Delivering COBie data - Focus on curtain walls and building envelopes

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Delivering of COBie data - focus on curtain walls and building envelopes

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ABSTRACT: COBie is a standard data framework whose main purpose is to transmit useful, reliable and usable information collected throughout the whole building process and to be consumed in order to properly maintain the facility. Focusing on Facility Management information exchanges and considering the UK BIM policies and requirements, this paper shows the results obtained applying COBie to complex products such as curtain walls. Two Information Delivery Manuals (IDMs) were also developed, in order to provide a commonly known and standardized framework, which can regulate the COBie-based information exchanges. Future developments of this study could concern the application of the developed IDMs to different case studies in order to overtake that specificity characterizing each single project and verify the validity of the proposal.

1 INTRODUCTION

The way through which information is exchanged between the different stakeholders during the building process is a theme on which international organizations and software developers are deeply involved. In the last years, specifications and applications had been developed in order to make information exchange as efficient as possible.
This research looked at this topic focusing on that part of the entire set of information exchanged during the project realization needed for Facility Management. Considering the Industry Foundation Classes schema (IFC – ISO16739:2013), the open data format developed by buildingSMART International, this subset of information requires to be defined by a specific Model View Definition (MVD).
The Construction Operation Building information exchange (COBie) is a standard developed by the North American chapter of buildingSMART, buildingSMART alliance, that aims to define a MVD able to collect all that information needed to properly maintain the facility. In this study, the exchange of information following the COBie standard was applied to specific products, namely curtain walls and building envelopes, in order to understand if this existing standard could be a proper solution also for a complex product in terms of geometry, description and classification, such as those considered ones.

2 STATE OF THE ART

COBie provides a structured framework to collect specific data across the different project stages, ensuring an effective data transmission between the main actors involved in the building process: the Design and Construction teams, the Owner and the Facility Manager. This set of information aims to provide a comprehensive knowledge in order to properly run the maintenance operations.

COBie was developed starting from the assumption that entrusting the delivery of FM information to paper documents and PDFs, the current information vehicles, was not and will never be the best solution. Nowadays, in fact, this behavior has the only result to produce hundreds of paper or file that are virtually useless to facility managers and often these pieces of information are not available at the time of occupancy during the building process, but months or even years after the actual beginning of the 'in use' phase, they are stored in a room and never used (East et al., 2013). Moreover, a lot of time could be wasted by the builder delivering handover documents every time he has to recreate information already specified by architects and manufacturers, but not in a way that allows its inclusion in such documents.

Before COBie, two different approaches have been noticed regarding electronical capture of facility management information:

– the owner has maintenance staff involved in re-

typing information from the handover documents to the chosen maintenance management software;
– the owner requires the contractors to provide information directly in the chosen FM application or in a specific data format ready to be imported in the FM system (East et al., 2013).

COBie aims to provide a solution to the problems related to the methods described above, defining a unique container for this pieces of information, delivered in an electronic format with a standard, open and reusable structure based on the IFC schema (ISO 16739:2013) that allows facility managers to handle a concretely useful and usable set of information. COBie is defined, in fact, as a MVD, since it represents a specific subset of the building information model, and it does not handle any geometric information, as it is "a performance-based specification for facility asset information delivery" (East, 2009, p.18).

The first COBie release was published in 2007 by the Construction Engineering Research Laboratory of US Army Corps of Engineer. Today the definition of COBie is jointly maintained by buildingSMART alliance, and the British and Irish chapter, buildingSMART UKI. The technical definition of the standard can be found in the National BIM Standard-United States version 3 (NBIMS-US v.3), lastly updated in July 2015 and in the buildingSMART alliance website, where COBie was officially published as a MVD in October 2013. Moreover, since COBie is expected to become mandatory for public commissions in UK from April 2016, the British Standard BS1192-4:2014 provides a code of practice that should be followed in the UK scenario. COBie-compliant information can be delivered in three formats: IFC, IFCXML and the XML format, a simple spreadsheet file editable with Microsoft® Excel that is the format chosen by the British Government.

As a part of the IFC schema and BIM literature (ISO/TS 12911:2012) COBie captures information for both spatial and physical assets in the facility. A unique COBie file is created for each building in a project and once the required information is collected, it is organized following the diagram reported below (fig. 1). Using a standard for FM information exchange requires the relations between the information and the different stakeholders involved in the project to be precisely defined. The owner, in particular, is then responsible to specify: which assets are going to be managed, which is the level of detail of the information to be provided and when, during the building process, information has to be transmitted. These specifications make COBie's content 'project-specific'. Regarding the physical assets, all the equipment that needs preventive maintenance plan, has consumable parts and requires management and regular inspections, are supposed to be included in COBie. COBie could also handle architectural and structural elements if they are subjected to maintenance operations (East, 2013). As stated above, the conducted research focused on curtain walls and building envelopes (from now the term curtain wall will describe both the products considered by this research). Two main reasons drive this paper focusing on the UK scenario:

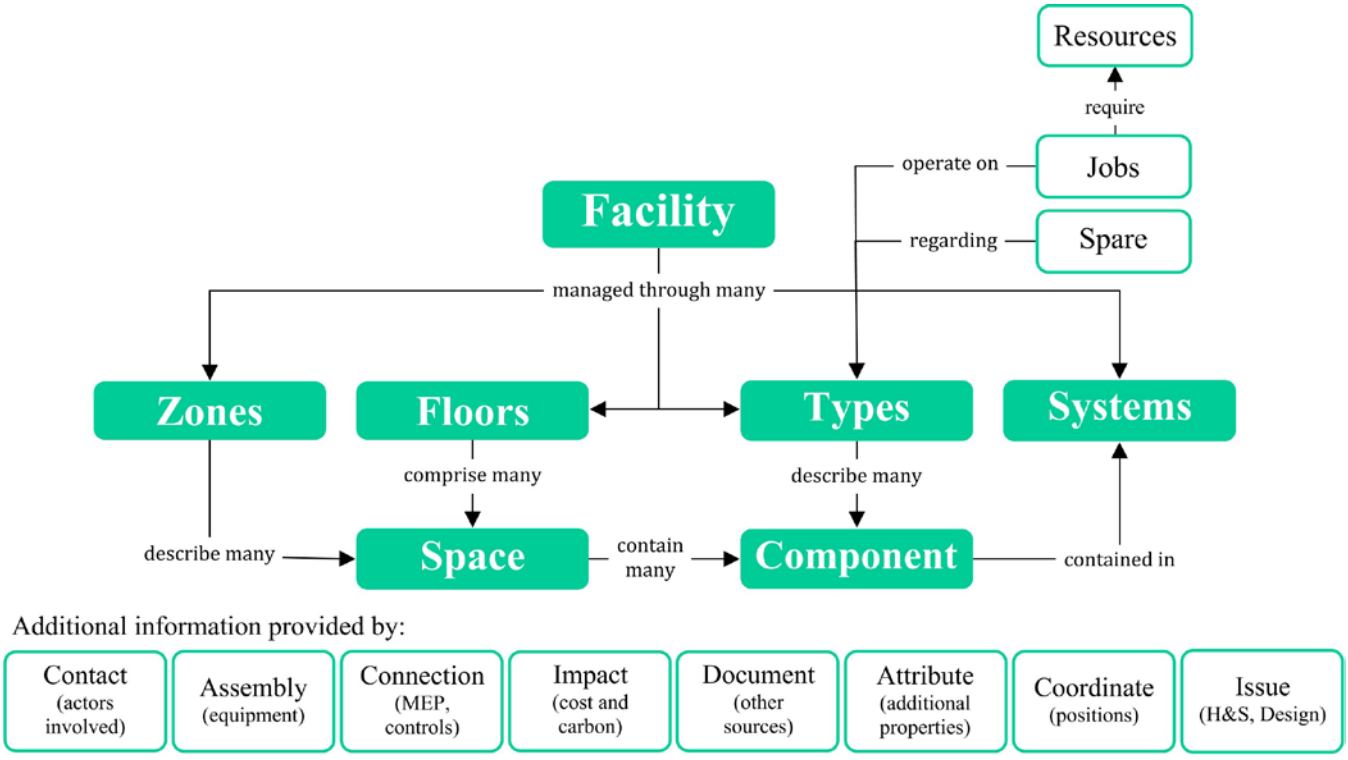

Figure 1. COBie's content structure

– the BIM Task Group work and the UK Government's initiative could become a framework for other states of the European Union, which does not yet submit a BIM policy.
– the UK construction business shows how notable the impact of new private housing and private commercial is (UK Office for Nation Statistics, 2016). Since curtain walls are commonly used in both these fields, it becomes an important research discipline.

From a construction point of view, the research faces the complexity within curtain walls' definition and description.

1. Product. A 'curtain wall' can be simplified as a unique object, the whole envelope system, but it can be also seen as an assembly composed by any subsystems that constitute the envelope (Herzog et al., 2004). Therefore, the whole system can be further subdivided in the several elements that make up the envelope.
2. Sub components variability. In buildings like skyscrapers, for example, the hundreds of panels that cover the whole building could seem at a first sight the same panel type repeated for hundreds of times, but, actually, they usually differ, for instance, for dimensions. Namely building envelopes imply a high number of different objects belonging to different types.
3. Integration. Curtain walls' information overlap among building based information, such as design collaboration, construction and FM, and manufacturing based information, which have different requirements and procedures.
4. Interferences. Curtain walls are related to other discipline components, such objects from structure and MEP systems.

By the COBie point of view, this complexity requires specific considerations about the exportation of Type, Component, Assembly and System worksheets, in order to align the COBie schema and requirements to the particular features of curtain walls.

3 METHODOLOGY

3.1 *The problem of the manageable assets*

As previously said the content of COBie in a specific project should be specified by the employer, who firstly has to decide which facility assets are going to be managed during the facility life-cycle. However, the definition of 'manageable assets' could potentially include a wide set of different objects.

The COBie specification reported in NBIMS-US v.3 provides a list of the IFC entities which are not part of the IFC subset expected by the COBie MVD and so which are not supposed to be handled by COBie. Regarding the specific purpose of the conducted research, it must be underlined that entities such as IfcCurtainWall, IfcPlate, IfcMember and the respective IFC Type entities, are part of this exclusion list. However, the COBie specification itself specifies that software vendors may also allow the user to apply different exclusion lists, in order to satisfy specific owner's requirements or regional directions (NBIMS-US v.3). Since building envelopes are products that typically require to be maintained during the facility life-cycle, in this research it was chosen to loosen the constraints imposed by the COBie specification and include the considered product in the outgoing COBie file.

One of the main purpose of this report, pursued through the development of two Information Delivery Manuals (IDM) on the delivery of COBie data, was to identify the best way to manage curtain walls within COBie, defining what can be considered a manageable asset in this particular case and how the template expected by COBie should be compiled.

3.2 *Producing COBie data*

To understand how to produce COBIE-compliant information, an experimentation phase was also included in this study. Since the XML format of COBie is the one which is going to be required in UK, the tests aimed to create COBIE files in spreadsheet format.

Apart from filling the COBie template manually with the relevant information, which is an extremely time consuming procedure and easily related with compiling errors, two different methods were followed: creating COBie data directly from the chosen BIM authoring tool, using a specific exporter; creating COBie data exporting an IFC model from the native one and using external applications able to transform the IFC file in COBie XML format.

Considered the complexity of the analyzed product and its relationships, the use of the first method aims to demonstrate the information exchange's maximum quality from the point of view of a unique stakeholder. However, it is clear that it requires each actor in the process to produce his single COBie file from his own model. In this case, at the end of the process, there could be several issues in aligning the information deriving from different professionals, with manual copy and paste operations and corrections. An OpenBIM scenario in which every contribute is merged in a unique model, necessarily through the IFC format, and then the required information is extracted (following the COBie MVD or a specific FM MVD) seems to be the best solution. The second procedure tries to verify the same quality standards used before.

3.3 *FM MVD and IDM procedure*

It is not possible to deal with the COBie standard without referring to IFC: as already highlighted, COBie is not just a spreadsheet; it is intended to be a standard way to provide a defined information content of an IFC model. The IFC format should enable the different stakeholders to exchange information, thanks to its interoperability and standardization supported by software systems implemented for different fields (See et al., 2012).

However, at the time of writing, it has been noticed that there is not any Model View Definition named 'COBie' supported by the used software application. The current procedure asks the user to export data through the so called 'Extended FM Handover View', a specific MVD made to cover the FM information exchanges between the design and operational phase, but still not officially approved by buildingSMART International and, therefore, not stable. In other words an MVD enabling the different stakeholders to exchange usable and functional information for the Facility Management during the whole building process is still needed. As a consequence it is not possible to exchange just COBie-related information through the IFC format so far, since the available Model View Definitions include a greater amount of data.

In addition to these considerations, it must be pointed out that the IFC format is responsible to carry the informative content of a model, but it does not provide any information related to the process. To gain the best results from interoperability, the quality of communication must be as high as possible and the process should be standardized and commonly recognized (Wix & Karlshøj, 2010). The IDM is intended to define in detail a specific business process where at least one information provider and one receiver are involved: 'who', 'when', 'what' and 'why' represent the content of the IDM in relation to an information exchange. The main purpose of IDM is to apply a standardized methodology to describe and define already existing or new processes, in order to assist the different stakeholders in their tasks throughout the entire lifecycle of a facility. It must be noted that there is not a direct correspondence between the content of an IDM and the IFC data: the MVD is responsible to establish a link between the technical specifications of the IFC schema and the human-readable information defined by the IDM.

The development of an IDM is one answer to the AEC industry need of a structured framework for its business processes, throughout all their complexity. For this reason, the cited IDM methodology has as a primary focus the definition of the flow of information, besides the information content itself: once identified the specific need associated to a business case and the purpose subtended by the information exchange, the development process of an IDM begins. The attention could be focused on the different building systems, with the main purpose of managing their peculiarity and specific characteristics.

4 DEVELOPMENT

4.1 *Brief analysis of the used model*

The research consequently moved to the experimentation phase, where the two possible ways to deliver COBie data from a project during its different stages were tested. The tests were conducted using Autodesk Revit 2014 as BIM authoring tool; the typical curtain walls' breakdown made of panels and mullions, also proposed by the used software, was not implemented in the analyzed model, where the curtain systems were modeled as an association of panels only. Consequently, each panel actually represents a container (from now named as 'cell', intended as the main component of a unitized curtain wall systems) of typologically different elements.

4.2 *COBie Extension*

The COBie Extension for Revit is an internal add-in of the used authoring software that allows the export of a COBie XML file directly from Revit. In particular it allows exporting the following worksheets: Contact, Facility, Floor, Space, Zone, Type, Component, System, Attribute and Coordinate. For the specific scope of this study, the attention was mostly directed to those worksheets that expect information for which a specialist subcontractor involved in the field of interest is responsible, namely the ones from Type to Coordinate. It must be said that once the information is inserted in the model, the COBie Extension for Revit requires the user just to define some settings to export the COBie data. For how concern the classification system, that is an information to be included in COBie, it was possible to force Revit reading Uniclass2015 values, instead of OmniClass ones, even if the followed procedure is not sufficient to immediately assign the expected value to the relevant properties, as it requires the user to select it between a range of possible choices.

4.3 *COBie via IFC*

Since the COBie spreadsheet format is just a mapping of the COBie MVD developed to show the information content in a human-readable way, the route of getting COBie via IFC is the natural way of doing and the one which can, referring to the whole building process, return a complete and representative COBie file.

The delivery of COBie data via IFC is a process that has to be subdivided in two phases:

1. the exportation of the native model in IFC format;
2. the transformation of the IFC model in COBie spreadsheet format.

Of course, the way the chosen BIM authoring tool translates the native model into IFC format depends on the specific exporter application used by the software.

It must be underlined that even if the used model did not include Curtain Mullions, some tests conducted on a trial model showed some issues in the exportation of mullions from Revit. In particular, each mullion instance is correctly defined by the IFC entity IfcMember, but no type entity (IfcMemberType) is assigned to the mullion instances. Furthermore, mullions are not correctly named in the IFC file; it means that the name associated to mullions in the Revit model, is not the same through which mullions are identified in the IFC file, while it occurs for all the other elements in the model.

It is also possible to specify the MVD to be applied as a filter in the model exportation. The standard MVD that Revit uses is the Coordination View 2.0 based on IFC2x3, but the exporter allows to choose other MVDs like the mentioned IFC2x3 Extended FM Handover View, used in these tests.

The properties associated to each object in the Revit model are exported in IFC through specific data records called property sets: it is possible to map data defined within the used BIM authoring tool to the desired parameters in the outgoing IFC file.

To realize the second step in the process and obtain the outgoing COBie spreadsheet file from the IFC model, four different external applications were tested: BIMserver, COBie Toolkit (based on BIMserver and issued before the inclusion of a specific application within BIMserver itself), and the first and the last version of BimServices, a software developed by AEC3 since the first COBie release. However only COBie Toolkit and the last version of BimServices allowed the generation of COBie data for curtain walls, since they are the only ones that allow the user to modify the exclusion list the COBie specification proposes.

4.4 *Brief analysis of the resulting content of the COBie worksheets*

The results obtained through the export of the relevant COBie data of the entire model were evaluated in relation to the product and the specific stakeholder considered and as a consequence those COBie worksheets whose compilation he is responsible for.

About the exportation of the Type and Component worksheets, that can represent the basic content of COBie in the considered case, both the analyzed procedures (namely the COBie Extension and the IFC method) showed the expected results. In particular the Type worksheets was filled with what is defined as type in Revit; as a consequence Types were exported regardless dimensions, since this is the meaning of 'type' in Revit, even if the COBie schema expects Types to be defined also in relation to dimensional parameters (*NominalLength*, *NominalWidth* and *NominalHeight*). However, it must be underlined that the COBie Extension do not allow the exportation of the curtain system Type, so the entire curtain system cannot be described by a type of product in the COBie file; instead, following the IFC method, it is not possible to export mullion Types, because of the explained issues about the exportation of curtain mullions from Revit to IFC.

For both Types and Components the relevant properties were correctly exported in the outgoing COBie file, using the values introduced by the user in the specific COBie fields generated in the type and instance property menu by the COBie Extension (if this was the chosen procedure), or using the values still introduced by the user in Revit, but included in the property sets of the IFC file. About the association of the relevant Space to each Component, the undertaken tests did not show any value in the relative column since no information about the spatial subdivision of the facility was included in the used model. This fact reinforces again the use of IFC models for information exchange between different stakeholders: in this way the considered subcontractor, which is not supposed to deal with the spatial organization of the building, can work on a model that already contains this information, producing consistent COBie data.

About the other COBie worksheets, many of them are not supported by the COBie Extension; these are: Assembly, Connection, Spare, Resource, Job, Impact, Document, Issue. Considering these worksheet, the IFC method showed a partial exportation of some of the Assembly one, describing each Curtain System as an assembly of the several panels and mullions (each one included in COBie as a row in the worksheet) that compose the entire system. The fact that both the analyzed procedures do not allow the exportation of some information is because Revit, as a design software, is not able to handle information that are typically exchanged during the construction phase, for example that one related to Spare, Job and Resource worksheets.

Finally, all the methods allow the user to export in the Attribute worksheet all those properties not relevant to the columns of the other ones in the COBie template.

It must be underlined that the existing literature is still not clear enough to define the content of many COBie worksheets (i.e. Impact, Connection) or their content could be strongly different from project to project in relation to specific requirements (i.e. System, Coordinate). For these reasons, and considering those worksheets whose compilation is defined as 'Optional' by BS1192-4 (Assembly, Connection, Coordinate, Issue), the results had been evaluated without considering the mentioned worksheets.

4.5 *IDM development*

The development of the IDM, needed for the definition of the information to be exchanged, followed the specific methodology proposed by (Mondrup et al., 2014), based on a modular approach in the organization of the workflow and the management of data. As a consequence it is possible to define reusable IDM packages that specify the information exchanges that occur at a specific life cycle stage involving specific actors of the process.

With this perspective, for the purpose of this research, two IDMs were defined in relation to the specific actor involved and to the phases of the process during which the exchanges of COBie data occur, the so called COBie Data Drops. The two IDM packages were then named 'COBie Data Drop 3 - Specialist Designer' (fig.2) and 'COBie Data Drop 4 - Subcontractor', considering the roles proposed by the British regulation BS 1192:2007 and the COBie Data Drops specified by the BIM Task Group (BrydenWood, 2012), both specifically referred to the British scenario. Each IDM package should be composed by four key documents: Business Use Case, Process Map, Exchange Requirements and Exchange Requirements Model. For the sake of simplicity, the latter IDM deliverable was not considered, since it exceeded the boundaries of this study. Moreover, the Business Rules must be considered as a constituent part of the IDM, even if they are just external references used to define constraints, indications, regulations to be observed in the management of specific data, within the framework outlined by the IDM.

The expected result deriving from the use of this approach should be a more reliable exchange of data during the lifecycle of a facility between the different actors developing BIM data. The proposal suggested by (Wix & Karlshøj, 2010) was taken as a reference concerning the practical development path to be followed to deliver a complete IDM. The *Business Rule Localization* was the followed method, since the COBie IDM already existed, as well as the Exchange Requirements associated to the information exchange of interest. The Business Rules that drove the writing of the IDMs were the BS1192:-4:2014 and the Uniclass2015, in order to get aligned to the UK scenario. What the research aimed to do was the re-definition of the already existing IDM in relation to the COBie UK standard, in relation to a specific actor, involved in the field of curtain walls and building envelopes, during specific stages of the building process. The problem of the 'manageable asset', namely the definition of which object and related information should be included in COBie, concretely affected this phase.

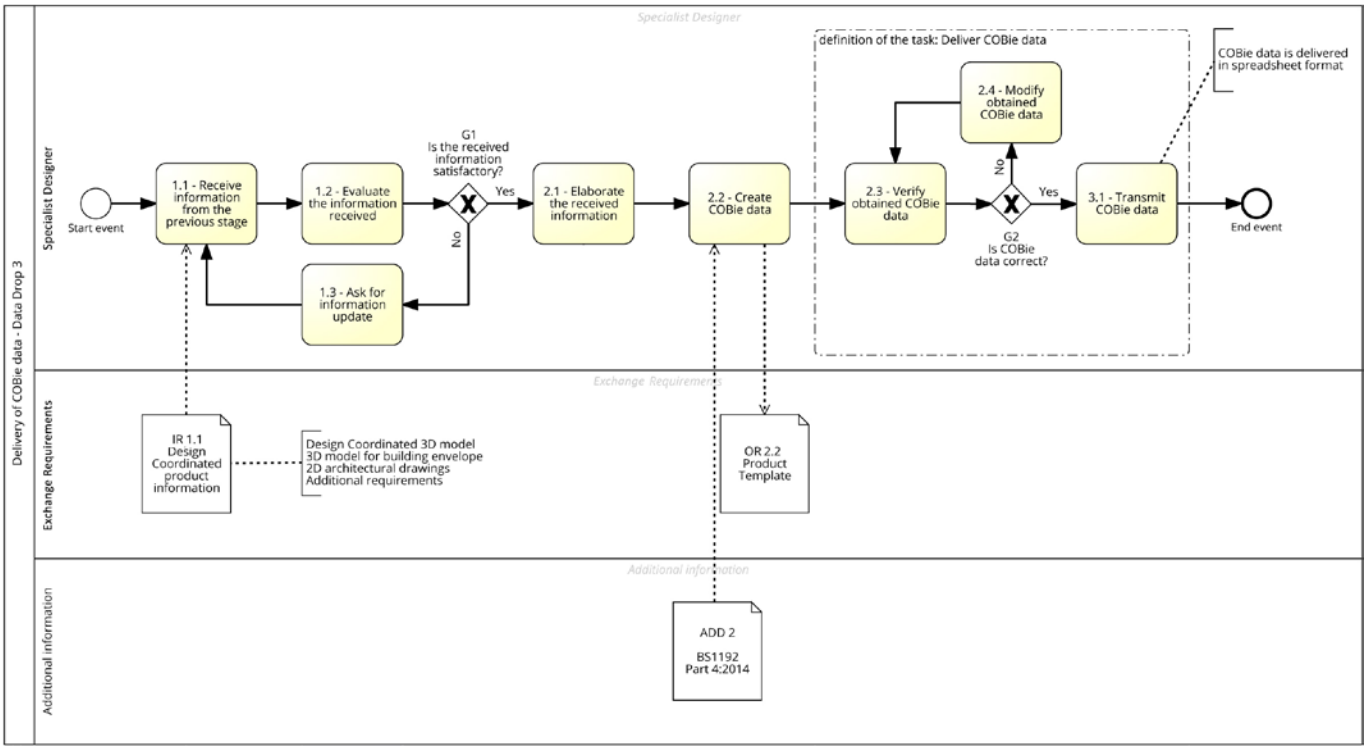

Figure 2. COBie Data Drop 3 – Specialist designer, Process Map.

The deep analysis of the COBie 2.4 specification and the available COBie spreadsheet examples taken from the BIM Task Group website led to a final consideration concerning the actual practice related to COBie: where precise indications from the employer are not given, as long as a wide and well-known practice on COBie is not established, the project team has to define which the best way to model COBie data is, according to the specific knowledge each member is able to provide on its particular field of work.

To fulfill the objective of the research, the COBie 2.4 specification (NBIMS-US v.3) and the COBie Responsibility Matrix were taken as references; in particular, the first was used to establish a connection between the Exchange Requirements (ERs) expected by COBie and the COBie Data Drops, the second allowed to precisely define when each cell of the COBie template should be compiled during the project life-cycle. Regarding the definition of what to include in COBie, the leading consideration was the following: every element of the building envelopes which needs maintenance operations, is provided with replacement parts or requires to be specified by additional documents, is described as a specific Type in COBie. Moreover, all those objects that need to be specified with those properties expected by the Type worksheet (for example those objects for which warranty information is required) are exported as Types too. It must be clearly pointed out that the criteria used to define the object Types is not dimension-related. This way of doing was chosen in order to mitigate the complexity of the considered product and to simplify the exportation which, otherwise, will lead to the definition of hundreds of different Types and an unusable COBie file.

Concerning this matter, only the cells are exported as Components, even if this procedure would not be allowed by BS1192:2014, since *"every Type should apply to at least one Component"*. This simplification, however, seems to be necessary for managing the complexity of the specific case, keeping into account that the relation between different objects can be showed by the Assembly worksheet. Finally, in the general case where a subdivision in cells is not needed or useless, all the elements of the building envelope should be exported as Components. Panels and mullions, in fact, represent in the most general and diffuse practice the composing elements of curtain walls: therefore each one of them must be seen as a single component, needing specific maintenance, or being part of a specific system, for example.

Through all these considerations the expected standardization and specificity were pursued.

5 CONCLUSIONS AND FUTURE DEVELOPMENTS

5.1 *Considerations upon the way of modeling*

Regarding how the model should be produced, the process and the standard through which information is exchanged need to be known and considered. Starting from the objective, namely the delivery of COBie data, its requirements, and considering the IFC schema, its structure and the possible relations to define the elements in their complexity, the user should find the best way of modeling in order to ensure the best result in the final COBie file. In this sense and referring to the curtain wall product, the definition of IfcPlate given by buildingSMART seems to be enlightening, enhance different types of relations with the spatial structure and its subcomponents. Of course, the results highly depend on the specific BIM authoring tool used and the ability of its IFC exporter to translate the native model in IFC format.

5.2 *Consideration about the two methods*

A first observation regarded the purpose of the generation of COBie data: if the objective is simply delivering COBie in its spreadsheet format, in order only to fulfil a contractual requirement, the COBie Extension for Revit can be seen as the best solution (fig. 3).

The reason supporting this statement is the ease of using and customizing the Extension within the Revit environment, without the necessity of additional IT capabilities, besides the fact that it allows to define all the same user-defined properties that could be exported to COBie via the IFC file obtained from Revit. The manual compilation of the several blank COBie fields is required in any case and it is comparable between the two proposed methods.

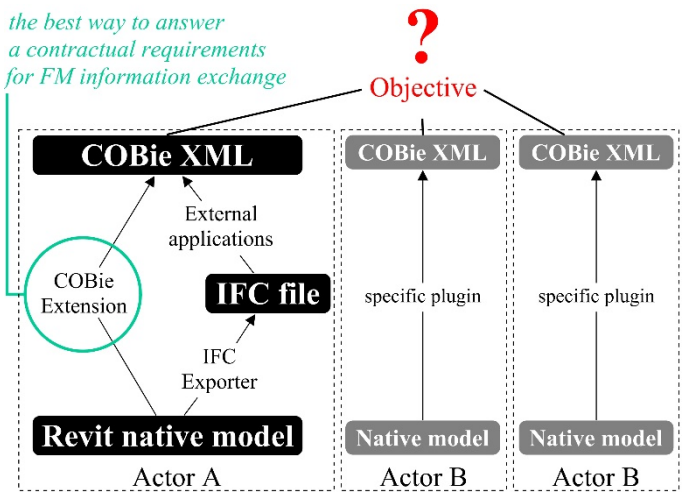

Figure 3. Issue in delivering COBie data using a single stakeholder perspective.

Still, if the expected output is a COBie spreadsheet, the method used to obtain it does not affect its final appearance: an XML file is just a table, in any case, either it is generated through the COBie Extension or transforming an IFC file. However, a wider perspective leads to reconsider the method based on the translation of an IFC model into the XML format. It must be kept in mind that IFC is the open format designated for enabling interoperability between the different actors of the building process. In this light, delivering COBie data through IFC could be considered as just one aspect of the entire building process based on IFC in order to perform interoperable exchanges where functional and usable information is transmitted (fig. 4).

Moreover this aspect is of primary interest also in the UK scenario, where the IFC standard is one of the essential requisite to reach BIM maturity Level 3. For this reason, gaining familiarity with the IFC environment could represent a wise decision for any stakeholder in the AEC industry. These considerations make clear that an MVD supporting this kind of information exchange is strongly needed: the different actors of the building process need to manage information in a collaborative way, where the content of the exchange is clearly defined and the data flow is structured in a standardized way. IFC seems to be the natural answer to these requirements.

As said, panels and mullions represent the standard way through which curtain system are organized. Regardless the encountered issue related to mullions, this is also the organization used within the IFC schema. However, IFC allows also the definition of curtain systems made by cells that contain subelements, but it was discovered the used BIM authoring tool do not give the possibility to map this kind of relation between the different components.

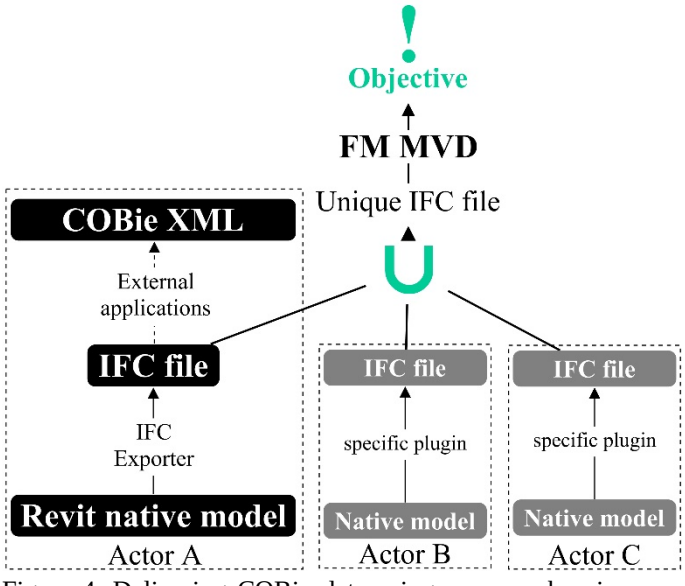

Figure 4. Delivering COBie data using a comprehensive perspective.

With this regard, future consideration upon the adequacy of how BIM tools translate curtain wall product's complex relations, from the literature review point of view, within IFC schema could be made. Future developments of this study could also concern the application to different case studies of the developed IDMs, in order to overtake that specificity characterizing each single project and verify the validity of the proposal. With this wider perspective, the IDMs themselves could be adjusted in relation to the actual requests of the AEC industry, in order to reach an as high as possible optimization of the building process.

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