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EVALUATION OF IFC AND COBIE AS DATA SOURCES FOR ASSET REGISTER CREATION AND SERVICE LIFE PLANNING[1]

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ABSTRACT: *Operation and Maintenance costs in buildings represent a large part of the total building lifecycle cost. However, project delivery methods in the Architectural, Engineering Construction (AEC) industry are often focused on capital delivery and associated costs, which occur prior to the building handover to owners and occupiers. With the emergence of data specifications such as COBie (Construction and Operation Building information exchange) and the IFC (Industry Foundation Classes) open standard, there has been an increased interest in developing approaches that integrate building operation with the capital delivery phases. In this context, this research aims to assess how open BIM standards (i.e. IFC) and data specifications (i.e. COBie) can support information requirements of facility managers. A literature review of current studies on Building Information Modelling (BIM) for facilities management (FM) in general, and on IFC and COBie applications in FM in particular was conducted. Based on the results from the literature review, a use case was developed according to the Information Delivery Manual (IDM) methodology, in order to assess the applicability of IFC and COBie as sources of information for asset register creation and service life planning. The results from this use case highlighted shortcomings in IFC/COBie standards and commercially available tools and suggested improvements. In future work, the proposed research approach will be applied on a wider number of use cases in order to develop a decision support system that utilises asset information from BIM to enable lifecycle cost planning during the use phase of buildings.*

KEYWORDS: *BIM, Facilities Management, Asset Register, IFC, COBie, IDM*

❖ INTRODUCTION

Construction projects are often driven by the consideration of time, cost and safety constraints during the capital delivery phases of projects. When making design decisions, owners and project stakeholders are often focused on initial construction costs without much consideration for operation and maintenance costs, which could amount to over half of the total building lifecycle costs (Becerik-Gerber et al. 2012).

Maintenance can be defined, according to ISO as the "Combination of all technical and associated administrative actions during service life to retain a building or its parts in a state in which it can perform its required functions." (ISO 2011, p.2). In the case of high-use buildings, such as public, healthcare, education, and commercial buildings, maintenance operations are frequent during the use phase of their lifecycle, which can last for several decades. It is therefore essential to plan for maintenance from the inception phase of projects considering owners' requirements for the building.

Building maintenance activities are multidisciplinary efforts with extensive information requirements. Maintenance efforts during the occupancy and post-occupancy stages of the building lifecycle should be accounted for from project inception and checked throughout lifecycle phases in order to maximize the use of buildings, and minimize risk and maintenance costs (BSRIA 2009). The Building Information Modelling (BIM) methodology aims to provide means to support the seamless exchange of information throughout the lifecycle of buildings through the integration of technologies, while supporting industry stakeholders' processes. The use of BIM in a whole lifecycle approach can provide the support of the needed information for asset maintenance planning and execution, provided that information is kept in an organized management system (CIC 2012). BIM can contribute to facilities management both as an information source and as a repository to support the planning and management of building maintenance activities in both new and existing buildings (Volk et al. 2014).

The need for the provision of structured data for asset information models has been recognized in PAS1192-3:2014, which specifies an information management methodology for the operational phase of building assets

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based on open BIM standards IFC and COBie (BSI 2014a). Also, standardisation efforts are proposing the use of open BIM standards IFC and COBie for service life planning – ISO 15686-4:2014 (ISO 2014) - and lifecycle costing during the maintenance phase of buildings – BS 8544:2013 (BSI 2013).

HM Government's BIM Programme has mandated the use of level 2 BIM (file-based collaboration and library management) on all centrally procured Government projects by 2016, and has adopted COBie as the selected format for the information exchange between project capital delivery phases and the operational phase (BSI 2014a). While recent research has identified requirements to support building maintenance tasks with BIM (Becerik-Gerber et al. 2012, CIC 2012, Motamedi et al. 2014), it is necessary to evaluate how existing tools and current open BIM standards IFC and COBie can support these requirements and inform decision making for maintenance from the early stages of project development. The role of construction clients in the definition and continuous checking of detailed requirements also needs to be accounted for (BSRIA 2009). In this context, this paper is focusing on research to a) determine methods for clients' maintenance requirements capture into BIM and b) evaluate IFC/COBie support for information requirements to carry out maintenance planning and execution tasks.
The research question that drives this study is:
How to support and enable decision making for owners and facility managers during the use phase of buildings using an asset information modelling methodology based on open BIM standards (IFC/COBie)?

RESEARCH METHODOLOGY

The main objective of this research is to support the decision-making processes in facility management tasks considering the planning and optimization of lifecycle costs during the use phase of buildings.

In order to fulfil this objective, this research aims to assess the suitability of open BIM standards (IFC/COBie) and building modelling tools to capture and integrate the information from BIM into FM, in order to support proactive asset planning and maintenance methodologies in buildings. For this purpose, a literature review has been carried out focusing on current methodologies and research for FM, and how they can be supported by BIM. Based on findings from the literature, an analysis is carried out to evaluate how BIM can provide the required information for asset registers in order to support owners' requirements in facility management tasks. A use case is developed based on the IDM methodology with the goal of producing COBie data drops according to specific owners' requirements. A discussion is carried out focusing on the results of the analysis and use case development, and improvements are proposed.

LITERATURE REVIEW

BIM and FM

Facilities management can be defined as an integrated approach to operating, maintaining, improving and adapting buildings and infrastructure of an organization in order to support its primary objectives (Atkin, Brooks 2009). FM constitutes an extensive field encompassing multidisciplinary independent disciplines whose overall purpose is to maximize building functions while ensuring occupants wellbeing (Atkin, Brooks 2009, Becerik-Gerber et al. 2012). FM functions hold extensive information requirements from various fields in order to fulfil their purpose. Currently, information is mostly organized and maintained in dispersed information systems (CMMS, EDMS, EMS, and BAS), which require various inputs. Information typically has to be introduced several times and is not synchronized between systems, resulting in error-prone processes (Becerik-Gerber et al. 2012). Equally significant is the lack of use of standards which can define what information is needed for specific FM tasks. There is a need for open systems and standardised data libraries that can be utilised by any FM system (BIFM 2012), however, in existing buildings, FM legacy systems which do not support open BIM standards may be used during the next decades (Kelly et al. 2013).

BIM allows the management and integration of the information needed for FM through the use of open standards, providing a single source of accurate and up to date information. The potential of BIM for FM was realized during early development of the IFC standard. With the aim of improving the facilities management practice, early developments of BIM for FM focused on standardized open data models in order to enable information sharing among computer applications (Yu et al. 2000). In this study the authors proposed a data model for FM - Facilities management core model (FMC) – along with mapping between IFC and FMC.

Open BIM standards such as IFC (registered with ISO as ISO16739 (buildingSMART 2014a)) and COBie are continuously being developed by buildingSMART with input from the AEC industry, in order to support information exchanges according to the industry's business processes. These standards allow models to be structured in a universal way, allowing owners and their project teams to define attributes unambiguously, enabling product data to be exchanged between designers, suppliers, constructors and operators (Atkin, Brooks 2009). The definition of COBie data drops has also been introduced in the UK in order to capture and check client's requirements throughout the lifecycle of buildings. Data drops specify data requirements for key stages of building lifecycle development and are aligned with RIBA Plan of Work stages (Cabinet Office 2012).

In order to support the use BIM for asset maintenance tasks, and to meet the HM Government's BIM Programme target to have all centrally-procured Government projects adopt BIM Level 2 by 2016, the PAS1192-3:2014 specifies an information management methodology for the operational phase of buildings. This specification proposes the use of open standards, IFC and COBie, for the definition of Asset Information Models (AIMs) and for the interface between AIMs and existing enterprise systems (BSI 2014a).

BIM and FM case studies

BIM can support FM functions both for new and existing buildings (Volk et al. 2014). One example of the support of BIM for FM in an existing building is the Sydney Opera House (CRC 2007). In this project, the Sydney Opera House was modelled specifically for FM purposes and the IFC standard was evaluated regarding its support for FM functions. This project demonstrates the possibilities of BIM for FM and highlights changes needed in current work processes to support the proposed methodology. The project also highlights the lack of support of the IFC standard from FM tools. A more recent application of BIM for FM can be found in the BIM-FM Manchester Town Hall Complex report (Codinhoto et al. 2013). This project aimed to investigate the key issues in migrating from traditional FM to a BIM-based FM system to perform reactive maintenance. The main findings indicate that BIM can facilitate the search for the needed information to perform reactive maintenance tasks, allowing FM managers to perform better diagnosis of reported issues.

The use of BIM for FM allows for the provision of accurate information to inform decision-making processes in building maintenance. Motawa and Almarshawad (2013) have proposed a methodology to support decision-making in building maintenance activities. The authors proposed the combined use of BIM and case-based reasoning to capture and manage knowledge in building information models in order to inform maintenance teams about the history of the building and its components. In order to provide decision support for facility management and maintenance, Shen et al. (2012) have proposed an information integration framework supporting software and hardware applications using agent-based web-services.

The visualization capabilities of BIM and their role in decision making for O&M tasks have also been the focus of recent research. Motamedi et al. (2014) have proposed the integration of CMMS data with BIM in order to use BIM visualization capabilities for failure root cause detection in FM. Fault tree analysis was used to capture knowledge about building systems failures and to provide decision support to FM technicians. In order to capture failure mechanisms the authors proposed the use of IFC model relationships. Rasys et al. (2013) have proposed an information integration framework for the management of civil and oil & gas facilities using Web3D technology for the integration and visualization of assets information in 3D models. Hallberg and Tarandi (2011) have proposed a lifecycle management system for construction assets based on the IFC standard and 4D visualization. The authors state that IFC models constitute a clearer and more efficient source of information when compared to traditional database solutions. However, according to the authors, IFC2x3 does not support lifecycle management during the maintenance phase and needs further development in order to support all lifecycle management system functions. The use of spatial relationships represented in BIM for visualization and analyses of facilities data has also been considered for the planning of maintenance activities and repair works in buildings (Akcamete et al. 2010). While there have been many research efforts in BIM for FM, industry-wide applications are still lacking. Standardization efforts such as IFC and COBie can contribute to the organization of information for FM tasks. The definition of COBie data drops specifies which information in the COBie spreadsheet should be filled out during each stage of project development. However further research is needed in order to determine to what level of detail this should be carried out in order to effectively support clients requirements throughout the lifecycle of the building. This way it should be possible to support maintenance tasks for the occupancy and post-occupancy stages from earlier phases of the building lifecycle, supporting a whole lifecycle approach for maintenance (BSRIA 2009).

EVALUATION OF IFC/COBIE SUPPORT FOR ASSET REGISTERS

In order to assess IFC and COBie support of facility managers' information requirements, an initial analysis was carried consisting of the evaluation of the support of asset register information requirements by IFC/COBie data entities. This analysis compares asset register requirements specified in section 9.7.4 of BS 8210 (BSI, 2012) with IFC/COBie entities from the buildingSMART IFC4 specifications (buildingSMART 2014b). The definition of COBie data drops adopted in study follows the definition proposed in the COBie Data Drops document (Cabinet Office 2012). The results from this analysis can be found in Table 1.

Table 1 - Evaluation of IFC/COBie support for asset register requirements defined in BS 8210 (BSI, 2012, buildingSMART 2014b)

Asset register information requirements (BSI, 2012)	IFC 4	COBie 2.4 (Spreadsheet xml)	COBie Data drop
a) identification number or unique reference for the asset;	SerialNumber (Pset_ManufacturerOccurrence)	component sheet - SerialNumber	4 – as-built
	BarCode (Pset_ManufacturerOccurrence)	component sheet - BarCode	4 – as-built
		component sheet - TagNumber	4 – as-built
		component sheet - AssetIdentifier	4 – as-built
b) make and/or model;	ModelReference (Pset_ManufacturerTypeInformation)	type sheet - ModelReference	4 – as-built
c) manufacturer;	Manufacturer (Pset_ManufacturerTypeInformation)	type sheet - Manufacturer	4 – as-built
d) vendor, if different to manufacturer;	Manufacturer (Pset_ManufacturerTypeInformation)	type sheet - Manufacturer	4 – as-built
e) date of manufacture;	ProductionYear (Pset_ManufacturerTypeInformation)		4 – as-built
f) date of acquisition, installation or completion of construction;	AcquisitionDate (Pset_ManufacturerOccurrence)	component sheet - InstallationDate	4 – as-built
	WarrantyStartDate (Pset_Warranty)	component sheet - WarrantyStartDate	4 – as-built
g) location of asset;	IfcSpace	Component sheet - Space	4 – as-built
h) whether or not access equipment is required;		Job sheet	5 – O&M
i) whether or not the asset is subject to a permit-to-work requirement		Job sheet	5 – O&M
j) initial cost;	IfcCostValue		4 – as-built
k) predicted lifetime;	ExpectedLife (Pset_ServiceLife)	type sheet - Expected Life	4 – as-built
l) specification;		type sheet - all	4 – as-built
m) replacement cycle;		Job sheet	5 – O&M
n) cost breakdown;			5 – O&M
o) servicing requirements, including type and frequency of service;		Job sheet	5 – O&M
p) other maintenance required;		Job sheet	5 – O&M
q) maintenance costs;	ReplacementCost	type sheet - ReplacementCost	5 – O&M
r) accumulated depreciation;			5 – O&M

s) written-down value;			5 – O&M
t) source of components and spare parts, where applicable			5 – O&M
u) energy consumption and, where applicable, energy-efficiency rating;	SustainabilityPerformanceDescription / Environmental (IfcTypeObjectProperty)	type sheet - SustainabilityPerformance	4 – as-built
v) identification of hazardous or other risks to people or property.	Pset_Risk		4 – as-built
Total number of unsupported attributes	**10/22**	**7/22**	

USE CASE DEVELOPMENT

In the context of this research, a use case has been developed in order to demonstrate IFC/COBie support of specific data used in lifecycle planning (i.e. Service Life), and how building owners can specify these data requirements. The development of this use case was based on the Information Delivery Manual (IDM) methodology and the definition of Employer's Information Requirements (EIR). The IDM methodology aims to document processes and support information exchanges between AEC industry stakeholders. Information Delivery Manuals can be used to support specific use cases in the AEC industry in the form of general guidance for the involved stakeholders, as well as for the development of software specifications (ISO 2010, Volk et al. 2014). IDMs can be bound to specific data types and software applications, or remain independent from these (ISO 2010). EIR specify the owner's requirements throughout the lifecycle of the building, and can be supported by COBie data (BSI 2014b).

The goal of the developed use case is to showcase the production of COBie data drops according to the owner's requirements. Specific owner requirements in this use case include the specification of Service Life data for mechanical components according to ISO 15686-4 (ISO, 2014). Use case development follows the IDM methodology for the definition of the overall process, relationships between actors, and exchange requirements which support the defined tasks. In this use case, specific tools, data models, and standards were used. EIR was used in the identification of standards supporting the data exchanges as well as IT tools used in the use case.

Figure 1 outlines the underlying process supporting the development of the use case, depicting the sequence of tasks and data support in the form of exchange requirements. Table 2 specifies the owner's information requirements. In the following sections, the development of tasks 5.1 to 5.4 will be detailed.

Figure 1 – Overall process supporting the development of the use case

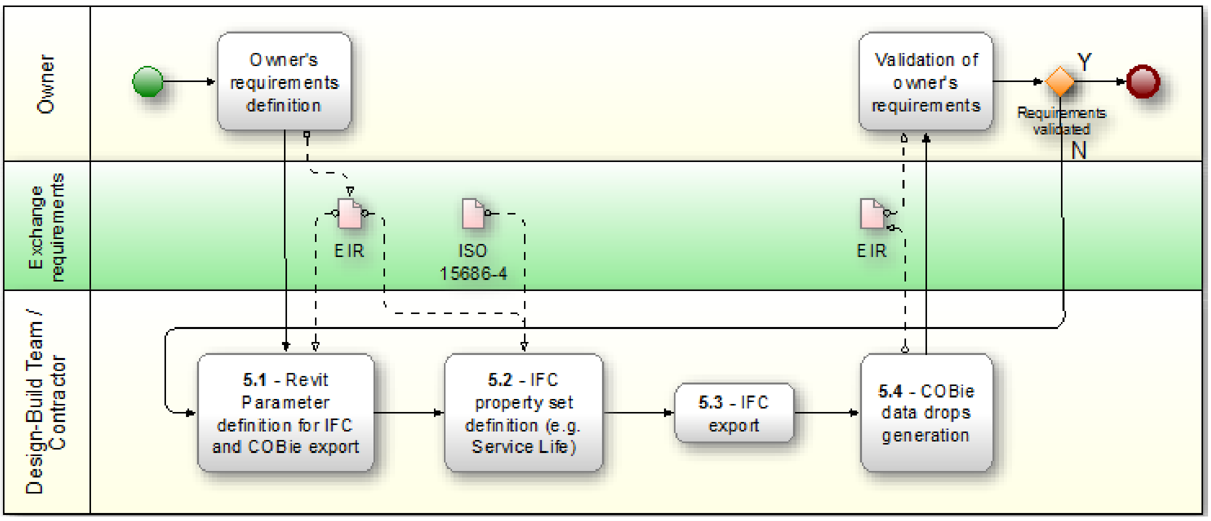


Table 2 – Employer's Information Requirements (EIR) definition

Task	Software requirements	Supporting standards
5.1	Revit 2014	ISO 15686-4

5.2	Visual C# Express	**Exchange objects**
5.3	Open IFC Revit Exporter	Pset_ServiceLife (ISO 15686-4 Annex A)
5.4	COBie Toolkit	

Revit Parameter definition for IFC and COBie export

The development of this use case is based on an existing building model “Project 1. Duplex Apartment” (East 2014). Since COBie is a subset of IFC, COBie files will be generated from IFC files. Revit allows the mapping of specific objects to IFC entity types through definition in the IFC Export Classes dialog box (Autodesk 2014b). Since Revit object categories are defined more broadly than the corresponding IFC entities, when exporting from Revit to IFC using the default settings, some components will not be correctly mapped (USACE 2011). Two additional parameters have been added to the Revit project template as shared project parameters available to every object type to override an individual family’s IFC export category (Autodesk 2014a):

- IfcExportAs: This parameter should be filled in with a valid IFC entity type.
- IfcExportType: This parameter should be filled in with the IFC Predefined Type setting.

The mapping of these parameters to IFC types and instances can be accomplished using the IFC 2x3 final release documentation (buildingSMART 2014c). These parameters had already been defined in the obtained building model for selected M&E components.

The Open IFC export for Revit plugin allows the definition of custom property sets in a text file which provides the correct mapping of COBie parameters from the IFC files generated in Revit. COBie parameters were defined as shared project parameters in Revit and their specification was defined based on the template file from the IFC for Revit project “IFC2x3 Extended FM Handover View.txt” (Autodesk 2014b). In order to automate the creation of shared parameters, the Revit API was used to define shared type parameters for the Type sheet and to automatically assign the category field from the NBS Uniclass 2 Keynote file for Revit (Hamil 2012).

IFC Property Set definition

To demonstrate the support of specific asset register requirements identified in Table 1, property set Pset_ServiceLife proposed by ISO 15686-4 (ISO, 2014) was added to the exporter as a common property set. This was achieved by editing the source code from the IFC for Revit project (Autodesk 2014b).

The source code consists of a C# Solution including 3 projects: Install, BIM.IFC.Common, and Revit.IFC.Export. In order to add property sets to the exporter, the ExporterInitializer.cs file from the Revit.IFC.Export project was edited to include the property set definitions. The Revit.IFC.Export was then compiled and the resulting Revit.IFC.Export.dll file was used to replace the default class library from the Open source IFC Exporter.

An excerpt from the method `InitPropertySetServiceLife` for the definition of properties from the Pset_ServiceLife proposed in ISO 15686-4 can be found below (not all properties are included):

```
private static void InitPropertySetServiceLife(IList<PropertySetDescription> commonPropertySets)
        {
            //property set description
            PropertySetDescription propertySetServiceLife = new PropertySetDescription();
            propertySetServiceLife.Name = "Pset_ServiceLife";
            //sub-type of ifcelement
            propertySetServiceLife.EntityTypes.Add(IFCEntityType.IfcElement);
            PropertySetEntry ifcPSE = PropertySetEntry.CreateText("ServiceLifeType");
            propertySetServiceLife.AddEntry(ifcPSE);
            ifcPSE = PropertySetEntry.CreateRatio("Utilization");
            propertySetServiceLife.AddEntry(ifcPSE);
```

Finally, Service Life parameters were defined as shared type parameters in Revit to enable export to IFC and

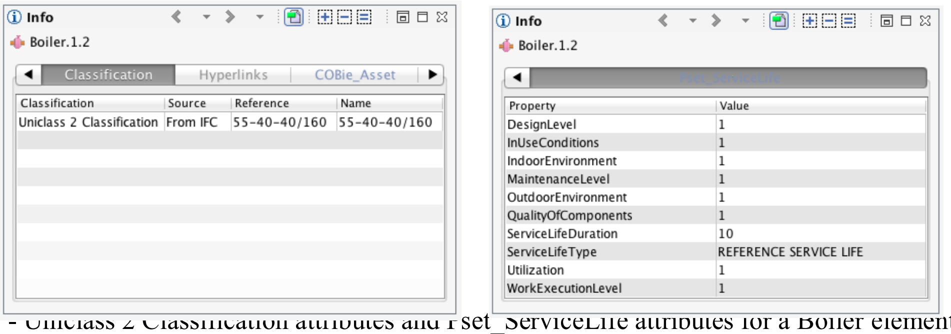
COBie.

IFC Export

Following the definition of shared project parameters for IFC and COBie entities and to support the Service Life property set, it is possible to export the building model as an IFC file.

A specific export setup was defined in the open source IFC exporter for Revit to support the definition of custom property sets in a text file. Specific COBie parameters defined in the text file are accounted for by selecting the "Export user defined property sets" option. The Service Life Property set is accounted by selecting the default option "Export IFC common property sets". In order to support the use of Uniclass 2 classification in COBie, shared project parameters defined for classification fields were indicated in the IFC assignments panel of the open IFC exporter.

Solibri Model Viewer was used for the visualization of Uniclass 2 Classification attributes and Pset_ServiceLife attributes for a Boiler element in the model (Figure 2).



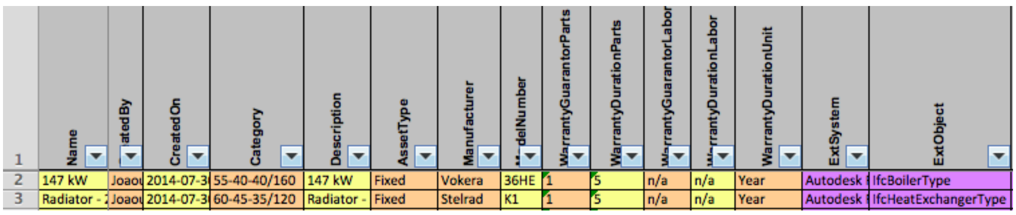
Classification	Source	Reference	Name
Uniclass 2 Classification	From IFC	55-40-40/160	55-40-40/160

Property	Value
DesignLevel	1
InUseConditions	1
IndoorEnvironment	1
MaintenanceLevel	1
OutdoorEnvironment	1
QualityOfComponents	1
ServiceLifeDuration	10
ServiceLifeType	REFERENCE SERVICE LIFE
Utilization	1
WorkExecutionLevel	1

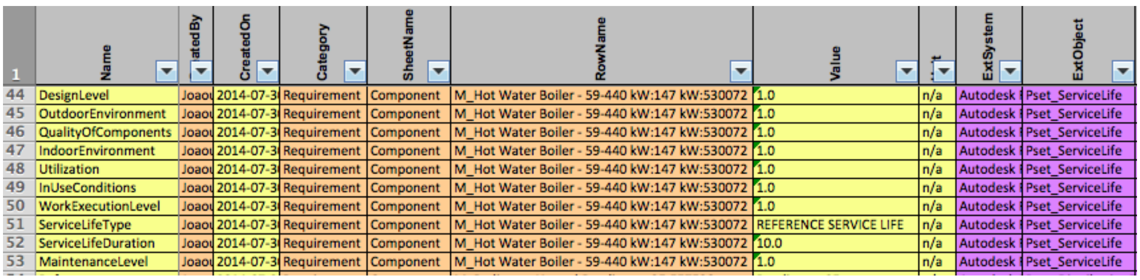
Figure 2 - Uniclass 2 Classification attributes and Pset_ServiceLife attributes for a Boiler element in the IFC model in Solibri Model Viewer

Generation of COBie Data Drops from IFC files

In order to generate COBie data drops from the IFC exports, the COBie Toolkit was used. COBie Toolkit allows for the export of certain IFC entities based on ObjectIDM plugins. These can be used to manage the contents of COBie drops, e.g. through the exclusion of information about products which are not tracked as assets by facility operators (ERDC 2013). In this experiment, the default COBieIDMPlugin was used. The IFC file is loaded into the COBie toolkit and it is converted to COBie internally (ERDC 2013). It is then possible to export the file in the preferred COBie format. In this experiment the file was exported as a COBie spreadsheet. Figure 3 shows the representation of several attributes in the Type sheet for Heat Exchanger and Boiler elements, including: Uniclass 2 Classification; Asset Type, Manufacturer, Model Number, Warranty parameters and reference to the element's IFC Type. Figure 4 shows the representation of the property set Pset_ServiceLife in the Attribute sheet.



1	Name	atedBy	CreatedOn	Category	Description	AssetType	Manufacturer	delNumber	WarrantyGuarantorParts	WarrantyDurationParts	WarrantyGuarantorLabor	WarrantyDurationLabor	WarrantyDurationUnit	ExtSystem	ExtObject
2	147 kW	Joaou	2014-07-3	55-40-40/160	147 kW	Fixed	Vokera	36HE	1	5	n/a	n/a	Year	Autodesk	IfcBoilerType
3	Radiator -	Joaou	2014-07-3	60-45-35/120	Radiator -	Fixed	Stelrad	K1	1	5	n/a	n/a	Year	Autodesk	IfcHeatExchangerType



1	Name	atedBy	CreatedOn	Category	SheetName	RowName	Value	t	ExtSystem	ExtObject
44	DesignLevel	Joaou	2014-07-3	Requirement	Component	M_Hot Water Boiler - 59-440 kW:147 kW:530072	1.0	n/a	Autodesk	Pset_ServiceLife
45	OutdoorEnvironment	Joaou	2014-07-3	Requirement	Component	M_Hot Water Boiler - 59-440 kW:147 kW:530072	1.0	n/a	Autodesk	Pset_ServiceLife
46	QualityOfComponents	Joaou	2014-07-3	Requirement	Component	M_Hot Water Boiler - 59-440 kW:147 kW:530072	1.0	n/a	Autodesk	Pset_ServiceLife
47	IndoorEnvironment	Joaou	2014-07-3	Requirement	Component	M_Hot Water Boiler - 59-440 kW:147 kW:530072	1.0	n/a	Autodesk	Pset_ServiceLife
48	Utilization	Joaou	2014-07-3	Requirement	Component	M_Hot Water Boiler - 59-440 kW:147 kW:530072	1.0	n/a	Autodesk	Pset_ServiceLife
49	InUseConditions	Joaou	2014-07-3	Requirement	Component	M_Hot Water Boiler - 59-440 kW:147 kW:530072	1.0	n/a	Autodesk	Pset_ServiceLife
50	WorkExecutionLevel	Joaou	2014-07-3	Requirement	Component	M_Hot Water Boiler - 59-440 kW:147 kW:530072	1.0	n/a	Autodesk	Pset_ServiceLife
51	ServiceLifeType	Joaou	2014-07-3	Requirement	Component	M_Hot Water Boiler - 59-440 kW:147 kW:530072	REFERENCE SERVICE LIFE	n/a	Autodesk	Pset_ServiceLife
52	ServiceLifeDuration	Joaou	2014-07-3	Requirement	Component	M_Hot Water Boiler - 59-440 kW:147 kW:530072	10.0	n/a	Autodesk	Pset_ServiceLife
53	MaintenanceLevel	Joaou	2014-07-3	Requirement	Component	M_Hot Water Boiler - 59-440 kW:147 kW:530072	1.0	n/a	Autodesk	Pset_ServiceLife

Figure 4 - Pset_servicelife: Property definitions for a Revit Family in Attribute sheet – COBie spreadsheet

DISCUSSION

The objective of this use case was to assess the suitability of open BIM standards (IFC/COBie) and a building modelling tool (Revit) to capture and integrate asset register and service life information in order to support specific owners' requirements.

In this use case it was demonstrated how service life parameters defined in ISO 15686-4 can be represented in IFC and COBie. The representation of service life and service life factors are an important input for the assessment of life cycle costs in the use phase of buildings (ISO 2011). They can also be considered as inputs in the decision making process to support Design for maintainability as proposed in the Soft Landings methodology (BSRIA 2009).

IFC/COBie support for Asset Register data

In order to evaluate the support of asset register information requirements defined in BS 8210 (BSI, 2012) by IFC/COBie, an analysis was carried out comparing how these requirements can be captured in specific IFC/COBie entities and its results presented in table form (Table 1). It can be noted that several of these requirements are not directly supported in IFC (10 out of 22) and COBie (7 out of 22), especially for the use phase of buildings (data drop 5). Gaps that were identified in this analysis include capital information such as costs breakdown, written down value of assets, accumulated depreciation, and sources of components (Table 1). Several information requirements for maintenance tasks which are not directly supported in IFC can be represented in the Job sheet (COBie): requirements for access equipment, permit-to-work requirements, replacement cycle, servicing requirements and other maintenance requirements.

Gaps found in this analysis are consistent with previous results from the literature stating that the current IFC standard does not include all the required properties and relationships related to the O&M phase (Motamedi et al. 2014). However, it should be noted that in the case of IFC, and due to the flexibility of its schema, FM software providers might be able to support the missing information requirements in an indirect fashion. Also, the possibility to include additional information in IFC and COBie files using custom property sets, or through extensions to the model schemas, could contribute to increase the support of these information requirements.

Generation of COBie data drops for the in-use stage

The approach adopted to provide accurate IFC exports from Revit in order to support the creation of COBie files was based on the definition of specific type and instance IFC parameters for M&E components using IfcExportAs and IfcExportType shared project parameters and the specification of dedicated shared parameters for the mapping of COBie entities.

Using the proposed approach in select M&E components, it was possible to obtain well defined IFC models and COBie data drops (Figures 2, 3 and 4). It should be noted however that the application of this process for a real project can be time consuming, since the user has to find out which components are not correctly exported to IFC, and define the correct IFC types and entities for each of these components. Also, COBie shared parameters must be defined for each COBie entity and they must be edited for each component and/or type. In this regard, it was shown that the Revit API can automate this task, through the definition of shared type parameters for the COBie Type sheet and automated assigned of the category field based on the NBS Uniclass 2 Keynote file. In order to support specific requirements from the client and from facility managers, the definition of COBie parameters and the contents of the COBie Attribute tab – which includes IFC property sets - should be agreed on beforehand. The management of information in COBie data drops can also be supported by the use of ObjectIDM plug-ins in the COBie Toolkit, which specify what elements are included in the COBie drops.

IFC Property Set definition

In order to demonstrate the support of specific owner's requirements by IFC/COBie, property set Pset_ServiceLife was defined by editing the open IFC Revit exporter source code. This property set has been proposed by buildingSMART for IFC4 (buildingSMART 2014b) and by ISO 15686-4 (ISO, 2014), but is currently not supported in the open source IFC Revit exporter. The definition of this property set demonstrates how it is possible to customize the open source IFC Revit exporter by adding custom property sets to IFC. The process followed in this use case shows how custom property sets can be defined and represented in IFC and in the COBie attribute sheet in order to support specific maintenance tasks (e.g. Service Life Planning).

However, some limitations were found in this process: Upon checking the official IFC4 documentation (buildingSMART 2014b) against the list of supported IFC Entity Types by the open source exporter (defined in IFCEntityType.cs file), it was found that not all IFC Entity Types are supported. For example, the IFC exporter does not support the definition of IfcPropertyBoundedValue, which defines a property object which has a maximum of two (numeric or descriptive) values assigned, the first value specifying the upper bound and the second value specifying the lower bound (IFC documentation). For this reason, while the official IFC documentation recommends the use of IfcPropertyBoundedValue entity type for the Service Life property, the definition from ISO 15686-4 Annex A using type Real was used instead. While this shows current limitations in the open source IFC exporter for Revit, in the future this functionality can be added to the code.

CONCLUSIONS

This study focused on the development of a use case based on the IDM and EIR methodologies, with the objective of assessing the suitability of open BIM standards (IFC/COBie) and building modelling tools for the capture and integration of FM information.

Results from this use case have shown that while IFC/COBie do not support all information requirements for asset management by default, they allow the user to add some of the required information, particularly in the form of property sets. It can be concluded that IFC and COBie can be used for the definition of asset registers and to support owners' requirements. In this use case, limitations in the IFC/COBie standards and used tools have been highlighted and improvements have been proposed.

The obtained results constitute an important input for future developments in this research, including the evaluation of IFC/COBie capabilities to provide decision support to owners and facility managers based on the optimization of lifecycle costs in the maintenance phase. Having outlined the process and information requirements supporting the use case, the proposed approach can be improved through the automated checking of owners' requirements against the COBie deliverables, following the BS 1192-4 code of practice (ISO 2014b). This process should increase the support of owner's requirements throughout the lifecycle of the building, and specifically improve the transition between the construction and use phases, in line with the Soft Landings framework. It is also expected that the results from this study can be used to improve current BIM standards and software applications to support the various stakeholders in the AEC industry. Finally, these results constitute an important contribution for the main objective of this research, which is to enable decision support to building owners and facility managers during the use phase of buildings.

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