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Building Information Modelling (BIM) standardization

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1 Introduction

BIM, short for Building Information Modelling, is a digital tool disrupting the construction industry as a platform for central integrated design, modelling, asset planning running and cooperation. It provides all stakeholders with a digital representation of a building's characteristics in its whole life-cycle and thereby holds out the promise of large efficiency gains.

One particular area where standardisation on BIM is needed is the exchange of information between software applications used in the construction industry. The leading organisation in this domain is buldingSMART which has developed and maintains Industry Foundation Classes (IFCs) as a neutral and open specification for BIM data model. Other standardisation work include data dictionaries (International Framework for Dictionaries Libraries) and processes (data delivery manuals).

ISO/TC 59/SC 13 "Organization of information about construction works", a subcommittee of the International Organization for Standardization (ISO) on the worldwide and CEN/TC 442 "Building Information Modelling", a technical committee of European Committee for Standardisation (CEN) on the European level develop and maintain standards in the BIM domain. Liaisons with a plethora of different institutions ensure the completeness and inclusiveness of the process as well as the smooth acceptance of adopted standards.

Although BIM was originally devised for buildings the benefits such as less rework, fewer errors, enhanced collaboration, and design data that can ultimately be used to support operations, maintenance, and asset management mad it an attractive option also for infrastructure projects. As geographic information system (GIS) is a key element in any infrastructure project there is the need to integrate BIM and GIS. Both technologies use standard and open data formats, but they are different and presently there is no direct translation.

2 Building Information Modelling (BIM)

Technology is shaping our world in ways never seen before. While most other industries quickly embraced the new technologies and opportunities, the construction sector responded hesitantly. In the report of the World Economic Form **Error! Reference ource not found.** several new technologies are identified together with their possible impact on the industry (Figure 1).

It's easy to imagine 3D printing or swarms of drones erecting structures before our eyes. But these technologies, as important as they are, aren't on the same level as integrated BIM (Building Information Modelling). BIM is both happening now and has a pivotal effect on construction.

2.1 Integrated BIM

Digitalization – the development and deployment of digital technologies and processes – is central to the required transformation of the construction industry. Innovations of this kind enable new functionalities along the entire value chain, from the early design phase to the very end of an asset's life cycle at the demolition phase.

Whether caused by poor commercial interfaces, breakdowns in supply chain communications or inefficient work processes, much of the drain in construction productivity is caused by information problems. If individual project team members cannot access accurate, complete and timely information, then they cannot deliver the best result in the most productive manner.

BIM, combined with more collaborative types of contracts, is helping to solve that challenge. By upholding the integrity and transparency of information across the life cycle of built assets, BIM-enabled projects are more productive, predictable and profitable.

For the first time in the history of construction, the industry is amassing large volumes of high-integrity information and can understand the relationships among that data. Huge data pools are created both on construction projects and during the operations phase of existing assets. The information lives in 3-D models, applications and databases, but it is

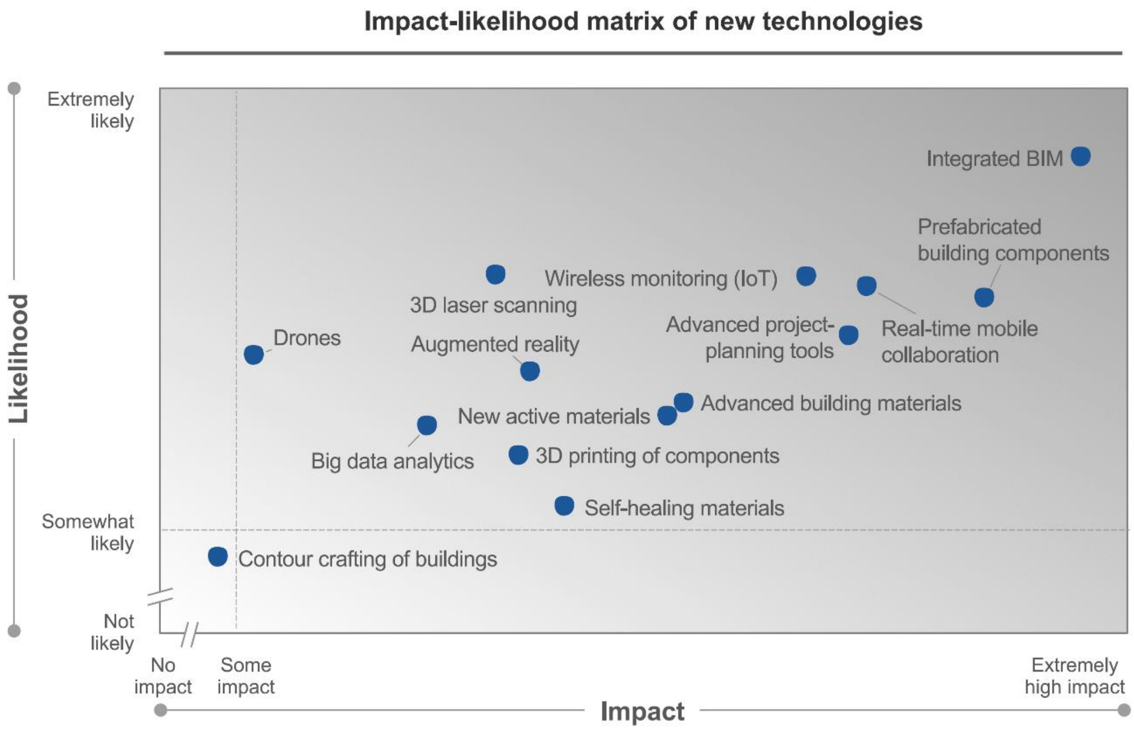

Figure 1: Future impact and likelihood of technologies (Source: Shaping the Future of Construction)

becoming increasingly connected.

Data is the key – the ownership of it and the ability to understand and act on it. Industry, organisations and professionals need to be ready to adjust in order to take advantage of the emerging opportunities. Early adopters stand to gain the most benefit. Everyone in the industry has a choice as to how fast they respond to the changes that "Smart Buildings" will bring and everyone will be affected.

Algorithms generate new insights from the huge data pools and such create digital infrastructure. New methods of simulation and virtual reality help to identify interdependencies and clashes during the design and engineering stages, and enable a virtual experience of the building even in the early design stage. They provide information for better asset management in construction, commissioning, operations, renovations and even demolition phase. Such integrated BIM generates continues flow of information and knowledge build up throughout the life cycle of a building creating enormous value for contractor and stakeholders.

Prior to achieving large-scale implementation and all the potential benefits of BIM, however, various obstacles must be overcome:52 –– Implementing BIM, within a company and industrywide, requires a considerable build-up of expertise, especially appropriate employee training and substantial IT upgrading. Small companies will find that especially challenging, as they might struggle to afford the upfront investments.

- Technological standards have to be in place and interoperability must be ensured, so that the various stakeholders can share information and cooperate on planning.
- Project owners will be slow to adopt the technology until they acquire a greater understanding of the benefits of BIM for them.
- In BIM, data is created and shared in a more collaborative way, which leads to further issues regarding data ownership and liability.
- The benefits of large-scale BIM can only be realized when all participants along the value chain get involved; without this interlinking effect, there is little benefit for the first movers.

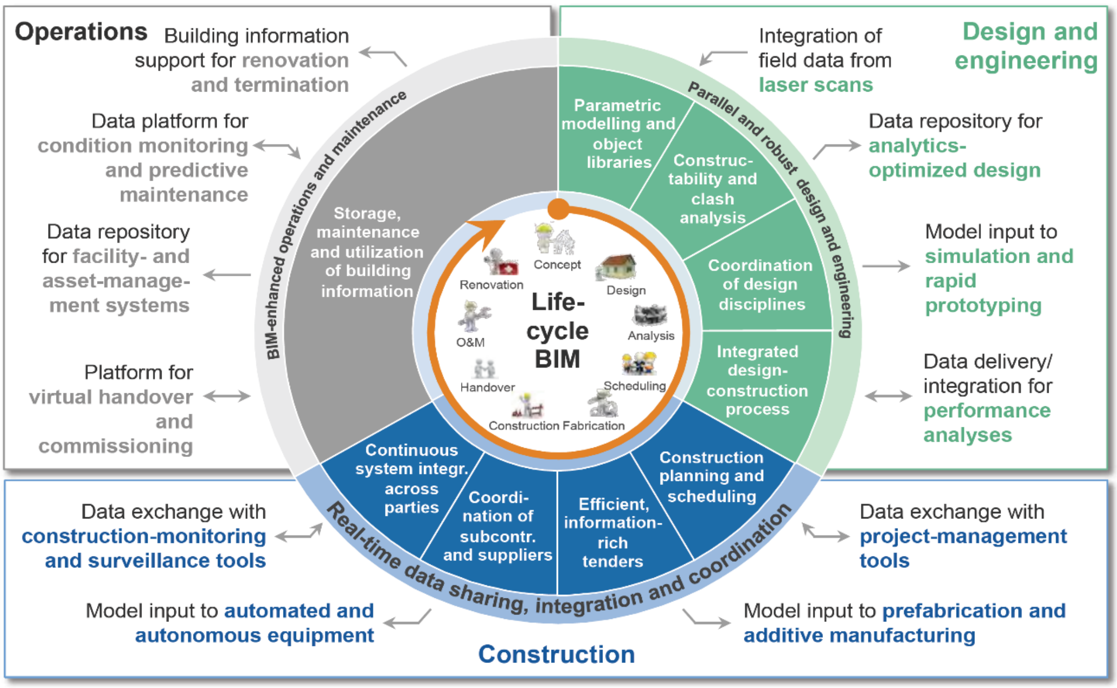

Figure 2: Applications of BIM along the engineering and construction value chain (Source: Shaping the Future of Construction)

The uptake and sophistication of BIM vary considerably from country to country, and from company to company – according to their size and position in the value chain. For some large engineering companies, BIM is already part of business as usual, but most small companies across the value chain have little BIM experience. In fact, even some of the major contractors have never used BIM on any of their projects. The difference in adoption rates within Europe is considerable; for example, 16% of E&C companies in the United Kingdom have never used BIM, while in Austria the figure is 49% **Error! eference source not found.**. What the industry needs is "big and open" BIM, which integrates the entire value chain and is characterized by full interoperability of software and open access to it. The technical challenges are likely to be overcome in the near future, but it might prove more difficult to change existing processes and to increase collaboration, including data sharing. Here are some potentially helpful steps in that regard.

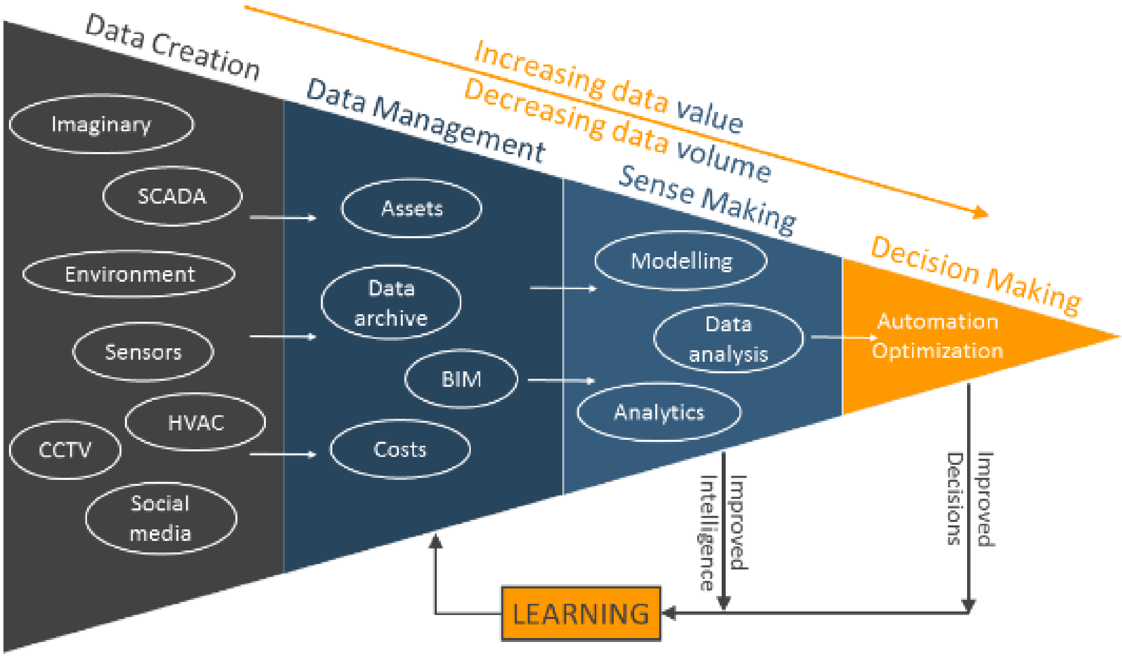

Figure 3: Smart Buildings: from data to information

2.2 BIM maturity

BIM maturity is associated to the fact that it not possible to move brutally from a traditional modelling approach towards an open BIM approach. The change has to be managed progressively as climbing up a stair step by step.

The BIM maturity is often presented as a "wedge". Compared to the UK wedge, some levels have been subdivided (Level 0 and Level 3) and a new level has been added (Level 4).

To evaluate which wedge level is reached, indicators have been introduced. These indicators measure four aspects: the content, the digitalization, the interoperability and the collaboration.

There are four aspects of evaluation (content, digitization, interoperability and collaboration) for the project stages and for the asset management. This picture could be a metric to define where the project is, assuming that the level reached could be different for each aspect.

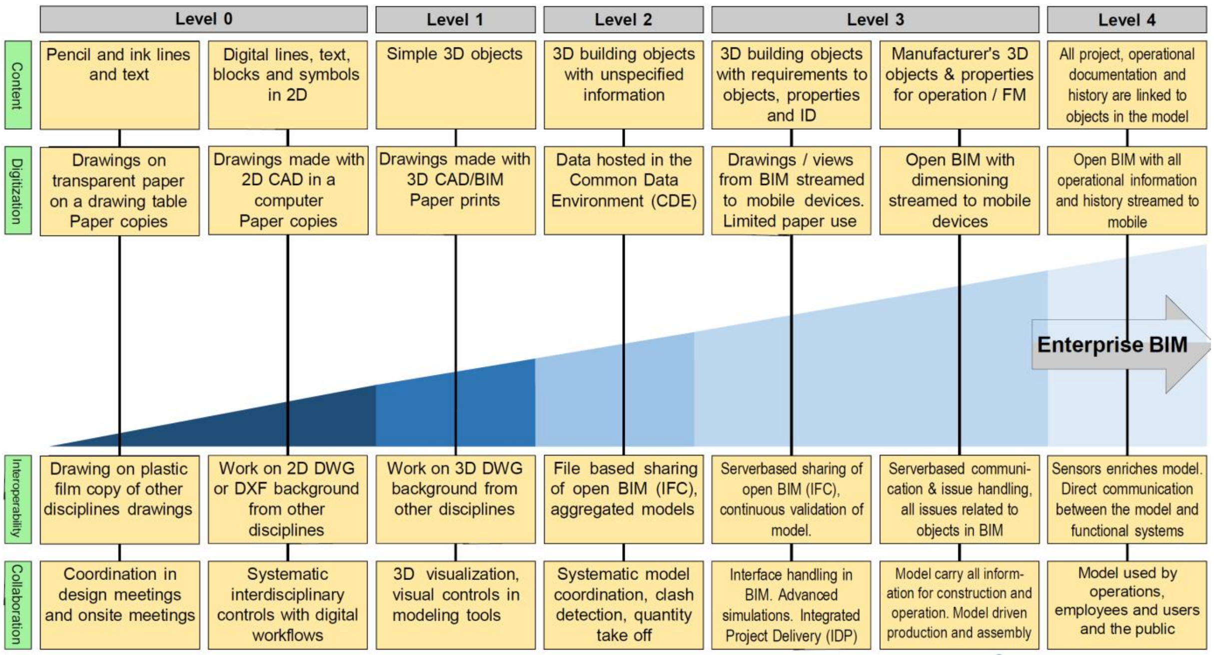

Figure 4: BIM maturity levels

3 Standardisation efforts

The construction industry, like many other production industries, is regulated by a myriad of standards, guidelines, codes of practice and regulations. These enablers and controls make construction projects safer, reduce failures and aim to increase. They also represent and disseminate a collective understanding of the relevant principles applicable to our projects, enable and align stakeholder's expectations of project results and aim to render the world equivalent across cultures, time, and geography. Be it material strength and suitability, calculation method, quality levels, practice methodologies and outputs, the use of standards ensure progress and wellbeing in society. They are critical when communicating between stakeholders in a fragmented industry in temporary project organisations.

Standardisation consists of building a society around a standard with an implied script that brings people and things together in a world already full of competing conventions and standards. There are tendencies in the sector culture to optimise at individual or organisation level only, not the entire process (since nobody owns in the whole process in construction). Consequently, it is important to categorise and understand the strategic difference between branch or sector standards and organisation standards (which may be even company secrets) in a BIM context. When we look at BIM as an end to end delivery methodology we see strong similarities with the ICT domain and we can learn from their experience. Standards related to ICT are usually divided into three parts (Figure) being: Concepts, Data Model and Process. Common concepts and classification of concepts are necessary for everyone to speak the same language. Neutral formats for data models required for systems and players to exchange information clearly. Finally, a uniform processes for information delivery and a common working methodology is necessary. Around these 3 divisions we can arrange BIM standardization themes.

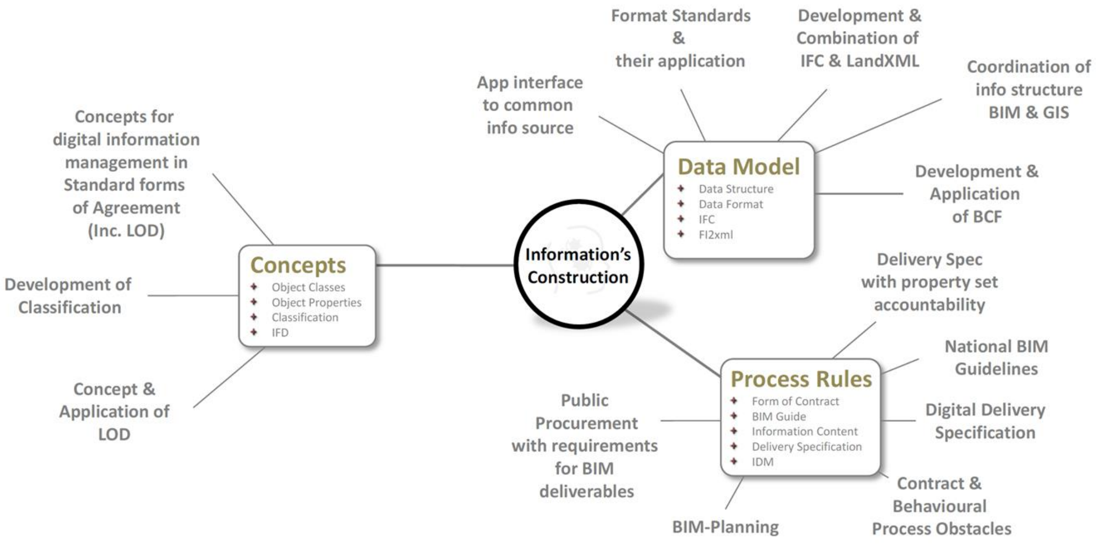

Figure 5: BIM standardization platform

International BIM standardization is a complex process involving many organizations as it is presented in Figure 6. Liaisons are not only established between the relevant ISO and CEN technical committees but also with geospatial and industrial entities as well as with buildingSMART. There are many more liaisons but only those among the most important are presented here.

The entities in Figure 6 are:

- CEN TC442 BIM: Standardization in the field of structured semantic life-cycle information for the built environment.
- CEN TC287 GIS: standardization in the field of digital geographic information for Europe.
- ISO/TC211 GIS: Standardization in the field of digital geographic information.
- ISO/TC59/SC13 BIM: Organization of information about construction works.
- ISO/TC184/SC4 STEP: Standards that describe and manage industrial product data throughout the life of the product.
- Open Geospatial Consortium: International not for profit organization committed to making quality open standards for the global geospatial community.
- buildingSMART: International organization which aims to improve the exchange of information between software applications used in the construction industry.
- EU BIM Task Group: It's aim is to bring together national efforts into a common and aligned European approach to develop a world-class digital construction sector.

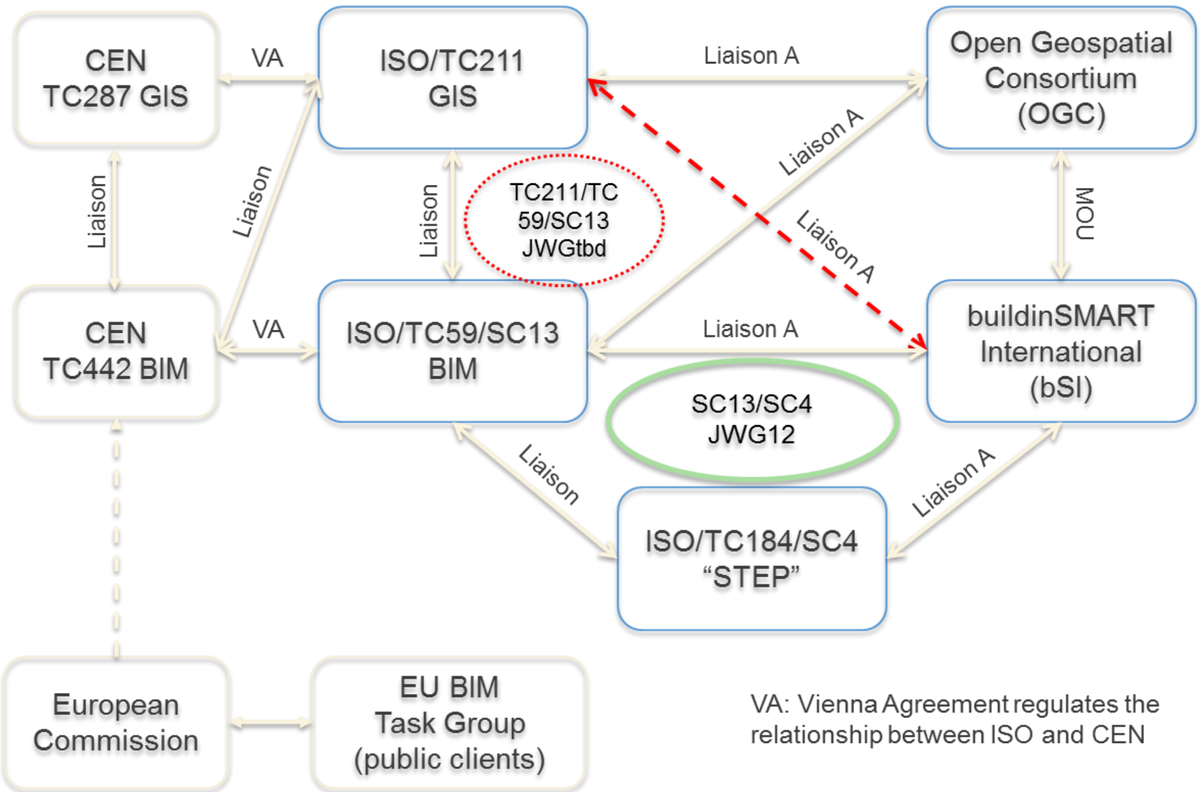

Figure 6: International BIM standardization

3.1 CEN TC442 Building Information Modelling (BIM)

Standardization in the field of structured semantic life-cycle information for the built environment. The committee will develop a structured set of standards, specifications and reports which specify methodologies to define, describe, exchange, monitor, record and securely handle asset data, semantics and processes with links to geospatial and other external data.

With the introduction of common standards and operating methods using BIM will:

- Reduce barriers to operation and trade across the European market area and beyond.
- Reduce both the capital and operating cost of construction assets.
- Improve the overall coordination of the constriction works and certainty of the construction output including increases in quality and reductions in defects.
- Improve resource efficiency of construction products and materials, improving both operating and embodied carbon performance.
- Support improvements in team working and collaboration.

Priorities of the technical committee are:

- Understand existing activities and standards in use within the European market.
- Adopt suitable standards and technical specifications from ISO and then extend to cover new areas including infrastructure as well as records management.
- Develop new standards to support process management and associated guidance, as well as standards to enable the representation of European sustainability standards in BIM.
- Develop relationships with key stakeholders including the European Commission.

3.1.1 Benefits expected from the work of the CEN TC442

The overall benefits of the work from CEN/TC 442 are through BIM to support the visions for sustainable growth based on better resource efficiency through data sharing in the construction industry in Europe.

- The benefits and opportunities of adopting BIM are summarized as follows:
- Increase the competitiveness of the European Construction sector (e.g. engineering firms, contractors, designers and product manufacturers) in their world-wide activities;
- Deliver efficiencies for client organizations regarding requirements of legacy systems;
- Facilitate the information exchange between client’s asset management systems and contractors/designers BIM systems thanks to interoperability;
- Deliver efficiencies for contractors and manufacturers through standardized product selection and ordering processes;
- Substantial reduction in cost and resources in the European Construction Industry
- European ICT support of increased sustainability and greenhouse-gas emission goals for the Construction Industry;
- Increased certainty for construction clients to achieve their built asset objectives and improvements in briefing as a result of improvements in post occupation evaluations;
- Provide a common understanding regarding the design of built environment between owners, operators and users, designers, contractors and manufacturers

of construction products, insurers for construction works, building and its operation;
- Facilitate the exchange of information about construction services between stakeholders;
- Facilitate the marketing and use of construction products and offsite assemblies;
- Provide a common basis for research and development in the construction sector;
- Allow the preparation of common design aids and software packages;
- Support the objectives of European Governments in achieving their targets for BIM adoption.

Data sharing is a complex process where effective rules and controls need to be defined to ensure secure and reliable transactions. This process is generically termed interoperability. "Interoperability" is an international programme in which Europe can take the following roles:

- Better "resource efficiency" (including cost and carbon) is a key area of European contribution and expertise;
- European contribution should focus on language and translation issues towards an open market, for construction products and services. Align with Roadmap (1.4)
- The creation of CEN/TC 442 has created a focus for national and international coordination and implementation of BIM.

The geometry part of BIM has reached a high maturity level, and its potential is understood. However, the full potential of BIM is far from being utilized since the information (data) part, interoperability and implementation (e.g. work flow) remain immature.

3.1.2 Defined objectives of the CEN TC442

The aim is to help the construction sector to be more efficient and sustainable by enabling a smooth and comprehensive information exchange and sharing between partners in the value chain.

The objectives of CEN/TC 442 are:

- To deliver a structured set of standards, specifications and reports which specify methodologies to define, describe, exchange, monitor, record and securely handle asset data, semantics and processes with links to geospatial and other related built environment data;
- Advise EU Commission and industry on policy for implementing BIM in Europe;
- To be the home for European BIM standardization. CEN/TC 442 shall support BIM coordination across relevant CEN/TC's. CEN/TC 442 shall consider New Work Item proposals to be developed in accordance with the Vienna agreement.

These objectives should support the work carried out by either other TCs or organizations dealing with standardization of products and systems or TC's dealing with specific construction topics (e.g. Eurocodes, acoustics, environment...). These objectives aim at providing methods and tools for taking into account and integrating the BIM needs related to their own domain. Therefore, CEN/TC 442 has to set up the conditions and methods for collaborating with the ad-hoc TC's and technical organizations. Reversely each TC in charge of either standardization of product and system or dealing with specific construction topics would take over and integrate these tools and methods to identify and provide directly the needed BIM elements related to its activity domain.

3.1.3 Interoperability

Interoperability is a characteristic of a computer system to work with other computer systems in either implementation or access without any restrictions. In BIM context, a supportive way of interoperability is machine readable information facilitating communication and collaboration. It is a basic requirement to allow interdisciplinary work in the construction industry. Without complete interoperability no benefit could be expected neither on the efficiency nor on the effective side of working together.

Beyond the ability of two or more computer systems to exchange information, semantic interoperability is the ability to automatically interpret the information exchanged meaningfully and accurately in order to produce useful results as defined by the end users of both systems. To achieve semantic interoperability, both sides must refer to a common information exchange reference model. The content of the information exchange requests are unambiguously defined: what is sent is the same as what is understood.

Beyond interoperability, cognitive computing allows to extend the efficiency of computer systems over the context of exchange information. Computer systems are able to learn, research, explore and optimize. In this context computer systems should be able to optimize buildings and infrastructure in a way, which will never be accessible to a human being.

Interoperability can be achieved without standardization but it conditions the project to agree on its own rules and deliveries. A high level of expertise and resources is required, and utilization of information in the construction life-cycle is not ensured. Efficient interoperability requires a set of standards and implementation. The three pillars of interoperability are:

- a standardized way to store and exchange data models and implement them in software
- packages;
- a common understanding of terminology and data-semantic structure;
- an agreed set of information delivery specifications for the information sender to support the processes of the information recipient.

An efficient object-based interoperability is conditioned by three sets of standards:

- Data Model standards to specify data structure for entities, geometry and related properties as well as classification for exchanging data models. The data model ensures exchange of object based information;
- Data Dictionary standards to specify data structure for defining data-semantic concepts (entity, property, classification...) and relations between them;
- Process standards to specify how to describe the required information supporting a given process.

Interoperability imply open standards.

3.1.4 Exchange Information - Enhance IFC standards

IFC (Industry Foundation Classes) is an international standard, EN ISO16739:2017- Industry Foundation Classes (IFC) - for data sharing in the construction and asset management industries. It specifies a conceptual data schema and an exchange file format for Building Information Model data. It represents an open international standard for BIM data that is exchanged and shared among software applications used by the various participants in a built environment construction or asset management project. buildingSMART International has the ownership for the IFC standard. ISO and buildingSMART International has signed a copyright agreement securing both organizations right to publish the standard.

In this context TC442 should:

- **Extend and develop standards for industrial assets and infrastructure**
  BIM extensions are requested, in particular regarding industrial assets and infrastructure. The description of the industrial process being already defined by ISO 15926 Industrial automation systems and integration -Integration of life-cycle data for process plants including oil and gas production facilities - ISO/TC 184/SC 4, a link between the two standards is required.
- **Extend and develop standards for geolocation of built assets**
  As built assets are always located in a geographical area, BIM should rely on the work already carried out and associated standards to tackle that purpose. This work will be carried out in close co-operation with ISO standards on BIM and CEN/TC 287 on geographic information.
- **INSPIRE directive**
  In order to avoid duplication of work or to embrace already existing work, and according to the INSPIRE Directive [Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community].
- **Support asset management**
  Collaborate with the organizations responsible for managing the built assets. Editing group to develop text
- **Support Record management**
  Record management on BIM's data is necessary. In practice, to be efficient, the BIM's data produced for a built asset shall be readable and useful during all the stages of the whole life cycle (from design, construction, operation, maintenance to deconstruction). This work is broader than BIM and relates to Long Term Record Management. It will be carried out in close co-operation with ISO standards in order to avoid duplication of work or to embrace already existing work.

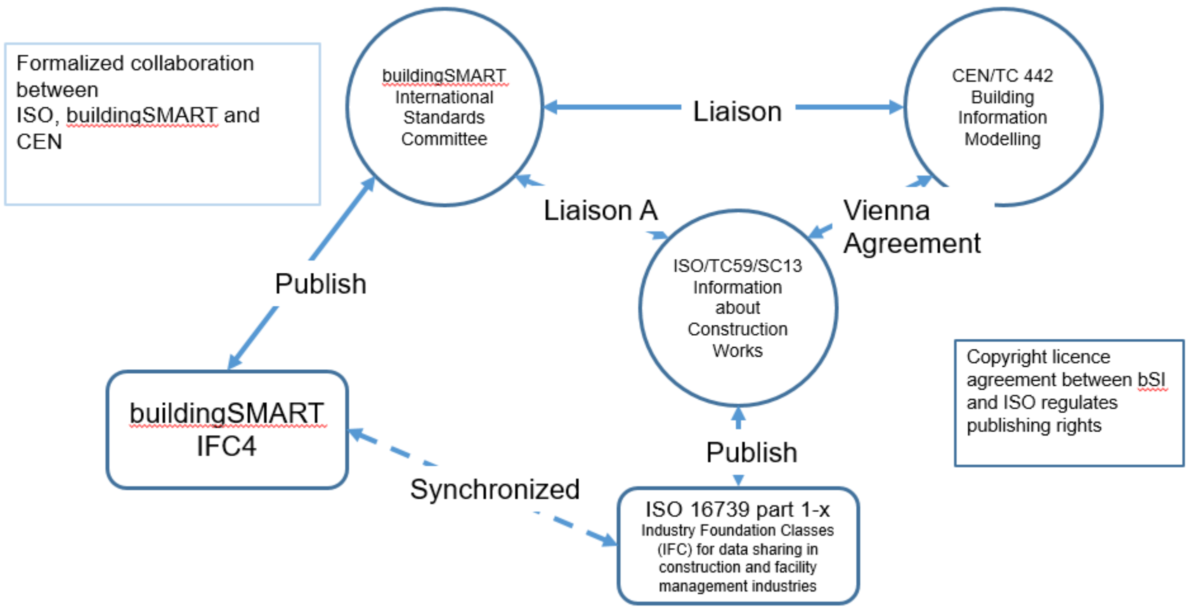

Figure 7: IFC development coordination

3.1.5 Information Delivery Specifications

ISO16739:2013 is an international standard for BIM data exchanged and shared among software applications used by the various participants in a built environment construction or asset management project. The content of the data exchanged is highly driven by the lifecycle stage, the involved disciplines and the level of development, or more generally speaking by the process.

Information Delivery Specifications should capture (and progressively integrate) construction processes whilst at the same time providing detailed specifications regarding the information that a user fulfilling a particular role would need to provide at a particular point within an assets lifecycle.

From the end-user point of view, this leads to the so-called Information Delivery Manual (IDM- EN ISO 20481:2017); from a BIM point of view, the associated description is called Model View Definition (MVD) defining a subset of the complete IFC model or equivalent, with strict specifications regarding the attribute description.

An Information Delivery Manual comprises the following:

- An interaction/transaction map and/or a process map
- Exchange requirement(s)

The interaction/transaction map defines the roles involved and the transactions between roles.

The process map shows the activities for each role and interactions/transactions between activities for different roles. A swim lane diagram is commonly used as a process map.

To achieve the BIM information highway, there are many IDM's and MVD's to be developed. MVD are not only required for a specific data exchange schema and for quality checks, but also having a solution that can be used as a master file that could be adapted on project level.

In this context TC442 should:

- Develop a framework for BIM Guidelines (see ISO 12911);
- Define current Use Cases;
- Support Energy Assessment for practical implementation of EN 15603;
- Support lifecycle cost estimation and assessment, in order to provide a practical implementation of CEN/TC 350 related standards
- Support asset Management and Operation, documentation of which is a common challenge in all projects;
- Support building Application, in which digital rules and processing can substantially improve both efficiency and quality of the industry interaction with Planning and Regulatory Authorities.

3.1.6 Data Dictionaries

EN ISO 12006-3:2016 – Organization of information about construction work – Part 3 Framework for object-oriented information is a standard for Data Dictionaries (EN ISO 12006-3). A Data Dictionary connects the entire world's domain terminology with internationally standardized and machine-readable concepts. Data Dictionaries can link together all existing and new databases and registries in the world. It provides the ability to search information from around the world with a standardized interface. Data dictionaries can be used both to secure unambiguous information flow with IFC files and in direct communication with databases without the use of the IFC model.

There are several areas of standardization and implementation of a European Data Dictionary:

- establish a European standard for the data structure of data dictionaries by adopting EN ISO 12006-3 as a European standard. Adoption of EN ISO 12006 does not include adoption any of the current implementations;
- produce standards for Product data templates based on CEN/CENELEC standards in an open European Data Dictionary, e.g. ISO 16757;
- produce an agreement for specific content of particular interest to the European market, expressed by the standard structure of EN ISO 12006-3 by developing high-value common European content and standard APIs;
- (potentially multiple) commercial implementations of a data dictionary server, using the standardized data structure of EN ISO 12006-3 and delivering the agreed content for the European market combined with services is out of scope of the CEN/TC 442.
- Guidelines ISO 16354 (Guidelines for knowledge libraries and object libraries)

In this context TC442 should:

- **European Data Dictionary and Application Programming Interfaces**
  The aim is to establish some common Data Dictionary content including definitions of entities and properties based on a common object classification in order to support the European market and sustainability. Common Data Dictionary content will act as the shared placeholder for national and regional context projects and make them generally accessible. An effective implementation of a link between a harmonized standard dictionary of concepts and IFCbased modelling will act as a unifying element for trade in national and regional projects. Production of standardized Application Programming Interfaces (API) for Data Dictionaries ensures that different context projects are related and accessible.
- **Harmonization of construction product properties**
  Regarding Product Dictionaries, the ISO standards define the framework. The current challenge is related to the number of product dictionaries and the need to avoid misunderstanding of attribute naming convention: same name but different meaning or values or same concept but different names and values. A standard is necessary to address the topic, e.g. ISO 16757.
- **Harmonization of European classification tables**
  Clarify the practice of classification (based on and according to ISO 12006-2) related to the existing standards like EN ISO 16739:2016 and EN ISO 12006-3:2016. The focus is on the mapping of national and international tables and not primary to establish a future European classification table.
- **Dictionaries and Object Libraries**
  Access to generic and product specific object libraries is a key for effective design and access to properties on available products. An Object Library is a structured set of digital objects (e.g. a door or a lighting fixture) which can both specify geometry, properties, classification and links to other documentation. An object library is established in a given data model.

The TC Work Items include:

- a standardized European Dictionary framework based on either common classification tables or national tables cross referenced according to the Data Dictionary framework standard;
- The standardization of rules for BIM object libraries makes it possible to use object libraries from all of the CEN countries regardless of local documentation

requirements. Object Library rules will be standardized with the use of Data Dictionaries and common rules and guidelines for modelling and documenting naming and properties.
- The standardization of rules for linking object type libraries and data dictionaries.

3.2 Environmental sustainability aspects

Construction Industry energy use represents about 40% of total energy consumption (Norwegian figures). A reduction of the Construction Industry's energy consumption and production waste is necessary to meet future emission goals. In addition, the UK "CarbonBuzz" project had identified a 30% performance gap between the design carbon performance of a project and it's "in use" performance. Key to the reduction of carbon emissions is the ability to perform complex performance analysis creates a potential to focus on environmentally low-impact design, construction, operation and demolition. Standardized handling of information can help predict environmental performance and thereby improve decision on impact from:

- construction (emissions, resource consumption and waste)
- operation (energy consumption, construction product life-cycle, maintenance)
- construction in local setting (transport, exchange of heat/cooling and electricity, shade, wind effect, water treatment)

Benefits:

- Better planning and design on energy and emissions;
- Coordination of domains during design and construction to reduce waste;
- Resource effective operation;
- Long-term BIM analysis of Cost and Resource;
- Documentation of Environmental Impact Values to elements of the Building Information Modelling;
- Performance measurement and feedback;
- Identification of reuse opportunities;
- Collaboration with environmental sector.

3.3 To standardize or not to standardize

A process is only successfully standardized if it is executed each time in a predefined (optimal) way by processing the same activities in the same order and producing exactly the same specified output. Standardisation of workflows is desirable within manufacturing and prefabrication industries where the same products are generated repetitively, however there is less clarity whether this definition is applicable to BIM processes within AEC industry.

However, the existence of the NBIMS and other similar standards worldwide is testament to the need to standardize what we in the AEC industry have been doing for centuries. The latitude those standards allow, and the lax enforcement of those standards from office to office testifies to the difficulty of setting standards for conveying information that everyone can live with all of the time. Hence, some prefer guidelines only.

Today the larger contracting companies employ standardized BIM-Manuals when procuring design services. They set out particular demands on BIM-Authors (the design team) categorised into general requirements and project-specific, and may include modelling guidelines pertaining to particular BIM-Uses which are desirable to be executed. The question here then is: what is within these so-called organisation-specific BIM-Manuals that may be standardized to the benefit of the wider industry?

Other studies consider the positioning and impact of a broad range of existing national BIM guideline documents and standards worldwide. Impact of discrete in-house BIM-Manuals which are emerging in Europe as a response to a lack of leadership in BIM adoption may have an adverse effect on the competitiveness. Furthermore, because many BIM practice procedures are hidden within organisation's discrete BIM-Manuals, with restricted audiences, we may run a real risk of developing a constellation of fragmented.

Many industry practitioners consider a lack of standards a major obstacle to the effective utilisation of ICT in construction. The same survey reveals Architects invest the most amongst consultants in BIM and drive comes mostly from enthusiastic individuals (bottom-up) as opposed to management (top-down).

4 Integration of BIM and GIS

There is an increasing interest in the integration of Building Information Modeling (BIM) and Geospatial Information Systems (GIS). A number of publications and projects showed promising results however, the ‘BIM people’ and the ‘GIS people’ still seem to live in different worlds. They use different technology, standards and syntax descriptions.

Previous attempts to integrate BIM and GIS seem to focus on either BIM or GIS. The two options seen so far are (1) integrating BIM data in the GIS world by using GIS technology, GIS standards and is done by ‘GIS people’ that look at buildings as information in a geospatial context. The other work we see (2) is done by ‘BIM people’ who are modelling advanced detailed 3D buildings with high semantics. They model more buildings including streets; terrain and maybe some underground piping and call this integration of GIS into BIM. Until today the two worlds do not really integrate.

BIM is seen as an essential data source for built environments by GIS users. GIS is seen as a crucial data source for design and integration of new BIM models in a spatial context. However, while these two worlds are interested in each other’s data, they do not seem to intent to switch in technology or work processes. We can see two different worlds that both try to import the other world into their own. Therefore we should aim to develop technology to integrate both worlds and create a synergy between the strong (technology) parts of both worlds.

4.1 Where BIM and GIS can learn from each other

The BIM world and GIS world are quite different. Both worlds have strengths, but both worlds also make progress and first steps in new technologies. A small comparison: The AEC/BIM sector makes intense use of 3D geometry modelled using Industry Foundation Classes (IFC). The ISO standard IFC has a strong focus on constructive solid geometry, boundary representation, Boolean operations and so on. The IFC modelled data are mostly file based and exchanged as files (as snapshots of a BIM) by project partners. IFC and BIM usually model buildings and structures above the ground. It is typically used for new buildings and structures. Important concepts in BIM models are the decomposition and specialisation of objects in the model. The relation between objects is of strong importance.

On the other hand, the GIS world has a server-focused approach. GIS data obviously have a strong focus on the geolocation (using real world coordinates). The relation between geospatial objects is based on the coordinates. The GIS modeller typically models existing data or policies. GIS is strong on 2D geometry and is just starting with 3D.

We believe the BIM and GIS world can create strong synergy. The server approach is getting more and more attention in the BIM world and BIM developers can learn a lot from the experience of the GIS developers. The 3D questions and issues discussed in the GIS world have well known solutions in the BIM world. The BIM and GIS users meet in several complex projects. Both worlds however, try to solve the planning questions by using their own technology and way of working. The development and growing use of both CityGML and BIM servers may create a breakthrough in the integration of the two worlds.

4.2 Integrating BIM and GIS

Integrating the two worlds should be done by using the strengths from both the BIM and GIS world in the context of the other. This could be done by using a central model server for BIM and intense semantics (specialisation, decomposition and relations) and 3D in GIS. To do this, IFC models have to be available online, using a central model server. We have decided to use the open source BIMserver during this project, because it is the only available open source software for this purpose. It also means that the IFC semantics and relations should be available in a GIS context. We have decided to use CityGML for this. It is not possible to integrate IFC semantics into CityGML by default. Therefore we use the extension mechanism for CityGML. A new CityGML extension will create the possibility to integrate IFC semantics and properties. The open source BIMsever will be able to export IFC data to CityGML, including the IFC geometry, but more important also the semantics and properties. We call the extension on CityGML for IFC data the 'GeoBIM' extension. Of course the integration of BIM and GIS is depending on the assumption that there will be applications from both domains, which can deal with this GeoBIM extension. With the development we will try to encourage discussion on this topic also on European level.

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List of abbreviations and definitions

API

Stands for Application Programming Interface. It is a standardized access point to information and relations in a data model.

Asset management

The profession and processes that includes multiple disciplines to ensure functionality during operation of the built environment by integrating people, place, process and technology. In a wider definition, it covers operations of built assets.

Building application

Covers both the process of and the actual application to local building authorities to get a permit to build and use a construction.

BIM - Building Information Modelling

Is an industry term that covers the sharing of structured information for Built Assets. "Sharing" requires consideration of processes and interoperability, "structured" requires the use of a common data schemas and "information" may depend on development of common terminology (CEN/BT/WG215, 2014).

BIM - Building Information Model

Can be visualized as a virtual geometrical representation of the real asset and can report object properties and relations. BIM gives an intuitive understanding of complex building information and support many digital tools for effective information handling (CEN/BT/WG215, 2014).

buildingSMART International

Is the International, open and non-for-profit organization that has developed and maintains the IFC standard. buildingSMART International develops actual implementation based on their standard and work together with the Industry to ensure implementation of Open BIM. buildingSMART International is formally recognized by ISO as organization in cooperation.

buildingSMART Data Dictionary

A specific Data Dictionary based on EN ISO 12006-3:2016 and is developed and maintained by buildingSMART International. ISO 12006-3:2016 specifies a language-independent information model which can be used for the development of dictionaries used to store or provide information about construction works. It enables classification systems, information models, object models and process models to be referenced from within a common framework.

Built asset

is used as a more general word than "building" to include buildings, infrastructure and their context such as industrial facilities, bridges, tunnels, earthworks, the surrounding terrain etc. In this document, building always means built asset.

Construction works

everything that is constructed or results from construction operations. This term covers both building and civil engineering works.

Data model

A specified set of entities and their related properties and attributes representing a virtual model of one or more domains structured by a modelling language. The buildingSMART Data Model is the same as the IFC data model.

Data dictionary

A data-semantic dictionary specifying concepts (entities, properties, classification and other concepts) and their relations. A data dictionary defines entities and properties uniquely, understandable and machine readable. It is possible to connect different data dictionaries and to harmonize the understanding of the content we want to share. Such a harmonized dictionary of properties could be used for an unambiguous information exchange either in direct communication with Data dictionaries or other exchange flows based on IFC.

Exchange requirement (ER)

Defined set of information units that needs to be exchanged to support a particular business requirement at a particular process phase (or phases)/stage (or stages). (EN ISO 29481-1:2016).

IFC

Stands for Industry Foundation Classes. It is a neutral data format to describe, exchange and share information typically used within the building and facility management industry sector. IFC is the international standard for openBIM and registered as EN ISO 16739:2016.

Information Delivery Manual (IDM)

Documentation which captures the business process and gives detailed specifications of the information that a user fulfilling a particular role would need to provide at a particular point within a project. (EN ISO 29481-1:2016).

Information Delivery Specification

The same as an IDM.

IDM components

Basic elements that form an IDM: Interaction maps/transaction maps, process maps and exchange requirements. (EN ISO 29481-1:2016).

Information unit

Individual information item, such as a window identifier or a room depth. (EN ISO 29481-1:2016).

Interaction map

Representation of the roles and transactions relevant for a defined purpose. (EN ISO 29481-1:2016).

Interaction framework

Formal description of the elements of interaction, including definitions of roles, transaction, messages in transaction, and data elements in messages. (EN ISO 29481-1:2016).

Life-cycle

Covers both the process perspective and the actual life span of a given physical structure. The lifecycle perspective focuses to improve the sum of performances of a physical structure in its various relation to e.g. function, people, environment and economy.

Model

Representation of a system that allows for investigation of the properties of the system. (EN ISO 29481-1:2016).

Model View Definition (MVD)

Computer-interpretable definition of an exchange requirement, specifically bound to one or more particular standard information schemas. (EN ISO 29481-1:2016).

Object

Part of the perceivable or conceivable world. (EN ISO 29481-1:2016).

Object library

A set of virtual objects representing a physical construction object. An Object Library can be generic and product specific.

openBIM

means the deployment of BIM based on open standards, not dependent on proprietary formats, allowing the separation of the information from the applications that manage it. In this document, BIM means always openBIM.

Property

A single characteristic of an object or system.

List of figures

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