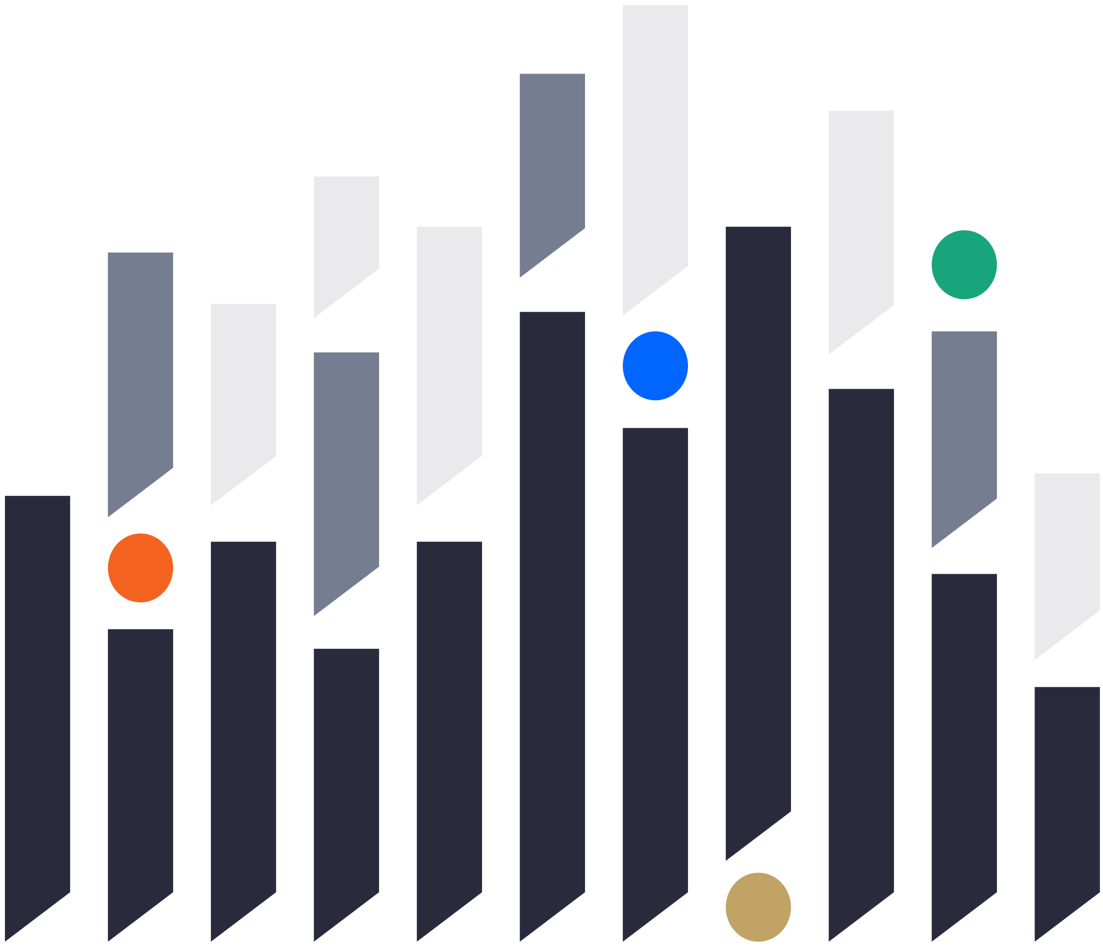
UNIVERSITY OF CAMBRIDGE
Centre for Digital Built Britain

CDBB L2C PROGRAMME

Standards landscape and information management systems



urban innovation labs

WP4: Comparison of COBie and IFC as information exchange structures today and in the future

V2.0 - Issued

Executive summary

Industry Foundation Classes (IFC) and the Construction, Operation and Building information exchange (COBie) have been shown to admirably achieve the function they are intended for, as described in their respective standards. This has been illustrated in the plethora of projects completed across a range of sectors around the world. This work package has shown that many of the issues reported, and the folklore that develops around this, is caused by a mixture of the following: asking for things that were not contemplated in the data structures, incorrect implementations, or the features being unavailable at this point in time. This has highlighted the need for training and awareness activities to continue, ensuring this basic capability is embedded throughout the supply chain and client base, along with demonstrators that can showcase what is possible to achieve. At the same time, it is important to recognise that if a market need for enhancements to the existing structures are required, these should be considered.

An appraisal framework has been developed that describes the 14 characteristics and capabilities a future data structure should demonstrate. This framework was tested with experts from the solution community including data scientists and vendors, alongside demand from service providers and commissioners of services. This framework and expert dialogue demonstrated the current methods are being pushed to the limit. The mission of CDBB is only likely to increase the pressure, as capabilities will be needed that are simply outside of the scope for which IFC and COBie were developed. These characteristics will need translating into requirements that should be included as a part of any future CDBB solution.

The expert panel discussion has highlighted the size of the CDBB mission and ambition for the market, and the impact the necessary changes will have at a human, technical and operational level. There are numerous sectoral legacy systems that are providing some of the functionality to support the outcomes that CDBB seek to address and these need to be part the landscape. Fundamental challenges around classification exist; for example: what do you call something that exists in a variety of sectors for different purposes and has different requirements? These all need to be resolved, but the message was very clear - focus on the points of interface and not try to re-define what already works.

The timescales involved prompted discussion about the essential role of Government for the programme, how that role must be non-partisan, and how it must provide long term commitment to the activities if the benefits are to be realised.

The market demand expert panel underlined the importance that both the private and public market need to own this; it cannot be something forced upon them by Government or owned by a Software vendor. At the same time, we need to be mindful that the market probably does not know exactly what it wants or needs. This reinforces the need for communities to be formed to support those who will implement and benefit from the advances, working at a variety of intra- and inter-sectoral levels, and focussed on achieving the impacts and outcomes.

There needs to be an overall architecture and concept for the realisation of the mission with a custodian. This architecture must extend beyond the technical aspects of integration and objects, and include the commercial, operational, service and social aspects. That said, there are some fundamental technical decisions to be taken about the end-state and how to reach it. This reinforced the need to do the following: develop a roadmap that may include enhancements for IFC, COBie and other products using these features; consider legacy systems across the sectors; and develop an understanding of what information is needed to achieve the socioeconomic outcomes.

The expert panels were keen to see the causal benefits being articulated, today with the Level 2 work, as well as the real possibilities that exist with the final state and how the steps of intermediate benefit could be released through implementation.

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1. Introduction

There are many actors in the market who have polarised views of the different approaches to the building information data structure. Ahead of the subsequent work by the CDBB, a position of understanding needs to be established. The purpose of this workstream is to provide an impartial and informed comparison of COBie and IFC, along with an assessment of the merits and challenges of both formats for the post BIM Level 2 activity.

2. Methodology

A literature review was be undertaken of the different data structures. It will describe why interoperability between systems is important to the built environment and outline the principles and approaches taken by Industry Foundation Classes (IFC) and the Construction Operations Building Information Exchange (COBie) to achieve interoperability. The application use cases for each exchange system will be described along with an overview of the key benefits and challenges faced by the market with each approach.

Two expert panels have been formed with a perspective from the market demand: commissioners of service providers and supply; and domain experts and technology providers. The expert panels were provided with a briefing document included in Appendix A and B for background, and participated in a round table discussion about the market needs, challenges and opportunities and how the information structure will help facilitate this.

3. Literature Review

3.1. Interoperability of building information

Interoperability is defined as the ability of computer systems or software to exchange and make use of information[1]. The built environment sector has struggled with the issue of interoperability since computer systems emerged in the industry due to a range of social and technical issues. Social issues are due to the reluctance of individuals to share individual or company knowledge, and actual or perceived contractual limitations. At the same time, the technical issues have accelerated as the complexity of the products and the functions they provide have advanced[2]. The cost of this lack of interoperability is reported to be as much as 1-2% of the construction industry budget[3] or as much as 3% of project budgets[4]. The economic imperative to increase market adoption of the different software tools is considered the greatest leaver for interoperability[5] across different sectors, and the built environment was no different.

Interoperability based on an open standard, whether a file-based exchange or a server-based data exchange, has many theoretical benefits. If a common open standard does not exist, each individual software application must develop and implement direct interfaces and translation to other software

[1] https://en.oxforddictionaries.com/definition/interoperability

[2] Bloor M, Owen J (1995). Product data exchange. UCL Press, London, pp. 262

[3] Gallaher M, O'Connor AC, Dettbarn J, Gilday L (2004). Cost analysis of inadequate interoperability in the US capital facilities industry. NIST GCR.

[4] Young NW, Jones SA, Bernstein HM, Gudgel J (2009). *The Business Value of BIM - Getting Building Information Modeling to the Bottom Line*. McGraw Hill Construction SmartMarket Report, pp. 52

[5] David P, Greenstein S (1990). The economics of compatibility standards: an introduction to recent research. *Economics of Innovation and New Technology*. Vol 1 (1), 3-41

products. If an open standard is used, the software product must map only to that open standard in order to interoperate with the functionality that standard affords. However, this does not mean that an open interoperable standard will support all the functionality of a given software product or tool chain.

3.2. Background to Industry Foundation Classes (IFC)

The Industry Foundation Class (IFC) initiative began in 1994 when Autodesk formed an industry consortium with 12 US companies. This subsequently expanded to other interested parties to develop a series of classes that could support data interoperability within construction. This consortium, originally called the Industry Alliance for Interoperability, has been known as buildingSMART since 2005, and acts to develop and maintain the IFC specification. In 2013, IFC was registered with the International Standardisation Organisation as: ISO16739 'Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries'.

The structure of the IFC[6][7] is defined in the adapted model[8] in Figure 1. It has four layers: domain, interoperability, core and resource. The layers are strictly defined and cascading, meaning they are independent and do not reference classes higher in the stack. The resource layer describes the resource schema containing definitions for describing the layers above. The core layer consists of the kernel and extension modules. The Kernel determines the model structure and decomposition, providing basic concepts regarding objects, relationships, type definitions, attributes and roles. Extensions are extended features or specialisations of classes defined in the Kernel. The interoperability layer provides the interface for domain models delivering an exchange mechanism for enabling interoperability across domains. The domain layer contains models for processes in specific fields or types of applications including architecture, structural engineering and MEP.

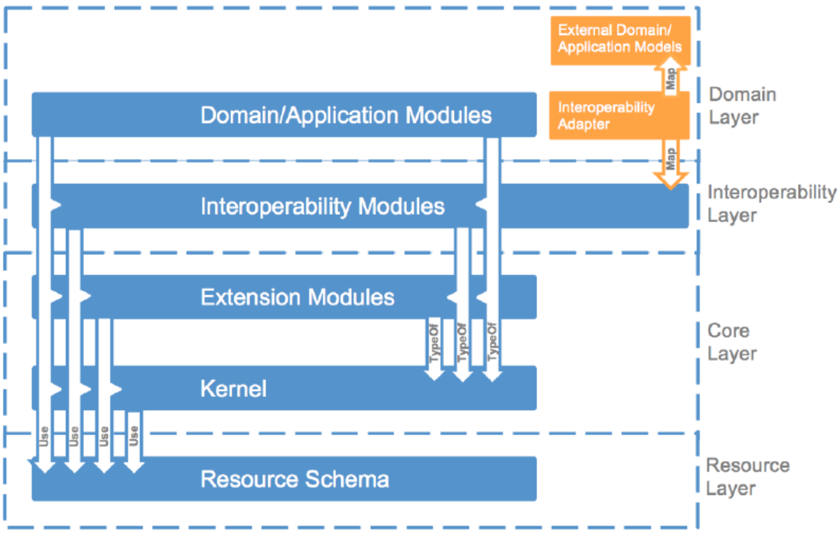


Figure 1 - Structure of the IFC data model

[6] IAI (1999b). IFC Object Model Architecture Guide. Ed. Liebich T and See R. International Alliance Of Interoperability (IAI). Specification Task Force, pp. 9

[7] IAI (2000). IFC Technical Guide - Enabling Interoperability in the AEC/FM Industry. Ed. Liebich T and Wix J. Modeling Support Group. International Alliance Of Interoperability (IAI), pp. 46

[8] Laakso, Mikael & Kiviniemi, Arto. (2012). The IFC Standard - A Review of History, Development, and Standardization. Electronic Journal of Information Technology in Construction. 17.

The IFC provides the 'guidelines' or 'rules' to determine what information is exchanged between applications while maintaining meaning. Although it may include geometry it is not limited to this; it presents tangible building components such as walls, doors and M&E, and also enables the linking of alphanumeric information to building objects (for example, properties, quantities or classifications) and maintains these relationships. IFC provides a set of definitions for the object's element types encountered in the building industry and a text-based structure for storing those definitions in a data file.

An IFC is an exchange definition as well as a schema. An IFC model contains both geometric and non-geometric data about the building project, while the schema defines an entity-relationship model based on 'EXPRESS'. The properties themselves have a specific structure. Properties are normally grouped in property sets or as a group of building elements and components that are working together, such as an electrical system or heating system. An IFC also defines relationships between the building elements. Some of the relationships are used to build the connections such as systems, types and property, whilst others define how the components are connected to become a building, or the information needed to complete tasks during build or operation.

This spatial data structure is shown in Figure 2.

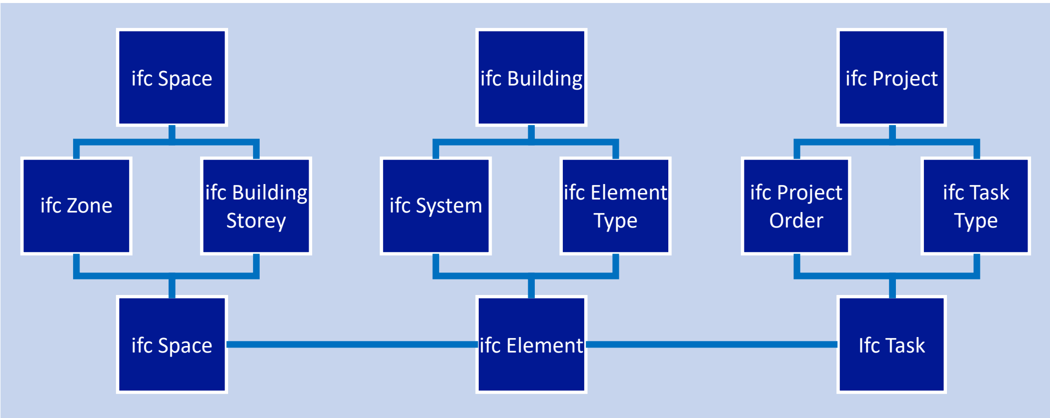


Figure 2 - Spatial data structure of IFC[9] (Reproduced image ©AEC3)

The premise of an IFC is to create a single model schema enabling any data to be exchanged between tools. This can viewed by different actors in the value chain in a unique way dependant on the information they require. These views are known as the Model View Definition (MVD). Common views are the coordination view to support clash detection, the space boundary to support thermal analysis, and the 2D annotation to generate floor plans. One such view is the Facility Management (FM) handover view known as COBie (Construction Operations Building information exchange).

IFC in its most basic form common form is a plain text ascii file. The schema defines how the plain text is used to create relationships and type inheritance. Even though the information is readable, it is the software applications that are the creators and consumers of the file contents. The format of the IFC

[9] © Nick Nesbit, AEC 3

file itself is based on an ISO standard (10303-21) called STEP-file. ifcXML and ifcOWL or the SDAI API are the alternative forms to aid machine-to-machine data exchange.

The IFC schema have been developed over a number of years, with IFC2X3 being the dominant version supported by broadest set of tools. The current IFC schema is IFC4 which extends support for geometries and parametrics, and has extended the building services and structural domains. The next release in its early stage of definition is IFC5, which will include infrastructure.

3.3. Background to the Construction Operations Building information exchange (COBie)

In June 2007, the US Army Corp issued a schema specification: 'Construction Operations Building Information Exchange (COBie) - Requirements Definition and Pilot Implementation Standard'[10]. In December 2011, the US National Institute of Building Sciences approved it as part of its National Building Information Model Standard (NBIMS). In September 2014, a code of practice was released in line with the British Standards Institute (BSI): BS1192-4 'Collaborative production of information Part 4: Fulfilling employer's information exchange requirements using COBie – Code of practice' which underpinned the UK Government's 2011 Construction Strategy[11] mandating the use of BIM on UK Government Departments on projects by 4th April 2016.

COBie is a standard for building data exchange, with its most common use in product data handover from construction to operations. The COBie standards do not dictate what information is required for a specific project handover - that responsibility still lies with the owner. The COBie data model is a subset or model view of the IFC. COBie is only concerned with the structure and format of the data, not the relationships between the data. Being a model view of IFC, COBie shares the data model with IFC. The most familiar format of COBie is the spreadsheet that is used for data collection and delivery.

One of the main principles of COBie is the data structure and hierarchy that details the relationship between components, systems and types with zone, space, floor and facility. This is shown in Figure 3.

10 Construction Operations Building Information Exchange (COBIE) - Requirements Definition and Pilot Implementation Standard ERDC/CERL TR-07-30, E.William East

11 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/61152/Government-Construction-Strategy_0.pdf

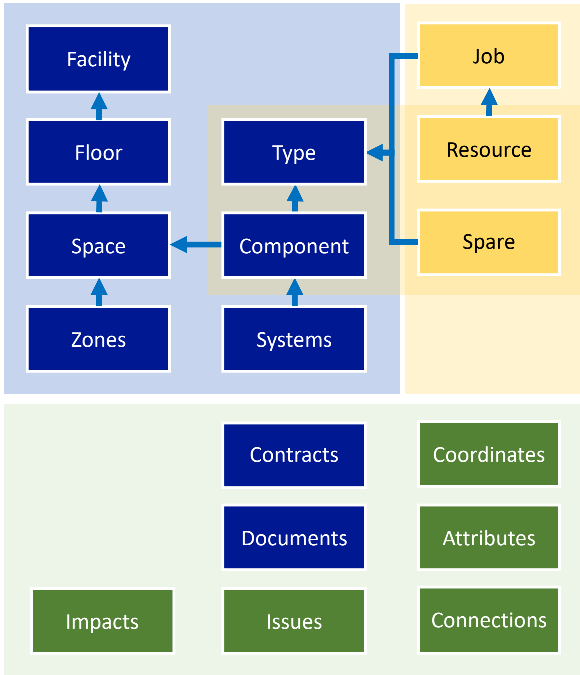


Figure 3 - COBie relationships

The Component is the central piece of the asset register. The owner needs to keep track of what equipment they have, who made and delivered it, when it needs maintenance, how to inspect it and a way to track the history of service requests and work orders. The owner needs to specify what items require management and maintenance and what information is needed for each component. The Type concept defines a component by their type or product category. Systems is a way to group equipment in a form that is commonly understood.

Spaces in COBie are similar to what we normally would call rooms. However, there are some deviations or additions, such as outside spaces. Also, where it makes sense from a management point of view, large rooms can be divided into multiple spaces. The space is key to COBie for two reasons. In itself, space objects are important for space management, tenant management, energy management and so on. In addition, spaces are important for locating equipment. All equipment should be tagged with the spaces from where you access them for operation or maintenance. Zones are space grouping and are quite flexible in use. They can be used to divide the facility into ventilation zones, access zones, rental zones and so on. Usually the use of zones is more prevalent after handover. An alternative to using the zone object is classifying spaces either using classification reference or by using custom properties, so you may not even use the zones during design and construction. Facilities are the buildings themselves. Important common information like units and phase goes here. Another purpose is to have a unique building for these spaces to belong to and for this equipment, when you merge COBie sheets and import into the CAFM system. Floors are a part of the building spatial structure and a way to group the spaces. They are important parts of supporting the location and grouping of spaces and equipment.

The Job, Resource and Spare are metadata that defines the components and collects the unstructured, non-standardized O&M data that normally is found in documents such as operating manuals, maintenance guides and spare parts lists.

The area highlighted as common items shows that all of this could be linked to items in any of the other COBie sheets or lists, such as a document is usually linked to a type, but it could also be more generic in nature such as describing a system or being relevant for the whole building. The most important sheets or item types here are contacts and documents. Contacts are people involved in the delivery of products and generators of information. Documents are primarily documentation about the delivered equipment. Attributes are a method to tag custom data to any item type to expand on the properties or columns that are included in the main sheet. These are similar to the properties in the IFC data model.

3.4. Classification

The built environment, like many other sectors, is classified to help organise information for a particular purpose. For example, a building owner could classify information for maintenance, development planning and cost estimate, while a contractor could classify construction management, scheduling and cost. The use of a classification system is a key foundation making navigation across datasets easier and more familiar. The main global classification systems are:

- MasterFormat: A master list for organising construction work results, requirements, products, and activities. Mostly used in bidding and specifications, MasterFormat originated in North America and is produced by the Construction Specifications Institute (CSI) and Construction Specifications Canada (CSC).
- UniFormat: For arranging construction information, organised around the physical parts of a facility known as functional elements, and mainly used for cost estimates. UniFormat originated in North America and is produced by the Construction Specifications Institute (CSI) and Construction Specifications Canada (CSC).
- Uniclass: For all aspects of the design and construction process. In particular, for organising library materials and structuring product literature and project information. Uniclass originated in the UK and is produced by the Construction Industry Project Information Committee (CPIC) and the National Building Specification (NBS).
- OmniClass: For the organisation, sorting, and retrieval of product information for all objects in the built environment in the project lifecycle. OmniClass originated in North America and is produced by the Construction Specifications Institute (CSI) and Construction Specifications Canada (CSC).
- 3451: Is based on Omniclass and developed for the Norwegian market.

In the UK, Uniclass[12] is prevalent, whilst in the US, Omniclass[13] is preferred and in Norway, the 3451[14] standard is most common. A comparison of the different classification systems[15] is shown in Table 1. With each community or country having its own preferred method, it is unlikely that there will be a unilateral decision to select a single classification system. The challenge recognised by the NIBS in the

[12] https://www.iso.org/standard/61753.html
[13] http://www.omniclass.org
[14] https://www.standard.no/fagomrader/bygg-anlegg-og-eiendom/ns-3420-/ns-3450----ns-3451---ns-3459-2/
[15] www.researchgate.net/publication/303484920_A_Comparison_of_Construction_Classification_Systems_Used_for_Classifying_Building_Product_Models

US[16] is the sector and the tool vendors, and one of completeness and interoperability between the different systems with an agreed and functioning mapping. MasterFormat and UniFormat are now unsupported, but still being used in the market and are consolidated within UniClass.

Classification system	OmniClass	MasterFormat	UniFormat	UniClass
Country of origin	North America	North America	North America	UK
Produced by	CSI & CSC	CSI & CSC	CSI & CSC	CPIc & NBS
Language	English	English	English	English
Purpose and properties	Organisation, sorting, and retrieval of product information for all objects in the built environment in the project lifecycle.	Master list for organising construction work results, requirements, products, and activities. Mostly used in bidding and specifications.	For arranging construction information, organised around the physical parts of a facility known as functional elements and mainly used for cost estimates.	For all aspects of the design and construction process. For organising library materials and structuring product literature and project information.
Framework	ISO 12006-2, ISO 12006-3 MasterFormat, UniFormat EPIC	Industry practice and gradual development	ISO 12006-2, Professional judgment	ISO 12006-2, SfB, CAWS, EPIC, CESMM
Grouping principle	Faceted	Hierarchical	Hierarchical	Faceted
Organisation and taxonomies	15 inter-related tables categorised by number and name. A combination of Table 21, Table 22, and Table 23 allows for classifying a product precisely.	One table with a series of six numbers and name: Level one with 50 divisions (2004 version) each is made up of level two, level three, and sometimes level four numbers and titles for more detailed areas of work results.	One table with alphanumeric designations and titles in five levels: level one is in nine categories separated by their special function. Level 2 separates them into constituent parts, level 3, 4, and 5 further subdivide them.	The division among facets is based on the alphabet in 11 tables and within each facet by decimal scale up to 6 digits.

Table 1 - Comparison of classification systems

3.5. When to use IFC and when to use COBie?

COBie is a subset of IFC and therefore an intrinsic association within the Model View Definition. IFC is normally created during the establishment of the geometric information about a building with the

[16] www.nibs.org

COBie data being supplied as a consequence of the development process, rather than as an exclusive process or activity. The choice about COBie or IFC depends on the purpose.

3.6. Experiences of using IFC and COBie

As with many sectors, the built environment BIM community is established, educated and rather communicative. There are numerous comments, opinions, assertions, frustrations and successes shared at conferences, through industry dialogue and using the various BIM forums such as NBS[17], areo blog[18], designing buildings[19], BSBIM[20], Bill East[21][22], practicalBIM[23] and B1M[24]. This section augments a selection of these sources, extracting the essence of the key positive and negative aspects for IFC in Table 2 and COBie in Table 3.

IFC	Comments
Positive	• Extracting a sub-set of the information for a specific task, for example, the structural information for structural calculations or a floor plan. • Data viewing for downstream activities such as facility management who may not need to modify the data. • Coordination, as clash detection is the static model geometry. • ISO standard exists.
Negative	• Parametric design information is lost. • Round tripping is still not supported, even though there have been big improvements in making IFC4 better at supporting parametric design and design transfer from one application to another.
Comments	• ifcIntrastructure not currently available and ifcBuilding is has been used for infrastructure projects. • There are reports of data loss when moving data from one authoring tool to another. This may because of the incorrect configuration of the tool sets or because of other causes that would need investigating.

Table 2 - Summary of market experience of IFC

17 https://www.thenbs.com/knowledge
18 http://blog.areo.io
19 https://www.designingbuildings.co.uk/wiki/
20 https://www.youtube.com/channel/UCOFrilMKDe1J8Z1mxxs_V1w
21 https://www.youtube.com/channel/UCOh7P2O-BE8ebEzN6i9w1Tw
22 https://www.prairieskyconsulting.com
23 http://practicalbim.blogspot.co.uk
24 https://www.theb1m.com

COBie	Comments
Positive	• COBie is endorsed by UK BIM Task Group and described in BS1192-4. • Provides the relevant information needed for handover. • Wide market adoption.
Negative	• Has a geometric sense of a design's core spaces, it does not contain the same geometric detail as a corresponding IFC. • Fixed number of levels of hierarchy is insufficient for a logical match at all levels of the many networks.
Comments	• Definition of floor and its analogue region, which could make its use for infrastructure possible.

Table 3 - Summary of market experience of COBie

The use of IFC and COBie within infrastructure has brought differing views to the surface. There are examples of where this has been successfully deployed using the existing definitions and features. Equally there are reports that challenges have arisen. These challenges may have come from incorrect tool configuration or may be genuine causes for concern.

3.7. Summary

Since their conception both IFC and its subset, COBie, have provided the data structure that underpins the BIM processes and helped transform how things are built. It is sometimes easy to forget the progress that has been made by what is considered a conservative industry in a relatively short time. Both data structures perform their best when they are used for the purpose they were intended, albeit both have their challenges that are being addressed through the ongoing updates based on industry feedback. Industry adoption and participation is high, with both systems being taught to build market capability and capacity.

4. Appraisal framework

The mission for the Centre for Digital Built Britain is 'to develop and demonstrate policy and practical insights that will enable the exploitation of new and emerging technologies, data and analytics to enhance the natural and built environment, thereby driving up commercial competitiveness and productivity, as well as citizen quality of life and well-being'. This is a far-reaching mission that will impact every asset, everywhere, and at any time.

This section, informed by industry, academia and Government input, will provide a perspective on what the mission scope means for a data structure, will evaluate IFC and COBie against that perspective, and synthesis the feedback.

The appraisal framework (shown in Table 4) was constructed building on the work of the BIM Task Group, the work of West[25], Robinson et al[26] and Nativi et al[27], and decomposing the characteristics of a data structure that would fulfil the mission of the Centre for Digital Built Britain. This will be used to appraise the relative merits of IFC and COBie, and be used to assess how actors in the service and social sectors value the characteristics. This table was refined during the expert panels to clarify terms.

Characteristic	Characteristic descriptions
Extensible	• Framework can be grown in the future to adapt to any object, anywhere and at any time.
Adoptable and Scalable	• The framework should not create barriers to entry, thus maximising the chance of adoption to critical mass. • Scalable, supporting industry wide adoption at all levels of the supply chain (millions of users conducting secure business critical transactions).
Universal	• Applies to whole asset life cycle and value chain: CapEx, OpEx, asset ownership and service delivery related markets for public and private sector clients based on a set of common standards. • Temporal factors are considered. • Functions in all geographic regions – natural and political regions.
Secure and Trusted	• Secure by design. • Trusted management of data for citizens, organisations and regulators to ensure the data can be used as part of a business ecosystem. • Allows commercially sensitive or security-related information to be protected and managed with trust and confidence. • Policies, standards and business models to ensure secure and trusted solutions.
Transactable	• The framework permits the automation of transactions throughout the lifecycle and value chain. • Recording of results and the decisions made based on them, explicitly linked to the data used to generate them.

25 West, Matthew. (2010). Developing High Quality Data Models

26 Robinson, Arbez, Birta, Tolk, and Wagner. (2015) Proceedings of the 2015 Winter Simulation Conference

27 Stefano Nativi, Paolo Mazzetti & Max Craglia (2017) A view-based model of data-cube to support big earth data systems interoperability, Big Earth Data, 1:1-2, 75-99,

Characteristic	Characteristic descriptions
Understandable	• The approach is to be presented in an unambiguous, specific and need to know manner, with an understandable learning package suitable for different types of government and private sector asset procurers, maintainers, operators, service providers and socioeconomic beneficiaries. • The approach can codify the standards, methods and rules in automated processes, removing the need for interpretation.
Non-proprietary and Open	• All requirements are non-proprietary as to applications and the required formats of the deliverables. • Interoperability of standards, protocols and tools to address the context of the control within the asset being monitored.
Verifiable and Validated	• All contractual expectations are documented with transparent and testable measurement of pass and fail. Contractual exchanges such as the agreement to provide a good or service or the actions required by a previously agreed contract (for example, payment, transfer of responsibility/ownership.)
Compliant	• Measurement of Regulatory/WLC/Carbon/Sustainability and so on is published to UK, EU and ISO standards. • Existing regulatory framework and segregation of responsibilities enables a collaborative and 'joined-up' approach to address whole-system problems. • Can be applied and adapted to reflect operational and regulatory requirements such as GDPR.
Governance	• An agile defined Governance process, roles, Terms of Reference and responsibilities exists for all aspects of the framework.
Industry Operating model	• Coherent approach to sharing data between organisations to provide insight into whole-system problems both intra-sector and inter-sector. • Supports adjacency: increasing levels of automation are supported by the information and control processes to achieve it. • Service portfolio supports new information services that can be integrated and can be dynamically called.
Performance	• The business outcome or performance of the action can be measured and linked in pseudo-real-time to auditable causal factors.
Data Model	• Structure and class of physical data models provide the underlying structure of data, from which queries are supported to provide information to the industry operating model. • An integration architecture exists to provide integration between any framework and any data model of any asset. • Reference Data or Master Data is founded on a suitable upper ontology and constructed to support distributed RDLs (reference data libraries). • Includes geospatial information regarding asset location, proximity and adjacency. • Process that allows integration and interaction with pseudo-real-time data sources (for example, Operational Data) and the sharing of data with adjacent areas, such as Geospatial, City Services, Transport, or Utilities. Different activities will require a different time response, by enlarge true real-time feedback is not necessarily needed, although it can be critical for specific infrastructure systems. • Integration of lifecycle stages for asset definition, delivery and operation encourages transition to an 'asset as service' or 'soft landings' model including operational data capture model. • The approach is agile and future proofed.
Quality	• Automated verification and validation of information quality, regulatory adherence and provenance. • Automated, rule based or guided definition of requirements and standards. • Integrates into overall business QMS.

Table 4 - Appraisal Framework

The assessment of each characteristic was be undertaken based on a qualitative assessment of the need for a future structure as shown in Table 5 and for the capability of IFC or COBie against the same criteria in Table 6. A quantitative appraisal would have been the preferred approach to this assessment, but time constraints prevented this. However, the experience of the expert panels assembled is such that even if the absolute value is not comparable, the trends of the assessment will be valid.

Rating	Description
0	Not required
1	Characteristic may be useful to the fulfilment of objectives
2	Characteristic helpful to the fulfilment of objectives
3	Characteristic necessary to the fulfilment of objectives
4	Characteristic essential to the fulfilment of objectives
n/a	Unable to comment

Table 5 - Rating for evaluation of need for future data structure to achieve mission of CDBB

Rating	Description
0	Does not meet the characteristic description
1	Achieves some of the characteristic description
2	Partially achieves the characteristic description
3	Achieves most of the characteristic description
4	Demonstrably achieves the characteristic description
n/a	Unable to comment

Table 6 - Rating for evaluation of IFC and COBie

5. Demand expert panel

Both expert panels were constructed by identifying experts in their respective fields with a recognised market knowledge. They are all actively engaged with the subject within their own organisations, and are contributing to the development of the subject on a national or international stage. A total of 12 participants were invited, including local Government, but the timescale and timing (being close to the year-end) proved to be problematic. That said, the participants detailed below have a breadth of experience greater than just their own organisation and current job title and were able to provide an excellent insight into what is needed. The demand expert panel consisted of:

Karen Alford: FCRM Manager, Environment Agency

Ross Denton: Head of Information Management, Crossrail

Andrew Cowell: past-President of BIM4Water, Director at Stantec Treatment

Doug Galloway: Head of Engineering, Power Systems, National Grid

James Heaton: PhD student UoC, previous Head of BIM, Highways England

Jennifer Schooling*: Director CISC, University of Cambridge

Jarmo Eskelinen*: CTO Future Cities Catapult, Member of SmartLondon Board, Vice-Chair Open and Agile Smart Cities, Chair IoT for Smart Cities and Communities Group for EU

Dan Palmer*: Head of Smart Cities, BSI

Simon Rawlinson*: Partner, Arcadis, former UK BIM Task Group and DBB member

Patrick Bossert*: Associate Partner, EY

** interviewed: not a direct participant in expert panel but views provided to expert panel*

The demand expert panel was structured around a series of questions developed to help identify the needs of commissioners of services and service providers for today and in the future. The questions were formulated based our professional judgement and understanding of the challenges of the domain, literature review and mission of CDBB. The expert panel was conducted in person and through telephone or face-to-face interviews when key participants were not available. The questions were:

Q1. What are the main challenges you believe society and industry face that should be addressed by better use of information about the built environment?

Q2. Do you believe these are or could be addressed (partially or fully) using current levers and mechanisms? If so, how?

Q3. If not, a) what needs doing, and b) what are the barriers from your perspective?

Q4. What role do you think the Government should play in this process?

Q5. What is the role of standards in this process?

Q6. To what level do you believe the standards should go? Strategy, i/o and quality, or specific step-by-step statements?

In addition, the expert panel responded to the appraisal framework design and assessment. The results of this activity are included in section 7.

5.1. Questions to the expert panel

This next section provides a summary of the discussions from each question.

5.1.1. What are the main challenges faced by society and industry that should be addressed by better use of information about the built environment?

The key points raised during this discussion were:

- There was full agreement that information should be an enabler to make the built environment deliver service and societal benefits.
- It was noted that we are using material at an unsustainable rate to build things without assessing how well they perform or whether they provide the function or service needed.
- There is visible waste and inefficiency throughout almost every system. Information could address many of the problems but it just seems "too difficult" to get those who need to participate in the solution to work together.
- The benefits of a future state need to be clearly articulated and at present they are not.
- There is a need for service providers and citizens to value and own their data.
- The service providers and those who represent the citizens need to be defining the 'what', rather than having technology companies taking over. This is not just an ICT or data problem, this is a mind shift in approaching what we actually want and need.
- The data is held in silos; this is limiting the lifecycle and system of system benefits.
- The mantra of 'give me your data and I'll make things better' has run its course and recent events about data misuse by large corporations will reduce trust.
- The size of the task to create a model or even a data model of everything was recognised as very large indeed. This is perhaps even too large or not necessary.
- Individual sectors or sub-sectors already have their own data landscapes that are functioning and the inertia to change from this state would be considerable.
- What actually needs to be shared in order to achieve the benefits? Is there a sub-set of information required at the boundaries, that can be defined using whatever language works for that group?
- The definition of the parts of the equation is not always understood: what is the supply, how much is really needed, is that available, and how is the system performing?
- Once people are brought into the equation, they process information and make decisions in a way different to a computer. To name just a few characteristics:, they have perception, bias, they can be irrational and change their minds. These aspects also need to be considered.

5.1.2. Are or could the challenges of society and industry be addressed (partially or fully) using current levers and mechanisms? If so, how?

The key points raised during this discussion were:

- The level of adoption of the current data exchange approaches is not uniform. This varies between the public and private sector and depends on where you are in the supply chain.

- (Further) policy and regulation changes are necessary to ensure what we have is used more widely.
- The adoption of Government online services has transformed the way many of our services are provided. A change was mandated, the route to the beneficiary (the Government) is clear; it simply works and there is no alternative.
- Data is present in a variety of forms and available to a range of users. The use cases for how it should be presented and who needs it for what purpose needs exploring.
- There are many pockets of excellence being established (or silos, depending on your perspective) but these are not always being used to full effect. For example, Crossrail have developed a new classification set for rail as part of their legacy mandate and HS2 are developing another.
- Both IFC structure has been used to interoperate measurement data, and COBie to signpost the associated data. This would allow performance to be assessed but the application level is not high.
- There is a need to leverage industry groups to ensure all of this work is utilised and built upon.
- The current levers are largely technical standards: a necessary foundation but not the whole solution.
- The current levers do not necessarily describe what the outcomes should be and how to describe what the outcomes should be in terms that allow all of the good work on the detail to tie-in.
- How decisions are being made is a key element to this challenge, and the role of the current approaches need to work with and inform the decision-making process.
- The consolidation of the geospatial, infrastructure and building information communities needs some work to ensure a shared objective can be achieved.

5.1.3. What needs to be addressed and what are the barriers in making better use of the current levers?

Many of the points to this question were inevitably covered in the previous section. The key points raised during this discussion were:

- A centralised view or architecture how all of this could and should work together.
- Examples and benefit cases to support adoption.
- Definition of outcomes and not just outputs.
- Have established decision-making frameworks.
- Incorporation of how people feel about a service.
- What is the asset whole life view of a decision and not just the immediate or CapEx perspective.
- Training to enable capability, at a level to be established.
- The promotion or problems and their associated data-driven solutions.
- The promotion of ‘problem eco-systems’ bringing relevant stakeholders, data sets and service providers together. Increased collaboration within sectors and across different sectors.
- The development of relevant standards to enable the convergence of problem eco-systems around common solutions.
- Data and information quality standards and a means of determining provenance.
- Common definitions, with industry names for the attributes at point of interface.

- This is a long game: greater than a company's annual accounting period, a service contract, a parliament or an investment period. There has to be a way of creating an entity that holds this vision and mandate, and has the ability to deliver this over a longer period.

5.1.4. What should the role be for Government?

The key points raised during this discussion were:

- To take a long view that is party agnostic, integrated across departments, that recognises the points of interface and takes into consideration the scope of CDBB.
- The discount rates used on strategic investment planning can be quite high which results in shorter payback period investments being prioritised. The vision of CDBB and the market needed is a long game and will need a different perspective.
- Market making, using its role as an asset owner and service provider to shape market responses to information-enabled data challenges. This could be achieved indirectly through regulation as well directly through executive action.
- Market enabling, promoting the use of data through the provision of more data sources, for example, along the lines of open-data London. This could include the provision of a security framework to ensure sensitive information is treated accordingly along with the source data.
- Direct investment in market intervention, for example, Standards development.
- Behavioural economics, 'nudging' users, providers and other stakeholders to change practice in line with policy outcomes.
- Define policy, define method of adherence: mandate, regulation etc, advocate and walk-the-talk on own works. Measure and hold to account.
- Integration of different strategies of construction, digital, communities and so on.
- Ensure the regulators are integrated in their approach and supportive of overall objectives.
- Taking a whole life view. We have great work done by the IPA, but the P is for projects and this is often felt in the approach taken.

5.1.5. What is the role of standards?

The key points raised during this discussion were:

- Fundamental foundations to ensure interoperability, integration and communication between parties working on the same physical or logical asset.
- There are different levels of standards and the most appropriate for the task should be selected, whether this is an ISO, CEN, BS, PAS, Guidance note or other.
- There are many standards and they can be difficult to use; it is not possible to easily apply at a service level or between silos.
- There are many sector specific technical standards that are not under the control of any NSB (National Standards Body). How these are considered or interfaced with in the future development should also be within scope.
- The panel noted they were unaware of any outcome or service based standards.
- The standards need to be relevant for what the people and industry need to do and how they underpin a personal or organisational objective.
- It is essential to have experts involved in the process with a sectoral and contextual perspective.

- The standards must not limit innovation, hold back growth or restrict interaction.

5.1.6. To what level of detail do you believe the standards should be defined?

The key points raised during this discussion were:

- It depends on what the standards are for. If it is detailed technical specification, it may be appropriate for definition at a bits and bytes level. If it is a strategic level, the outcomes and performance with interfaces and measurement of success may be appropriate.
- There was discussion that those involved in the development of a standard need to be clear to the purpose and have guidance from standards professionals on the best way of achieving this.
- It was questioned whether the existing guidelines for standards definition will produce the outcomes needed at a system and systems level.

5.1.7. What do the future data structures need to include to achieve the mission of CDBB?

The key points raised during this discussion were:

- Have a vision with a roadmap for development with the necessary governance.
- Focus on data exchange and interoperability.
- Be owned by the market and not by the IT vendors.
- Be curated and managed.
- Be discoverable for those that need it.
- Have provenance and trust.
- Be transferable to other sectors.
- Be scalable.
- Be open: to those who need access to particular information, not to all.
- Interface with legacy systems; there can be hard cut-over.

5.1.8. Commentary

The demand side expert panel provided very considered and insightful observations. Of all the comments summarised in the previous sections, the key ones that stand out are:

- There is a shared belief that information can play a role in achieving the needs of society, the economy and the vision of CDBB.
- People need to be at the heart of everything that is considered.
- The challenge needs to be owned by the market and not IT vendors.
- This is a long game and will need an implementation strategy that is owned by the beneficiaries across parliament terms, investment cycles and business reporting periods.
- The challenge will need curation to address across a wide community and CDBB is perfectly placed to achieve this.
- To create a new data model that will describe everything, anywhere, and at any time, is a big task.
- A roadmap with stepped improvements in bankable benefit will be needed.
- There are lots of existing systems that need to be considered as part of the future state.

- The performance of an asset in achieving the economic and societal goals is key.
- Describing what these assets do and what information is needed at an interface level with existing systems will be a necessary step.
- Standards are core to achieving the objectives.
- The existing solutions are very powerful and continued focus on embedding knowledge through training, case studies and proof of concepts is needed.

6. Solution expert panel

The solution expert panel consisted of experts who have been working with the challenges of information in the built environment for decades and, in many cases, are the forefathers of the methods, standards and processes that are deployed worldwide including IFC, COBie, 1192 and 18x. They bring with them detailed domain knowledge with practical experience of what works, what is challenge and a passion to make the future of information management a better place. The solution expert panel consisted of:

Dr Mark Bew: Chair of PCSG, Strategic Advisor to CDBB, previous Chair of BIM Task Group

Mervyn Richards: University of Reading, author of 1192:2 :4, member of the BIM Task Group

Nick Nesbitt*: Director AEC3, vice-chair of BuildingSmart International

Al Cook: CPNI, previous member of DBB phase

Julian Schwarzenbach: Director, DP Advantage

Nick Hutchinson: Managing Director, Glider BIM

Steve Rukuts: Technical Director, Glider BIM

Carl Collins: Consultant, CIBSE

Colin Nocetti: Senior Developer, Business Collaborator, GroupBC

Manuel Davila Delgado: Research Fellow, University of the West of England

Ioannis Brikalis: Academic Advisor for the Centre of Digital Built Britain

The solution expert panel was structured around a series of questions developed to help identify the performance of current data structures today and reflect on what is needed in the future. The questions were formulated based our professional judgement and understanding of the challenges of the domain, literature review and mission of CDBB. The expert panel was conducted in person and through telephone or face-to-face interviews when key participants were not available. The questions were:

Q1. What are your thoughts on data interoperability or integration?

Q2. What are the differences between IFC and COBie?

Q3. When would you use IFC or COBie?

Q4. What are the limitations of IFC and COBie?

Q5. Looking to the future, when we seek to take BIM to the services that have socioeconomic impact, what are the limitations or concerns about the current data structures and definitions?

Q6. What is the role of standards in this process?

Q7. What is the role of Government?

Q8. Comments to summary from the demand expert panel.

In addition, the expert panel responded to the appraisal framework design and assessment. The results of this activity are included in section 7.

6.1. Questions to the expert panel

This next section provides a summary of the discussions from each question.

6.1.1. What are your thoughts on data interoperability or integration?

The key points raised during this discussion were:

- Level 2 BIM focussed on the exchange of information between parties and generally involves a manual input. This is a method of interoperating between systems with a defined schema.
- Interoperability. Two (or more) systems are interoperable if they can share data in pre-defined ways. As a minimum they require interfaces over which they can exchange data.
- Integration. Two (or more) systems are integrated if they are combined in a way that they perform activities or actions as one. The interactions go well beyond data exchange and can encompass information operations that are automated, assured and also meet the needs of other integrated information systems that may require the information at different times, locations and in different contexts.
- Interoperability is the ability of two or more systems (or components) to exchange and subsequently use that information. Interoperability is concerned with the ability of systems to communicate. The interoperability between two systems could be fine, but whether the two systems as a whole actually performed any useful function would be irrelevant as far as the interoperability was concerned. Interoperability is therefore involved with the interfaces but not with whether the communicating systems as a whole behaves as specified.
- Integration is concerned with the process of combining components or sub-systems into an overall system to provide seamless functionality. This does not necessarily mean a single instance or solution, and nor should it: a federated solution is more likely to succeed.
- The expert panel suggested that even though an interoperable model may work beyond Level 2, it is more likely a federated integration model would be needed.

6.1.2. What are the differences between IFC and COBie?

The key points raised during this discussion were:

- The literature review gave a good overview, coupled with reference to the appropriate standards.
- COBie is a Model View Definition (MVD) of IFC and is commonly viewed as a spreadsheet (but other viewers are available).
- IFC has geometry and COBie does not.

- IFC has relationships between entities.

6.1.3. When should you use IFC and COBie?

The key points raised during this discussion were:

- It was accepted that there is a misunderstanding of what and when IFC or COBie should be used. This is causing problems for clients who wish to achieve something and are disappointed, and by the supply chain not having a uniform understanding of implementation.
- It was suggested that IFC is capable of providing a complete representation of the built environment and can include IoT or other sensor data.
- IFC to transfer geometric information that can be a file of an object (ifcOWL).
- COBie for exchanging a file base level of information during the design and build ahead of handover.
- There are proprietary products such as IBM Maximo that use COBie as their exchange format.
- Challenge with COBie is static and not being developed; a road map for enhancement would ensure further adoption and application.
-

6.1.4. What are the limitations of IFC and COBie?

There was agreement that the summary provided in Appendix B was an accurate of representation of the limitations. Additional explanations of key points raised during this discussion were:

- Both methods are designed to fulfil a particular need and application. If you use them for what was intended (see previous question) the limitations are minor or zero. If you use them for a purpose they were not intended, they naturally have limitations.
- There was an acknowledgement that many of the perceived limitation are caused by poor implementation of the solution. There is a need to ensure the training is in place to provide a base level of capability and sufficient references to demonstrate implementation.
- COBie: not suitable when geometric information is required or when the element relationships are needed.
- IFC: parametric information is lost during an IFC creation. Round tripping is not fully supported with the current level of IFC4.
- When fundamental deployment issues of either method are encountered, there needs to be a way of working with an expert team who can either debug or take that use-case into consideration for further development.
- COBie for exchanging a base level of information during the design and build ahead of handover.
- There are proprietary products such as IBM Maximo that use COBie as their exchange format.
- The use of COBie and IFC on infrastructure projects was discussed in detail. Both exchange structures have been successfully deployed on projects such as Crossrail and Highways England projects. This success has been achieved by expert application of the available features and in the absence of ifcInfrastructure or the use of COBie Region, for example, which would aid wider adoption but not limit application.

6.1.5. Looking to the future, when we seek to take BIM to the services that have socioeconomic impact, what are the limitations or concerns about the current data structures and definitions?

In each of the previous sections the discussion invariably shifted to the future. This section aims to captures those points and other specific points raised during this discussion:

- The ability to create a digital brief that draws regulations and guidelines that can be verified during design, build and operate would help close the loop between planning and outcomes.
- As we seek to measure impact, there needs to be a way of including measurement data with the other built environment information. There are ways of achieving this with both IFC and COBie today, but the discussion challenged whether this is a scalable or extensible solution.
- It was noted that a measurement occurs of an event; but is the target event (or brief) adequately described using existing methods?
- A key aspect of measuring a service or socioeconomic impact is the concept of time and how the outcome will change with respect to time. This leads to the requirement to have the ability to define state.
- To achieve the ambition of CDBB, it is essential to have the ability to transact information at an object level only with those parties who need to act upon it or receive only the information needed for a specific purpose.
- The Product Data Template is recognised being fairly generic and would benefit from being extended to be market specific.
- How to manage the requirements such as GDPR or other information privacy issues need to be addressed, especially if the social impacts are to be measured.
- The secure exchange of information by design rather than security mindedness needs to be established.

6.1.6. What is the role of standards in this process?

In each of the previous sections the discussion drew references to the standards today and possibilities in the future. This section aims to captures those points and specific points raised during this discussion:

- The expert panel was very supportive of standards and how they can be used to 'make markets', drive change and consolidate across large communities. It was seen that there is a role for CDBB in the definition of future standards, whether formal standards or guidelines are essential to achieving the mission.
- A PAS (Publicly Available Specification) is an excellent tool for the rapid consolidation of opinion, particularly in fast moving and innovative areas into a framework that can be tested before becoming a standard. It was noted that in hindsight 1192 should have been a PAS first and then taken to a British Standard. This was acknowledged by the whole expert panel.
- The purpose of the standards should be better defined to ensure that level instruction or definition is appropriate for the task in hand. For example, it was suggested that 1192:4 would have included guidance on the data schema implementation to ensure interpretation errors are minimised.
- The time taken to reach consensus to an ISO level was discussed and viewed as a potential limiting factor and that a faster method that kept the integrity of the solution will be necessary. The approach taken with the GSM standards and WC3 were cited as exemplars

where it was industry driven, supported by experts, had a road map for development and the elements necessary for integration were defined leaving the execution open for innovation.

6.1.7. What should be the role of Government?

The key points raised during this discussion were:

- The Government needs to understand this will be a long journey that will require cross-party support and implementation with follow-through of intra-Governmental department policy, with decisions being taken for the whole asset lifecycle.
- The creation of the CDBB is seen as a positive step.
- The Government should create policy to stimulate the market and protect citizens.
- Provide regulation that is underpinned and tested against an electronic brief and as-built information.

6.1.8. Comments to summary from demand expert group?

There was discussion around the key points from the demand expert group. There was a broad agreement with the points raised and an acknowledgment that the reasons for the changes need to be front and centre in the development, not sliding into a solution-based discussion. The key points raised during this discussion were:

- No one will ever need all of the information from everywhere at any time. The challenge should be to identify what is needed to respond to the question that underpins the service provided that yields positive socioeconomic impact.
- Agree that business cases and references are needed to demonstrate, probe and test.
- It is impossible to define the class of everything, and we need to focus on what needs defining to determine the outcomes.
- Is there a broader question to be answered about identifying and not just classifying?
- The challenge of legacy systems is understood, but there will probably need to be a migration path as part of the roadmap.
- We need to ensure that whatever structure is used takes the ultimate ambition into account, and that earlier decision-making does not preclude functionality.

6.1.9. Commentary

The supply side expert panel provided a deep level of understanding and were able to unpick the perceived complexities that may exist and what should be considered in the future. Of all the comments summarised in the previous sections, the key ones that stand out are:

- Interoperability is not a solution for the future; integration is necessary.
- Secure transaction for future applications will need objects to be used rather than files.
- It is not a question of IFC or COBie, it is a question of selecting the most appropriate view of the information for the purpose that is needed and remembering that COBie is an MVD of IFC.
- There is a misunderstanding of what IFC or COBIE can do by clients and a capability gap in the application of IFC and COBie. This would benefit from training, references and demonstrators.

- An international perspective on how other nations are using IFC and COBie would be an advantage as China and Korea are making headway with the implementation of IFC for infrastructure.
- The relationship with GIS information should also be considered.
- A roadmap for the continued development of IFC and COBie should be established as part of an integrated view of the future state.
- There are good examples of how IFC and COBie manage measurement, but ability of either to fulfil the measurement needs to determine service outcome or socioeconomic impact is worthy of further investigation.
- Select the correct standard instrument for the purpose intended. A PAS can be an expedient method of getting industry to work on a problem and test it at scale. As can the approach used with the GSM and W3C development.

7. Requirements of a future data structure

The qualitative assessment of the expert panels has been consolidated in the graph in Figure 4. This shows the different characteristics with the expected level of performance with the red triangles and the assessment of the ability of IFC and COBie to achieve these requirements in the yellow and blue bars respectively. A narrative to the graph is included in Table 7.

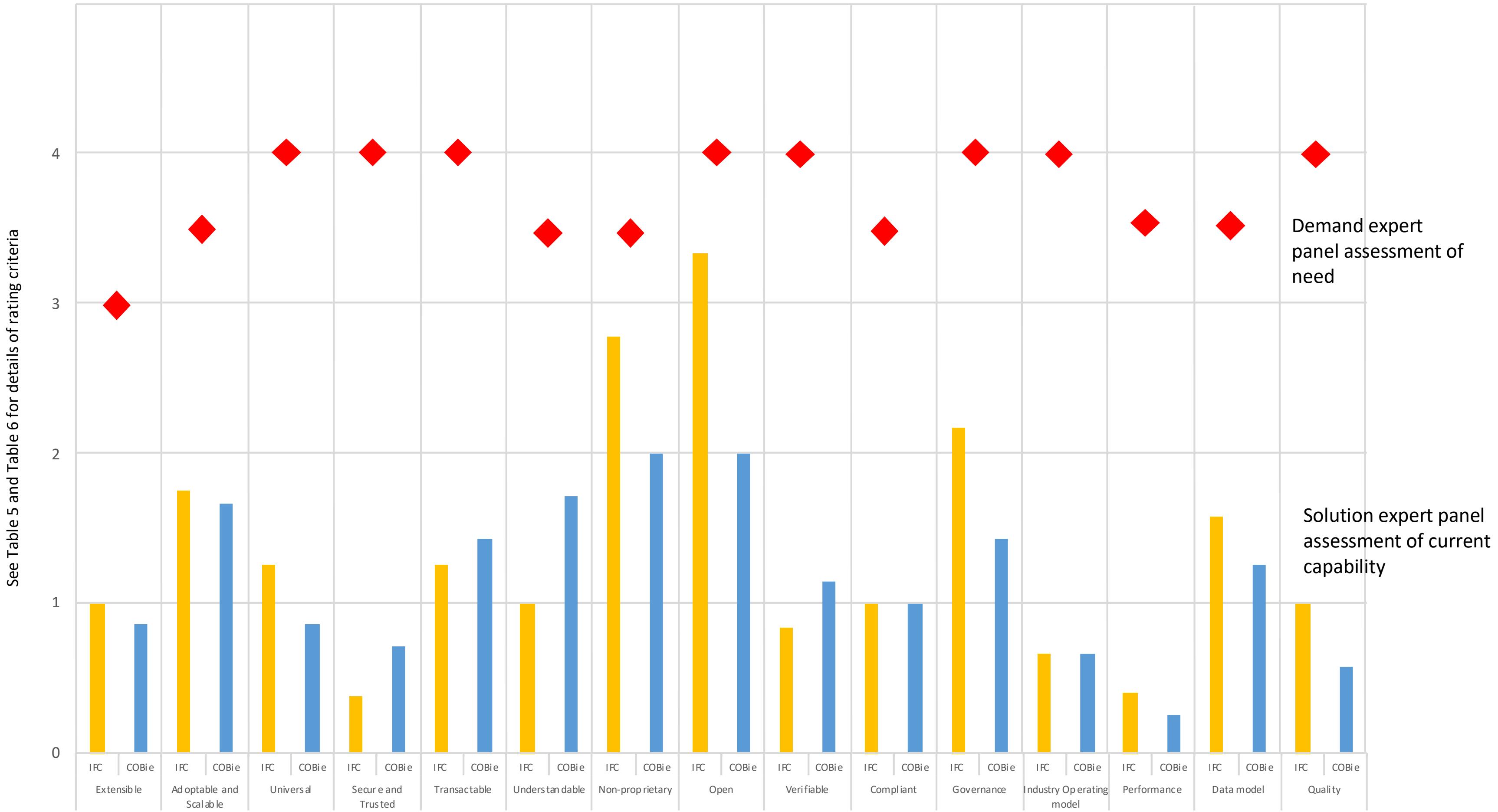


Figure 4 - Appraisal of desired characteristics of data structure and performance of state-of-the-art

Characteristic	Demand requirement	Current solution capability
Extensible	Essential as we develop the extent of the Asset Management process. We are just starting the journey and will only ever grow. Need to future proof the maturity of asset information journey: we don't know all the attributes and classifications we might need. Allow different software to interact,	IFC: not designed to be, but yes for the types of activities it is designed to be. IFC XML extends ability. Care to be taken user defined objects enables partial extensibility as many objects not included in language. COBie: limited potential but as designed. COBie XML extends ability. Could be improved by some minor changes. Easier to describe objects not included in IFC language but struggles with the boundary of objects.
Adoptable and Scalable	Must be easy to adopt and scale to the size of the ambition. Must encourage ease of adoption. We are on the first steps of the digital journey and it will only increase as people start seeing the benefit. Adoption across the sectors is key otherwise it will be wasted effort.	IFC: To author data/info you need to pay for an authoring application. Complexity and verbosity of the standard does create some barriers, not fit for client needs entirely or the trades. Underlying technology is old and not user friendly which limits adoptability. COBie: Restricted scope (no geometry, and so on) but can be free. Relatively rigid and unlikely to scale in the future without massive changes. Excel version makes it seem more user friendly.
Universal	Essential in connection sector and phases of asset lifecycle. Make sense and help to break the existing siloes that exist between designer, contractor and asset owner. Enable the link to other data sources that are relevant or influence the asset activities. 'Assembly' approach to facilitate more official performance management in the future.	IFC: you need to capture files which time stamp the whole volume scope. This has limitations. Mostly used for design and partially construction but not operations. No support from multiple states or temporal data. There is a claim that it does, with no evidence. There is evidence that it can't satisfy the need using proxy elements. Limited capabilities can be achieved. COBie: you need lots of files. Mostly used for design and partially construction but not operations. Needs extension and examples.
Secure and Trusted	Fundamental and without this the ambition will be limited. Transaction management versus information/data management. Relationship with ERP system to hold financial and contract data…	IFC: once you have the file you have all the data. The value strategy is utilised to support operator or service outcomes. Security constraints not inherently secure as is seen as a separate matter so far. No encryption. Unmanageable and security controls are absent from the model (and can't be added). IFC not designed to be secure. COBie: for simple exchange only. Measures can be employed to limit access to exchange data. Needs careful application to ensure security constraints are complied with.
Transactable	Avoid data duplication, thus more efficient and less errors. Automation of transactions is clearly a requirement and business driver. Provenance of information will be essential for this to work in practice.	IFC: no transition engine. All transactability is based on file based exchange using 1192/x and the CDE. Both IFC and COBie were conceived initially as solutions to the interoperability problem, hence they are advanced in the matter of transactions. They are still far from solving the whole problem. Transaction loops commonly lend to substantial information issues. No file version, no locking mechanism, no transaction status. COBie: both IFC and COBie were conceived initially as solutions to the interoperability problem, hence they are advanced in the matter of transactions. They are still far from solving the whole problem. Transaction loops commonly lend to substantial information issues. Only for the transaction for which it was defined but can't be automated.

Characteristic	Demand requirement	Current solution capability
Understandable	Essential for adoption. Some current approaches seen as too academic, for example, COBie, IFC. Same for all aspects of information management including classification.	IFC: a black box to most users. Both were originally conceived (wrongly) with direct user interaction in mind (recordable formats) rather than machine language. They should be encapsulated instead. Accessibility is difficult, and users of proprietary software just have to trust the result. If it works it is as a result of not having to understand it. COBie: some data may be readable in Excel. The wider view is that users will never have to understand this. Both were originally conceived (wrongly) with direct user interaction in mind (recordable formats) rather than machine language. They should be encapsulated instead too much effort to cater for anything more than a building.
Non-proprietary and Open	This is tough. How do we take out the commercial tension? Essential this is cracked otherwise the supply chain is either delayed or sub optimal return Open to who and make sure the security concept is considered.	IFC: all specs are publically available however questions round implementation. Yes, open and interoperable which is their perceived advantage. Yes, but interoperability of other standards has not been considered COBie: to be established in more detail. Round trips seem to be unreliable. Yes, open and interoperable, which is their perceived advantage. Hard to import and use despite being 'open'. FM software doesn't have a happy input process.
Verifiable and Validated	Essential for adoption and confidence. Automated verification and validation to the brief, standards and regulation would be very useful. Provide the facility for this characteristic but may depend on owner's business rule.	IFC: there is no validation in the current specification set. Yes minus the problems caused by transaction losses. Plus not all contractual data are included. No concept of digital AIR, no digital signature. COBie: there is a section on verifiability, validation and version, 1192/4. However, I haven't seen many people achieve it. It could be clearer. Yes, minus the problems caused by transaction losses. Plus, not all contractual data are included no digital signature.
Compliant	Essential for adoption and confidence. Terms of reference need to which compliance will be assessed and how this changes on the international scale.	IFC: As international standards, they are not used to comply with any one given standard. Rather they are open to being used in various national systems. Has never been a request. Documented mismatch of 'as designed' versus 'as used' performance. COBie: the variables if declared externality can be exchanged either as 'impacts' or 'documents'. As international standards, they are not used to comply with any one given standard. Rather they are open to being used in various national systems.
Governance	Essential for adoption and confidence. Will need to be integrated with business owners' processes.	IFC: there is a building smart certification process. It would appear to only be partially both standards have parents. The parents are active in monitoring the standards. Defined governance, it may be deficient but it's there and is providing a basis. COBie: 1192/x/4 provides a process but not a governance framework. It is expected that 9002 provides this. Both standards have parents. The parents are active in monitoring the standards what about who does what during OpEx? Fits with 1192 process and has a defined exchange role.
Industry Operating model	Essential for the terms of CDBB. Needs to include insight across the sectors.	IFC: the standards are not sector specific but are generic across sector. Neither standard has been particularly able to tackle this area in practice. The reason is largely the procurement models behind this. Only where there is absolute trust into the tools. COBie: Neither standard has been particularly able to tackle this area in practice. The reason is largely the procurement models behind this so constrained it

Characteristic	Demand requirement	Current solution capability
		could be used in basic format. Buildings only. Used only if client mandated.
Performance	Fundamental in achieving the goals of impacts, as the ability to measure is core.	IFC: out of scope, not directly. Indirectly through case studies . Can't deal with time., state, and so on. COBie: out of scope. Not directly. Indirectly through case studies. Absent.
Data model	A fundamental aspect. Consider the importance of data model flexibility for future proofing.	IFC: except via multiple files in the CDE. COBie: handles construction phase activities well.
Quality	Underpins all other factors.	IFC: very little and out of scope. Difficult linking an entity in the model to an external source that doesn't use the same object model. Data model provides a standard but no enforcement. If data is missing, how is that resolved? COBie: 1192 is based on being linked to ISO9001 framework. Often irrelevant. COBie checker too, not sure this links to QMS.

Table 7 - Narrative summary to support analysis

7.1. Commentary

The expert panels provided rich feedback on the subject matter, summarised in the graph in Figure 4 and the narrative in Table 7. This has supported the earlier literature review that explained that COBie is a model view of IFC and when either structure is used for the purpose they are intended, they are successful. In order to achieve the mission of CDBB, enhancements and changes to both IFC and COBie will help with their functionality and adoption. However, there are some fundamental aspects identified that neither IFC, nor by default COBie, have been designed or are being developed to support. With the exception of Non-proprietary and Open, the other criteria have all highlighted the need for functionality that is greater than is either understood or applied with the existing structures.

8. Conclusions and Recommendations

This workstream has described the IFC and COBie data structures, illustrating the commonality that exists when COBie is in fact a model view of an IFC for the purpose of handover to operations. It has shown that rather than it being a question of either/or, it is a decision to be taken about the purpose of the information being collected or shared and selecting the most appropriate method for the application. This has highlighted the need for a better level of understanding about IFC and COBie within the client base and supply chain, and to support this with training and case studies to ensure a capability exists with sufficient capacity.

The expert panel focussing on the demand from service operators, commissioners of services and city administrations gave a vital insight it how those involved in achieving the socioeconomic impact view the use of information to drive improvements. They are advocates of the use of information to drive better decision-making but urge caution about the magnitude of the task. They prompted for a better understanding of what information needs to be shared with the associated business cases.

The number of legacy systems, definitions and classifications also needs to be considered. With any thought of a 'big bang' change to a future state quickly dismissed, it is important to develop an understanding of a roadmap built on levels of capability that could be grown across the markets and within organisations. Any future development steps need to consider an appraisal of the characteristics of a future information structure, where all of the aspects identified are of high importance.

The expert panel focusing on the supply of the assets, data scientists and vendors, concurred with the description of IFC and COBie and recognised the boundaries of application and the challenges that arise. The panel reinforced the assessment that even though considerable progress has been made, this could be crystallised and embedded with training and demonstrators. The reported challenges around infrastructure, M&E and measurement were discussed in detail. Although the expert panel had confidence in their application of each area, there was a recognition that more work is needed to ensure this know-how is distributed. The appraisal of both IFC and COBie against the framework for characteristics of future data structures demonstrated that both approaches are excellent at doing what they have been designed for, but they will not be able to achieve all of the aspects that the demand expert identified as necessary.

Both expert panels recognised the importance of standards and therein the importance of the right strategy for the standard development and application. This would need to be followed by ensuring the standards are developed at a pace that will match the maturity of the aspect being standardised. They also recognised the key role that Government has in market making through policy, regulation and mandates.

The recommendations for the next steps with COBie and IFC are:

- Training: continue with support for training in the public and private sector.
- Awareness: provide case studies and demonstrators for new and difficult application such as infrastructure, M&E and measurement, and common challenges such as round tripping and data loss.
- Roadmap: the current data structures and legacy systems have a future and should continue to be developed as part of the development landscape to the future of CDBB. All of these aspects should be considered as part of an integrated roadmap for the centre.
- Features: functionality could be developed today, such as the creation of a digital brief and the validation of designs or operations against regulations. Other features using the existing data structures are undoubtedly possible and should be explored further.

Appendix A - Demand expert panel briefing pack

CDBB L2C PROGRAMME

Standards landscape and information management systems

WP4: Comparison of COBie and IFC as information exchange structures today and in the future

Delivering socio-economic outcomes through an information enabled built environment, today and in the future

Introduction

Thank you for agreeing to join us on the 27th March for what we hope will be a very informative workshop as part of the Centre for Digital Built Britain (CDBB) programme. This project is looking at the standards landscape and information management systems and we are delighted you will be supporting the workstream comparing the COBie and IFC exchange formats, their relative merits and areas for future consideration.

Joining instructions:

Date:	27th March 2018
Time:	9:00
Location:	IET London: Savoy Place, 2 Savoy Place, London WC2R OBL
Room:	Blumien Room, Ground Floor (ask at reception to be guided to the room)

If you have any questions before on the day, please contact Teresa Gonzalez Rico on 07487 780 543 or email tgr@uil.io

Purpose

The purpose of this paper is to set-out some background information to inform the discussion on Tuesday. We are seeking to describe an overview of the challenges faced by the market which are grounded in the reality and practicalities of real world experience. As clients, asset owners and managers, we are seeking to understand how you define the requirements for information.
This discussion, alongside other engagements with industry, academia and Government, will serve to ground the assessment of different data exchange systems that are currently available in the market. Looking to the future and the scope of the CDBB, an appraisal is made about the key issues – strategic, technical and cultural – to determine the suitability of these solutions and highlight other approaches that should be considered for further appraisal.

Introduction

The Centre for Digital Built Britain is a partnership between Government, academia and industry with the mission 'to develop and demonstrate policy and practical insights that will enable the exploitation of new and emerging technologies, data and analytics to enhance the natural and built environment, thereby driving up commercial competitiveness and productivity, as well as citizen quality of life and well-being'.

The Level 2 Convergence (L2C) programme is a component of that portfolio, that seeks to unify the siloed stakeholder groups and their information perspectives throughout the asset lifecycle building on the current approaches, standards and methodologies developed from the BIM Level 2 activities of the BIM Task Force, the Smart Cities work developed by DCLG/BEIS and City Standards Institute and the Interoperability standard developed by the Hypercat consortium with BSI. This will provide the bridge between existing Level 2 and the future Level 3 developments.

Standards are often interpreted in silos, due to their descriptive and technical nature. In the case of the L2C programme, one of the key success indicators is to develop a new suite of standards and guidance that will enable better information sharing across the built environment industry/sector silos. The purpose of this work is to identify the key information pathways across the lifecycle and how standards (current or new) support this now and in the future.

State of play

Almost all economic and social activities rely on the built environment to take place. The number of activities and processed linked to it are more and more reliant on information about its performance, user preference, environmental conditions, adjacent systems and activities. However, without a common approach to creating, storing, sharing and using data of the built environment we are unable to truly achieve higher levels of optimisation for our assets. Digital information about our assets, and the ability to use this information across the lifecycle is essential to enable the socio-economic outcomes that we seek to achieve while still increasing productivity and ensuring the right level of service provision to meet the needs of people.

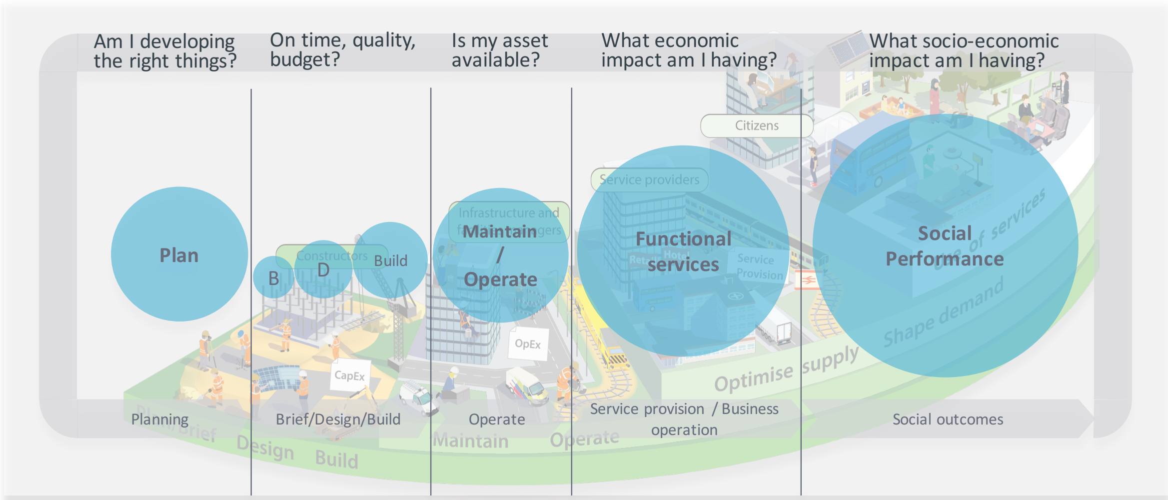
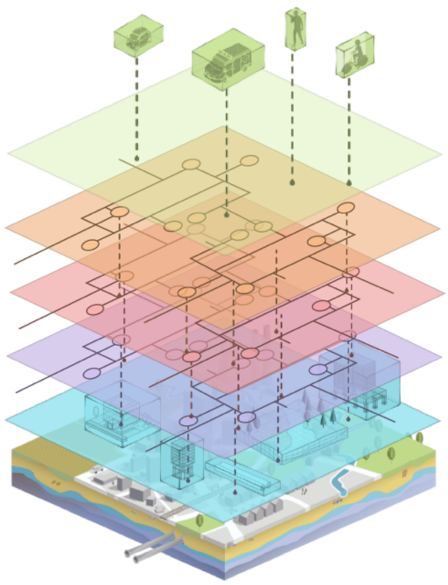


Figure 5: Asset lifecycle

Significant work has been developed to create the standards and industry best practice that underpin information of the asset for the purpose of construction, asset management or city planning. However, the way in which the information is described in these worlds is not always interoperable, and the data models used are not able to capture different descriptions and functions of the same data object.

The UK does not optimise the value from existing and planned built and natural environment assets throughout their full lifecycle. Addressing this issue is essential to secure the greatest value from these assets if the economic growth and needs of citizens are to be met at an acceptable cost. A data model that is scalable from the home level to the city level is necessary to be able to access the information at different levels of scale and enable better decisions with the right information. Scalability and access to right information is essential, and especially useful when making strategic decisions at regional or national level. However, scalability is not useful if the information is not discoverable, retrievable and useful bearing in mind that the information might be needed for a purpose different to that intended when the information was created.

The increase of available data in the built environment provides an opportunity to optimise the use of assets and the consumption of services. However, there is no effective market for usage of built environment data to support asset optimisation. Current data management practices and information systems are not robust enough to back the growth in this market. Data is not interoperable, it cannot be usefully used alongside other data sets, and there are no set rules for how to define data. The description of these data models is essential to get information flowing.



Unless very significant changes are introduced to information management practices, opportunities to capitalise on the developments in digital design, asset management and artificial intelligence, Smart Cities and the Internet of Things (IoT) will not be exploited. All these developments have extensive applications across all service systems, and most of these systems rely on the built environment to deliver.

Creating data about assets is not the only challenge. More and more, clients are specifying BIM level 2, or even BIM level 3, for their projects, sometimes without clarity of why. It has never been more important to be an intelligent client. When the rate of information creation is as high, understanding what information is needed and why is paramount. Clients, whether they are private developers, central government or local authorities, need to understand how their organisational goals and requirements translate to performance and outcomes and consequently, define information requirements. Information driven decisions are only as good as the frameworks that organisations assemble to qualify, measure and interpret the information.

Within the construction industry, a large amount of data is created for the purpose of building assets. However, this data is used once, archived, and then hardly ever used again. This poses a real challenge as the potential value of the data that is created is never fully realised. While BIM has supported the construction industry to deliver faster and better, the latent value residing in the digital description of the asset is not realised throughout the lifecycle. The solution to this challenge needs to take into account both sides of the market, client and suppliers, when defining the data structures and guidance to specify the right information requirement that suppliers can deliver against.

The challenge

In defining the data structure for such a complex system of systems, it is important to find consensus in how this information is captured and communicated.

In order to ensure that the solution developed is fit for purpose and capable of delivering the right information to the right user it is important to be able to describe the capability, capacity, state and level of service that we require to deliver a service. This in turn enables a shift in thinking about assets; from a set of specifications about materials to a system that delivers an agreed performance, and that does so with the integration of technology which can measure activity.

During the session, we will pose a number of questions to explore the following topics:

- The role of asset information in the context of challenges such as environmental impact and climate change, social equality, digitization of legacy infrastructure and outdated governance systems.
- The role of government, academia, industry and quango organisations to support the vision of the CDBB
- What should we expect from the standards and guidance landscape and what is the role of the client when setting standards
- Incentives for a lifecycle approach to information management. What will be the biggest challenges for this industry change management programme?
- Requirements for a data exchange system that cater for the needs of the DBB agenda. How do clients future proof their data needs when it comes to extensibility, scalability, transactability or security? What importance is placed in adoptability, compliance or governance?

We encourage you to take a look at the questions in Appendix A and spend a few minutes answering them. These will form the basis for an open discussion during the upcoming session.

Appendix A - Workshop questions

The session will pose several questions for discuss and to aid your preparation for the event these are listed below. We will not get chance to cover all topics, but if you would like to provide written responses to aid our research it would be appreciated:

Part 1 - General

Q1) What are the main challenges you believe society and industry face that should be addressed by better use of information about the built environment?

Q2) Do you believe these are or could be addressed (partially or fully) using current levers and mechanisms, if so how?

Q3) If not, what a) what needs doing, and b) what are the barriers from your perspective?

Q4) What role do you think the Government should play in this process?

Q5) What is the role of standards in this process?

Q6) To what level do you believe the standards should go? Strategy, i/o and quality, or specific step-by-step statements?

Q7) To achieve the mission of CDBB, what do you believe the future information and data structures need to address?

Part 2 – COBie and IFC (these were asked of technical experts, and we are happy to get your input if you have particular expertise on these – however, they will not be discussed in the session).

Q8) What are your thoughts on data interoperability or integration?

Q9) From your perspective what is the difference between COBie and IFC?

Q10) When would you use COBie or IFC?

Q11) What are the limitations of each data structure and can you give example of the limitations?

Q12) Looking to the future of BIM, when we seek to properly include O&M and take BIM to the services that have socioeconomic impact, what are the limitations or concerns about the current data structures and definitions?

And finally ….anything else about the data structure and the use of the data about buildings and infrastructure you would like to add?

Appendix B - Solution expert panel briefing pack

CDBB L2C PROGRAMME

Standards landscape and information management systems

WP4: Comparison of COBie and IFC as information exchange structures today and in the future

Comparison of COBie and IFC as information exchange structures today and in the future

V1.4

Introduction

Thank you for agreeing to join us on the 27th March for what we hope will be a very informative workshop as part of the Centre for Digital Built Britain (CDBB) programme. This project is looking at the standards landscape and information management systems and we are delighted you will be supporting the workstream comparing the COBie and IFC exchange formats, their relative merits and areas for future consideration.

Joining instructions:

Date:	27th March 2018
Time:	13:00
Location:	IET London: Savoy Place, 2 Savoy Place, London WC2R OBL
Room:	Blumien Room, Ground Floor (ask at reception to be guided to the room)

If you have any questions before on the day, please contact Teresa Gonzalez Rico on 07487 780 543 or email tgr@uil.io

Purpose

The purpose of this paper is to set-out some background information to inform the discussion on Tuesday. It will describe why interoperability between systems is important to the built environment and outline the principles and approaches taken by Industry Foundation Classes (IFC) and Construction Operations Building Information Exchange (COBie) to achieve interoperability. The application use cases for each exchange system will be described along with an overview of the key benefits and challenges faced by the market with each approach. Looking to the future and the scope of the CDBB, an appraisal is made about the key issues to determine suitability of these methods and highlight other approaches that should be considered for further appraisal. This is all augmented with the results from a number of industry, academia and Government round tables to debate the subject.

Interoperability of building information

Interoperability is defined as the ability of computer systems or software to exchange and make use of information[28]. The built environment sector has struggled with the issue of interoperability since computer systems emerged in the industry due to a range of social and technical issues. Social issues due to the reluctance of individuals to share individual or company knowledge and actual or perceived contractual limitations. Whilst the technical issues have accelerated as the complexity of the products and the functions they provide have advanced[29]. The cost of this lack of interoperability is reported to be as much as 1-2% of the construction industry budget[30] or as much as 3% of project budgets[31]. The economic imperative to increase market adoption of the different software tools is considered the greatest leaver for interoperability[32] across different sectors and the built environment was no different.

Interoperability based on an open standard, whether a file-based exchange or a server-based data exchange, has many theoretical benefits. If a common open standard does not exist, each individual software application must develop and implement direct interfaces and translation to other software product. If an open standard is used the software product must only map to that open standard in order to interoperate with the functionality that standard affords. This does not mean that an open interoperable standard will support all the functionality of a given software product or tool chain.

Background to Industry Foundation Classes (IFC)

The Industry Foundation Class (IFC) initiative began in 1994 when Autodesk formed an industry consortium with 12 US companies, that subsequently expanded to other interested parties, to develop a series of classes that could support data interoperability within construction. This consortium originally called the Industry Alliance for Interoperability, since 2005 is known as buildingSMART, who develop and maintain the IFC specification. In 2013 IFC was registered with the International

[28] https://en.oxforddictionaries.com/definition/interoperability

[29] Bloor M, Owen J (1995). Product data exchange. UCL Press, London, pp. 262

[30] Gallaher M, O'Connor AC, Dettbarn J, Gilday L (2004). Cost analysis of inadequate interoperability in the US capital facilities industry. NIST GCR.

[31] Young NW, Jones SA, Bernstein HM, Gudgel J (2009). *The Business Value of BIM - Getting Building Information Modeling to the Bottom Line*. McGraw Hill Construction SmartMarket Report, pp. 52

[32] David P, Greenstein S (1990). The economics of compatibility standards: an introduction to recent research. *Economics of Innovation and New Technology*. Vol 1 (1), 3-41

Standardisation Organisation as ISO16739 'Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries'.

The structure of the IFC[33][34] is defined the adapted model[35] in Figure 1, it has four layers: domain, interoperability, core and resource. The layers are strictly defined and cascading, meaning they are independent and not reference classes higher in the stack. The resource layer describes the resource schema containing definitions for describing the layers above. The core layer consists of the kernel and extension modules. The kernel determines the model structure and decomposition, providing basic concepts regarding objects, relationships, type definitions, attributes and roles. Extensions are extended features or specialisations of classes defined in the Kernel. The interoperability layer provides the interface for domain models providing an exchange mechanism for enabling interoperability across domains. The domain layer contains domain models for processes in specific domains or types of applications including architecture, structural engineering and MEP.

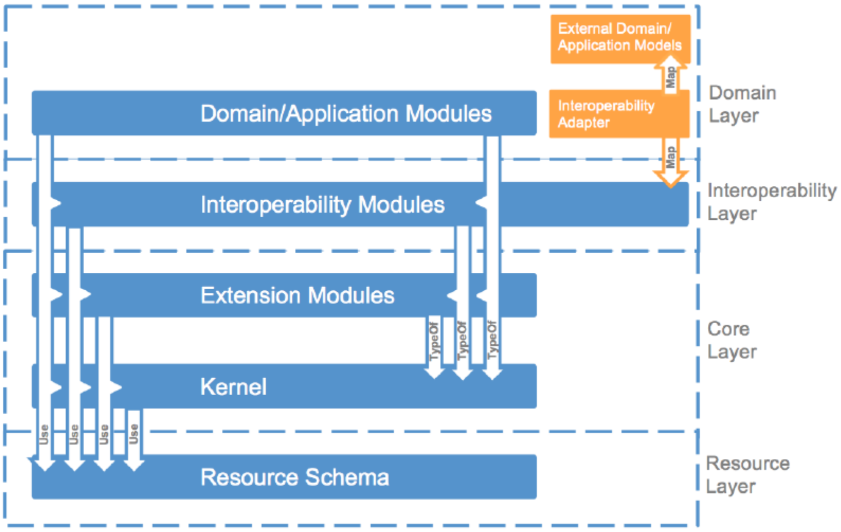


Figure 6 - Structure of the IFC data model

provides the 'guidelines' or 'rules' to determine what information is exchanged between applications while maintaining meaning. Although it may include geometry, it is not limited to this; it presents tangible building components such as walls, doors and M&E, and also enables the linking of alphanumeric information (properties, quantities, classification, etc.) to building objects and maintaining these relationships. IFC provides a set of definitions for objects element types encountered in the building industry and a text-based structure for storing those definitions in a data file.

An IFC is an exchange definition as well as a schema. An IFC model containing geometric, non-geometric data about the building project. The schema defines an entity-relationship model based on 'EXPRESS'. The properties themselves has a specific structure. Properties are normally grouped in

33 IAI (1999b). IFC Object Model Architecture Guide. Ed. Liebich T and See R. International Alliance Of Interoperability (IAI). Specification Task Force, pp. 9

34 IAI (2000). IFC Technical Guide - Enabling Interoperability in the AEC/FM Industry. Ed. Liebich T and Wix J. Modeling Support Group. International Alliance Of Interoperability (IAI), pp. 46

35 Laakso, Mikael & Kiviniemi, Arto. (2012). The IFC Standard - A Review of History, Development, and Standardization. Electronic Journal of Information Technology in Construction. 17.

property sets or as a group of building elements and components that are working together such as an electrical system or heating system. The IFC also defines relationships between the building elements. Some of the relationships are used to build the connections such as systems, types and property, whilst others define how the components are connected to become a building, or information needed to complete tasks during build or operation.

This spatial data structure is shown in Figure 2.

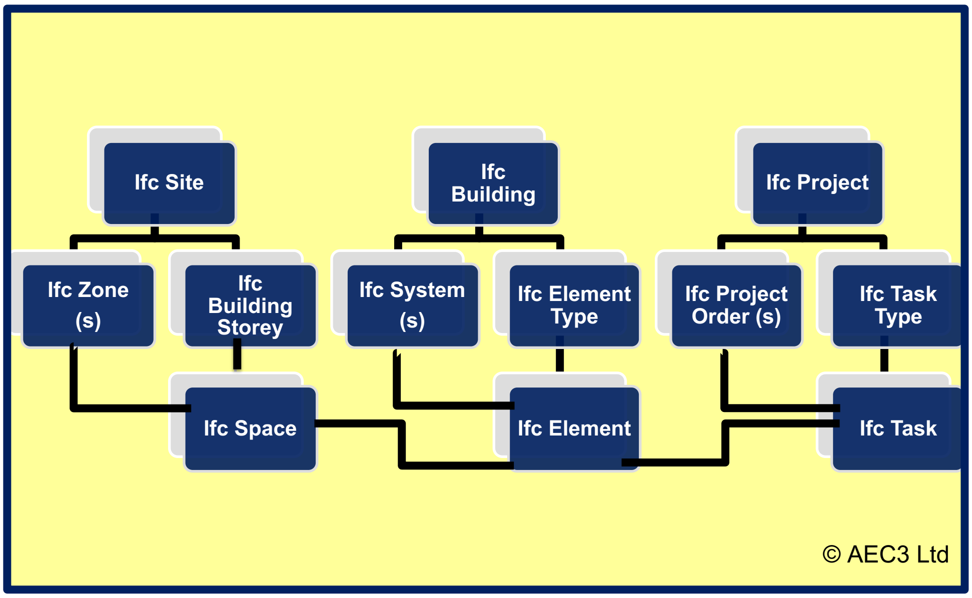


Figure 7 - Spatial data structure of IFC

The premise of an IFC is to create a single model schema enabling any data to be exchanged between tools and can viewed by different actors in the value chain in a unique way dependant on the information they require. These views are known as Model View Definition (MVD). Common views are the coordination view to support clash detection, space boundary to support thermal analysis and 2D annotation to generate floor plans. One such view is the Facility Management (FM) handover view known as COBie (Construction Operations Building information exchange).

IFC in its most basic form common form is a plain text ascii file. The schema defines how the plain text is used to create relationships and type inheritance. Even though the information is readable, it is software applications that are the creators and consumers of the file contents. The format of the IFC file itself is based on an ISO standard (10303-21) called STEP-file. ifcXML and ifcOWL or the SDAI API are alternative form to aid machine-to-machine data exchange.

The IFC schema have been developed over the years, with IFC2X3 being the dominant version supported by broadest set of tools. The current IFC schema is IFC4 which extends support for geometries and parametrics, extended the building services and structural domains. The next release in its early stage of definition is IFC5 which will include infrastructure.

Background to Construction Operations Building information exchange (COBie)

In June 2007 the US Army Corp issued a schema specification 'Construction Operations Building Information Exchange (COBie) - Requirements Definition and Pilot Implementation Standard'[36]. In December 2011 it was approved by the US National Institute of Building Sciences as part of its National Building Information Model standard (NBIMS). In September 2014 a code of practice was released British Standards Institute (BSI), BS1192-4 'Collaborative production of information Part 4: Fulfilling employer's information exchange requirements using COBie – Code of practice' which underpinned the UK Government's 2011 Construction Strategy[37] mandating the use of BIM on UK Government Departments on projects by 4th April 2016.

COBie is a standard for building data exchange, its most common use is in product data handover from construction to operations. The COBie standards do not dictate what information is required for a specific project handover. That responsibility still lies with the owner. The COBie data model is a subset or model view of the IFC. COBie is only concerned with the structure and format of the data, not the relationships between the data. Being a model view of IFC, COBie shares the data model with IFC. The most familiar format of COBie is the spreadsheet that is used for data collection and delivery.

One of the main principles of COBie is the data structure and hierarchy that details the relationship between components, systems and types with zone, space, floor and facility. This is shown in Figure 3.

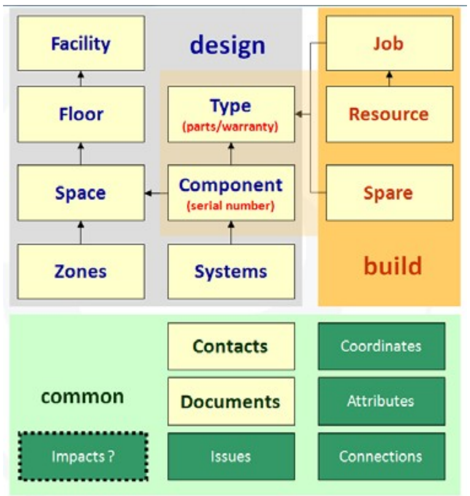


Figure 8 - COBie relationships

The Component is the central piece of the asset register. The owner needs to keep track of what equipment they have, who made and delivered it, when it needs maintenance, how to inspect it and track history of service requests and work orders. The owner needs to specify what items require management and maintenance and what information is needed for each component. The Type concept defines a component by their type or product category. Systems is a way to group equipment in a form that is commonly understood.

Spaces in COBie are similar to what we normally would call rooms. However, there are some deviations/ additions such as outside spaces. Also, large rooms can be divided into multiple spaces

36 Construction Operations Building Information Exchange (COBIE) - Requirements Definition and Pilot Implementation Standard ERDC/CERL TR-07-30, E.William East

37 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/61152/Government-Construction-Strategy_0.pdf

where it makes sense from a management point of view. The space is key to COBie for two reasons. In itself space objects are important for space management, tenant management, energy management etc. In addition, spaces are important for locating equipment. All equipment should be tagged with the spaces from where you access them for operation/ maintenance. Zones are space groupings. They are quite flexible in use. They can be used to divide the facility into ventilation zones, access zones, rental zones etc. Usually the use of zones is more prevalent after handover. An alternative to using the zone object is classifying spaces either using classification reference or by using custom properties, so you may not even use the zones during design and construction. Facilities are the buildings themselves. Important common information like units and phase goes here. Another purpose of this is to have a unique building for this equipment and these spaces to belong to when you merge COBie sheets and import into the CAFM system. Floors are a part of the building spatial structure and a way to group the spaces. They are important parts of supporting the location and grouping of spaces and equipment.

The Job, Resource and Spare are metadata that defines the components and collect the unstructured, non-standardized O&M data that normally is found in documents such as operating manuals, maintenance guides and spare parts lists.

The area highlighted as common items is that all of this could be linked to items in any of the other COBie sheets/lists such as a document is usually linked to a type, but it could also be more generic in nature such as describing a system or being relevant for the whole building. The most important sheets/ item types here are contacts and documents. Contacts are people involved in the delivery of products and generators of information. Documents are primarily documentation about the delivered equipment. Attributes are a method to tag custom data to any item type to expand on the properties/ columns that are included in the main sheet. These are similar to the properties in the IFC data model.

Classification

The built environment, like many other sectors, is classified to help organise information for a particular purpose. For example, a building owner could classify information for maintenance, development planning and cost estimate while a contractor could classify construction management, scheduling and cost. The use of a classification system is a key foundation making navigation across datasets easier and more familiar. The main global classification systems are:

- MasterFormat: A master list for organising construction work results, requirements, products, and activities. Mostly used in bidding and specifications, MasterFormat originated in North America and is produced by the Construction Specifications Institute (CSI) and Construction Specifications Canada (CSC).
- UniFormat: For arranging construction information, organized around the physical parts of a facility known as functional elements, and mainly used for cost estimates. UniFormat originated in North America and is produced by the Construction Specifications Institute (CSI) and Construction Specifications Canada (CSC).
- Uniclass: For all aspects of the design and construction process. In particular, for organizing library materials and structuring product literature and project information. Uniclass originated in the UK and is produced by the Construction Industry Project Information Committee (CPIC) and the National Building Specification (NBS).

- OmniClass: For organisation, sorting, and retrieval of product information for all objects in the built environment in the project lifecycle. OmniClass originated in North America and is produced by the Construction Specifications Institute (CSI) and Construction Specifications Canada (CSC).
- 3451: Is based on Omniclass and developed for the Norwegian market

In the UK Uniclass[38] is prevalent, whilst in the US Omniclass[39] is preferred and in Norway the 3451[40] standard is most common. A comparison of the different classification systems[41] is shown in Table 1. It is unlikely that there will be a unilateral decision to select a single classification system with each community or country having a preferred method. The challenge recognised by the NIBS in the US[42] is the sector and the tool vendors, is one of completeness and interoperability between the different systems with an agreed and functioning mapping. MasterFormat and UniFormat are now unsupported, but still being used in the market and are consolidated within UniClass.

Classification System	OmniClass	MasterFormat	UniFormat	UniClass
Country of Origin	North America	North America	North America	UK
Produced by	CSI & CSC	CSI & CSC	CSI & CSC	CPIc & NBS
Language	English	English	English	English
Purpose and properties	Organisation, sorting, and retrieval of product information for all objects in the built environment in the project lifecycle.	Master list for organising construction work results, requirements, products, and activities. Mostly used in bidding and specifications.	For arranging construction information, organised around the physical parts of a facility known as functional elements and mainly used for cost estimates.	For all aspects of the design and construction process. For organizing library materials and structuring product literature and project information.
Framework	ISO 12006-2, ISO 12006-3 MasterFormat, UniFormat EPIC	Industry practice and gradual development	ISO 12006-2, Professional judgment	ISO 12006-2, SfB, CAWS, EPIC, CESMM
Grouping Principle	Faceted	Hierarchical	Hierarchical	Faceted

38 https://www.iso.org/standard/61753.html
39 http://www.omniclass.org
40 https://www.standard.no/fagomrader/bygg-anlegg-og-eiendom/ns-3420-/ns-3450----ns-3451---ns-3459-2/
41 www.researchgate.net/publication/303484920_A_Comparison_of_Construction_Classification_Systems_Used_for_Classifying_Building_Product_Models
42 www.nibs.org

Organisation and taxonomies	15 inter-related tables categorised by number and name. A combination of Table 21, Table 22, and Table 23 allows for classifying a product precisely.	One table with a series of six numbers and name: Level one with 50 divisions (2004 version) each is made up of level two, level three, and sometimes level four numbers and titles for more detailed areas of work results.	One table with alphanumeric designations and titles in five levels: level one is in nine categories separated by their special function. Level 2 separates them into constituent parts, level 3, 4, and 5 further subdivide them.	The division among facets is based on the alphabet in 11 tables and within each facet by decimal scale up to 6 digits.

Table 8 - Comparison of classification systems

When to use IFC and when to use COBie?

COBie is a subset of IFC and therefore an intrinsic association within the Model View Definition. IFC is normally created during the establishment of the geometric information about a building with the COBie data being supplied as a consequence of the development process rather than as an exclusive process or activity. The choice about COBie or IFC depends on the purpose.

Experiences of using IFC and COBie

As with many sectoral groups, the built environment BIM community is established, educated and rather communicative. There are numerous comments, opinions, assertions, frustrations and successes shared at conferences, through industry dialogue and using the various BIM forums such as NBS[43], aero blog[44], designing buildings[45], BSBIM[46], Bill East[47][48], practicalBIM[49] and B1M[50]. This section augments a selection of these sources, extracting the essence of the key positive and negative aspects for IFC and COBie.

IFC

Positive

- Extracting a sub-set of the information for a specific task, for example the structural information for structural calculations or a floor plan
- Data viewing for downstream activities such as facility management who may not need to modify the data.
- Coordination as clash detection is the static model geometry

43 https://www.thenbs.com/knowledge
44 http://blog.areo.io
45 https://www.designingbuildings.co.uk/wiki/
46 https://www.youtube.com/channel/UCOFrilMKDe1J8Z1mxxs_V1w
47 https://www.youtube.com/channel/UCOh7P2O-BE8ebEzN6i9w1Tw
48 https://www.prairieskyconsulting.com
49 http://practicalbim.blogspot.co.uk
50 https://www.theb1m.com

- ISO standard exists

Negative

- Parametric design information is lost.
- Round tripping is still not supported. Even though there have been big improvements in making IFC4 better at supporting parametric design and design transfer from one application to another.

Comments

- ifcIntrastructure not currently available and ifcBuilding is has been used for infrastructure projects
- There is report of data loss when moving data from one authoring tool to another. This may because of the incorrect configuration of the tool sets or because of other causes that would need investigating.

COBie

Positive

- COBie is endorsed by UK BIM Task Group and described in BS1192-4
- Provides the relevant information needed for handover
- Wide market adoption

Negative

- Has a geometric sense of a design's core spaces, it does not contain the same geometric detail as a corresponding IFC.
- Fixed number of levels of hierarchy is insufficient for a logical match at all levels of the many networks.

Comments

- Definition of floor and its analogue region which could make its use for infrastructure possible

The use of IFC and COBie within infrastructure has surfaced differing views. There are examples of where this has been successfully deployed using the existing definitions and features. Equally there are reports that challenges have arisen. These challenges could well have arisen from incorrect tool configuration or may be genuine causes for concern. The workshop will seek to surface concrete examples of success or challenge of deployment for further consideration.

Summary

Since their conception both IFC and its subset, COBie have provided the data structure that underpins the BIM processes and helped transform how things are built. It is sometimes easy to forget the progress that has been made by what is considered a conservative industry in a relatively short time. Both data structures perform their best when they are used for the purpose they were intended. Albeit both have their challenges that are being addressed through the ongoing updates based on industry feedback. Industry adoption and participation is high, with both systems being taught to build market capability and capacity.

We welcome the opportunity to capture the richness of input from the workshop participants and include these views and insights in the final report to the Centre for Digital Built Britain.

Appendix A - Workshop questions

The workshop will pose several questions for discuss and to aid your preparation for the event these are listed below. We will not get chance to cover all topics, but if you would like to provide written responses to aid our research it would be appreciated:

Part 1 - General

Q1) What are the main challenges you believe society and industry face that should be addressed by better use of information about the built environment?

Q2) Do you believe these are or could be addressed (partially or fully) using current levers and mechanisms, if so how?

Q3) If not, what a) what needs doing, and b) what are the barriers from your perspective?

Q4) What role do you think the Government should play in this process?

Q5) What is the role of standards in this process?

Q6) To what level do you believe the standards should go? Strategy, i/o and quality, or specific step-by-step statements?

Q7) To achieve the mission of CDBB, what do you believe the future information and data structures need to address?

Part 2 – COBie and IFC

Q8) What are your thoughts on data interoperability or integration?

Q9) From your perspective what is the difference between COBie and IFC?

Q10) When would you use COBie or IFC?

Q11) What are the limitations of each data structure and can you give example of the limitations?

Q12) Looking to the future of BIM, when we seek to properly include O&M and take BIM to the services that have socioeconomic impact, what are the limitations or concerns about the current data structures and definitions?

And finally ….anything else about the data structure and the use of the data about buildings and infrastructure you would like to add?

urban innovation labs

Dr. Andrew Robinson
t. +44 7484 214 093
e. arobinson@uil.io

Teresa Gonzalez Rico
t. +44 7487 780 543
e. tgr@uil.io