BLOCK I_Introduction to BIM

Title: International Standards and Specifications of BIM methodology

1 – Aims

The objectives of this tutorial are the following:
- To became acquainted with the principles of BIM methodology as well as the major challenges, barriers and potentials.
- To became familiar with the International BIM Standards.
- To became acquainted with the BIM Level of Development and Classification Systems and Specifications.

2 - Learning methodology

- The teacher will provide an explanation of the course material with practical examples or videos.
- Students will read this tutorial and analyse videos/practical examples.
- To evaluate the achievements each student will answer questions provided.
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3 - Tutorial duration.

It will last 2/3 teaching hours.

4 – Necessary teaching resources

Hardware required: computer room with internet access.

5 – Contents

5.1 – What is BIM

5.2 – BIM: Challenges and Potential

5.3 – Historical Development

5.5 – AIA Specifications: Level of Development

5.6 – International BIM Standards: Benefits and Limitations

5.7 – BIM Classification Systems

6 – Deliverables

The student will have to answer and submit test questionnaire.

7- What we have learned

The student has become acquainted with International BIM Standards, Level of Development and Classification Systems and Specifications.

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5 – Contents & tutorial.

5.1 – WHAT IS BIM

BIM is the acronym used to define "Building Information Modelling". But what does BIM mean? There are several definitions in the bibliography that can help us understand the concept of this digital tool that is used to manage project data and information of buildings. Among them, the definition of Eastman et al. (2011), in the Encyclopedia of Sustainable Technologies (2017), that defines BIM as "*a collaborative way for multidisciplinary information storing, sharing, exchanging, and managing throughout the entire building project lifecycle including planning, design, construction, operation, maintenance, and demolition phase*". Some common connotations of multiple BIM terms are resumed by Succar (2009) in figure 1.

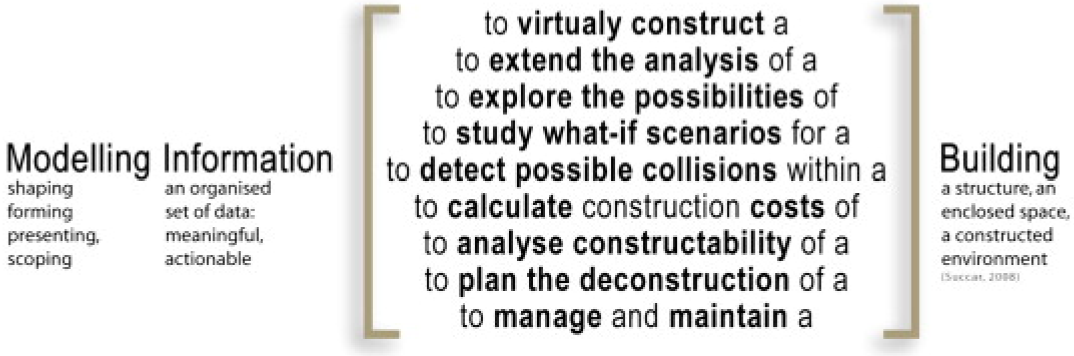


Figure 1: Common connotations of multiple BIM terms (Succar, 2009)

The best way to understand the BIM concept is by participating in it! The presentation video of the BIMVET3 project (https://youtu.be/Fx1z2fLenzM) summarizes this concept, and briefly answers the initial question "what is BIM"?

References:
Abraham M. (2017), “Encyclopedia of sustainable technologies”, Elsevier
Eastman, C., Eastman, C. M., Teicholz, P., & Sacks, R. (2011), “BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors”, John Wiley & Sons.
Succar. B, (2009),"Building information modelling framework: A research and delivery foundation for industry stakeholders, Automation in Construction, V.18 (3), pp. 357-375

5.2 – BIM: Challenges and Potential

The Building Information Modelling (BIM) is the foundation of digital transformation in the architecture, engineering, and construction (AEC) industry. The information of design, planning, construction and operations (Facility Management), is collected and organized in a collaborative digital model, usually saved in the cloud, which can support and help the decisions, during the design phase until the utilization phase, with the digital representation of an asset throughout its lifecycle.
Thus, BIM is a methodology for sharing digital information and communication between all stakeholders during all the phases of the life cycle of a construction that is supported by a digital model that allows the visualization in three dimensions (3D). At the same time the model is an information repository, consisting of information related with geometry and the properties of each element. It is an object-oriented modulation, with the building represented through elements, instead of the traditional methodology of geometrical modulation.

Several simulations in the design phase can be made, enabling the analysis of different options of space distribution and quality, producing different constructions solutions, which can also be evaluated from economic and environmental points of view. With that full information, not only can the decisions for the construction phase be better supported and more efficient options could be taken, but there can also be a contribution to a sustainable rehabilitation of the constructions and a change of use during its lifecycle.

The model is organized with interoperability layers, sharing building elements, building services elements and facilities elements. A more expert management of all the process will reduce failures in communication. The various options and the final solution of the construction will be tested in the design phase, with a reduction in construction costs (5D BIM), as well as the reduction of time construction with a well-organized planning (4D BIM).

Any changes made to the model in the design phase will be immediately updated and well understood by all the designers involved in the process. In the utilization phase, the built asset information will support the decisions to be made regarding the necessary maintenance of the construction.

The potential is huge and the most important challenge will be the introduction of these principles in the construction design, according to the lifecycle asset.

With BIM tools, the construction works will be carried out with an important cost control and exact resources definition for each phase of the works. The planning will be done with accuracy and any modification will be easy to prepare in the next steps. The final model, as built, will be the base for the decisions during the lifecycle asset. The Figure 2 illustrates the main potentialities of the BIM application for a project.

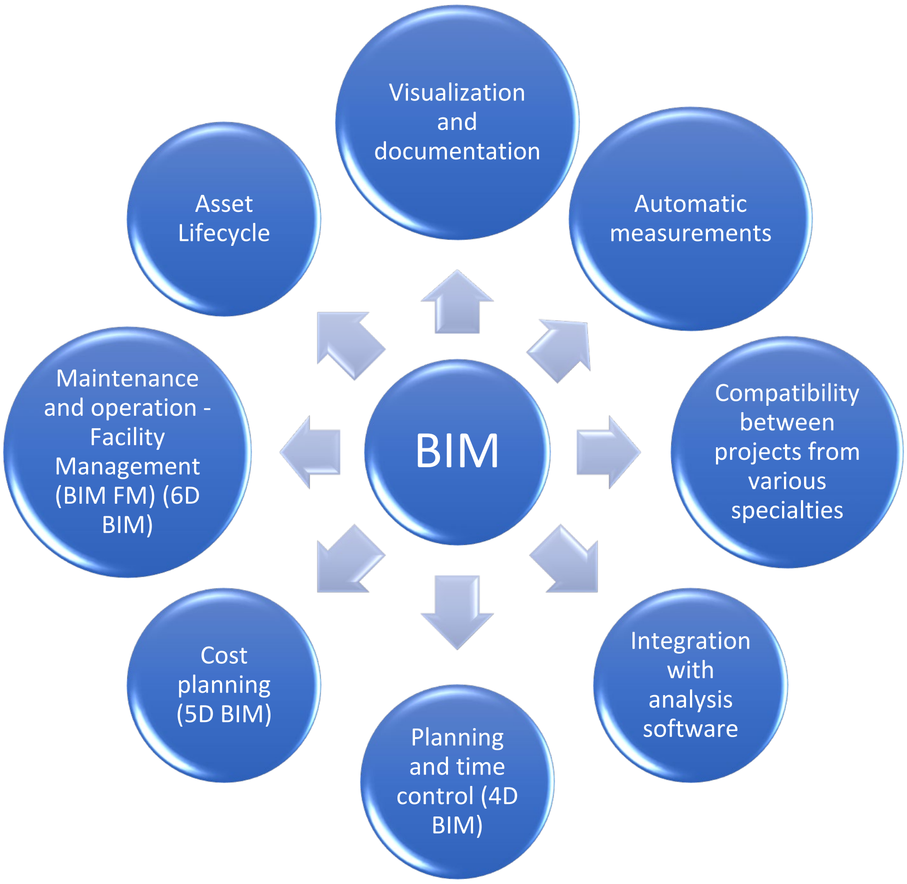
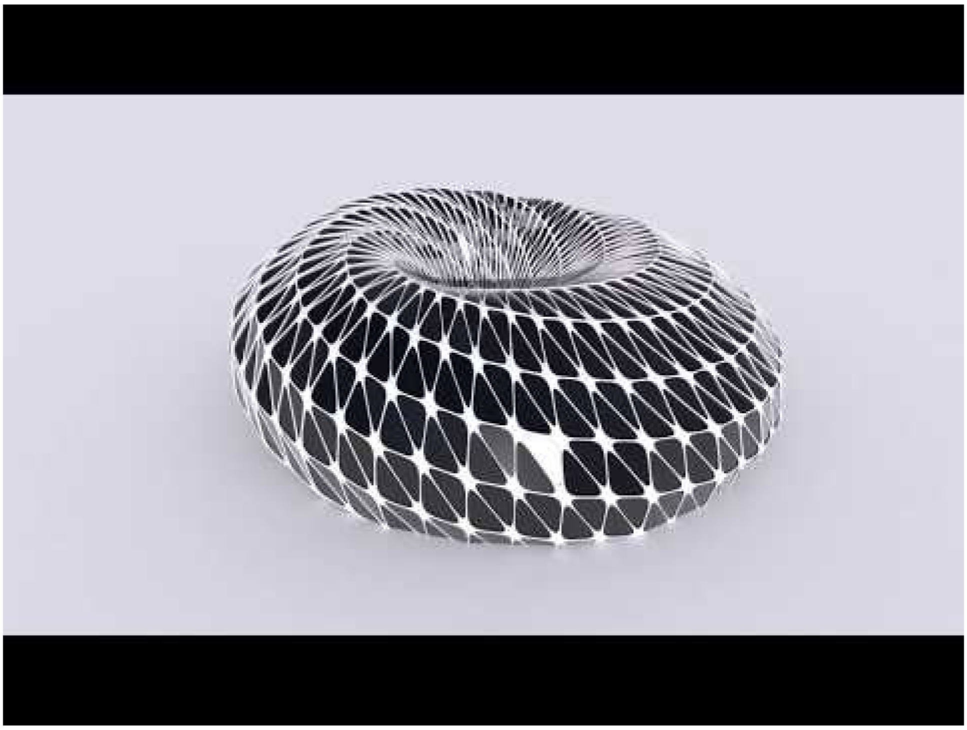


Figure 12: BIM Potential

5.3 – Historical Development

Research on digital modelling began in the early 1960s. In 1963, Ivan Sutherland was working with wireframe graphics and developed “sketchpad”, providing the kick-off for digital modelling. Surface modelling was later presented in 1967 by Steven Anson Coons in an MIT technical report titled “surfaces for computer-aided design of space forms”.
The beginning of BIM idea stated in 1974 with Charles Eastman is publication “An outline of the building description system: Research report no. 50”. The concept grew and was consolidated after the arrival of parametric modelling in 1990, since parametric modelling allowed all the shapes of the model to be changed and not only the individual elements. With the evolution of parametric modelling among other techniques, such as reality capture, the data obtained have enabled the entire collaborative process to be improved, resulting in the current BIM concept. An Autodesk video (https://youtu.be/gsm15cawHbY) briefly resumes the historical development of the BIM concept.



References:

Coons, S.A., (1967), “Surfaces for computer-aided design of space forms”, MAC-TR-41, M.I.T

Eastman C.M., Fisher D., Lafue G., Lividini J., Stoker D., Yessios C., (1974) “An outline of the building description system: Research report no. 50”, (Pittsburgh, PA: Carnegie-Mellon University)

5.5 – AIA Specifications: Level of Development

In 2008, the American Institute of Architects (AIA) released the E202–2008 BIM protocol. This protocol helped to define what model could be used, by creating a model progression specification and what kind of information could be derived from each progressive specification/level or what we could trust the model for. Thus, the *Level of Development (LOD) Specification* corresponds to the amount and type of information that is stored in a model and is a reference that enables practitioners in the AEC Industry to specify and articulate with clarity the content and reliability of Building Information Models (BIMs) at various stages in the design and construction process. This was also adopted by the AGC BIMForum (Figure 3), which is a US Construction Association. BIMForum intends to explore technology, deliver innovation and performance improvement through building information modelling and new means of collaboration. Furthermore, it intends to improve the design and construction industry through education and the development of best practices for these innovations, and to help implement these innovations into the broad AEC industry. By accessing the site of BIMForum, it is possible to download the most current Level of Development Specifications (LOD)**.** The *LOD Specifications,* available on the BIMForum site, utilize the basic LOD definitions developed by the AIA for the *AIA G202-2013 Building Information Modelling Protocol Form* [1] and is organized by CSI Uniformat 2010 [2]. More information can be consulted on the site https://bimforum.org/lod/

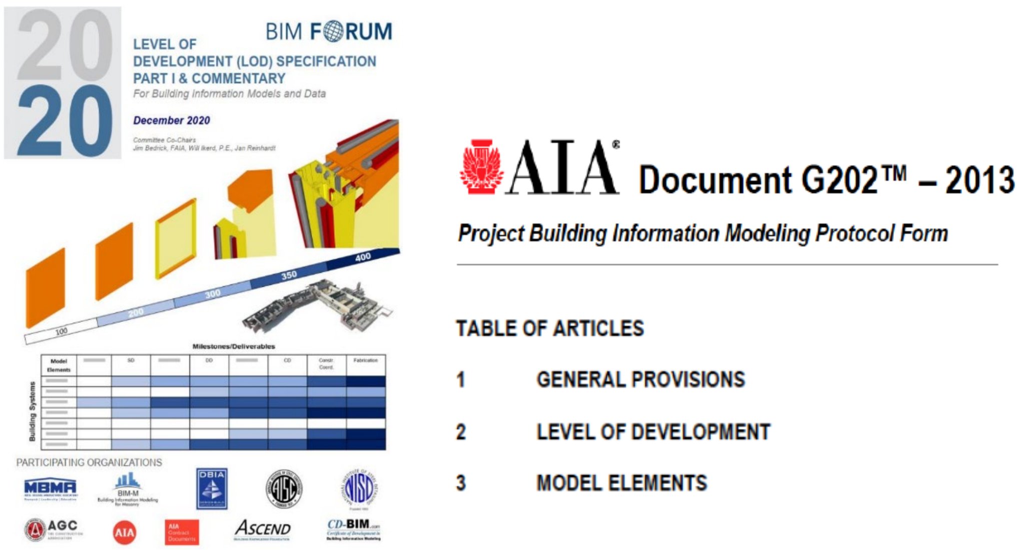


Figure 3: AGC BIMForum example

The proposed classification of LODs by AIA document G202 TM- 2013 consists of 5 levels (100 to 500), each of which can be associated with the following meanings:

LOD 100 – *Concept*;
Model content requirements: overall building massive indicative of area, height, volume, location and orientation may be modelled in three dimensions or represented by other data.
Authorized uses: Analysis, Cost Estimating, Scheduling.

LOD 200 – *Approximate geometry*;
Model content requirements: Model Elements are modelled as generalized systems or assemblies with approximate quantities, size, shape, location, and orientation. Non-geometric information may also be attached to model elements.
Authorized uses: Analysis, Cost Estimating, Scheduling.

LOD 300 – *Precise geometry*;
Model requirements: Model Elements are modelled as specific assemblies which are accurate in terms of quantity, size, shape, location, and orientation. Non-geometric information may also be attached to Model Elements.
Authorized uses: Construction, Analysis, Cost Estimating, Scheduling.

LOD 400 – Adapted to realization/ execution;
Model content requirements: Model Elements are modelled as specific assemblies accurate in terms of quantity, size, shape, location, and orientation with complete fabrication, assembly, and detailing information. Non-geometric information may also be attached to Model Elements.
Authorized uses: Construction, Analysis, Cost Estimating, Schedule

LOD 500 – "as built".
Model content requirements: Model Elements are modelled as constructed assemblies which are actual and accurate in terms of size, shape, location, quantity, and orientation. Non-geometric information may also be attached to Model Elements.
Authorized uses: General Usage
Each subsequent LOD is based on the previous level and includes all features contained in the previous levels. This makes it possible, at a certain stage of project development, to have different LODs for different elements of the model.

The BIMForum provides a guide with the LOD definition updates. The definitions available in the 2020 guide are the following:

LOD 100 - The Model Element may be graphically represented in the Model with a symbol or other generic representation, but does not satisfy the requirements for LOD 200. Information related to the Model Element (i.e. cost per square foot, tonnage of HVAC, etc.) can be derived from other Model Elements.

<u>BIMForum Interpretation</u>: LOD 100 elements are not geometric representations. Examples are information attached to other model elements or symbols showing the existence of a component but not its shape, size, or precise location. Any information derived from LOD 100 elements must be considered approximate.

LOD 200 - The Model Element is graphically represented within the Model as a generic system, object, or assembly with approximate quantities, size, shape, location, and orientation. Non-graphic information may also be attached to the Model Element.

BIMForum interpretation: In terms of this LOD, elements are generic placeholders. They may be recognizable as the components they represent, or they may be volumes for space reservation. Any information derived from LOD 200 elements must be considered approximate.

LOD 300 - The Model Element is graphically represented within the Model as a specific system, object or assembly in terms of quantity, size, shape, location, and orientation. Non-graphic information may also be attached to the Model Element.

BIMForum interpretation: The quantity, size, shape, location, and orientation of the element as designed can be measured directly from the model without referring to non-modelled information such as notes or dimension call-outs. The project origin is defined and the element is located accurately with respect to the project origin.

LOD 350 - The Model Element is graphically represented within the Model as a specific system, object, or assembly in terms of quantity, size, shape, location, orientation, and interfaces with other building systems. Non-graphic information may also be attached to the Model Element.

BIMForum interpretation. Parts necessary for the coordination of the element with nearby or attached elements are modelled. These parts will include such items as supports and connections. The quantity, size, shape, location, and orientation of the element as designed can be measured directly from the model without referring to non-modelled information such as notes or dimension call-outs.

LOD 400 - The Model Element is graphically represented within the Model as a specific system, object or assembly in terms of size, shape, location, quantity, and orientation with detailing, fabrication, assembly, and installation information. Non-graphic information may also be attached to the Model Element.

BIMForum interpretation. An LOD 400 element is modelled in sufficient detail and accuracy for the fabrication of the represented component. The quantity, size, shape, location, and orientation of the element as designed can be measured directly from the model without referring to non-modelled information such as notes or dimension call-outs.

LOD 500 - The Model Element is a field verified representation in terms of size, shape, location, quantity, and orientation. Non-graphic information may also be attached to the Model Elements.

BIMForum interpretation. Since LOD 500 relates to field verification and is not an indication of progression to a higher level of model element geometry or non-graphic information, this Specification does not define or illustrate it.

Despite the fact that, in America, LOD refers to 'Level of Development' In the UK, LOD is the commonly known acronym for 'Level of Detail'.
This was introduced within the BIM Protocol released by AEC (UK) in 2009 as Level of Detail/Grade within its Model Development Methodology. Later in 2013 PAS 1192-2 Specification for information management for the capital/delivery phase of construction projects using building information modelling (now replaced by BS EN ISO 19650) introduced ‘Level of Definition’ as a new classification system with seven levels (1-7) to include both aspects of ‘Level of Model Detail’ (LOD) and Level of Model Information’ (LOI). Table 1 shows this classification.

Table 1 – LOD classification

UK LOD	USA LOD	Description	Content
1		Preparation and Brief	A model communicating the performance requirements and site constraints. Building models would be block models only.
2	LOD 100	Concept Design	A conceptual or massing model intended for whole building studies including basic areas & volumes, orientation and costs.
3	LOD 200	Developed Design/ Approximate geometry	A design development model, "generalized systems with approximate quantities, size, shape, location and orientation."
4	LOD 300	Technical Design/Precise geometry	Production, or pre-construction, “design intent” model representing the end of the design stages. Modelled elements are accurate and coordinated, suitable for cost estimation and regulatory compliance checks. This LOD would typically be a model suitable for the production of traditional construction documents and shop drawings.
5	LOD 400	Construction/Fabrication	An accurate model of the construction requirements and specific building components, including specialist sub-contract geometry and data. This model would be considered to be suitable for fabrication and assembly.
6	LOD 500	As built	An “as built” model showing the project as it has been constructed. The model and associated data is suitable for maintenance and operations of the facility.
7		In USE	Asset Information Model used for ongoing operations, maintenance and performance monitoring

In reference to BS EN 19650-1 Level of Information Need defines the quality, quantity and granularity of information. Information can be in the form of geometric information (or Level of graphical Detail) and alpha-numeric (or Level of Information).

Coding for graphical representations, the Level Of Detail, is easy enough. The AEC (UK) BIM Protocols define the graphical appearance as (Figure 4):

G0 Symbolic. Not to scale, merely a "suggestion" of where the object will exist. In terms of doors, this might simply be a black rectangle in a 2D wall.

G1 Placeholder. While it may be to scale, the object may not represent the appearance of the final component. In terms of doors this would be a simple, plain object without frames, vision panels or hardware.

G2 Suitable for construction. This is where you would provide geometry representative of the final component. It may still not include hardware (as this would typically be specified separately) but could be a manufacturer´s downloaded object.

G3 High resolution, fully detailed object. Typically only used for visualisation, or in fact, manufacturing.

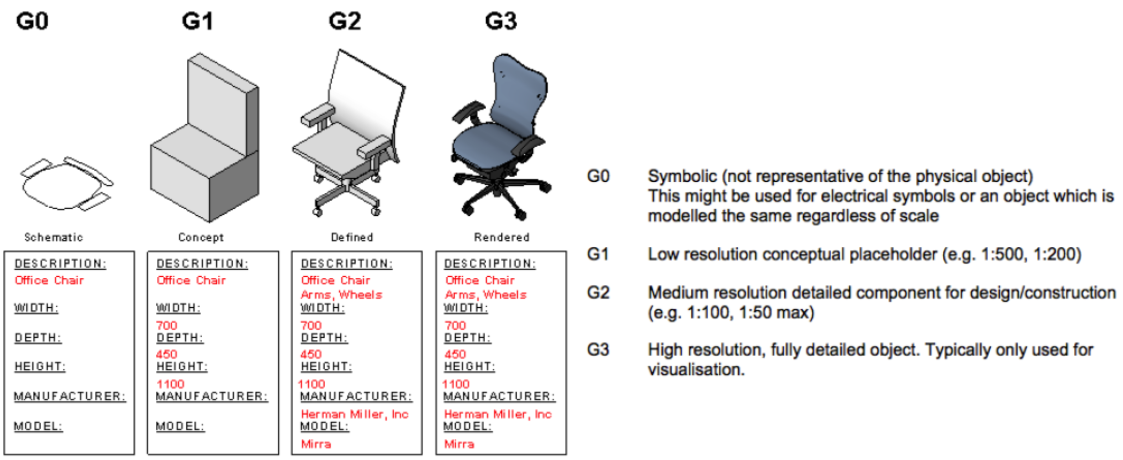


Figure 4: Example of graphical appearance

Notes and links:
[1] AIA Contract Document *G202-2013, Building Information Modelling Protocol Form* is part of a new series of digital practice documents the AIA published in June 2013. For general information on the documents and downloadable samples see www.aia.org/digitaldocs. For executable versions of the documents see http://www.aia.org/contractdocs.
[2] For a more in-depth explanation of UniFormatTM and its use in the construction industry visit http://www.csinet.org .

References:

AEC-UK (2009). AEC (UK) BIM Standard Version 1.0, ACE-UK Committee.

AIA (2008). AIA Document E202-2008 building information modeling protocol exhibit, Washington, DC 20006- 5292, the American Institute of Architects (AIA).

AIA (2013a). AIA Document E203™–2013, Building Information Modeling and Digital Data Exhibit, Washington, DC 20006-5292, the American Institute of Architects (AIA).

AIA (2013b). AIA Document G201™–2013, Project Digital Data Protocol Form, Washington, DC 20006-5292, the American Institute of Architects (AIA).

AIA (2013c). AIA Document G202™–2013, Project Building Information Modeling Protocol Form, Washington, DC 20006-5292, the American Institute of Architects (AIA).

AIA (2013d). Guide, Instructions and Commentary to the 2013 AIA Digital Practice Documents, Washington, DC 20006-5292, the American Institute of Architects (AIA).

BIMForum (2020). Level of Development Specification Part I § Commentary for Building Information Models and Data Version 2020, the Association General Contractors.

BIMForum (2020). Level of Development Specification Part I § Commentary for Building Information Models and Data Version 2020, the Association General Contractors.

5.6 – International BIM Standards: Benefits and Limitations

The interest in BIM has grown dramatically in the AEC industry in the last few years. Many countries have now started to investigate and implement BIM. As a consequence, in the last decade, several BIM standards have been developed and others have been updated.

BIM standardisation allows for entire sectors to scale their innovations. It allows companies to provide their clients with quality BIM implementation in every phase of construction and FM.

According to Cheng and Lu (2015) 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. 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 FiveYear Plan" in 2012. In May 2013, the China Institute of Building Standard Design &

Research gained recognition from the international authority of organization for BIM standardization – buildingSMART (BSA, an affiliate of American Institute of Building Sciences), and the established BSA Chinese division. Its establishment marked China's national BIM standard system, successfully integrating it into the advanced countries' BIM standards (Bingsheng Liu et al. 2017).

Thus, in this section, it is not the intention to exhaustively present all BIM standardisation produced worldwide but to present only the most significant standards.

Australia

Australia Cooperative Research Centre (CRC) for Construction Innovation released its National Guidelines for Digital Modelling (CRC-CI, 2009) in 2009 to promote the adoption of BIM technologies in the Australian building and construction industry. The guidelines provide an overview of BIM and recommendations for key areas of model creation and development, simulation, and performance measurement (Cheng and Lu, 2015).

A government-supported non-profit organization, Construction Information Systems Limited (trading name NATSPEC founded in 1975), also released its BIM guide, namely The NATSPEC National BIM Guide (NATSPEC, 2011) in 2011 that was updated in 2016. It defines uses of BIM, modelling methodology, presentation styles and deliverable requirements. In 2012, NATSPEC published a Project BIM Management Plan Template (NATSPEC, 2012) as a supplementary document to the National BIM Guide (Cheng and Lu, 2015).

Another important document is the BIM Object/Element Matrix which is a Spreadsheet/Worksheet to be used for identifying and tracking BIM information during the project. It depicts Building Information Typologies/Types, when they are relevant, and to what level of development (LOD) throughout a building lifecycle. It is an expansion of AIA Document E202 BIM Protocol Exhibit to support a greater level of understanding of BIM information use. The information is referenced by its OmniClass Table so that the correct table element can be determined.

Furthermore, NATSPEC maintains the Australian National Classification System to assist specification writers organise the content of specifications, and their users to find the information they are looking for. The system structures information in a logical and consistent way to introduce predictability from project to project. The most important documents are presented in table 2.

For example, the NATSPEC TECH report provides an overview of the use of classification systems for organising construction information for various purposes. It outlines the relationship of existing national systems, including NATSPEC, to ISO 12006-2: 2015 Organisation of information about construction works – Part 2: Framework for classification of information. It also examines the significance of classification systems for the Australian design and construction industry, particularly for digital information technologies such as Building Information Modelling (BIM).

Nordic Countries

Nordic countries have been implementing BIM in the public and private sectors for over a decade.

Finland has been researching innovation in the construction sector for many decades. Finland's state property services agency, Senate Properties, is the largest government owned enterprise under the Finnish Ministry of Finance and has used BIM in all its projects since 2001. Senate has required the use of IFC/BIM for its projects since 2007, and published Senate Properties' BIM Requirements for Architectural Design (Senate Properties, 2007) in the same year.
Furthermore, in 2007, the Confederation of Finnish Construction Industries began requiring that all design software packages had IFC certification (Cheng and Lu, 2015).
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)
Finland is also part of the BuildingSmart initiative. It aims to employ a Data Dictionary, Information Delivery Manual, Model View Definitions, and Building Collaboration Format nationally.

Sweden started the research and development programme IT in Building and Property in 1998. It focused on standardisation, research, and implementation of new technologies. With standardisation, they studied how to implement IFC into their current system.
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.
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, which was an extended CAD guideline for delivering and managing digital information within construction projects in Sweden (Cheng and Lu, 2015).
In 2014, the BIM Alliance Sweden brought the public and the private sector together. The aim is to promote and enhance construction innovation.
Additionally, the Swedish Transport Administration has mandated the use of BIM since 2015.

In **Denmark**, there is considerableinterest from the public sector regarding BIM.

The government of Denmark launched 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 (Cheng et al. 2015). From this, they developed guidelines for using 3D CAD in future projects.

Since 2007 the Palaces and Properties Agency, the Danish University and Property Agency, and the Defence Construction Service have piloted BIM in their projects following the requirements set by the Digital Construction project, having a large impact on the construction market due to IFC requirements.

Bips, a private company, built on the Digital Construction project, has actively pursued R&D for BIM. They published BIM guidelines in 2006.

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 (Cheng and Lu, 2015).

Nowadays, BIM is part of Denmark's building regulatory laws.

**Norway** has a host of documents related to BIM standards. From 2008, the public sector in Norway started drafting and releasing their BIM standards. Statsbygg, a public sector administration company and the Norwegian government's key advisor was the first to release a BIM manual in 2008 in order to describe its requirements for IFC-compatible BIM (Fatt, 2012).

In 2010, the Norwegian government stated its commitment to BIM adoption and many public sector bodies in Norway launched BIM programs to follow the government. Statens vegvesen (The General Directorate for National Roads and Highways), began developing a handbook in 2010. This V770 handbook for model output was published in 2012, and it states that all future projects need to use 3D modelling.

The Norwegian Home Builders 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 modelling methodology of various software tools and focuses on four main areas: energy simulations, cost calculation, ventilation, and roof trusses (Cheng and Lu, 2015).

Furthermore, the BIM manual released by Statsbygg in 2008 has had several versions. The Statsbygg Building Information Modelling Manual v1.2.1 (SBM) was released in 2013 (Statsbygg, 2013) and again in 2021.

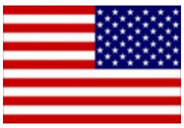
SBM is the result of government initiatives and is compulsory for state projects. It contains Statsbygg's general requirements and discipline specific requirements for BIM in projects and facilities and is positioned to be the best practice for applying BIM in Norway in the whole AEC field.

Singapore

Singapore is a leading country for BIM adoption and standards development in Asia. Most of the BIM standards cover Modelling Methodology and Component Presentation Style and Data Organization.

In 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 (Cheng and Lu, 2015). As a result, various BIM e-submission guidelines were prepared and released to highlight the major points of submission requirements. The first version of BIM e-Submission Guideline was developed in 2008 to support the CORENET project (Cheng and Lu, 2015).

A 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 early 2010, BCA then officially released the BIM and 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)



United States

The United States is the country which has developed the greatest number of initiatives related with BIM and where the implementation has had a huge increase in the last two decades.

There is a significant number of organisations and universities that have published standards and guides. Thus, the production of BIM standards is very widespread and there is a huge number of guides and recommendations for the implementation of BIM published by different organisations.

The United States General Services Administration (GSA) builds and manages federal buildings and is the largest public building owner in the United States. In 2007, GSA set a goal to require IFC BIMs on projects for improving design quality and construction delivery.

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 a project level had made such a public and ground breaking statement (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.

In 2007, the National Institute for Building Sciences (NIBS) established the NBIMS-US™ project committee to develop the national BIM standards and to discuss the possibility of incorporating BIM into college curricula. NIBS published National Building Information Modelling Standard (NBIMS-US™) Version 1.0 - Part 1: Overview, Principles, and Methodologies (NIST, 2007b) in 2007 and NBIMS-US™ Version 2.0 in 2012 (NIST, 2012). NBIMS V1-P1 is a conceptual description of the overall standard, the methodologies of development, and the intended use (Bazjanac, 2008). NBIMS V2 is a more technical standard and includes three types of contents – Guidelines and Applications, Information Exchange Standards, and Reference Standards (Cheng and Lu, 2015)
In early 2014, NIBS presented its first course – “The Introduction to COBie” – on the Institute’s newly launched Building Sciences Online Academy (Cheng and Lu, 2015).

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). In conformity with the increasing use of BIM, the AIA released AIA Document E202™– 2008 Building Information Modelling 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 Modelling 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 Modelling Protocol Form (AIA, 2013c). In the meantime, AIA also published Guide, Instructions and Commentary regarding the 2013 AIA Digital Practice Documents (AIA, 2013d) to provide a guide on how to use these documents (Cheng and Lu, 2015).

The Department of Veterans Affairs (VA) and two other non-profit organizations, the National Institute of Standards and Technology (NIST) and the Association of General Contractors (AGC), also published BIM guidelines individually. In 2010, AGC released the second edition of the BIM Guide (AGC, 2010). BIMForum, a forum of AGC which 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 (Cheng and Lu, 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 Modelling Protocol Form (AIA, 2013c).

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 years. For example, New York City (NYC) is active in BIM adoption and the NYC Department of Design and Construction (DDC) published a city-wide BIM Guide in July 2012 (Cheng and Lu, 2015).

Even public universities have published their own BIM Standards starting in 2009. For example, as a buildingSMART project, the Pennsylvania State University (PSU) has published several BIM standards since 2009. 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 (Cheng and Lu, 2015).

buildingSMART is a not-for-profit organization and is the worldwide authority driving the digital transformation of the built asset environment, through the creation and adoption of open, international standards for infrastructure and buildings.

buildingSMART is the international authority for a set of standards known as the Industry Foundation Class (IFC) which deal with process, data, terms and change management for the specification, management and effective utilization assets in the built asset industry. buildingSMART Compliance provides guidance and governance for certification of software, people, and organizations through compliance training and testing.

buildingSMART standards cover a wide range of process and information capabilities unique to the built environment industry, including:

- An industry-specific data model schema - Industry Foundation Classes [IFC];
- A methodology for defining and documenting business processes and data requirements - Information Delivery Manual [IDM];
- Data model exchange specifications - Model View Definitions [MVD];
- Model-based, software-independent communication protocols - BIM Collaboration Format [BCF];
- A standard library of general definitions of BIM objects and their attributes - buildingSMART Data Dictionary [bSDD].

More information about buildingSMART can be found in the link: https://www.buildingsmart.org/


United Kingdom

For the public sector in the United Kingdom, the Construction Industry Council (CIC) and BIM Task Group co-produced some BIM guidelines in response to the United Kingdom government’s 2016 goals. With the technical support and leadership of the BIM Task Group, CIC drafted two BIM documents in 2013 (Cheng and Lu, 2015). 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 encounter in BIM projects (CIC, 2013a). Other 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.
The AEC-UK Initiative was formed in 2000 to improve the process of design information production, management and exchange. Initially the initiative addressed CAD layering conventions as the primary concern for users of design data. As design needs and technology have developed, the initiative has expanded to cover other aspects of design data production and information exchange. The committee was re-formed in 2009, including new members from companies and consultancies highly experienced in BIM software and implementation, to address the growing need within the UK AEC industry for the application of UK standards in a unified, practical & pragmatic manner within a design environment. The AEC (UK) BIM Protocol was 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. The updated version collates the learning and experience gained since then. This generic document provides platform-independent protocols which are further enhanced by the software specific supplements. 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).

ISO

ISO is an independent, non-governmental international organization with a membership of 165 national standards bodies. Through its members, it brings together experts to share knowledge and develop voluntary, consensus-based, market relevant International Standards that support innovation and provide solutions to global challenges.

The International Organization for Standardization (ISO) has published the first global Building Information Modelling (BIM) standards ISO 19650-1:2018 published in December 2018.
The new standards include ISO 19650-1:2018 “Part 1: Concepts and principles"; ISO 19650-2:2018 "Part 2: Delivery phase of the assets" and ISO 19650-3:2020 “Part 3: Operational phase of the assets”.
This document outlines the concepts and principles for information management at a stage of maturity described as "building information modelling (BIM) according to the ISO 19650 series". In addition, it specifies requirements for information management, in the form of a management process, within the context of the delivery phase of assets and the exchanges of information within it, using building information modelling.

The standards, according to the ISO, will provide the necessary framework to help designers and contractors from different countries collaborate more efficiently in all phases of construction projects and will encourage BIM’s wider use.
ISO 19650 is based on British standard BS 1192 and public standard PAS 1192-1, which the ISO said has helped reduce user construction costs by 22%.

Table 2 – A resume of International BIM Standards

Country	Organization	Standard Name	Publication Data/Last Update
Australia	NATSPEC	National Worksection Matrix	2021
		National Classification System	2021
		TECH report TR 02 - Information classification systems and the Australian construction industry	2021
		TECHnote GEN 015 Using the NATSPEC classification system to organise information	2021
		National BIM Guide	2011 reviewed in 2016
		BIM Reference Schedule	2011
		BIM Object/Element Matrix	2011
		Management Template V1.0	2012
Denmark	Byggestyrelsen	3D CAD Manual 2006	2006
Finland	buildingSmart Finland/ Senate Properties	Common BIM Requirement (COBIM) V1	2012
Norway	Statsbygg	Statsbygg Building Information Modelling Manual v1.2	2011
		BIM Manual v1.2.1	2013
	Norwegian Home Builders' Association	BIM Manual v1	2011
Singapore	BCA	BIM e-Submission Guideline for Architectural Discipline v3.0	2008
		BIM e-Submission Guideline for Architectural Discipline v3.5	2010
		[Singapore, BCA] BIM e-Submission Guideline Structural v2.1	2011
		BIM e-Submission MEP v3	
		BEG for: BIM Adoption in an Organization; BIM Execution Plan; Architectural Consultants; Contractors; CS Consultants; MEP Consultants	2012
		BIM Guide v1.0	2012
		BIM Guide v2.0	2013
United Kingdom	AEC	BIM Standard v1.0	2009
		Building Protocols	2012
	BSI/CPIC	Building Information Management – A Standard Framework and Guide to BS 1192	2010
	CIC	Building Information Model (BIM) Protocol v1	2013
		Best Practice Guide for Professional Indemnity Insurance When Using BIMs v1	2013

		Outline Scope of Services for the Role of Information Management v1	
	BSI	PAS 1192-2: 2013	2013
		PAS 1192-3: 2014; BS 1192-4: 2014	2014
United States of America	National Institute of Building Science (NIBS)-buildingSMART alliance (bSa)	National BIM Standards (NBIMS)	2012
	American Institute of Architects (AIA) contact documents	E201™–2007, Digital Data Protocol Exhibit	2007
		E202-2008 BIM Protocol Exhibit	2008
		E203™–2013, BIM and Digital Data Exhibit	2013
	New York City Department of Design Construction	BIM Guidelines	2012
	United States Department of Veterans Affairs (VA)	The VA BIM Guide	2010
	United States General Services Administration (GSA)	National 3D-4D Building information Program BIM Guide Series 01 v0.6	2007
	United States General Services Administration (GSA)	BIM Guide Series 02 v2.0	2015
	PSU	BIM Project Execution Planning (PEP) Guide v2.0	2010
		BIM Planning Guide for Facility Owners v2.0 ; The Uses of BIM v0.9	2013
	AGC, BIMForum	Level of Development Specification v2020	2020

References:

AEC-UK (2009). AEC (UK) BIM Standard Version 1.0, ACE-UK Committee.

AEC-UK (2012a). AEC (UK) BIM Protocol for Autodesk Revit Version 2.0, ACE-UK Committee.

AEC-UK (2012b). AEC (UK) BIM Protocol for Bentley AECOsim Building Designer Version 2.0, ACE-UK Committee.

AEC-UK (2012c). AEC (UK) BIM Protocol Version 2.0, ACE-UK Committee. AEC-UK (2013). AEC (UK) BIM Protocol for Graphisoft ArchiCAD Version 1.0, ACE-UK Committee.

AGC (2010). The Contractor's Guide to BIM Edition 2, Arlington, VA 22201, the Association General Contractors of America.

AIA (2007a). AIA Document C106™–2007 Digital Data Licensing Agreement, Washington, DC 20006-5292, the American Institute of Architects (AIA).

AIA (2007b). AIA Document E201™–2007, Digital Data Protocol Exhibit, Washington, DC 20006-5292, the American Institute of Architects (AIA).

AIA (2008). AIA Document E202-2008 building information modeling protocol exhibit, Washington, DC 20006- 5292, the American Institute of Architects (AIA).

AIA (2013a). AIA Document E203™–2013, Building Information Modeling and Digital Data Exhibit, Washington, DC 20006-5292, the American Institute of Architects (AIA).

AIA (2013b). AIA Document G201™–2013, Project Digital Data Protocol Form, Washington, DC 20006-5292, the American Institute of Architects (AIA).

AIA (2013c). AIA Document G202™–2013, Project Building Information Modeling Protocol Form, Washington, DC 20006-5292, the American Institute of Architects (AIA).

AIA (2013d). Guide, Instructions and Commentary to the 2013 AIA Digital Practice Documents, Washington, DC 20006-5292, the American Institute of Architects (AIA).

BCA (2010). BIM e-Submission Guideline for Architectural Displine v3.5, MND Complex Singapore 069110, Building and Construction Authority.

BCA (2012). Sigapore BIM Guide Version 1.0, MND Complex Singapore 069110, Building and Construction Authority.

BCA (2013a). BIM Essential Guide for BIM Adoption in an Organization, MND Complex Singapore 069110, Building and Construction Authority.

BCA (2013b). BIM Essential Guide for MEP Consultants, MND Complex Singapore 069110, Building and Construction Authority.

BCA (2013c). Sigapore BIM Guide Version 2.0, MND Complex Singapore 069110, Building and Construction Authority.

Bingsheng Liu, Min Wang, Yutao Zhang, Rui Liu, Anmin Wang, (2017), Review and Prospect of BIM Policy in China, IOP Conf. Series: Materials Science and Engineering 245 (2017) 022021 doi:10.1088/1757-899X/245/2/022021

BSI (2010). Building Information Management – A Standard Framework and Guide to BS 1192, London W4 4AL, British Standards Institution.

BSI (2013). PAS 1192-2:2013 Specification for information management for the capital&delivery phase of construction projects using BIM, London W4 4AL, British Standards Institution.

BSI (2014). PAS 1192-3: 2014 Specification management for the operational phase of assets using building information modelling, London W4 4AL, British Standards Institution

CIC (2013a). Best Practice Guide for Professional Indemnity Insurance When Using Building Information Models first edition, London WC1E 7BT, Construction Industry Council.

CIC (2013b). Building Information Model (BIM) Protocol v1, London WC1E 7BT, Construction Industry Council.
CRC-CI (2009). National Guidelines for Digital Modelling, Brisbane QLD 4001, Australia, Cooperative Research Centre for Construction Innovation.

Hagan S., Ho P. and Matta H. (2009). BIM: the GSA story, Journal of Building Information Modeling. Spring 2009 ed. Washington: Matrix Group Publishing Inc.

Henttinen T. (2012). COBIM 2012 COMMON BIM Requirements. Finland: Gravicon Oy

Jack C.P. Cheng, Qiqi Lu (2015). A review of the efforts and roles of the public sector for BIM adoption worldwide. Journal of Information Technology in Construction (ITcon), Vol. 20, pg. 442-478, http://www.itcon.org/2015/27

NATSPEC (2011). NATSPEC National BIM Guide v1.0, Sydney, New South Wales, Australia 2000, Construction Information Systems Limited.

NATSPEC (2012). NATSPEC BIM Management Plan Template v1.0, Sydney, New South Wales, Australia 2000, Construction Information Systems Limited.

NBS (2015). NBS National BIM Report 2015. the UK: National Building Specification (NBS), RIBA Enterprises Ltd.

NIST (2007a). General Buildings Information Handover Guide Principles, Methodology and Case Studies, Department of Commerce, U.S. National Institute of Standards and Technology.

NIST (2007b). National Building Information Modeling Standard Version 1 - Part 1: Overview, Principles, and Methodologies, Washington, DC 20005, National Institute of Building Science.

NIST (2012). National Building Information Modeling Standard Version 2, Washington, DC 20005, US National Institute of Building Science.

Norwegian Home Builders' Association (2011). Norwegian Home Builders' BIM manual Version 1.0, Norway, Norwegian Home Builders' Association.

Norwegian Home Builders' Association (2012). Norwegian Home Builders' BIM manual Version 2.0, Norway, Norwegian Home Builders' Association.

Senate Properties (2007). Senate Properties' BIM Requirements for Architectural Design, 00531 Helsinki, Finland, Senate Properties.

Statsbygg (2013). Statsbygg Building Information Modelling Manual v1.2.1, 0032 Oslo, Norway, Statsbygg.

5.7 – BIM Classification Systems

There are huge amounts of complex information, which needs to be filed, retrieved and referred. This is particularly true for a construction project where there can be a vast breadth and depth of information and fields of specialism which use different terminology. Classification allows us to order this information in a controlled and consistent manner, to provide a common understanding between specialisms. Fundamentally, classification means grouping things according to a common quality or characteristic. In the first place, it is necessary to define the purpose of the classification and then distinguish the properties for interest to the classification. After that, the subjects can be sorted into classes with regard to the selected properties.

A hierarchy is defined, in a series of classes or groups in successive subordination. Each characteristic is related to a subgroup of a larger group, in a process of division, according to certain characteristics. In this process of hierarchical classification, each subject should only have one place where it fits into the scheme.

Related with the fact that different people can use the same object, on different occasions, it there should be a common language and significances. Thus, a consistent terminology could enable the organisation of the objects and its characteristics, in a classification scheme, to depend on agreed definitions of terms and consistent usage.

According to the NATSPEC TECHreport TR02 (October 2021), the main benefits of classification systems in the construction industry, to facilitate the management of construction information are:

- Filing and retrieval of information about construction products, technical reference material, costs, and so on.
- Structuring the contents of individual documents in a consistent manner.
- Co-ordinating information between individual documents found in sets of documents.
- Communications and collaboration between members of a project team by providing a common language.
- Interoperability of digital systems.
- Organising BIM object libraries.
- Searching for objects or items of a similar type in models.
- Aggregating similar objects or items in models for the purposes of measurement, analysis, monitoring, and so on.
- Benchmarking measured values for assets of a similar type.
- Exchanging and integrating asset information.

- Standardising and consolidating reporting on items of interest.
- Decision making about whole-of-portfolio investments.

Some of the most important construction information classification systems are based on the principles of ISO 12006-2 *Building Construction – Organization of information about Construction Works – Part 2: Framework for Classification and Part 3: Framework for Object-oriented Information*. This influence is a reflection of the convergence of systems based on shared international standards, in order to trend away the separate development of incompatible national systems.

ISO 12006-2 defines a framework for the development of built environment classification systems and recommends a set of classification tables and their titles for a range of construction object classes according to particular views, e.g. buildings, construction elements and spaces. It also defines each class and shows how they are related to each other.

ISO 12006-2 does not describe a complete operational classification system. It is a framework level standard written for developers of classification systems with the aim of providing the basis for harmonising local classification systems. Several national classification systems applied the 2001 edition of the standard (Figure 5). The lessons learnt from these implementations have been applied to the 2015 edition (NATSPEC TECHreport TR02, October 2021).

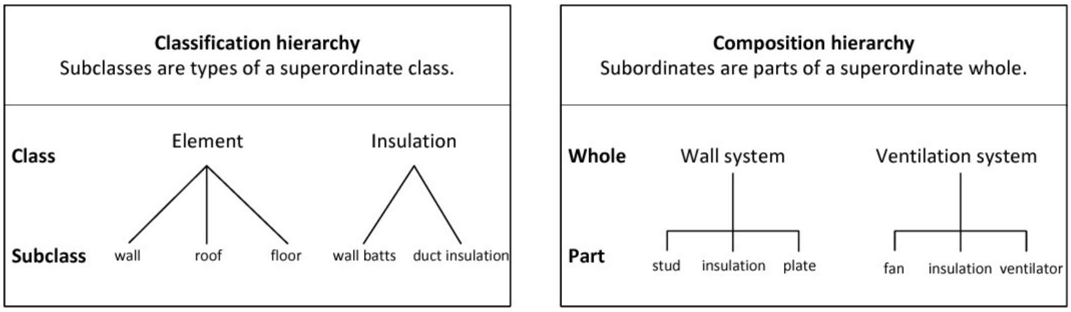


Figure 25: Classification hierarchy of ISO 12006-2 (adapted from NATSPEC TECHreport TR02, October 2021)

The actual classification systems most relevant to construction are:

- NATSPEC, from Australia.
- Masterspec, from New Zealand.
- Cuneco Classification System (CCS), from Denmark.
- Talo (Finnish for Building) 2000 classification system, from Finland.
- CoClass, from Sweden.
- Uniclass 2015, from the United Kingdom (UK).
- OmniClass, from North America.

In a historical context, OmniClass is the result of the adoption of two systems:

- The MasterFormat, the basis of OmniClass Table 22 Work results, is the pre-eminent means of organising commercial and institutional construction specifications, such as MasterSpec, in North America.

- The UniFormat, the basis of OmnCclass Table 21 Elements (including designed elements), which provides a standard method of arranging construction information, organised around the physical parts of a facility called systems and assemblies. It is used for formatting documents on project scope, quality, cost and time, such as cost estimates or reports.

There are several differences in classifications between these systems. For instance, OmniClass lists 211 types of doors (18 in Table 21 Elements, 66 in Table 22 Work results and 127 in Table 23 Products), and the Cuneco Classification System and CoClass (ISO/IEC 81346 based) lists one type of door with the option to add many properties.

Figure 6 and Figure 7 illustrate the differences between a typical or traditional classification (with different classification tables for different participants and purposes and specialized subtype classes incorporating more and more properties embedded in the code), and an object-oriented, generic and stable classification (with one entry class that is used all through the lifecycle, combined with an increasing number of properties).

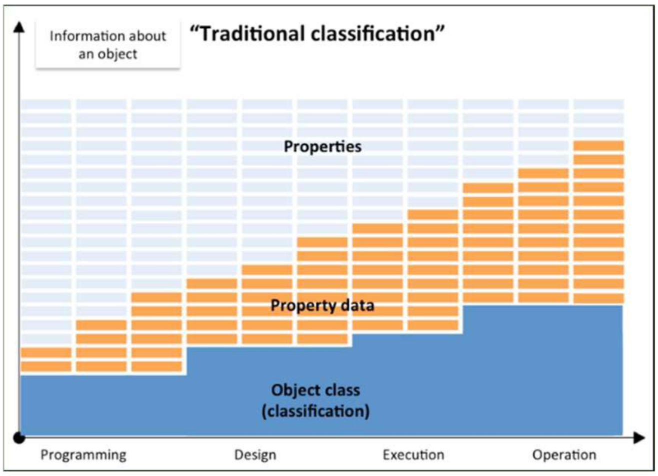


Figure 36: A typical or traditional classification system with different classification tables for different participants (adapted from NATSPEC TECHreport TR02, October 2021)

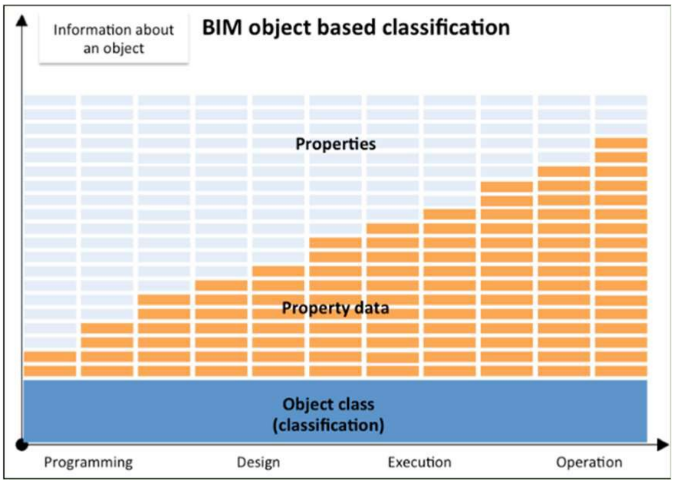


Figure 47: An object-oriented, generic and stable classification system with one entry class (adapted from NATSPEC TECHreport TR02, October 2021)

Regarding the example of the NATSPEC TECHreport TR02 (October 2021), it is possible that all these systems are multifaceted or multi-table classification systems aligned to ISO 12006-2.

Comparing OmniClass and Uniclass 2015, they followed a similar development path in that they were both assembled from pre-existing single table systems. Both are based on ISO 12006-2, though each places them in a slightly different order and splits or combine some of them differently.

Uniclass 2015 does not match OmniClass detail in some sectors, in spite of covering buildings, civil and landscape works, transport and utilities infrastructures and processes engineering more uniformly and consistently within tables. For both systems, Excel files of tables can be readily downloaded online at no cost. OmniClass tables are also available as PDF files.

OmniClass is a multifaceted system designed within the parameters of ISO 12006-2 and ISO 12006-3 covers some sectors in detail but not others. The majority of the 15 OmniClass tables were first published in 2006 and revised some Tables in 2013.

Uniclass 2015 is a more consistent and integrated system than OmniClass, perhaps because it was created from scratch and could build on the lessons of previous systems. The internal structure of tables follows a more consistent configuration, because the basis of specialisation has been more consistently applied.

This more stable hierarchical organisation of the notation system in Uniclass 2015, allows a multifaceted classification of items across tables and makes patterns in the organisation of the system more recognisable for users. It is one of the reasons why Uniclass 2015 is updated more often and changes and extensions to the system are easier to make than in OmniClass.

The Cuneco Classification System (CCS) and CoClass have been developed in parallel and have similar tables aligned to ISO 12006-2 such as OmniClass and Uniclass. However, they diverge from these systems with the incorporation of principles derived from ISO/IEC 81346. CCS and CoClass have had a number of national predecessors – CCS was preceded by the DBK and BC/SfB systems; CoClass was preceded by the BSAB and SfB systems.

Comparing the group OmniClass/Uniclass and the group CCS/CoClass, it is possible to say that OmniClass and Uniclass 2015 represent a more established approach to classification. They will be more recognisable to most industry stakeholders. In OmniClass/Uniclass a list is found of multiple types of each element across a number of tables, with different notations in each table, by the properties assigned to them.

However, CCS and CoClass systems, after implementation, are easier to understanding. These systems list a single element and the subtypes are created by the properties assigned to them. This organization has the advantage that the initial, or root, notation for each element remains unchanged throughout a project. The details of the element are progressively defined during the design, documentation, acquisition and operational phases of a project simply by adding or modifying relevant properties, an approach that is well suited to BIM processes (NATSPEC TECHreport TR02, October 2021).

About the notation to identify and order individual items, OmniClass/Uniclass use a numerical code, generally of six digits, yet that can be extended by adding more digits after a decimal point. It reflects the hierarchical ordering of items familiar to regular users of classification systems. CCS/CoClass notations are based on the three-part Reference Designation System (RDS) described in ISO/IEC 81346, which is both human and machine-readable.

In all the cases are simply notations that consist of one, two or three relatively simple letter codes. However, more sophisticated implementations could be applied, with advanced functionalities such as making it possible to identify an individual item and its precise location/relationship to other items within a project. In these cases and for many, these notations will not be readily interpretable at first sight.

Reference:

NATSPEC TECHreport TR02 (October 2021), Information classification systems and the Australian construction industry