling Methodology, (3) Levels of Detail

(LoDs, including level of development), and (4) Component Presentation Style and Data Organization. Based on the review of BIM deliverables and implementations, the roles of the public sector in adopting BIM are summarized and discussed. Findings and discussion of the efforts and roles of the public sector are given based on the review result, followed by the conclusion of this study.

The remaining of this paper is organized as follows. Public BIM efforts in the United States are discussed in four levels (national, state-wide, city-wide, and public university-wide) in Section 3. In Sections 4 to 6, the efforts of the public sector for BIM adoption in Europe, Asia and Australasia are introduced. In Section 7, the potential roles of the public sector for BIM adoption are discussed. In addition, how the identified roles can help the public sector in other countries to promote BIM adoption is also discussed in this section. Findings and discussion of the efforts and roles of the public sector are given in Section 8. Finally, Section 9 concludes the paper.

3. EFFORTS OF THE PUBLIC SECTOR FOR BIM ADOPTION IN THE UNITED STATES

3.1 BIM Goals and Promises in the United States

The United States is one of the pioneering countries for using BIM technology and is currently the biggest producer and consumer of BIM products. The biggest difference in BIM adoption between the United States and other countries may be that different levels of the public sector in the United States, from national organizations to public universities, all contribute to BIM implementation.

In 2006, the United States Army Corps of Engineers (USACE) released *A Road Map for Implementation To Support MILCON Transformation and Civil Works Projects within the United States Army Corps of Engineers* (Brucker et al., 2006), in which USACE announced the vision to be a leader in using BIM and set six goals for BIM implementation. In 2007, the United States General Services Administration (GSA) set a goal to require IFC BIMs on FY07 projects for improving design quality and construction delivery. It was the first time that an organization at the project scale had made such a public and groundbreaking statement (Hagan et al., 2009). The United States Department of Veterans Affairs (VA) also mandated BIM for all major construction and renovation projects (over $10M), starting in 2009 (VA, 2010).

Not only do national government organizations in the United States set their BIM goals, but some state governments also set BIM promises, and even public universities require BIM implementation on their campus-wide projects. In July 2009, for example, the state of Wisconsin issued guidelines to design firms requiring the use of BIM on all projects totaling more than $5 million and new construction projects of more than $2.5 million (Beck, 2012). For another example, Indiana University (IU) required BIM on all construction projects with total project funding of $5M or greater (IU, 2012).

3.2 BIM Implementation in the United States

Apart from setting BIM goals and promises, the public sector in the United States launched BIM programs, established BIM committees, and held various BIM conferences and training courses. As early as 2003, the GSA Public Buildings Service (PBS) Office of the Chief Architect (OCA) established the National 3D-4D-BIM Program. They implemented BIM in over 200 active projects for the program, which were valued at over $12 billion (Hagan et al., 2009). With support from industry technology leaders, the GSA BIM team drafted eight BIM Guide Series 01 to 08 over the past decade. GSA's success with BIM up to now could be a roadmap for other owner organizations in the country and even over the world.

The USACE updated the original roadmap published in 2006 and officially released a new *Roadmap for Lifecycle BIM* (Engineer Research and Development Center, 2012) in 2012 for BIM use in military construction and civil works projects. USACE also directly funded a CAD/BIM Technology Center (Woods, 2011), which

was a R&D center aiming to explore new CAD and BIM technologies and provide BIM training within the United States Department of Defense (DoD). National Institute of Building Sciences (NIBS) established the NBIMS-US^{TM} project committee to develop the national BIM standards and to discuss the possibility of incorporating BIM into college curricula. In early 2014, NIBS presented its first course – "The Introduction to COBie" – on the Institute's newly launched Building Sciences Online Academy.

3.3 BIM Standards and Guidelines in the United States

Different levels of the public sector in the United States have released BIM standards in order to effectively implement BIM. As at 2015, 47 BIM standards developed by the public sector in US were publicly available (see Table 1). Among them, 17 were from government bodies whereas 30 were from non-profit organizations. As shown in Table 2, most of the standards cover PEP, modeling methodology, and component presentation style and data organization. The largest gap falls in LoDs categorization. About half of the standards do not provide detailed information about how much graphical scale each model should meet. In addition, Table 2 shows that some of the standards, such as those released by Pennsylvania State University (PSU) and Association of General Contractors (AGC), contain all these four types of information. The following will provide detailed description about the BIM standards developed in US in different levels of the public sector – national level, state level, city level, and public university level.

TABLE 1: The number of BIM standards/guidelines in different regions.

Region	**Country/ Organization**	**Year Range**	**Quantity**		
			Gov. Body	**Non-profit Org.**	**Total**
The United States	Nation-wide	2007-2015	9	15	24
	State-wide and city-wide	2009-2013	8		8
	University-wide	2009-2013		15	15
	Sub-Total		17	30	47
Europe	the United Kingdom	2007-2015	3	15	18
	Norway	2008-2013	4	2	6
	Finland	2007-2013	2	1	3
	Denmark	2007		4	4
	Sweden	2009		1	1
	Netherlands	2013	2		2
	Sub-Total		11	23	34
Asia	Singapore	2008-2013	12		12
	Korea	2009-2011	5	1	6
	Japan	2012-2013		3	3
	Mainland China	2013-2015	4		4
	Taiwan	2010-2014		4	4
	Hong Kong	2009-2014	4	2	6
	Sub-Total		25	10	35
Australasia	Australia	2009-2015	3	5	8
Total					123

TABLE 2: BIM standards in the United States.

Year	BIM Standards/Guidelines	PEP	Modelling Methodology	LoDs	Component Presentation Style and Data Organization
2007	[NIBS] NBIMS v1.0	√	√		√
2007	[NIST] General Buildings Information Handover Guide		√		√
2007	[GSA] BIM Guide Series 01 v0.6				
2007	[GSA] BIM Guide Series 02 v0.96	√	√		√
2007	[AIA] Document E201™–2007, Digital Data Protocol Exhibit	√			
2007	[AIA] Document C106™–2007 Digital Data Licensing Agreement	Not Found			
2008	[AIA] Document E202-2008 BIM protocol exhibit		√	√	√
2008	[AGC] The Contractor's Guide to BIM v1	√	√	√	
2009	[Wisconsin] BIM Guidelines and Standards for Architects and Engineers		√		√
2009	[PSU] BIM PEP Guide v0.1	√	√		
2009	[PSU] BIM PEP Guide v0.2	√	√		
2009	[PSU] BIM PEP Guide v1.0	√	√		
2009	[GSA] BIM Guide Series 03 v1.0		√		√
2009	[GSA] BIM Guide Series 04 v1.0		√		
2009	[GSA] BIM Guide Series 05 v1.0		√		√
2010	[VA] The VA BIM Guide v1.0	√	√	√	√
2010	[LACCD] LACCD BIMS v3	√	√		√
2010	[PSU] BIM PEP Guide v2.0	√	√		
2010	[AGC] The Contractor's Guide to BIM v2	√	√	√	
2011	[PSU] BIM PEP Guide v2.1	√	√		
2011	[UF] BIM Execution Plan v1.1	√			
2011	[University of Connecticut] CAD Standards Guideline				√
2011	[GSA] BIM Guide Series 08 v1.0	√	√		√
2011	[Ohio] State of Ohio BIM Protocol	√	√		
2012	[NIBS] NBIMS v2.0	√			√
2012	[NYC DDC] BIM Guidelines	√	√	√	√
2012	[IU] BIM Guidelines and Standards for Architects Engineers and Constructors	√	√	√	√
2012	[PSU] BIM Planning Guide for Facility Owners v1.0	√	√	√	√
2012	[PSU] BIM Planning Guide for Facility Owners v1.01	√	√	√	√
2012	[PSU] BIM Planning Guide for Facility Owners v1.02	√	√	√	√
2012	[University at Albany] AECM BIM Guidelines 2012		√	√	
2013	[NYC DOB] BIM Site Safety Submission Guidelines and Standards		√	√	√
2013	[NYC SCA] BIM Guidelines and Standards for Architects and Engineers v1.1	√	√	√	√
2013	[SPU/SDoT] CAD Manual SPU/SDoT Inter-Departmental CAD Standard				√
2013	[Tennessee] BIM Requirements V1.0	√	√		√
2013	[PSU] BIM Planning Guide for Facility Owners v2.0	√	√	√	√
2013	[PSU] The Uses of BIM v0.9		√		
2013	[NYC DDC] Design Consultant Guide Appendix		√		
2013	[AIA] Document E203™–2013, BIM and Digital Data Exhibit				√
2013	[AIA] Document G201™–2013, Project Digital Data Protocol Form				√
2013	[AIA] Document G202™–2013, Project BIM Protocol Form			√	
2013	[AIA] Guide, Instructions and Commentary to the 2013 AIA Digital Practice Documents			√	√
2013	[AGC, BIMForum] Level of Development Specification v2013		√	√	√
2015	[AGC, BIMForum] Level of Development Specification v2015 (draft)		√	√	√
2015	*[NIBS] NBIMS v3.0	Not Published			
2015	*[GSA] BIM Guide Series 06 v1.0	Not Published			
2015	*[GSA] BIM Guide Series 07 v1.0	Not Published			

3.3.1 National Public Sector BIM Standards/Guidelines

Among the 47 BIM standards in the United States, 24 were developed by national public organizations that have released or are in the process of publishing BIM standards (see Table 1). Fig. 2 shows the timeline of the national public sector BIM guidelines in the United States.

(1) The United States General Services Administration (GSA)

GSA PBS OCA houses the National 3D-4D-BIM Program. In order to provide good support in its program and projects, GSA intended to release eight BIM Guide Series since 2007, from Series 01 to 08. Each series in the BIM Guide is standalone, but related. They have published six BIM Guide Series officially from 2007 to 2011. *Series 06 – Circulation Security Validation* (GSA, 2007c) and *Series 07 – Building Elements* (GSA, 2010) are still under public review and comment.

Among the six series that have been published, Series 01 (Overview v0.6) is intended for GSA stakeholders engaging in BIM practices for the design of GSA projects (GSA, 2007a). It is an introductory document serving as a foundation to support BIM technology. Series 02 (Spatial Program Validation v0.96) describes the tools, processes, and requirements to effectively use BIM technologies (GSA, 2007b). Series 03 (3D imaging v1.0) contains three sections and provides guidelines for the solicitation of 3D imaging services and evaluation criteria (GSA, 2009a). Series 04 (4D Phasing v1.0) introduces the tools and processes to explore how time-related information will affect project development and potential benefits of 4D modeling (GSA, 2009b). Series 05 (Energy Performance and Operations v1.0) discusses BIM in energy modeling for Design, Construction and Operations (GSA, 2009c). Series 08 provides implementation guidance of BIM for facility management and states the minimum technical requirements that BIM models should meet (GSA, 2011).

(2) The United States National Institute of Building Sciences (NIBS)

NIBS published *National Building Information Modeling Standard (NBIMS-US^{TM}) Version 1.0 - Part 1: Overview, Principles, and Methodologies* (NIST, 2007b) in 2007 and *NBIMS-US^{TM} Version 2.0* in 2012 (NIST, 2012). Currently, they are preparing *NBIMS-US^{TM} Version 3.0*, which covers the full life cycle of buildings—from planning and design through construction and operations and will be released in late 2015. NBIMS aims at developing a full consensus standard for BIM. NBIMS V1-P1 is a conceptual description of the overall standard, the methodologies of development, and the intended use (Bazjanac, 2008). It is just a guidance document which is followed by specific standards. NBIMS V2 is a more technical standard and includes three types of contents – Guidelines and Applications, Information Exchange Standards, and Reference Standards (MARZOUK and ATY, 2012).

(3) The American Institute of Architects (AIA)

In order to provide guidance to the construction industry on how to use BIM and other digital data, the American Institute of Architects (AIA) published its first Digital Data documents in 2007. It contains two files, *AIA Document E201™ – 2007 Digital Data Protocol Exhibit* (AIA, 2007b) and *C106™–2007 Digital Data Licensing Agreement* (AIA, 2007a). E201 – 2007 is an attachment to the various parties' agreement which defines the procedures the parties should follow regarding the exchange of digital data. C106 – 2007 is a separate agreement between two parties for the Transmitting Party to grant a license to the Receiving Party for the use of digital data. In conformity with the increasing use of BIM, the AIA released *AIA Document E202™–2008 Building Information Modeling Protocol Exhibit* (AIA, 2008) in 2008 to establish five levels of development (LoD) requirements and applications of BIM. In 2013, the AIA updated its Digital Practice documents which includes *AIA Document E203™–2013, Building Information Modeling and Digital Data Exhibit* (AIA, 2013a); *AIA Document G201™–2013, Project Digital Data Protocol Form* (AIA, 2013b); and *AIA Document G202™–2013, Project Building Information Modeling Protocol Form* (AIA, 2013c). In the meantime, AIA also published *Guide, Instructions and Commentary to the 2013 AIA Digital Practice Documents* (AIA, 2013d) to provide a guide on how to use these documents.

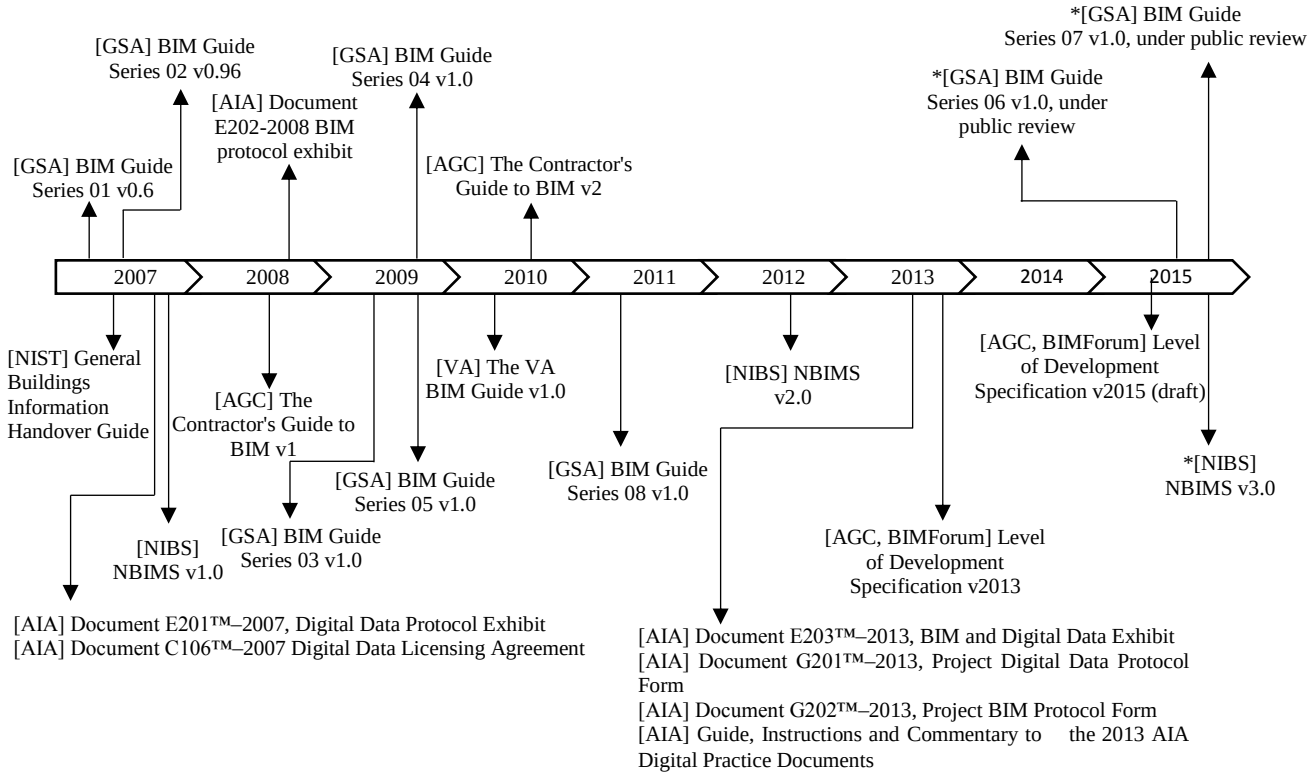

FIG. 2: National public sector BIM standards/guidelines timeline in the United States ("" means that the standard is under preparation).*

(4) Other Public Sector Bodies

The Department of Veterans Affairs (VA) and other two non-profit organizations, the National Institute of Standards and Technology (NIST) and the Association of General Contractors (AGC), also published BIM guidelines individually. The *VA BIM Guide v1.0* (VA, 2010) is a project-oriented BIM guide. It defines VA's building information life cycle vision, and introduces BIM management plan and modeling methodologies. In 2007, NIST identified the building industry's need for guidance in information handovers between parties and thus released *General Buildings Information Handover Guide: Principles, Methodology and Case studies* (NIST, 2007a). It provides a primary guidance on the technology concepts and definitions as well as modeling methodology. The *Handover Guide* also presents six case studies on the use of advanced BIM technologies and the attendant information handovers. The *Contractor's Guide to BIM Edition 1* (AGC, 2010) released by AGC aims to help contractors understand how to get started with BIM technology. In 2010, AGC released the second edition of the *BIM Guide* (AGC, 2010). BIMForum, a forum of AGC focused on the utilization of virtual design and construction in the AEC industry, released its first BIM standard in 2013, known as *Level of Development Specification Version 2013* (BIMForum, 2013). In late April, 2015, the LOD 2015 draft version was released for public comment (BIMForum, 2015). The LOD specifications were developed under an agreement with AIA and utilized the fundamental LoD definitions of *AIA Document G202-2013 Building Document Information Modeling Protocol Form* (AIA, 2013c).

3.3.2 State-wide and City-wide BIM Standards/Guidelines

As shown in Table 1, 8 state and city government bodies in the United States have contributed to the release of BIM Standards, and three of them are state governments. They are State of Ohio, State of Wisconsin, and State of Tennessee. As shown in Fig. 3, in the middle of 2009, the Division of Facilities Development, State of

Wisconsin released *BIM Guideline and Standard for Architects and Engineers*, which was required for most projects of the division (DFD, 2009). Two years later, the *State of Ohio BIM Protocol* was released to serve as the foundation for BIM use and to provide the structure for BIM implementation in the State of Ohio (DAS, 2011). Later than the previous two states, in the middle of 2013, the State of Tennessee Office of the State Architect (TN OSA) established the first version of *BIM Requirements* for the consistent management of BIM on state building projects. It contains the general principles and obligation to use BIM, BIM requirements, details of requirements and BIM process for designers and contractors. It also includes two BIM Execution Plan outlines for designers and contractors, tips for preparing a BIM model for energy analysis, and requirements for Designers and Contractors (TN OSA, 2013).

Besides the state-wide efforts for BIM adoption, some city governments in the United States also participated in drafting and publishing BIM guidelines for public use in the past two years. As illustrated in Fig. 3, the public sector in New York City (NYC) is active in BIM adoption. The NYC Department of Design + Construction (DDC) published a city-wide BIM Guide in July 2012 and a supplementary specific project delivery guide for design consultants about one year later (DDC, 2012, DDC, 2013). In 2013, more and more public organizations in NYC such as NYC School Construction Authority (SCA) (SCA, 2013) and NYC Department of Buildings (NYC DOB) (NYC Buildings, 2013) joined in releasing their own BIM Guidelines. In late 2013, Seattle Public Utilities and Seattle Department of Transportation co-produced an inter-departmental CAD standard, which is probably the first standard aiming at civil projects in the United States. The standard was designed for making engineering data compatible with GIS data and delivering AutoCAD or AutoCAD Civil 3D compatible files as a final product (SPU/SDoT, 2013).

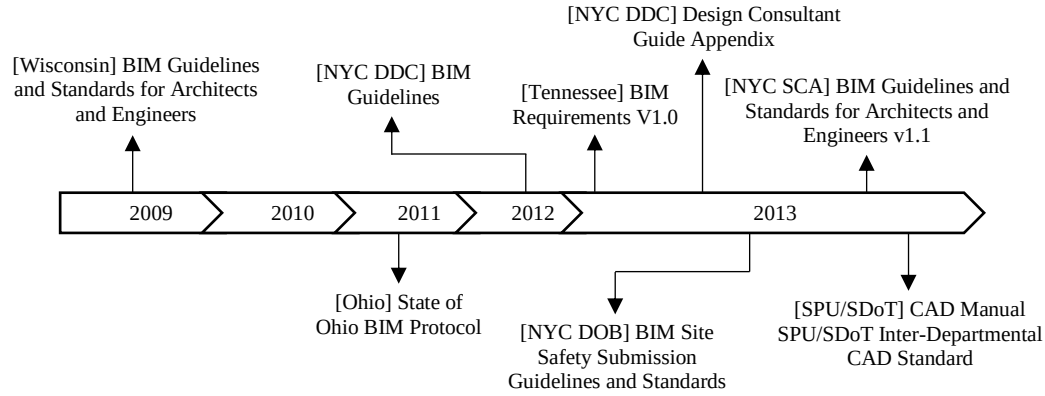

FIG. 3: State-wide and city-wide BIM standards/guidelines timeline in the United States.

3.3.3 University-wide BIM Standards/Guidelines

In the United States, even public universities have published their own BIM Standards starting from 2009. As described in Table 1, 15 BIM standards have been released by public universities in the United States as at 2013. For example, as a buildingSMART project, the Pennsylvania State University (PSU) has published several BIM standards since 2009, as shown in Fig. 4. PSU has drafted several versions of *BIM Project Execution Planning Guide* (BIM PEP Guide) (Computer Integrated Construction Research Program, 2009) and released *BIM PEP Guide version 2.1* officially in May 2011 (Computer Integrated Construction Research Program, 2011). The BIM PEP Guide can be considered as a strategic guide and provides a practical methodology for project teams to design BIM strategies and develop their own BIM PEP. In 2012, PSU started drafting four versions of *BIM Planning Guide for Facility Owners* (Computer Integrated Construction Research Program, 2012) and published the latest version 2.0 in 2013 (Computer Integrated Construction Research Program, 2013a). This guide presents three planning procedures to effectively integrate BIM within an organization, including strategic, implementation and procurement planning. In 2013, PSU published the first version of *The Uses of BIM*

(Computer Integrated Construction Research Program, 2013b), which provides a system for BIM use classification.

As indicated in Fig. 4, the Los Angeles Community College District (LACCD) released the *LACCD Building Information Modeling Standards (LACCD BIMS) Version 3* (BuildLACCD, 2010) in 2010 targeting at Design-Build (DB) projects. The standard defines the requirements and procedures for BIM models in various phases of DB projects. *The CAD Guidelines* (Office of University Planning, 2011) provided by the University of Connecticut contains drawing submission requirements for campus construction projects. Like University of Connecticut, Indiana University (IU) released the *IU BIM Guidelines and Standards* (IU, 2012) as a requirement for all the construction projects in IU with total funding of more than $5M. University of Florida also drafted its *BIM Execution Plan* (UF, 2011) for the campus minor projects and as an addendum to the project contracts. Unlike BIM standards designed by other universities, the *AECM BIM Guidelines 2012* (University at Albany, 2012) by the University at Albany requires e-submission of BIM files and contains related requirements for electronic file submission.

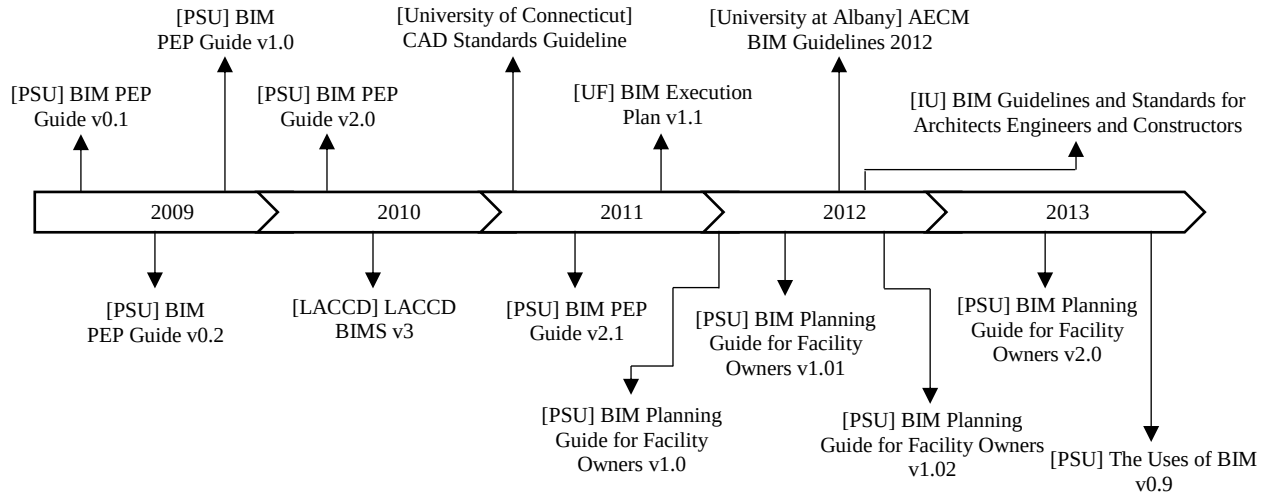

FIG. 4: University-wide BIM standards/guidelines timeline in the United States.

4. EFFORTS OF THE PUBLIC SECTOR FOR BIM ADOPTION IN EUROPE

4.1 Efforts of the Public Sector for BIM Adoption in the United Kingdom

4.1.1 BIM Goals and Implementation in the United Kingdom

The United Kingdom has a promising goal of BIM adoption and is one of the countries that are advanced in BIM technology. In May 2011, the Government Construction Strategy demanded that all central governmental departments would adopt Level 2 BIM by 2016 (see Fig. 5). In order to fulfill this goal and to strengthen the public sector's capability in BIM implementation, the BIM Task Group was established in 2011 (The BIM Task Group, 2013a). It is an industry consortium which brings together expertise from industry, government, public clients, professional institutions, and academia. There are six main work packages under the BIM Task Group, which aims to provide different BIM support to the Government's target for 2016. The BIM Task Group proposed a series of BIM briefing sessions and published the initial BIM Learning Outcomes Framework to provide early information for BIM training programme development (The BIM Task Group, 2013b). One work package focuses on the possibility of COBie for civil infrastructure. In late 2013, the BIM Task Group released a report about the requirements that COBie should meet to address information exchanges for civil infrastructure projects for public comment (BIM Task Group, 2013). Many public sector bodies also have put effort in BIM

adoption to get prepared for the governmental BIM strategy. For example, Construction Industry Council (CIC) drafted a BIM protocol for supporting BIM working at Level 2. In addition, the British Standards Institution B/555 committee (Construction design, modelling and data exchange) held various BIM activities and published some BIM standards in support of government's 2016 ambition.

4.1.2 BIM Standards and Guidelines in the United Kingdom

As shown in Table 1, there are 34 BIM standards listed from Europe, among which 18 of them (more than half) are from the United Kingdom. Table 3 presents these 34 BIM standards in detail. Half of the BIM standards from Europe are either not found online, not published or not in English. Most of them contain modelling methodology and component presentation style to facilitate the efficient use of BIM data and models. In addition, AEC-UK published several BIM protocols for different software platforms which contain these four types of information. Compared to the United States, there is no separate PEP and LoD files released to date in Europe. More technical BIM guidelines are suggested to effectively standards and instruct the industry.

For the public sector in the United Kingdom, CIC and BIM Task Group co-produced some BIM guidelines in response to the United Kingdom government's 2016 goals (See Fig. 6). With the technical support and leadership of the BIM Task Group, CIC drafted two BIM documents in 2013. The first one, namely *BIM Protocol v1*, identifies BIM requirements that project teams should meet for all common construction contracts (CIC, 2013b). The second one, namely the *Best Practice Guide for Professional Indemnity Insurance When Using BIMs v1*, summarizes the key risks that professional indemnity insurers would meet in BIM projects (CIC, 2013a).

In addition, many non-profit organizations in the United Kingdom such as the British Standards Institution (BSI) and the AEC-UK Committee released BIM standards. The BSI B/555 committee has released several standards for digital definition and exchange of life cycle information within the construction industry since 2007, as summarized in Table 4. For example, *PAS 1192-2: 2013* (BSI, 2013) specifies an information management process to support BIM Level 2 in the capital/delivery phase of projects, while PAS *1192-3: 2014* (BSI, 2014) focuses on the operational phase of assets. In addition, a maturity model namely the *B/555 Roadmap* was also introduced to illustrate the several standards and their relationships (The BSI B/555 committee, 2013). Apart from the committee, BSI/CPIC (Construction Project Information Committee) jointly published in 2010 a guide *Building Information Management – A Standard Framework and Guide* to BS 1192 (BSI, 2010), which is also included in the maturity model. As shown in Fig. 6, the AEC-UK Committee released the first version of the *BIM Standard* (AEC-UK, 2009) in 2009 and then the *BIM Protocol version 2.0* (AEC-UK, 2012c) in 2012. Since 2012, the AEC-UK Committee has explored the *BIM Protocol* for different software platforms, including Autodesk Revit (AEC-UK, 2012a), Bentley AECOsim Building Designer (AEC-UK, 2012b) and Graphisoft ArchiCAD (AEC-UK, 2013).

TABLE 3: The BIM standards in Europe.

Year	BIM Standards/Guidelines	PEP	Modelling Methodology	LoDs	Component Presentation Style and Data Organization
2007	[Denmark, Byggestyrelsen] 3D CAD Manual 2006		√	√	√
2007	[Denmark, Byggestyrelsen] 3D Working Method 2006	Not Found			
2007	[Denmark, Byggestyrelsen] 3D CAD Project Agreement 2006	Not Found			
2007	[Denmark, Byggestyrelsen] Layer and Object Structures 2006	Not Found			
2007	[Finland, Senate Properties] Senate Properties' BIM Requirements for Architectural Design	Not Found			
2007	[UK, BSI] BSI 1192: 2007				√
2008	[Norway, Statsbygg] BIM Manual v1.0	Not English			
2009	[Sweden, SSI] Bygghandlingar 90	Not Found			
2009	[Norway, Statsbygg] BIM Manual v1.1	Not English			
2009	[UK, AEC] BIM Standard v1.0	√	√	√	√
2010	[UK, BSI/CPIC] Building Information Management – A Standard Framework and Guide to BS 1192		√		√
2011	[Norway, Statsbygg] BIM Manual v1.2		√	√	√
2011	[Norway, Norwegian Home Builders' Association] BIM Manual v1	√	√		√
2011	[UK, BSI] BSI 8541-2	Not Found			
2012	[Finland, Senate Properties et al.] Common BIM Requirements 2012 v1		√		
2012	[UK, BSI] BSI 8541-1: 2012	Not Found			
2012	[UK, BSI] BSI 8541-3: 2012	Not Found			
2012	[UK, BSI] BSI 8541-4: 2012	Not Found			
2012	[UK, AEC] BIM Protocol v2	√	√	√	√
2012	[UK, AEC] BIM Protocol v2 for Autodesk Revit v2	√	√	√	√
2012	[UK, AEC] BIM Protocol v2 for Bentley AECOsim Building Designer v2	√	√	√	√
2012	[Netherlands, Rijksgebouwendienst] Rgd BIM Norm v1		√	√	√
2012	[Norway, Norwegian Home Builders' Association] BIM manual v2	Not Found			
2013	[UK, BSI] PAS 1192-2: 2013	√	√	√	√
2013	[UK, CIC] Best Practice Guide for Professional Indemnity Insurance When Using BIMs v1				
2013	[UK, CIC] Building Information Model (BIM) Protocol v1		√	√	
2013	[UK, AEC] BIM Protocol v2 for Graphisoft ArchiCAD v1	√	√	√	√
2013	[UK, CIC] Outline Scope of Services for the Role of Information Management v1				
2013	*[Finland, Finnish Concrete Association] BIM guidelines for concrete structures	Not Published			
2013	[Norway, Statsbygg] BIM Manual v1.2.1		√		√
2013	[Netherlands, Rijksgebouwendienst] Rgd BIM Norm v1.1		√	√	√
2014	*[UK, BSI] PAS 1192-3: 2014				
2014	*[UK, BSI] BS 1192-4: 2014				√
2015	*[UK, BSI] BS 7000-4: 1996	Not Published			

TABLE 4: The current and future standards developed by BSI B/555 committee.

Year	Standard	Description
2007	BS 1192: 2007 Collaborative Production of Architectural, Engineering and Construction Information. Code of Practice	A combined data and procedure standard, applicable at level 0 and 1
2011	BS 8541-2: 2011 Library Objects for Architecture, Engineering and Construction. Recommended 2D Symbols of Building Elements for Use in Building Information Modeling	2D building information, mainly targeting at level 1
2012	BS 8541-1: 2012 Library Objects for Architecture, Engineering and Construction -- Part 1: Identification and Classification -- Code of practice	Definition and classification of Library objects, for use from level 0 to level 3
2012	BS 8541-3: 2012 Standard due: Library Objects for Architecture, Engineering and Construction: Shape and measurements	3D symbols of detail LoDs, particularly focusing on level 1 to 2
2012	BS 8541-4: 2012 Standard due: Library Objects for Architecture, Engineering and Construction: Attributes for specification and simulation	Properties for specification and simulation, essentially targeting at level 2 to 3
2013	PAS 1192-2: 2013 Specification for Information Management for the Capital/Delivery Phase of Construction Projects using BIM	Capital delivery phase, early adopter document to Gov.'s Level 2 aim
2014	PAS 1192-3: 2014 Specification management for the operational phase of assets using building information modelling	Using and maintenance of asset information model, early adopter document to Gov.'s Level 2 aim
2014	BS 1192-4: 2014 Collaborative production of information Part 4: Fulfilling employer's information exchange requirements using COBie – Code of practice	Documenting best practice recommendations for COBie implementation in Gov. pilot project
2015*	BS 7000-4: 1996 Design Management Systems. Guide to Managing Design in Construction	Documenting and managing design data

4.2 Efforts of the Public Sector for BIM Adoption in Norway

In 2010, the Norwegian government stated its commitment to BIM adoption (Fig. 5), and many public sector bodies in Norway launched BIM programs to follow the government. For instance, the Norwegian Defense Estates Agency started running three BIM pilot projects after the government's statement. Statsbygg, a public sector administration company and the Norwegian government's key advisor, required IFC-compatible BIM for all new building projects (Fatt, 2012). To help promote BIM adoption, Statsbygg has conducted several R&D projects that focused on BIM for efficient building, indoor navigation, location-based simulation, and energy calculations. The Norwegian Home Builder's Association, a non-profit organization, also started the boligBIM project to develop a BIM-manual guideline.

From 2008, the public sector in Norway started drafting and releasing their BIM standards. As shown in Table 1, as at 2013, there are 6 BIM standards from Norway, 4 of which were released by Norwegian government bodies and 2 by a non-profit organization. In order to describe its requirements for IFC-compatible BIM, Statsbygg first drafted a BIM manual in 2008 (see Fig. 6). It has published four versions of the BIM manual and the latest one – *Statsbygg Building Information Modeling Manual v1.2.1* (SBM) was released in 2013 (Statsbygg, 2013). SBM is the result of government initiatives and is compulsory for state projects. It contains Statsbygg's general requirements and discipline specific requirements for BIM in projects and facilities and is positioned to be best practice for applying BIM in Norway in the whole AEC field. Furthermore, the Norwegian Home Builder's Association released its *BIM Manual* version 1 in 2011 and then version 2 in 2012 (Norwegian Home Builders' Association, 2011, Norwegian Home Builders' Association, 2012), which summarizes a general modeling methodology of various software tools and focuses on four main areas: energy simulations, cost calculation, ventilation, and roof trusses.

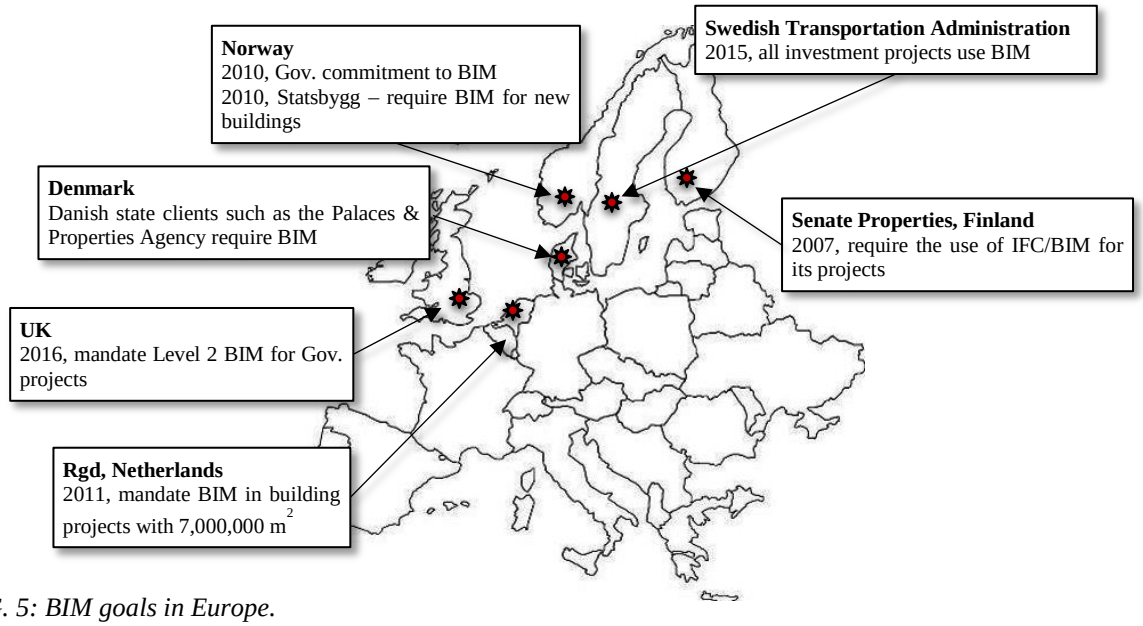

FIG. 5: BIM goals in Europe.

4.3 Efforts of the Public Sector for BIM Adoption in Finland

Finland's state property services agency, Senate Properties, is the largest government owned enterprise under the Finnish Ministry of Finance. As illustrated in Fig. 5, it has required the use of IFC/BIM for its projects since 2007, and published in the same year *Senate Properties' BIM Requirements for Architectural Design* (Senate Properties, 2007) (see Fig. 6). In 2012, with support from several construction companies, big cities and consulting companies, Senate Properties developed their *BIM Requirements for Architectural Design* into the *Finnish National BIM Guidelines (COBIM)*, generating the *Common BIM Requirements 2012 v1.0* (Parties to the COBIM project, 2012). The *Common BIM Requirements 2012 v1.0* contains 13 series of requirements, each of which was written by a company or organization with related experience. Therefore, the requirements are very practical. Following the publication of the COBIM requirements, the Finnish Concrete Association stated in 2012 that they were preparing BIM guidelines for concrete structures (Henttinen, 2012).

4.4 Efforts of the Public Sector for BIM Adoption in Denmark

In Denmark, the government initiated the Digital Construction project (Det Digitale Byggeri in Danish) in 2007, which aims to provide requirements for Information and Communication Technology (ICT) including BIM in governmental projects (Det Digitale Byggeri, 2007). Since 2007, state clients such as the Palaces & Properties Agency, the Danish University Property Agency, and the Defense Construction Service have piloted BIM in their projects and followed the requirements set by the Digital Construction project (Fig. 5). Commissioned by the Digital Construction project, the National Agency for Enterprise and Construction (Erhvervs – og Byggestyrelsen) released in 2007 four sets of guidelines for working with 3D CAD/BIM applications, namely *3D CAD Manual 2006*, *3D Working Method 2006*, *3D CAD Project Agreement 2006*, and *Layer and Object Structures 2006* (see Fig. 6 and Table 1). These guidelines are also available in English.

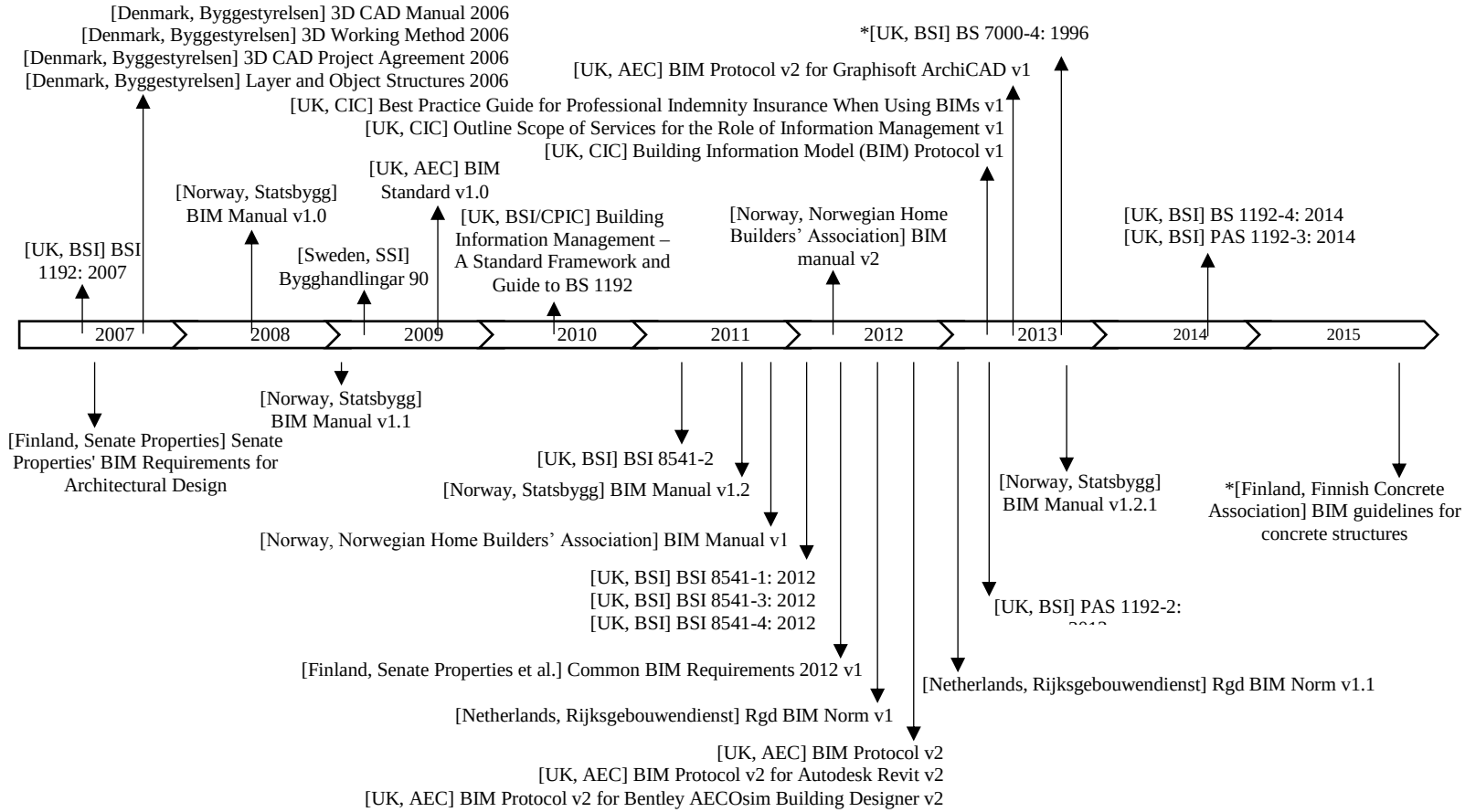

FIG. 6: BIM standards/guidelines timeline in European countries ("" means that the standard is under preparation).*

4.5 Efforts of the Public Sector for BIM Adoption in Sweden

BIM had been used in the Swedish construction industry for some years, but the Swedish government started to promote BIM when the Swedish Transportation Administration (STA) stated in late 2013 that they would use BIM step by step in the next few years. The STA also envisioned that all investment projects should use BIM to some extent from 2015 (Malmkvist, 2013) (as shown in Fig. 5). Therefore, the STA launched the BIM Implementation Project to standardize the internal processes and to create opportunities for their external suppliers to use BIM. For example, they used BIM in some big and complex infrastructure projects, such as the Stockholm Bypass and the Röfors Bridge, for demonstration and educational purposes. As for the BIM standards in Sweden, the non-profit organization Swedish Standards Institute (SSI) released in 2009 the *Bygghanlingar 90 (BH90)* (SI, 2008), which included a series namely *Digital Deliverables for Construction and Facilities Management* that was an extended CAD guideline for delivering and managing digital information within construction projects in Sweden (see Table 1 and Fig. 6). The series was just an administrative guideline and lacked specific examples and strategic insights. Therefore, the OpenBIM organization was launched in 2009 to establish BIM standards in Sweden (Hooper, 2011).

4.6 Efforts of the Public Sector for BIM Adoption in Netherlands

In the past few years, the use of BIM technology by the public sector bodies in Netherlands has substantially increased. For example, Rijkswaterstaat (RWS, the Dutch Directorate General for Public Works and Water Management), a part of the Dutch Ministry of Infrastructure and the Environment, set a 2012-2014 BIM-program with a budget of 12 million euro to involve research institutes and stakeholders in developing BIM for RWS and the Netherlands. As the first step, RWS tested BIM products in four pilot projects, the results of which was used to educate employees in RWS. Now RWS have established two databases, INFRA database and BIM database (Winkels, 2013). Another government agency in Netherlands, Government Buildings Agency (Rijksgebouwendienst, Rgd for short) mandated in 2011 that BIM should be used in building projects with 7,000,000 square meters (Fig. 5). They also required BIM in some pilot projects of three types of contracts to demonstrate how BIM facilitates different kinds of contracts, including 8 Design-Build-Finance-Maintain-Operate (DBFMO) contracts from 2011, 3 general contracts in 2012, and several Design-Build-Management (DBM) contracts. Based on their project experience, Rgd drafted and released the first version, *Rijksgebouwendienst BIM Standard (Rgd BIM Norm* in Dutch*) Version 1.0* (Rgd, 2012) in July 2012 (See Table 1 and Fig. 6), which describes the specifications of BIM and deliverable requirements. In addition, in early 2013, *Rgd BIM Norm Version 1.1* was released (Rgd, 2013).

5. EFFORTS OF THE PUBLIC SECTOR FOR BIM ADOPTION IN ASIA

5.1 Efforts of the Public Sector for BIM Adoption in Singapore

5.1.1 BIM Goals and Implementation in Singapore

As early as 1995, Singapore started to conduct the Construction Real Estate NETwork (CORENET) project to promote and require the use of IT and BIM for various levels of approval in the AEC industry. Later, several governmental agencies in Singapore including the Building and Construction Authority (BCA) participated in the e-submission system which requires BIM and IFC (Khemlani, 2005). As a result, various BIM e-submission guidelines were prepared and released to highlight the major points of submission requirements. In 2010, BCA implemented the BIM Roadmap in 2010 with the goal that 80% of the Singaporean construction industry would use BIM and e-submissions for all new building projects of a size greater than 5,000 square meters by 2015 (Fig. 7). This is also part of the government's goal to improve the productivity in the Singaporean construction industry by up to 25% using BIM technology over the next decade (Das et al., 2011a). After the implementation of the BIM Roadmap, BCA established a Center for Construction IT (CCIT) in 2010 to help key agencies and

construction firms to start using BIM. In addition, BCA launched a number of pilot projects in 2011. In order to prepare the whole industry for BIM, BCA has conducted a suite of BIM training programs and designed an in-depth training framework, as well as organizing BIM conferences for government entities and public sector bodies to acquire knowledge on BIM technology (Das et al., 2011b). Led by the Real Estate Developer's Association of Singapore (REDAS) and major government procurement entities (GPEs), BCA established a BIM steering committee, which is an industry consortium, to develop BIM requirement guidelines. BCA also established a BIM fund to encourage firms to put BIM technology into practice in actual projects and held many international and nation-wide BIM competitions to encourage BIM innovation (Fatt, 2012).

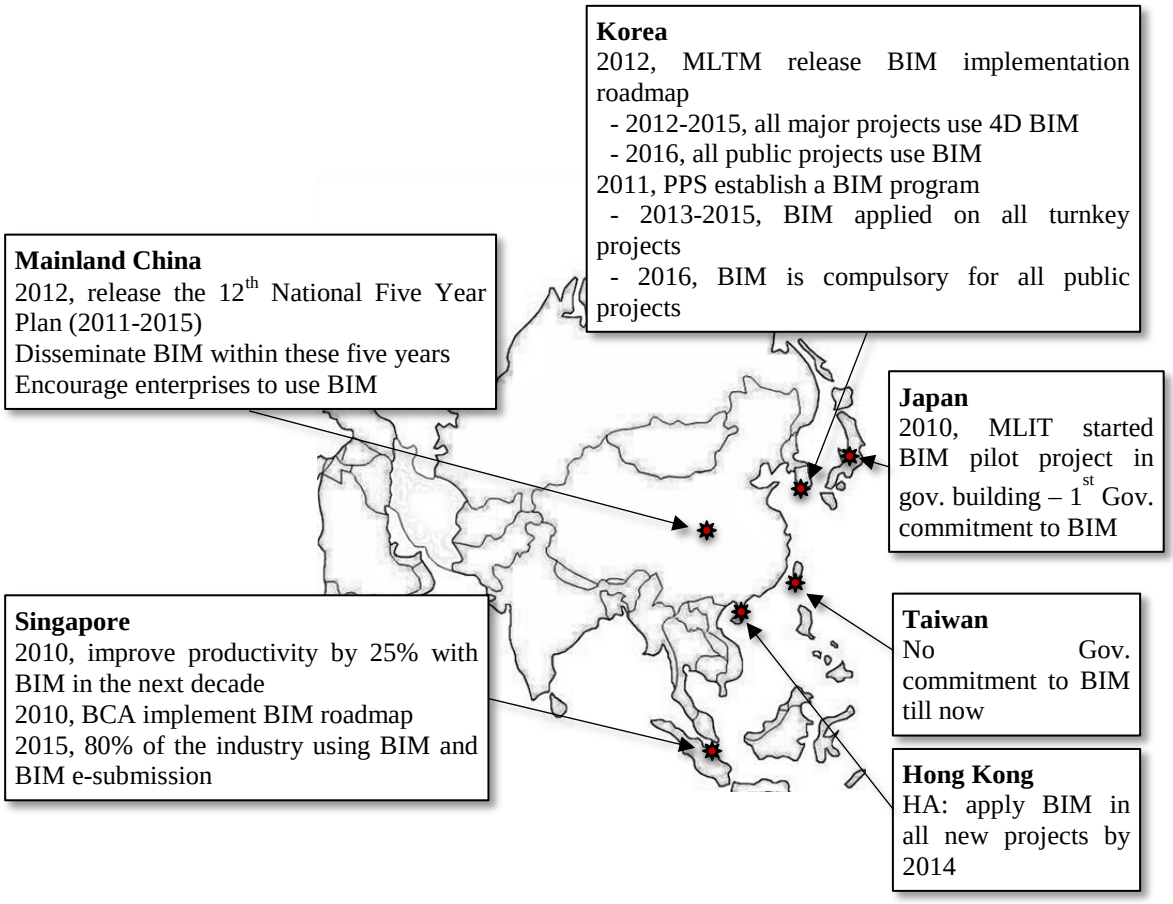

FIG. 7: BIM goals in Asia.

5.1.2 BIM Standards and Guidelines in Singapore

Singapore is a leading country for BIM adoption and standards development in Asia or even worldwide. As shown in Table 1, there are 35 BIM standards from Asia, 12 of which are from the public sector in Singapore. As shown in Table 5, most of the 12 BIM standards cover (2) Modeling Methodology and (4) Component Presentation Style and Data Organization. However, (1) Project Execution Plan (PEP) and (3) Levels of Detail are often missing in the standards. One exception is the *BIM Guide Version 2.0* published by BCA, which contains all the four elements of BIM standards. The *BIM Guide Version 1.0* and *BIM Guide Version 2.0* were released by BCA in 2012 and 2013, respectively, to outline the roles and duties of project members in using BIM at different stages of a project (BCA, 2012, BCA, 2013c).

In addition, with the help of all government regulatory agencies, the first version of *BIM e-Submission Guideline* was developed in 2008 to support the CORENET project. In early 2010, BCA then officially released the *BIM e-*

Submission Guideline for Architectural Discipline (BCA, 2010), which describes the requirements and guides for creating specific BIM objects, associated properties and presentation styles for visual processing of many regulatory agencies. BCA also published the *BIM Essential Guide (BEG) Series* to provide references on good BIM practices in an illustrated format. *BEG for BIM Adoption in an Organization* provides a quick start guide to help an organization to start its BIM adoption journey (BCA, 2013a). *BEG for BIM Execution Plan* contains details about BIM deliverables and processes. For different disciplines, specified BEGs were also created (BCA, 2013b).

5.2 Efforts of the Public Sector for BIM Adoption in Korea

5.2.1 BIM Goals and Implementation in Korea

The use of BIM in design and construction projects conducted by government and public organizations was increasing rapidly in Korea in recent years. In January 2012, the Korean Ministry of Land, Transport & Maritime Affairs (MLTM) released a BIM implementation roadmap, stating that they would implement BIM in three to four major construction projects in 2011 and use 4D BIM in all major construction projects in the period of 2012-2015 (see Fig. 7). MLTM also hoped that all public facility projects would use BIM by 2016. Another governmental organization, the Public Procurement Service (PPS), established a BIM program in 2011 and set a goal that by 2013-2015 BIM would be applied on all turnkey projects valued at over $50 million and that BIM would be compulsory for all public sector projects by 2016.

Many government bodies in Korea have been involved in BIM R&D projects as well. The most active one is MLTM, which has funded several R&D projects since 2009. The R&D projects funded by Korean MLTM included the SEUMTER (Building Permission System) Project and some Open BIM based research projects, such as the Open BIM Information Environment Technology for the Super-tall Buildings Project, and establishment of open BIM based Building Design Environment for Improving Design Productivity. PPS also set and funded a BIM R&D project – Cost Management Consulting in 2011 (Kim, 2012). The purpose of the project is to save cost and boost Green Construction in public areas by using BIM for energy efficiency analysis, simulation, and model based quantity takeoffs (Lee and Cho, 2011).

5.2.2 BIM Standards and Guidelines in Korea

Korea has released 6 BIM standards in total (see Table 1). Government bodies in Korea, including MLTM, PPS, and the Korea Institute of Construction and Transportation Technology Evaluation and Planning (KICTEP), as well as a university, the Korea Institute of Construction Technology (KICT) (Kim, 2012), are active in drafting and releasing BIM guidelines (see Fig. 8). In particular, the *National Architectural BIM Guide* project was launched and funded by MLTM in 2009, and was carried out by buildingSMART Korea and Kyung Hee University. The Guide contains three levels of BIM Guides – BIM working guide, technical guide, and management guide. PPS has also started developing a BIM Roadmap and common BIM guidelines since 2010. The development was jointly conducted by buildingSMART Korea, Kyung Hee University and Heerim Architecture. The effort resulted in two deliverables – *PPS Guideline v1: Architectural BIM Guide* which was released in 2010, and *PPS Guideline v2: BIM based Cost Management Guide* which was released in 2011.

TABLE 5: BIM standards in Asia.

Year	BIM Standards/Guidelines	PEP	Modelling Methodology	LoDs	Component Presentation Style and Data Organization
2008	[Singapore, BCA] BIM e-Submission Guideline for Architectural Discipline v3.0		√		√
2009	[HK, HA] BIM Standards Manual v1.0		√		√
2009	[HK, HA] BIM User Guide	√	√	√	√
2009	[HK, HA] BIM Library Components Design Guide v1.0	√	√		√
2009	[Korea, MLTM] National Architectural BIM Guide	Not Found			
2010	[HK, HA] BIM Library Components Reference v1.0				√
2010	[Taiwan, NTU] AEC (UK) BIM Standards for Autodesk Revit (translation)	√	√	√	√
2010	[Korea, PPS] Guideline V1: Architectural BIM Guide	Not Found			
2010	[Singapore, BCA] BIM e-Submission Guideline for Architectural Discipline v3.5		√		√
2011	[Singapore, BCA] BIM e-Submission Guideline Structural v2.1		√		√
2011	[Singapore, BCA] BIM e-Submission MEP v3		√		√
2011	[Korea, KICTEP] BIM Guideline	Not Found			
2011	[Korea, KICT] National Level Built Environment BIM Guidance Development	Not Found			
2011	[Korea, PPS] Guideline V2: BIM Cost Management Guide	Not Found			
2011	[HK, HKIBIM] BIM Project Specification		√	√	√
2011	[Taiwan, NTU] AEC (UK) BIM Standards for Bentley Building (translation)	√	√	√	√
2012	[Japan, JIA] BIM Guidelines	Not Found			
2012	[Singapore, BCA] BEG for BIM Adoption in an Organization	√			√
2012	[Singapore, BCA] BEG for BIM Execution Plan	√			
2012	[Singapore, BCA] BEG for Architectural Consultants		√		√
2012	[Singapore, BCA] BEG for Contractors		√		√
2012	[Singapore, BCA] BEG for CS Consultants		√		√
2012	[Singapore, BCA] BEG for MEP Consultants		√		√
2012	[Singapore, BCA] BIM Guide v1.0	√	√		√
2013	[Singapore, BCA] BIM Guide v2.0	√	√	√	√
2013	[China, Beijing Exploration and Design Association] Building Information Modeling Design Standard for Civil Building		√	√	√
2013	*[Japan, JFCC] Guidelines for BIM Collaboration in Construction Stage	Not Published			
2013	*[Japan, buildingSMART Japan et al.] BIM Guideline for Public Building	Not Published			
2013	*[Korea, KICTEP] BIM Standard Development and Application for Super Tall Buildings	Not Published			
2014	[China, CIBSDR et al.] Deliver Standard of Building Design-Information Modeling (draft)		√	√	√
2014	[China, CIBSDR et al.] Standard for classification and coding of building constructions design information model (draft)				√
2014	[HK, CIC] CIC Building Information Modelling Standards Draft 6.2	√	√	√	√
2014	[Taiwan, NTU] Level of Development Specification (V.2014)			√	
2014	[Taiwan, NTU] Facility Owner's Guide for Preparing BIM Guidelines (V.2014)		√	√	√
2015	[China, Shanghai] Shanghai Building Information Modeling Application Guide				

5.3 Efforts of the Public Sector for BIM Adoption in Japan

In 2010, the Ministry of Land, Infrastructure and Transport (MLIT) in Japan announced the start of BIM pilot projects in government buildings and repairs, as illustrated in Fig. 7. It was the first commitment of the Japanese

government to BIM adoption in Japan (Shiokawa, 2013). Since then, more and more MLIT departments started to use BIM in their projects. Besides the Japanese government, some industry consortiums in Japan also expressed willingness to utilize BIM technology. In 2010, the Japan Federation of Construction Contractors (JFCC) established a BIM Special Section under its Building Construction Committee to focus on BIM adoption. The BIM Special Section aimed at standardizing specifications and usage of BIM in order to increase the benefits of BIM in the construction stage. In 2011, JFCC conducted an investigation on the current BIM usage of subcontractors, manufacturers and fabricators in Japan and organized several BIM meetings. Cooperating with the Building Research Institute of Japan (BRI), an incorporated Administrative Agency, JFCC hosted an international one-day seminar on the theme of Integrated Design & Delivery Solutions (IDDS) and BIM in November 2013 (Building Research Institute, 2013). BRI also presented at the seminar and reported that they were studying electronic submission of building certificate procedures using BIM.

However, development of BIM guidelines is relatively slow in Japan. There has been no national BIM standard released by government bodies in Japan as at 2013 (see Table 1). According to Fig. 8, in 2012, the Japan Institute of Architects (JIA) released the *BIM guidelines*, which is a BIM manual for architects that contains BIM procedures and deliverable requirements. In 2013, JFCC were developing the *Guidelines for BIM Collaboration in Construction Stage*.

5.4 Efforts of the Public Sector for BIM Adoption in Mainland China

As a new starter, China is catching up fast in BIM technology. As shown in Fig. 7, in 2012, the Chinese government released the 12th National Five Year Plan which included BIM topics and a BIM framework. The AEC industry in mainland China has shown strong support in the BIM adoption. The Chinese government has set the goal of disseminating BIM within the next five years and encouraged enterprises to use BIM for different applications, including clash analysis, 4D project management, and visualization (The Ministry of Housing and Rural Urban Development, 2012). To follow the central government, some local government bodies have started to consider conducting BIM projects, BIM training programs and BIM guide to mandate BIM.

In early 2012, the Ministry of Housing and Rural Urban Development launched a program to start developing two BIM-related national standards, which are called *Deliver Standard of Building Design – Information Modeling* (CIBSDR, 2014a) and *Standard for Classification and Coding of Building Constructions Design Information Model* (CIBSDR, 2014b), and were prepared by the China Institute of Building Standard Design & Research (CIBSDR) together with other research institutes, design firms, contractors, software vendors and universities (Chinese Construction Newspaper, 2013). In late 2014, the draft versions of these two standards were released for public review. Not only does the national government puts effort into releasing BIM standards, some local governments also stated that they would draft their own local standards. One example is that Beijing released its own BIM standard – *Building Information Modeling Design Standard for Civil Building* in 2013 (BJEDA, 2013). Following Beijing Government, Shanghai Government released its *BIM Application Standard* in April 2015. Different BIM uses for different construction stage, from design, construction to facility management stage, were listed in and recommended by the standard (Shanghai Government, 2015).

5.5 Efforts of the Public Sector for BIM Adoption in Taiwan

As at 2015, there is no public commitment from the Taiwanese government for BIM adoption (Fig. 7). However, the government has shown its enthusiasm at BIM by funding many BIM research programs and industry projects, such as Taipei City MRT projects and New Taipei City Sports Centers. Some national universities, such as the National Taiwan University (NTU) and the National Kaohsiung University of Applied Sciences, are interested in BIM adoption and have established their own BIM centers. As early as in 2009, NTU set up a Research Center for Building & Infrastructure Information Modeling and Management (BIIMM) to facilitate collaboration for BIM adoption among industry, academia, and government. Besides undertaking research projects, the Research

Center has held a number of BIM related activities including conferences, forums, training workshops, consulting services, and publications. NTU also has published three books on Revit in MEP, Revit in Structure, and Revit in Architecture, respectively as early as in 1998. NTU has also translated the AEC (UK) BIM Standards for Autodesk Revit and for Bentley Building into Chinese in 2010 and 2011, respectively (NTU, 2010, NTU, 2011) (see Table 1 and Fig. 8). Based on the LOD Specification of US AGC BIMForum, NTU developed and released their own *LOD Specification* in 2014 (NTU, 2014). In addition, in order to help clients use BIM, *Facility Owner's Guide for Preparing BIM Guidelines* (V.2014) was released in the same year. However, there is currently no strategic BIM plan or national BIM standard published by the public sector in Taiwan (see Table 1).

5.6 Efforts of the Public Sector for BIM Adoption in Hong Kong

Hong Kong has started to implement BIM technology for almost a decade but the BIM implementation in Hong Kong is still not widespread. The public sector such as the Housing Authority (HA), Architectural Services Department (ArchSD), the MTR Corporation and the Construction Industry Council (CIC), and some non-profit professional organizations such as the Hong Kong Institute of Building Information Modeling (HKIBIM), have actively adopted and tried to explore the potential of BIM. For example, the HA, which is responsible for constructing public housings in Hong Kong, is one of the pioneers in BIM adoption in Hong Kong. The HA has set a target to apply BIM in all new projects by 2014 (see Fig. 7). Since 2006, the HA has adopted BIM technology in over 19 public housing projects, and prepared their in-house BIM standards (HA, 2009c), user guide (HA, 2009d), library component design guide (HA, 2009a) and references (HA, 2009b) (see Fig. 8). The HA BIM standards are the first set of BIM standards that are widely accepted in the Hong Kong AEC industry. Another governmental department, ArchSD, established a BIM Development Unit in early 2013 and provided BIM-related training courses for their own staff. In addition, ArchSD has utilized BIM in two pilot projects, which are Studios RTHK and Yau Ma Tei Theatre Center. These two projects are viewed as demonstrations to share the experience with staff and stakeholders. Other governmental departments such as the Development Bureau and Lands Department have applied BIM in different aspects. The MTR Corporation, of which the major shareholder is the Hong Kong Government, has applied BIM in many projects such as the MTR XRL West Kowloon Terminus project. The MTR Corporation required both its consultants and main contractors to submit BIM deliverables, which need to conform to MTR BIM Standards and its levels of detail (Collins, 2013).

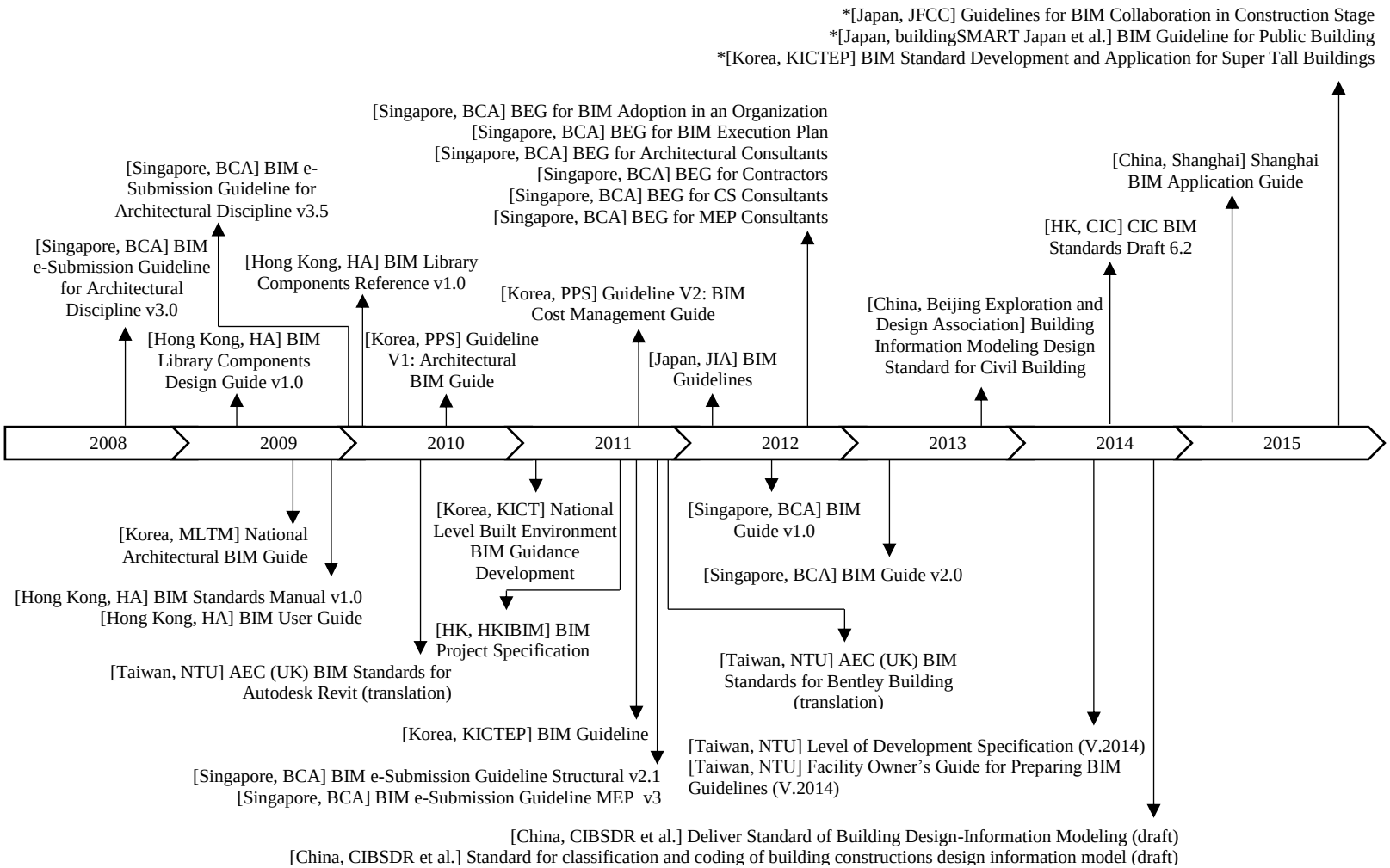

FIG. 8: BIM standards/guidelines timeline in Asian countries ("" means that the standard is under preparation).*

In 2013, the CIC in Hong Kong established a BIM Working Group to develop a roadmap for BIM implementation and be responsible for the development of the CIC BIM standards. The Working Group released a BIM adoption roadmap for the Hong Kong construction industry in the same year (HKCIC, 2013). After that, CIC has organized various seminars and promotion activities on BIM, and named the year 2014 as "The BIM Year". In the same year 2014, CIC launched the BIM Excellence Awards to recognize the parties who made contributions on the local BIM adoption. In early 2015, the first complete version of the draft CIC BIM Standards was released for public review (HKCIC, 2015). Professional organizations HKIBIM and buildingSMART Hong Kong have also organized seminars to educate local industry on BIM. HKIBIM has even developed a BIM standard namely *BIM Project Specification Rev 3.0* in 2011. The Project Specification is a BIM execution plan document which defines BIM scope, project participants' responsibilities and BIM deliverables requirements (HKIBIM, 2011).

6. EFFORTS OF THE PUBLIC SECTOR FOR BIM ADOPTION IN AUSTRALASIA

6.1 BIM Goals and Implementation in Australasia

Australia has indicated several national BIM adoption targets in the *National BIM Initiative* report (buildingSMART Australia, 2012), which was prepared by buildingSMART Australia in 2012 and commissioned by the Built Environment Industry Innovation Council (BEIIC), which is an advisory body to the Australian Government. The three main recommendations in the report are: (1) requirement of full 3D collaborative BIM for all Australia Government procurements by 1 July 2016, (2) encouragement of the Australian states and territories to require full 3D open BIM, and (3) implementation of the National BIM Initiative Plan. BEIIC also suggested that the government considers BIM as a key part of the government process (BEIIC, 2012). In addition, some industry consortia in Australia contributed to BIM adoption. For example, the Air Conditioning & Mechanical Contractors' Association (AMCA), a nation-wide industry association, launched the BIM-MEP^{AUS} initiative with the aim of facilitating the implementation of BIM and Integrated Project Delivery (IPD) within the Australian construction building services sector. Since 2010, AMCA has held a BIM-MEP^{AUS} Forum annually. AMCA has also prepared an 18-week-long training plan in order to provide training to BIM beginners in Australia.

TABLE 6: BIM standards in Australasia.

Year	BIM Standards/Guidelines	PEP	Modelling Methodology	LoDs	Component Presentation Style and Data Organization
2009	[Australia, CRC] National Guidelines for Digital Modelling		√	√	
2011	[Australia, NATSPEC] National BIM Guide v1.0	√	√	√	√
2011	[Australia-New Zealand, ANZRS Committee] ANZRS_family compliance pack portfolio_Version2				√
2012	[Australia, NATSPEC] BIM Management Plan Template v1.0	√	√	√	√
2012	[Australia-New Zealand, ANZRS Committee] ANZRS V3				√
2015	*[Australia, buildingSMART Australia] Industry Protocols for Information Exchange to Underpin BIM and Collaborative Practice	Not Published			
2015	*[Australia-New Zealand, ANZRS Committee] ANZRS V4	Not Published			
2015	*[Australia, buildingSMART Australia] Australian Technical Codes and Standards for BIM	Not Published			

6.2 BIM Standards and Guidelines in Australasia

As shown in Table 1, there are 8 BIM standards from Australasia region (3 from government bodies and 5 from non-profit organizations). Table 6 shows more details about these 8 standards. Australia Cooperative Research Centre (CRC) for Construction Innovation released its *National Guidelines for Digital Modeling* (CRC-CI, 2009) in 2009 to promote the adoption of BIM technologies in the Australian building and construction industry (Fig. 9). The guidelines provide an overview of BIM and recommendations for key areas of model creation and development, simulation, and performance measurement. A government-supported non-profit organization, Construction Information Systems Limited (trading name NATSPEC), also released its BIM guide namely *The NATSPEC National BIM Guide* (NATSPEC, 2011) in 2011. It defines uses of BIM, modeling methodology, presentation styles and deliverable requirements. In addition, the guide is adapted from the 2010 *VA BIM Guide* (VA, 2010). In 2012, NATSPEC published a *Project BIM Management Plan Template* (NATSPEC, 2012) as a supplementary document to the National BIM Guide.

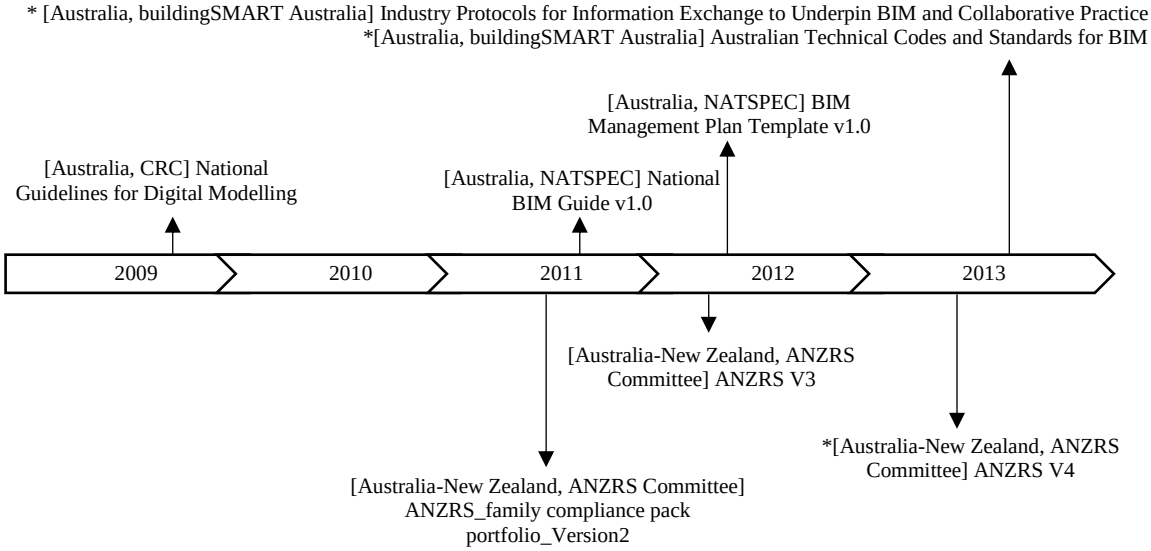

FIG. 9: BIM standards/guidelines timeline in Australasia countries ("" means that the standard is under preparation).*

Furthermore, the National BIM Initiative report shows that buildingSMART Australia are preparing two BIM Standards. They aim to develop industry protocols for information exchange to underpin BIM and collaborative practice and Australian technical codes and standards for BIM for adoption by 2015. In cooperation with New Zealand, the Australia and New Zealand Revit Standards (ANZRS) was produced. It was an initiative conceived at the Revit Technology Conference (RTC) 2009 in response to the user's frustration with lack of consistency in Revit families from Autodesk and other software platforms. In RTC 2011, the *ANZRS Family Compliance Pack* was released as a PDF Portfolio file (ANZRS Committee, 2011). The *ANZRS version 3* was published in January 2012 (ANZRS Committee, 2012) , while the *ANZRS version 4.0* will be released in late 2015.

7. POTENTIAL ROLES OF THE PUBLIC SECTOR FOR BIM ADOPTION

The public sector plays a primary role in leading industry towards BIM adoption. In some nations, the public sector is the major driver of BIM adoption. Undoubtedly, support and demonstrations by the public sector are important regarding BIM development. Wong et al. (2009) have studied the educational, R&D, and promotion efforts for BIM adoption in Finland, Denmark, and Norway. However, there is no systematic analysis and summary of the potential roles of the public sector for BIM adoption. Based on the review and comparison of BIM variables and implementations in different countries, six major roles of the public sector regarding BIM

adoption are analyzed and illustrated in Fig. 10, which are (1) initiators and drivers, (2) regulators, (3) educators, (4) funding agencies, (5) demonstrators, and (6) researchers. They are further discussed in the followings.

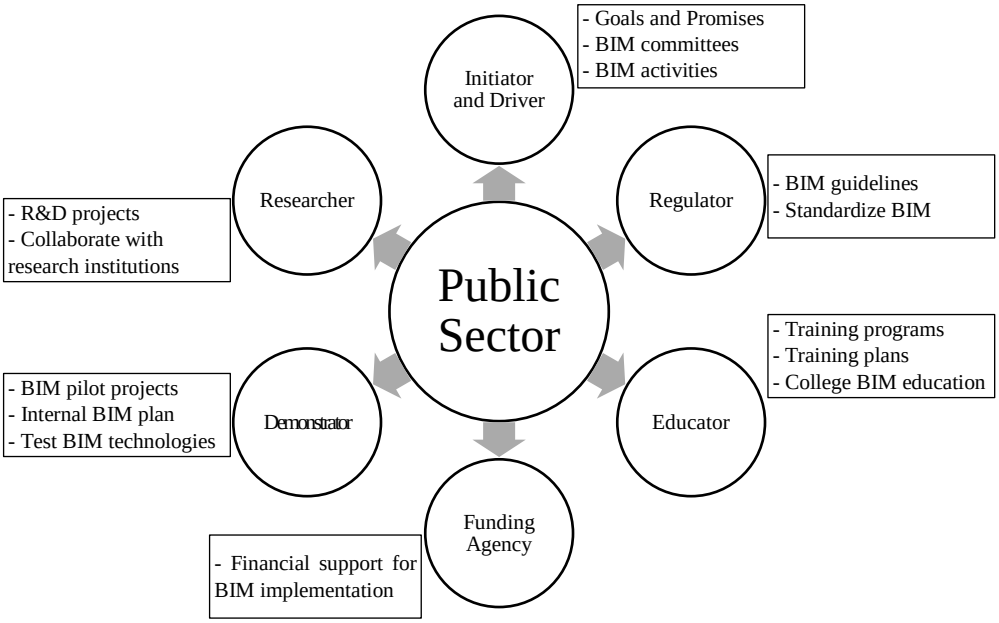

FIG. 10: Roles of the public sector for BIM adoption.

(1) Initiator and Driver

Undoubtedly the public sector plays a key role in initiating BIM. Public organizations in most countries has set their BIM goals and required the use of BIM in public construction projects when they first jumpstarted BIM technology. For example, the United Kingdom has set an ambitious target that all central governmental departments would adopt Level 2 BIM by 2016 (see Table 8). For another example, the US GSA required BIM in the projects in the fiscal year 2007. Besides setting BIM goals to drive the industry, some public organizations also established BIM working groups or committees to support BIM implementation. Examples include the BIM task group in the United Kingdom, the BIM Steering Committee in Singapore, and the ANZRS Committee in Australia and New Zealand. In addition, some public organizations published BIM roadmaps for the whole industry. For example, USACE in the United States released two BIM roadmaps in 2006 and 2012, respectively (see Table 8). All BIM related activities and actions launched by public organizations push the whole AEC industry to adopt BIM technology.

(2) Regulator

Common understanding on and consistent approaches to BIM implementations across the entire AEC industry is important for successful BIM adoption. The public sector can play the "regulator" role in BIM adoption and develop BIM guidelines to instruct and standardize BIM implementations in construction projects. Those BIM standards or guidelines could be region specific or universal. Some companies may have their own BIM standards. However, several national BIM standards have been released to guide the whole industry and to ensure consistency for BIM implementation, thereby avoiding conflicts and confusion among project participants which follow different BIM standards. One of the most influential BIM standards is the *National Building Information Modeling Standard* released in the United States, which aims at developing a full consensus BIM standard. As shown in Table 8, Australia and New Zealand have jointly developed the *Australia and New Zealand Revit Standards* (ANZRS) to have a uniform requirement for these two countries. This bi-national standard is a good example of multi-national efforts for BIM standard development.

(3) Educator

In-house BIM trainings for internal staff appear in many public organizations that have adopted BIM. However, the public sector can also take a leading role to educate the industry on BIM implementation. Some public organizations have published BIM training methods to teach other organizations on how to develop BIM training courses. One example is the initial BIM Learning Outcomes Framework that was published in the United Kingdom to provide supporting information for BIM training program development. In addition to providing training courses and establishing long-term training plan for the whole industry, the public sector can also consolidate BIM education in colleges. As shown in Table 8, the NBIMS-USTM project Committee in the United States, for instance, held a BIM Academic Education Symposium to discuss the possibility of incorporating BIM into college curricula.

(4) Funding Agency

Providing financial support for BIM-related projects is another way to encourage the industry to promote BIM. As described in Table 8, for the BIM adoption in Taiwan, the Taiwanese government funded many BIM research programs and projects, including the Taipei City MRT projects and New Taipei City Sports Center project. Another example is that USACE of the United States has directly funded 7 R&D laboratories, one of which is CAD/BIM Technology Center. With the funding provided by the public sector, the AEC industry would show more enthusiasm at BIM implementation, which may be perceived as costly in some construction firms.

(5) Demonstrator

Through pilot projects, the public sector can demonstrate and showcase the implementation of BIM technology in various kinds of construction projects. The pilot projects conducted by public organizations not only show the dedication of the organizations towards BIM adoption, but also can be used to share the success factors and lessons learnt among other organizations in the industry. New BIM or BIM-integrated technologies can also be promoted and evaluated in the projects. For example, RWS in Netherlands has tested BIM products in four projects, used the project results to demonstrate various BIM technologies in the industry. Public organizations in other countries such as BCA in Singapore have launched a few pilot projects to evaluate BIM as well (see Table 8).

(6) Researcher

As BIM technology is evolving rapidly, innovation is needed to advance the application of BIM technology in real-world projects. R&D is therefore important to help the industry keep improving the use of BIM in different aspects. The public sector can conduct BIM research internally, collaborate with research institutions, or financially support third parties on BIM-related research projects. For example, Statsbygg has conducted several R&D projects to help develop BIM adoption and explored potential applications of BIM in Norway. In Korea, several public sector bodies including MLTM and PPS were involved in BIM R&D projects, studying every aspect of BIM. For another example, JFCC in Japan has collaborated with the Building Research Institute of Japan on its BIM research.

8. FINDINGS AND DISCUSSION

8.1 Findings of the Efforts of the Public Sector

Table 7 summarizes the efforts in BIM adoption taken by the selected 14 countries/areas, which are grouped in the regions of the United States, Europe, Asia, and Australasia. BIM implementations in different countries worldwide, ranging from setting goals or promises, establishment of committees, holding various BIM activities, to developing BIM standards are summarized in Table 7. The United States is one of the most pioneering countries for using BIM technology. The biggest difference in BIM adoption between the United States and other countries may be that different levels of the public sector in the United States, from national organizations to public universities, all contribute to BIM implementation. As early as in 2003, the US GSA identified the

potential of BIM and established the National 3D-4D-BIM Program. In 2007, the first national BIM standard *NBIMS-US*^{TM} Version 1.0 was published to drive and standardize the implementation of BIM of the whole nation. In the same year, GSA set a goal to require IFC BIM on its public projects. It was the first time a public organization had made such s groundbreaking statement. Since then, various BIM guide series were published to provide guidance for continued use of BIM throughout a facility's life cycle for the whole industry. The successful adoption of BIM in the US up to now could be a roadmap for other countries.

Although the overall adoption rate in Europe is lower than that in the US in 2010 (McGraw-Hill, 2010), most of the European countries catch up rapidly in BIM technology and become leaders in this field during these years. For example, the UK set an ambitious goal of BIM adoption in 2011 to mandate the implementation of Level 2 cooperative BIM on all government infrastructure projects by 2016. Influenced by the central government, the industry shifts their traditional 2D workflow to a 3D BIM workflow and becomes a BIM proficient industry gradually. The early and strong commitment of the UK government to BIM makes the UK as a world leader in BIM adoption (NBS, 2015). The public sectors of other European countries listed in this paper have made efforts to promote BIM adoption in their nations and produced various BIM deliverables and standards. However, there is no national BIM standard released in Sweden till now.

BIM adoption in most Asian countries, except Singapore, lags behind that of the US and Europe in general. Singapore is a leading country for BIM adoption and standards development in Asia or even worldwide. As early as in 1995, Singapore government required the use of IT and BIM for various levels of approval in the AEC industry. As a result, various BIM e-submission guidelines were released to highlight the major points of submission requirements of different disciplines, including architectural, structural and MEP. It is a good way to standardize BIM adoption in the industry, since all the projects should follow the requirements stated in the guidelines to create and submit the model for approval. However, as shown in Table 7, there is no national BIM guideline released by Japanese government. Reports show that several government bodies are under preparation of national BIM standards. The development of national BIM standards in Mainland China started late, and only two draft versions have been released for public review as at late 2014. The official national BIM standards will be published in late 2015. In addition, there is no governmental commitment to BIM adoption in Taiwan as at 2015. A report shows that the central government in Taiwan has started to take some initiatives to study national BIM strategic planning and require BIM in major projects to promote BIM in the industry (Hsieh, 2015). Therefore, the BIM development in Taiwan will accelerate in the next few years.

The rate of BIM adoption in Australia continues to escalate in recent years. In 2012, Australia has indicated several national BIM adoption targets in the NBI report and published several national BIM standards. To follow in the government's footsteps, various industry consortia in Australia contributed to BIM adoption. In addition, the Australia and New Zealand Revit Standards (ANZRS), which can be used by these two countries, was produced. The standard is a good example of multi-national cooperation work on BIM standards development.

Findings also show that most of the selected public sectors or countries in the four regions have released national BIM standards. Sweden and Japan are currently in the process of releasing their own BIM guidelines. Various BIM standards have been developed around the world to standardize BIM implementation. Some are platform-specific while some are conceptual and generic. As mentioned earlier, BIM standards should cover four aspects, which are (1) Project Execution Plan (PEP), (2) Modeling Methodology, (3) Levels of Detail or Development (LoD), and (4) Component Presentation Style and Data Organization. For example, different modeling sequences of building components in BIM models may generate different results in quantity takeoff. Therefore, a common method to create BIM models is needed to ensure consistent analysis results using BIM software. However, very few existing BIM standards have covered all these four aspects. In addition, many public or private organizations have currently developed their own BIM standards in-house. Regional or even global efforts to consolidate the various BIM standards will be beneficial to the BIM community.

8.2 Findings of the Roles of the Public Sector

Based on the review of the efforts taken by the public sector for BIM adoption, six potential roles that the public sector can play have been summarized. As shown in Table 8, all the selected countries or cities have played the roles of initiator and regulator for BIM adoption. Most of them have set BIM goals to drive the market and developed BIM standards to regulate and standardize BIM implementation. One successful example is that the UK has become a world leader in BIM adoption through the BIM policy and strategy by the central government (NBS, 2015). After the UK government set its commitment to require Level 2 BIM in 2011, discussion about BIM has proliferated and awareness of BIM is now nearly universal. The latest NBS National BIM Report 2015 revealed that half of the respondents in the UK were currently using BIM in their projects (up dramatically from 13% in 2010).

However, only a few of the selected countries have played the roles of educator and funding agency. According to a McGraw-Hill Construction survey that studies the reasons for the lack of BIM adoption (McGraw-Hill, 2012), the high training cost and software cost were the main reasons that many people resisted using BIM. Therefore, it is highly recommended that the public sector in most of the European countries, Japan, Mainland China, Hong Kong and Australia, can take a more active role to train and educate the industry on BIM implementation and fund more BIM related projects to help the industry overcome the cost issue.

In addition, some of the selected countries, excluding the UK, Finland, and Mainland China, have played the roles of demonstrator and researcher. Although the UK government has set a promising goal about BIM adoption early in 2011, half of the respondents did not use BIM in their projects in the reporting year of 2014 (NBS, 2015). The main barrier for them to use BIM is the lack of in-house expertise. They were not familiar with the whole BIM process and how BIM would change their whole workflow. Therefore, pilot projects conducted by the government are necessary to demonstrate and showcase the implementation and workflow of BIM. In addition, only 45% of the BIM adopters were confident in their knowledge and skills in BIM in 2014 (NBS, 2015). As BIM technology is evolving rapidly, R&D is therefore important to help the industry keep improving the knowledge of BIM. The public sector can conduct BIM research internally, collaborate with research institutions, or financially support third parties on BIM-related research projects to improve BIM skills in the industry.

Table 8 also shows that the United States and Singapore are currently the only countries in which the public sector has played all these six roles for BIM adoption. The public sector of other countries could get a benchmark for the roles played on BIM adoption from identified roles and the impacts on the overall BIM adoption in other countries.

9. CONCLUSIONS

BIM changes the way that we work in the architecture, engineering and construction (AEC) industry. The public sector can potentially take the leading role to encourage and facilitate the adoption of BIM in the industry. In recent years, BIM implementations continued to increase intensively as more and more government bodies and non-profit organizations in various countries around the world have adopted BIM. Such divergence and coverage highlights the lack of and the necessity for a review of their efforts. Therefore, the efforts taken by the public sector for BIM adoption in different countries worldwide are reviewed and analyzed in this paper. This paper covers 14 countries/areas, which are grouped into four regions – the United States, Europe, Asia, and Australasia. Data were collected from various publicly available sources on the Internet. In each region, BIM implementations ranging from setting BIM goals, establishment of BIM-related committees, holding BIM activities, to developing BIM standards were described. The findings show that the United State is the most mature country in BIM adoption, as BIM has been implemented from the top national level down to the city and public university level. The early and strong commitment of the UK government to BIM makes the UK as a world leader in BIM adoption. Various national BIM e-submission guidelines regulate and standardize the

overall BIM adoption in the industry in Singapore. However, there is no public national BIM adoption target in Taiwan as at 2015. Sweden and Japan are currently in the process of releasing their own BIM standards. The findings also show that there have been many separate efforts in developing various local BIM standards to suit the local industry needs and characteristics, but a regional or global joint effort to consolidate these BIM standards may be beneficial to the broader BIM community.

The public sector plays an important and primary role for BIM adoption. This paper summarizes six roles that the public sector can play for BIM adoption. They are (1) initiator and driver, (2) regulator, (3) educator, (4) funding agency, (5) demonstrator, and (6) researcher. The roles played by the countries covered in this paper are also summarized and evaluated. Findings show that all the selected countries or cities have played the roles of initiator and regulator to promote and standardize BIM adoption. The public sector in most of the European countries, Japan, Mainland China, Hong Kong and Australia seldom plays as educator and funding agency. Since there is a large need in the industry for training and financially supporting BIM implementation and research, it is suggested that the public sector in these nations should play a more active role on training and funding BIM projects. In addition, the UK, Finland, and Mainland China, have not played the roles of demonstrator and researcher towards BIM adoption. As BIM technology is evolving rapidly, pilot projects and R&D projects are therefore important to help the industry keep improving the knowledge of BIM.

BIM adoption is a journey. It is foreseeable that more and more organizations will join this journey and more international effort will be put together to create a more consistent, advanced and innovative BIM-based working environment in the AEC industry.

TABLE 7: BIM adoption worldwide.

			BIM Adoption		
Region	**Country, City or Organization**		**Targets and Promises**	**BIM Implementation**	**BIM Standards and Guidelines**
The United States	Nation-wide	NIBS, USACE, GSA, VA, AIA, NIST, AGC	Require BIM on projects	BIM programs，committees, BIM workshops and training courses, fund BIM and R&D projects, USACE - BIM roadmaps	e.g. NBIMS-USTM V1, V2, BIM Guide Series 01 to 08
	State-wide	Wisconsin, Ohio, Tennessee	Require BIM on projects	BIM projects	e.g. State of Ohio BIM Protocol
	City-wide	New York, Seattle	Require BIM on projects	BIM projects	e.g. NYC BIM Guidelines
	University-wide	PSU, LACCD, IU, etc.	Require BIM on projects	BIM projects	e.g. BIM PEP Guide V1, 2, IU BIM Guidelines and Standards
Europe	the United Kingdom	BSI, CIC, AEC-UK	Adopt Level 2 BIM by 2016	BIM Task Group, BIM sessions, BIM training programs	e.g. BS series, AEC-UK-BIM Standard v1.0
	Norway	Statsbygg, etc.	2010, Gov. commitment to BIM 2010, Statsbygg – require BIM for new buildings	BIM programs, pilot and R&D projects	e.g. Statsbygg - SBM, BIM Manual v1.2.1
	Finland	Senate Properties	2007, require the use of IFC/BIM for its projects	BIM projects	e.g. Senate Properties' BIM Requirements for Architectural Design, COBIM
	Denmark	Palaces & Properties Agency, etc.	Danish state clients such as the Palaces & Properties Agency require BIM	Digital Construction project	e.g. 3D CAD Manual 2006, 3D Working Method 2006
	Sweden	Transportation Administration, etc.	2015, all investment projects use BIM	BIM implementation project, pilot projects to demonstrate BIM	No National BIM standard, BH90 Series 8 - CAD guide
	Netherlands	Rijkswaterstaat, Rijksgebouwendienst	2011, mandate BIM in building projects with 7,000,000 m2	BIM 2012-2014 program, pilot projects, BIM database	e.g. Rijksgebouwendienst BIM Standard
Asia	Singapore	BCA	2015, 80% of the industry using BIM and BIM e-submission	BIM center, pilot projects, BIM training programs, training framework, conference, BIM steering committee, BIM fund, nation-wide BIM competitions, BIM roadmap	e.g. BIM e-Submission Guideline for Architectural Discipline, Singapore BIM Guide
	Korea	MLTM, PPS, KICT, KICTEP	MLTM, PPS mandate BIM before 2016	MLTM - BIM implementation roadmap, BIM program, BIM R&D projects, PPS - BIM fund	e.g. National Architectural BIM Guide, PPS Guidelines
	Japan	MLIT, JFCC, JIA	2010, MLIT mandate BIM in government projects	MLIT-BIM pilot projects, JFCC - BIM special section, BIM seminar	No National BIM standard, JIA - BIM guidelines
	Mainland China	the Ministry of Housing and Rural Urban Development	2012, release the National 12th Five Year Plan (2011-2015)	BIM-related national standards program	e.g. Two national BIM standards draft versions, Beijing and Shanghai BIM standard
	Taiwan	NTU, etc.	No Gov. commitment to BIM	Fund BIM projects, centers, NTU - BIM conferences, forums, training workshops, publications and research projects	LOD Specification, Owner's Guide for preparing BIM Guidelines
	Hong Kong	HA, ArchSD, MTRC, HKIBIM, HKCIC, etc.	HA - BIM in all new projects by 2014	BIM projects, conferences, ArchSD - BIM development unit, training courses, pilot projects, Lands Department - 3D spatial database, BM seminar, HKIBIM - BIM committees	e.g. HA - BIM Standards Manual v1, BIM Project Specification Rev 3
Australasia	Australia	BEIIC, AMCA, NATSPEC	Require 3D BIM for Gov. projects by 2016	BEIIC - BIM plan, pilot projects, AMCA - BIM initiative, forums, training plans	e.g. The NATSPEC National BIM Guide, ANZRS

TABLE 8: Roles of the public sector worldwide for BIM adoption.

			Roles of the Public Sector for BIM Adoption					
Region	**Country, City or Organization**		**Initiator and Driver**	**Regulator**	**Educator**	**Funding Agency**	**Demonstrator**	**Researcher**
The United States	Nation-wide	NIBS, USACE, GSA, VA, AIA, NIST, AGC	Require BIM on projects, BIM roadmaps, programs, committees	BIM standards, e.g. NBIMS-USTM V1, V2	BIM training courses, Education Symposium	Fund BIM	BIM pilot projects	R&D projects
	State-wide	Wisconsin, Ohio, Tennessee	Require BIM on projects, BIM projects	BIM standards, e.g. State of Ohio BIM Protocol				
	City-wide	New York, Seattle	Require BIM on projects, BIM projects	BIM guidelines, e.g. NYC BIM Guidelines				
	University-wide	PSU, LACCD, IU, etc.	Require BIM on projects, BIM projects	BIM guides, e.g. BIM PEP Guide V1, 2, IU BIM Guidelines and Standards				
Europe	the United Kingdom	BSI, CIC, AEC-UK, etc.	Level 2 BIM by 2016, BIM Task Group, sessions	BIM standards, e.g. BS series	BIM training Framework			
	Norway	Statsbygg, etc.	Gov. commitment to BIM, BIM programs	BIM standards, e.g. Statsbygg - SBM			BIM pilot projects	BIM R&D projects
	Finland	Senate Properties	Require BIM on projects, BIM projects	BIM standards, e.g. COBIM				
	Denmark	Palaces & Properties Agency, etc.	Require BIM, BIM projects	BIM standards, e.g. 3D CAD Manual 2006			Digital Construction project	Digital Construction project
	Sweden	Transportation Administration, etc.	Require BIM, BIM projects	BH90 Series 8 - CAD guide			BIM pilot projects	
	Netherlands	Rijkswaterstaat, Rijksgebouwendienst	Mandate BIM on projects, BIM 2012-2014 program	BIM standards, e.g. Rijksgebouwendienst BIM Standard			BIM pilot projects	BIM database
Asia	Singapore	BCA	BIM goals, BIM center, steering committee, Nation-wide BIM competitions, roadmap	BIM guidelines, e.g. Singapore BIM Guide	BIM training programs, training framework	BIM fund	BIM pilot projects	BIM center
	Korea	MLTM, PPS, KICT, KICTEP	Mandate BIM before 2016, BIM roadmap, program	BIM guidelines, e.g. PPS Guidelines		PPS - BIM fund		BIM R&D projects
	Japan	MLIT, JFCC, JIA	Mandate BIM in government projects, BIM special section, BIM seminar	JIA - BIM guidelines			MLIT-BIM pilot projects	BIM research seminar
	Mainland China	the Ministry of Housing and Rural Urban Development	Encourage enterprises to use BIM, BIM-related national standards program	Beijing – BIM Standard for Civil Engineering (draft)				
	Taiwan	NTU, etc.	NTU - BIM conferences, forums	BIM standard translations	Training workshops	Fund BIM projects		Research projects
	Hong Kong	HA, ArchSD, MTRC, HKIBIM, HKCIC, etc.	HA - BIM in all new projects by 2014	BIM standards, e.g. HA - BIM Standards Manual v1 , BIM projects, conferences, BIM unit, committees	Training courses		BIM pilot projects	3D spatial database
Australasia	Australia	BEIIC, AMCA, NATSPEC	Require 3D BIM for Gov. projects by 2016	BIM guidelines, e.g. ANZRS	BIM training plans		BIM pilot projects	

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