Contribution to the development of a national BIM standard - Application of COBie to Portugal

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Abstract

This work is aimed to study the adaptation of Construction Operations Building Information Exchange (COBie) to Portugal, contributing to the development of a national BIM standard.

The framework, objective and methodology of the thesis are defined in the first chapter, where the overall scope is defined. Further is a simple BIM presentation, focusing on the advantages of the application, implementation and best practices. BIM is a very powerful tool to manage and organize information, being presented a maturity diagram showing the various standards that lead to a correct implementation. Still focusing information management, is assessed the most used taxonomies. Later it is presented some basic concepts that allow interoperability between the stakeholders. Proceeds to a detailed evaluation of the structure of COBie and the mandatory information in each design phase. It is presented one case of international application. It is also presented a case study that allows the application of COBie and an evaluation of results. The program used was Revit, being presented the export procedure in some detail. After an information entry work in the model it was possible to improve COBie file obtained. There has been an assessment of the exported data, and found that about half of the information is automatically populated. The purpose is to always avoid that the information isn't entered manually, which would lead to an increase in resources. The conclusions evaluates the fulfillment of the proposed objectives, verifying that have been largely achieved. Further general conclusions related to COBie are presented and necessary measures for its correct implementation in Portugal. Regarding the case study, the main conclusion is related to the importance of creating the right BIM model from the beginning of the project. It is presented as future work a phased implementation of the proposed Cobie in Portugal and use the Dynamo program to fill the missing information of COBie.

Keywords: BIM, COBie, IFC, standardization, interoperability

1. Introduction

1.1. Contextualization

The construction sector in Portugal is heavily dependent on state investment in large public works. Although signs of improvement in the national economy, public investment in 2014 was 33% lower compared to the previous year and less than 4% of government expenditure (CPCI, 2014). The lack of public and private investment is reflected in the decline in productivity in the construction sector.

To be added to the reduction of production index, there are causes related to non-compliance costs, deadlines and corruption which lead to deviations. To overcome these problems there must be "a significant change" of "procedures that give rise to them" (Santo, 2006). In response to the need for change in the industry that allows a new mindset and new processes, there has been developed in recent years the Building Information Modeling (BIM).

The goal of BIM is to integrate and coordinate all the stakeholders so that the workflow can be simplified. Although there are some difficulties in the correct implementation. This could also be explained by the rapid growth of the methodology that leads to nuances between various definitions of the BIM meaning.

Thus the two definitions given below are large organizations of the United States of America (USA) and the United Kingdom (UK). According to the National Building Information Modeling Standard (NBIMS) in 2007, BIM seeks to integrate information that is collected and applied throughout the life cycle of the project, to be easily exchanged and preserved. A definition of a more recent document is presented by Architecture Engineering Construction (AEC) of the UK in 2012, which argues that BIM is the creation and use of coordinated, consistent and computerized information on a project in the design and construction phases.

In Portugal there are no standards that respect the best practices of BIM. Several studies have been developed but its application has found great resistance. The fact that there is no obligation on its use in private and public procurement implies disinterest by of the construction sector. In Europe the use of BIM is mandatory in United Kingdom (UK), Denmark, Finland, the Netherlands and Norway. These countries are highly developed in the use of BIM, especially the UK which has contributed to the development of an European Union (EU) implementation.

The focus of this thesis will be the Construction Operations Building Information Exchange (COBie), a specification that aims to facilitate the transfer of information throughout the various phases of development, from the construction phase to the operational phase (East, 2007). The geometric information is not stored, in other words, the information refers to the equipment, products and spaces (East et al., 2013). Therefore it is necessary to make a transition from presenting the project on paper to present it in a digital format. The importance of this study is related to the lack of a Portuguese specification, which implies an assessment of the suitability of COBie in the Portuguese reality.

1.2. Goal of the thesis

It is intended to start the study with an analysis of the use of BIM on an international level and then progress to the national level. More specifically, it is intended with this thesis:

- Evaluate international initiatives in the adoption and application of BIM standards;
- Set the problems related to information management, mainly focusing on interoperability;
- Assess the adequacy of COBie to the Portuguese context;
- Identify the limitations of applying COBie in Portugal;
- Develop a case study for strengthening theoretical conclusions of the previous points.

1.3. Methodology

It is intended to develop a methodology that enables a solid study as a basis for development of the thesis. Initially the study will have a broad scope which will then be more restricted so that the proposed objectives can be achieved.

Literature review:

The literature review aims to establish a solid foundation on concepts and definitions related to BIM methodology. This study is important because throughout the thesis there will be no reference to the themes addressed in the review. Much of the review will refer international standards in the absence of Portuguese standards associated with BIM. It will be completed with the analysis of international standardization of COBie.

Theoretical analysis:

With the study of the international context is intended to review and adapt, if possible, to the national context. It is essential to understand the situation in Portugal which is currently quite far from BIM. For this reason, the implementation needs to be structured and phased so that it can be accessible, understood and applied by the construction sector in Portugal.

Case study:

The implementation of the theoretical analysis conclusions aims to validate the assumptions. If there is no validation of previously obtained results there must be a new theoretical analysis.

2. Literature Review

2.1. BIM

Especially in the last 70 years the construction sector has been fragmenting and specializing processes, (Fox, 2014), with an inevitable separation between architecture and construction. Adding to this, the exchange of information uses two-dimensional drawings (2D) having limitations in terms of space, storage and collaborative information (Alfred, 2011). The BIM intention is precisely to improve all these aspects using the involvement of all stakeholders at all stages of the development lifecycle using tools that are compatible (NBIMS, 2007). This implies that there is a storage of standardized information, which is the only way to ensure that exchanges are possible.

It is therefore important to analyze the interest of BIM in relation to costs associated with the project life cycle due to the paradigm shift. Boyd Paulson (1976) showed a correlation between the level of influence in the design and the cost of a change over time, Figure 2-1.

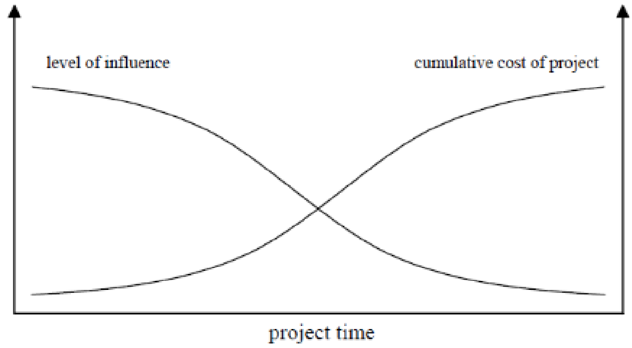


Figure 2-1 - Relationship between influence and costs throughout the project. Adapted from Paulson (1976).

In 1976 Paulson intended to demonstrate with Figure 1-1 the importance of making changes in the early stages of the project, since the associated costs are relatively low. In late project stages the opposite occurs, the ability to influence is substantially lower and represents a high value of accumulated costs. Also mentions terms like life-cycle costing, construction management, design-construct, which shows that the problems associated with early stages of investment resources and the importance of taking into account the operating costs of the facilities are long ago known. It is important to act when the level of influence is high, reducing the overall costs. To make this change it is essential to involve all stakeholders at an earlier stage of the project, using a collaborative work. In response to this need the methodology Building Information Modelling (BIM) emerged.

BIM arises as a new generation of information technology (IT) and computer-aided design (CAD) for buildings. BIM is the process of generating and managing the information associated with a development of interoperable and reusable form (Lee, et al., 2005). In other words, the information that is created throughout the project has to be storable and easily accessible for all involved. This implies a significant change in methods currently used in the construction sector, although with the adoption of these new concepts, it is difficult to apply, despite various theoretical studies already done (Sacks et al., 2003).

Barriers to BIM implementation are also related to the information technologies that are still in a development phase so that they can respond to the needs. It is important to create tools that facilitate the adoption of the methodology in order to encourage the parties concerned.

2.2. BIM implementation

In order to implement BIM in an organization, a plan has to be prepared that should contain an objective, in order to identify the aspects that will be covered and the degree of implementation to be obtained. The best development practices are set out in a guide developed by the University of Pennsylvania, more specifically by The Computer Integrated Construction Research Program (CIC). The guide defines the steps to create the BIM Execution Plan (BEP).

The various objectives to be attained by BIM Execution Plan for both the project and the project team are (CIC, 2011):

- Knowledge by the stakeholders to achieve the objectives for the implementation of BIM in the project;
- Understanding the organizations, their roles and responsibilities in implementation;
- Team ability to create running processes that are suitable for every member of the team and the organization;
- Establishing the plan for measuring the necessary resources and training for implementation;
- Establishing best practices for new participants in the project;
- Definition of language to use in the project, so that it is uniform;
- The initial plan will assess progress throughout the project.

Creating a plan also allows everyone involved to study BIM previously and which is especially important when familiarity with BIM is insufficient for its proper implementation. Reducing the risk of the new methodology is also possible if the organization resort an external element to the organization with BIM implementation experience.

The implementation of BEP can be divided into four phases: identification objectives and uses, processes, interoperability and implementation infrastructure, these are shown in Figure 2-2.

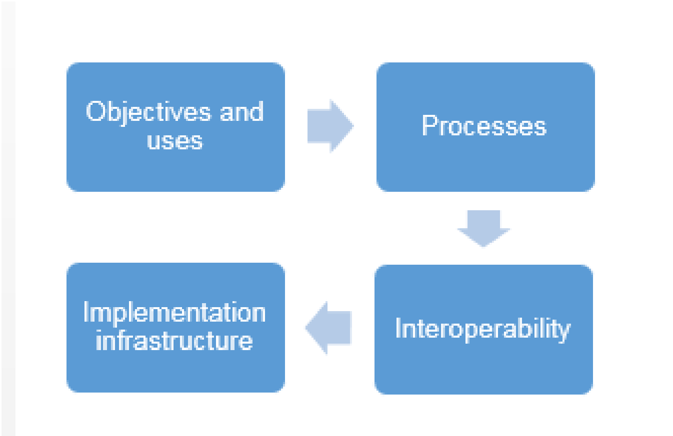


Figure 2-2 – BIM Execution Plan phases.

2.3. BIM – Support of information

2.3.1. BIM Information

A BIM model needs to contain related information and processes that allow their effective exchange between the stakeholders. These two aspects are critical to the use of BIM and evaluation of the maturity level. The level of maturity can be explained as the implementation status of an organization (CIC, 2013).

BIM representation in 3D contains associated information, unlike the CAD representation in 2D. Using the example of a wall, the CAD model is represented as several separate planar surfaces. In BIM there is a wall as a single element, being associated volumetric data with multiple surfaces, interconnections with adjacent elements, wall identification as an object, characteristics of its constituent materials, costs, among others. Additionally it is intended that the model is, as far as possible, equal to "as built". It is possible to conclude that the amount of information which can be considerable, as will be show forward, can lead to difficulties in information exchanges.

Currently it is possible to associate information to components, with the disadvantage of increasing the model size. A link to connect a component to an external file can be used alternatively, in other words the information is not within the model (Weygant, 2011). It is still necessary to ensure that the information for analysis is always inside the model.

2.3.2. Objects - ISO 12006-2

A BIM model consists of objects, being necessary a standardized form to enter and store all the information. An object can be defined as a component that operates independently in a BIM model, containing information about the identity, appearance, performance, so that is can be located, specified and analyzed along the project (Weygant, 2011). The international literature is always based on the ISO 12006-2 standard from 2001, which aims to standardize the classification of different countries. Is explicit in the purpose of this standard that is used to bring forward the construction industry so that it is possibly to manage all data. The displayed object definition is "any part of the perceptible or conceivable world".

2.3.2. LOD – Level of development

Next will be described the specification that defines the stages of evolution of a BIM project. The specification defines the Level of Development (LOD), developed by the American Institute of Architects (AIA), it aims to "be a reference enabling the parties involved in the AEC industry to specify and articulate with a great level of clarity, content and reliability the models in the different phases of the project "(BIMForum, 2013). In other words, each element will have several LOD along the project, starting with a lower and increasing with the definition of the criteria.

The specification allows the user to define each LOD at different stages of the project, only requiring that is documented so that all stakeholders understand what level to reach. So the important thing is to define each LOD, which are features associated with the objects in each level. The goal of this specification is to connect some initial shortcomings of BIM, such as the fact that initially in a BIM project only the author knew which LOD was under use, being fundamental a normalization for each level with a set of best practices. An evolution of a column is presented in Figure 2-3.

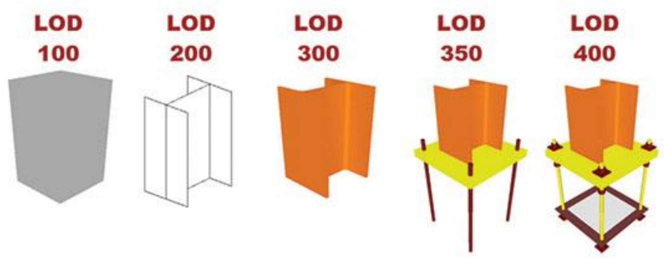


Figure 2-3 – Graphical representation of a column. Adapted from BIMForum (2013).

2.3.3. BIM Maturity Diagram

In the United Kingdom (UK) was developed BIM Maturity Diagram, which is presented in Figure 2-4. This diagram was developed by Mervyn Richards and Mark Bew in 2008 and has not been subject to major changes until the date of publication of the English standard PAS1192-2. The standard was developed with the aim of "reducing the cost of public sector assets 20% by 2016".

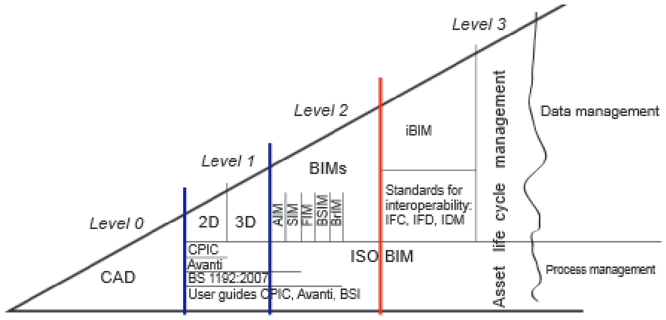


Figure 2-4 – BIM Execution Plan phases. PAS1192-2 (2013)

In order to meet the targets, the UK government set strategies for the construction sector to be achieved by 2016. It is intended that this date BIM is completely collaborative between design and information assets. In Figure 2-4 is shown the level to be achieved in 2016 with a vertical red line.

Level 2 involves 3D modeling of all specialties, there is no obligation to be a single model. It is intended that those involved have a following set of practices that allow an interpretation by all, with these also described in BS 1192: 2007. Yet there are still some difficulties to define the role and responsibility of each designer. Another aspect that causes some problems is the necessary information, input, to perform a certain phase of the project in order to obtain the final product output, which is not adequately explicit. So not defined the necessary information in each design phase, getting currently responsible for the design engineer.

2.4. Interoperability

Information exchanges are inevitably associated with the possibility of sending information between different systems, a term called interoperability (NBIMS, 2007). Currently it is recommended that teams or organizations to define from the start of the project which is the platform and the software version to use in order to avoid compatibility issues (CIC, 2013). As a basis for interoperability there must exist a universal information structure so that all applications may be used making it possible exchanges (NBIMS, 2007). This presupposes the industry itself working as one to achieve this goal.

The most important BIM concepts which allow an effective and efficient interoperability are:

- IFC - How to share the information;
- IFD - What if you are sharing;
- IDM - When and what information is shared;
- MVD - How does the information is displayed.

Their interaction is shown in Figure 2-5.

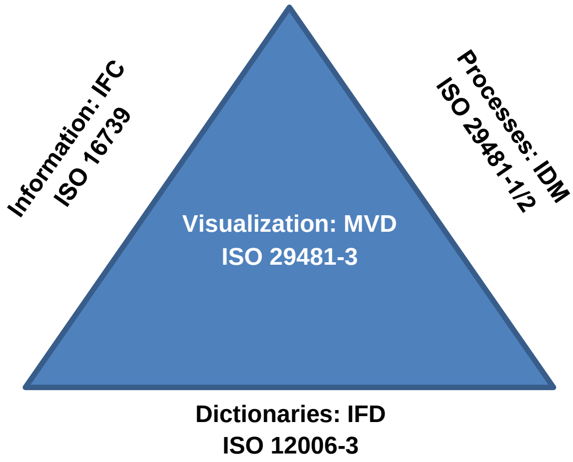


Figure 2-4 – Scheme of the main BIM concepts.

Throughout the project the necessary information at each stage varies with the type of project and the specialty. The Model View Definition aims to precisely define the required information. The different information flows have to be efficient among stakeholders, which implies a definition of spaces, floors, parts, components, etc. In other words all the information that enables the correct identification of the active features. The ISO 29481-3 is currently being developed to standardize the MVD concept.

3. COBie

3.1. Introduction to COBie

Being one of BIM aims to reduce the total costs of the project, as mentioned earlier, it is necessary to find an effective and efficient way to perform the exchange of information among stakeholders.

The Constrution-Operations Building information exchange (COBie) is an international standard established in the USA by buildingSMART, which aims to "manage the exchange of information assets" though "not add new requirements to contracts, only changes the form of delivery of documents a standard form ". COBie does not define the information needed at each stage, it only defines which no geometric information to be incorporated. In other words, the requirements are defined in the specification, but there is no reference to the design phase where should be introduced. Other relevant information is the fact that it is supported by various softwares, especially Autodesk, Bentley Systems, Graphisoft and Trimble.

In COBie, after the information is entered, it will have to be delivered to the asset manager, in other words the information entered during the project must be accessible to all until it reaches the manager.

3.2. COBie Structure

Initially, the phase of the program, information is reduced and when it reaches its operation (last phase contained in COBie) the amount of information is already considerable. This is because the information is never lost, or is established or new information is added to the existing supplemental information. It is expected that documents are submitted electronically, so the information is constantly evolving and there are no documents that have to be replaced. This happened when for each development phase of the drawn and written documents were printed. This leads to the need to first define some basic concepts. For example, is intended that the active areas of a facility are divided so that there is a designation that everyone can then assign the same number or a similar classification.

In Figure 19 it is presented how the information is organized. There are three main groups, design, construction and information common to the two previous ones. The organization of the figure presented is not random, each rectangle (representing specific information) has relations with other rectangles, when the information is inserted into COBie there is a relationship between two worksheets. The first rectangle column for the project covers the space division of the building, both vertically and horizontally. Thus the information to be entered in each space will be better defined, for example, the fire department will be the important fire resistance, so it makes sense that the sites with the same name also have the same fire resistance. The second column refers to the equipment installed in the building, the type of equipment, their components and the system in which it operates. The types of equipment can be found in the technical documentation that is automatically exported from the software to COBie.

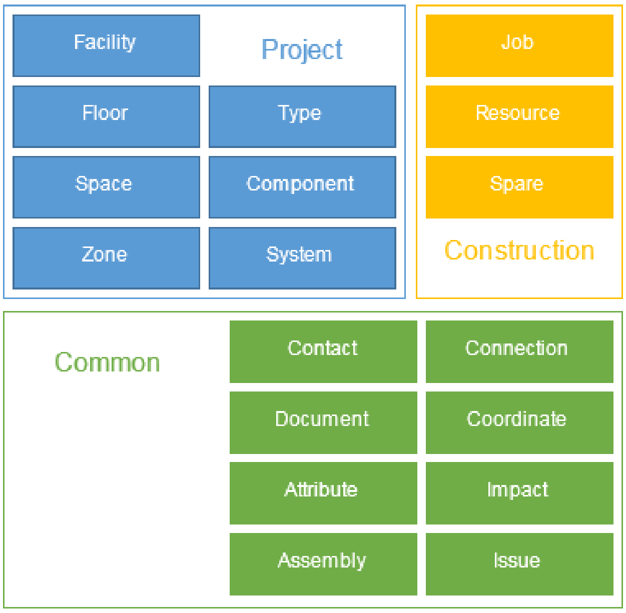


Figure 3-1 – Scheme of COBie information.

The sheets related to the construction are created by the contractor, spare category applies to parts, components, consumables and lubricants. Resources are intended to assist in future maintenance of the building. The work sheet serves for preventive maintenance and inspection requirements, or to the requirements of the scheduled activities.

In common information, contacts have data of all stakeholders that create of information in COBie. This sheet is an example of cross information in COBie, since it is also intended that there is information about those responsible for providing the guarantee. For the equipment, usually the information is in a document defining the mounting method, the necessary maintenance and to guarantee. Being a time consuming and complex task of placing information relating to each device, you can attach a file to COBie, thereby avoiding this difficulty. Reference to these attachments is found in the documents topic. The sheet of Attributes is where the information that has no place in the other sheets is introduced. The example of fire resistance previously used should be defined here.

COBie is not an Excel file, although it can be analyzed as such which simplifies its use since the format is XML Spreadsheet. To facilitate understanding of COBie is presented in Figure 3-2 one spreadsheet.

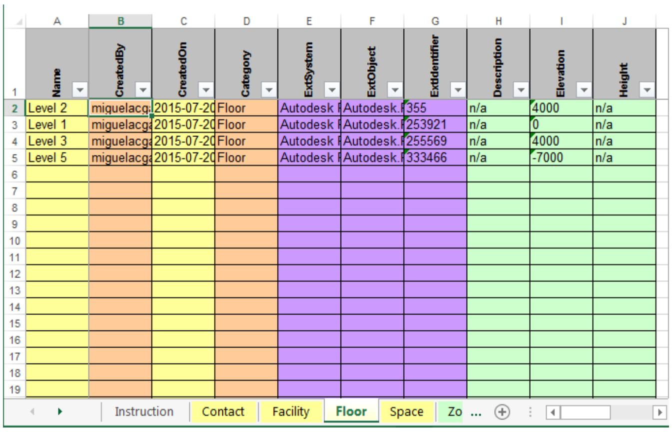


Figure 3-2 – Spreadsheet of floors in COBie.

There are some general aspects of conventions which must be taken into account when using and filling the COBie sheets. Not all the information can be changed, is the case name and order of the columns and tabs that cannot be changed, so that the file does not become corrupted. Where it is intended to refer to a specific field first is the name of the tab, followed by the name of the column, each separated by points. In the example of Figure 3-2 if we want to refer to column B which has information about who created the information would be COBie.Floor.CreatedBy. Is presented only one example of spreadsheet because the structure is similar for all the tabs, which facilitates understanding.

Information about the main theme of the sheet appears in the first column is the name that corresponds to the type of information entered. The next two columns contain information about the author and date of creation, so that there is a record over the life cycle. Category, Column D, represents the classification system used, in this case is OmniClass. The classification system shall be detailed in the last tab, designated as picklists.

The scheme of colors presented in the spreadsheet is very important. The yellow color is the information required, which means that the first column, Name, is always yellow. The salmon color is the information that is interconnected with other flap, being the easiest to understand the example of the Category, which, as mentioned above, relates to picklists tab. The purple color are references to external programs. Finally the green columns present specific information. This information is resumed in Table 3-1.

Table 3-1 – Color scheme used in COBie

Color	Designation

	Required
	Reference to other sheet or picklist
	External reference
	If specified as required
	Not required for the given phase

The various colors of each column aim to demonstrate the need to introduce the information depending on the design phase in which we find ourselves and are only a convention that facilitates communication among stakeholders. The example in Figure 3-2 is the delivery of COBie the user therefore must contain all data required for active operation.

In short, COBie is a specification that defines the requirements for the delivery of projects for future use, with an increase of the information contained throughout the project. It may seem that COBie file fill is something quite time consuming and laborious, but the most difficult is the first use since the same information can be used in different projects. An example is the sheet reserved for the contacts that can be imported from another project.

3.3. Required information

3.3.1. Data Drops

The data drops were developed by BIM Task Group and its aim is to establish delivery points of documentation and control of information. These phases must be established early in the project and in accordance with the agreement with the owner of the work or client. The information corresponding to each data drop will be described and documented in COBie file itself, which obviously implies a structure as soon as possible. It is also described that information to contacts should be entered manually though, as more will be analyzed ahead, the information regarding the contacts can be inserted directly into the model.

The information presented below is intended as a conceptual demonstration, being always subject to changes and adjustments according to the specific requirements of each project. The date drops can be divided into five main groups and develop as follows (BIM Task Group, 2014):

Date drop 1 - Requirements and constraints

It is intended that the information is necessary for the delineation of the purpose of the asset. The customer intentions have to be ensured in terms of function, cost, and carbon. There is this Carbon specification because, as mentioned earlier, the UK government has reduced carbon emissions as a goal. As for the model, it should contain indicative volumes of the occupation of space, general locations and customer requirements for the divisions. With this information feasibility studies can be carried.

Date drop 2 - Outline the solution

The aim at this stage is to choose the contractor, which enables the use for the tender stage. Validations are performed to ensure that customer requirements are met in terms of design and specifications. The model should contain information on the functionality of space, environmental conditions of space, finishes and a list of furniture and equipment for each division.

Date drop 3 - Building Information

The information serves to agree the maximum price. Validations have the same purpose of the previous drop. The model contains technical solutions used and thus can be used for the construction.

Date drop 4 - Operating and maintenance information

The information that is stored is highly dependent on manufacturers, since it is operational and details of the functionality of the objects. The model is a representation of the "as built" inevitably being dependent on contractors involved. The information of the model can be exported to be used in the asset maintenance.

Date drop 5 - Post-occupation validation of information and development operation and maintenance

There is still no consensus on the concept of post-occupation and how the review should be done in this case. Yet the general principles argue that this is an opportunity to update the previous drop of representative form of actual use of the asset and its equipment.

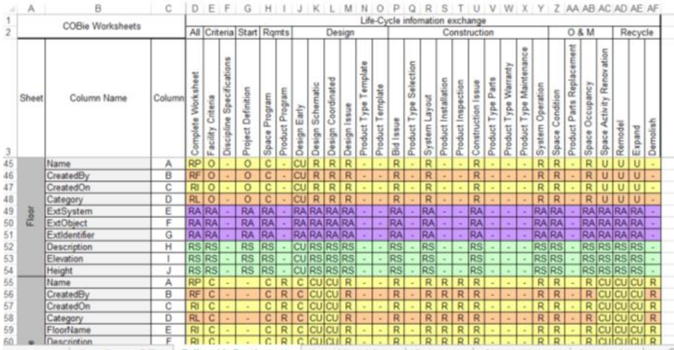
3.3.1. COBie Responsibility Matrix

NBIMS also developed a matrix whose goal is to assist users adapt to COBie to their project. The COBie Responsibility Matrix can be divided into three fundamental objectives:

- Specify the delivery points of each cell in the worksheet;
- Specify the requirements for the delivery of COBie data in each project phase;
- Specifying where, due to software limitations, there may be data truncation.

The second tab of the matrix, Deliverable Requirements, is the one with the highest interest for the development of this thesis, since discriminate fields of spreadsheets that have to be filled in each phase of the project. This is only a recommendation, since, according to the specificity of the project, the required information can be changed.

Since the spreadsheet of Deliverable Requirements has several lines, the given Figure 3-3 only corresponds to the COBie Floor spreadsheet.



COBie Worksheets			Life-Cycle infomation exchange: All	Criteria		Start	Rqmts		Design						Construction										O & M				Recycle		
Sheet	Column Name	Column	Complete Worksheet	Facility Criteria	Discipline Specifications	Project Definition	Space Program	Product Program	Design Early	Design Schematic	Design Coordinated	Design Issue	Product Type Template	Product Template	Bid Issue	Product Type Selection	System Layout	Product Installation	Product Inspection	Construction Issue	Product Type Parts	Product Type Warranty	Product Type Maintenance	System Operation	Space Condition	Product Parts Replacement	Space Occupancy	Space Activity Renovation	Remodel	Expand	Demolish
Floor	Name	A	RP	O	-	O	C	-	CU	R	R	R	-	-	R	-	R	-	-	R	-	-	-	R	R	-	R	U	U	U	-
	CreatedBy	B	RF	O	-	O	C	-	CU	R	R	R	-	-	R	-	R	-	-	R	-	-	-	R	R	-	R	U	U	U	-
	CreatedOn	C	RI	O	-	O	C	-	CU	R	R	R	-	-	R	-	R	-	-	R	-	-	-	R	R	-	R	U	U	U	-
	Category	D	RL	O	-	O	C	-	CU	R	R	R	-	-	R	-	R	-	-	R	-	-	-	R	R	-	R	U	U	U	-
	ExtSystem	E	RA	RA	-	RA	RA	-	RA	RA	RA	RA	-	-	RA	-	RA	-	-	RA	-	-	-	RA	RA	-	RA	RA	RA	RA	-
	ExtObject	F	RA	RA	-	RA	RA	-	RA	RA	RA	RA	-	-	RA	-	RA	-	-	RA	-	-	-	RA	RA	-	RA	RA	RA	RA	-
	ExtIdentifier	G	RA	RA	-	RA	RA	-	RA	RA	RA	RA	-	-	RA	-	RA	-	-	RA	-	-	-	RA	RA	-	RA	RA	RA	RA	-
	Description	H	RS	RS	-	RS	RS	-	CU	RS	RS	RS	-	-	RS	-	RS	-	-	RS	-	-	-	RS	RS	-	RS	RS	RS	RS	-
	Elevation	I	RS	RS	-	RS	RS	-	CU	RS	RS	RS	-	-	RS	-	RS	-	-	RS	-	-	-	RS	RS	-	RS	RS	RS	RS	-
	Height	J	RS	RS	-	RS	RS	-	CU	RS	RS	RS	-	-	RS	-	RS	-	-	RS	-	-	-	RS	RS	-	RS	RS	RS	RS	-
	Name	A	RP	C	-	-	C	R	C	CU	CU	R	-	-	R	-	R	R	R	R	-	-	-	R	R	-	R	CU	CU	CU	R
	CreatedBy	B	RF	C	-	-	C	R	C	CU	CU	R	-	-	R	-	R	R	R	R	-	-	-	R	R	-	R	CU	CU	CU	R
	CreatedOn	C	RI	C	-	-	C	R	C	CU	CU	R	-	-	R	-	R	R	R	R	-	-	-	R	R	-	R	CU	CU	CU	R
	Category	D	RL	C	-	-	C	R	C	CU	CU	R	-	-	R	-	R	R	R	R	-	-	-	R	R	-	R	CU	CU	CU	R
	FloorName	E	RI	C	-	-	C	R	C	CU	CU	R	-	-	R	-	R	R	R	R	-	-	-	R	R	-	R	CU	CU	CU	R
	Description	F	RI	C	-	-	C	R	C	CU	CU	R	-	-	R	-	R	R	R	R	-	-	-	R	R	-	R	CU	CU	CU	R

Team Responsibility | Deliverable Requirements | Spreadsheet Schema | Type Assets | Component Assets | Property Sets

Figure 3-3 – Scheme of COBie information.

The table is quite detailed, since the various phases of design, are represented in each column. The matrix lines represent the COBie file columns (compare Figure 3-2). Obviously the information evolves over the project life cycle, analyzing Name line, it can be created in the Facility Criteria phase, corresponding to the definition of the criteria specified by the Employer or the Project Definition phase. Necessarily it has to be created in the Space Program phase and again created and updated in the Design Entry step. After that will be read-only, and only updated again in cases of remodeling or expansion of space.

3.4. COBie application

A case of the COBie application is the Mark Center, located in Alexandria, the state of Virginia, it belongs to the Department of Defense of the United States, Figure 3-4. The building consists of offices, operations center, conference rooms, components of information technology, training centers, auditorium, gymnasium, cafeteria and garage. The project would be developed all in BIM and would have to be created a COBie file, making it a challenge because of its size. So two engineers were assigned full time, whose only function was to manage COBie during the different phases.

Figure 3-4 – Mark Center building.

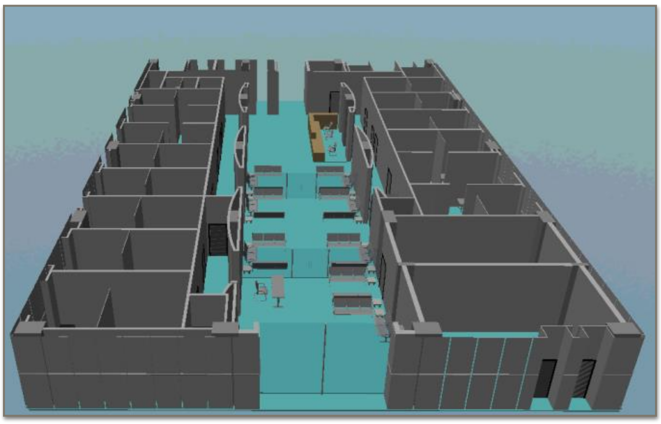
The application of COBie, part of the National Standard BIM-United States, was applied to the building by specification of the Employer that determined the information should only be delivered in digital file format. The aim was to get a list of equipment, products, warranties, spare parts, preventive maintenance schedules in order to be used in the operation and maintenance phase of the asset.

Thirty-seven days before the deadline, Mark Center building was completed and below the estimated cost, and was a proof that the application of COBie did not delay the completion date. Yet such it is understood that this happened because there were two engineers fully committed in creation and development of the file. The knowledge obtained in this case study formed the basis for the creation of a guidance document to define the information to be collected by COBie, Emerging Challenges and Opportunities in Building Information Modeling for the US Army Installation Management Command.

4. Case study

The case study is the Hospital da Luz in Lisbon, after October 15, 2014 became majority owned by Fidelidade and changed the name of Espírito Santo Saúde to Luz Saúde. In order to provide the best security and functionality possible for users there was a special care to the entire hospital architecture. They can be highlighted as key areas of activity specialties in oncology, cardiovascular disease, neurosciences, obesity, minimally invasive surgery, sports medicine and traumatology, continuing and palliative care.

It will be only used the waiting room floor, having been modeled architecture, HVAC and lighting Figure 4-1. To create the model it was used the 2D models that were imported into Revit aiming



to export at the end in IFC format.

Figure 4-1 – 3D model of Hospital da Luz waiting room

It should be noted that the model has not been developed taking into account the creation of a COBie file. Thus an attempt is made to further implementation to the completion of the model, getting to the last chapter the analysis of the implications and consequences of this adaptation.

4.1. Required information

The use of COBie in Revit is possible after installing an add-in, COBie Toolkit for Autodesk Revit, which simplifies the exporting of information for COBie. The process can be divided into three stages configuration, modification and export. In the configuration it is established the contacts of the stakeholders and set up some basic parameters for mapping the model. Then changes to the management of relation between the Revit zones and COBie zones. It is also intended at this stage to specify families, types and elements that will be exported. Finally, the export will be set up which spreadsheets to include, which is document format and the export location.

Setup

The first step to take in the Setup preparation is to create the contact list of those involved in the project. This list can be imported from a previous project if there is such a database, it is possible to considerably reduce the time taken by this step. There is a clear distinction between mandatory and optional information. Mandatory for each contact is: who created the information, e-mail, company, phone number and classification. Here it was used the classification system in use in the project to categorize specialty contact. In this case the classification used was the OmniClass with code 34-20 11 21 for a Civil Engineer.

Many other parameters must be choses in this step, Figure 4-2, the first is the location, there are two possibilities, United States of America and the UK.

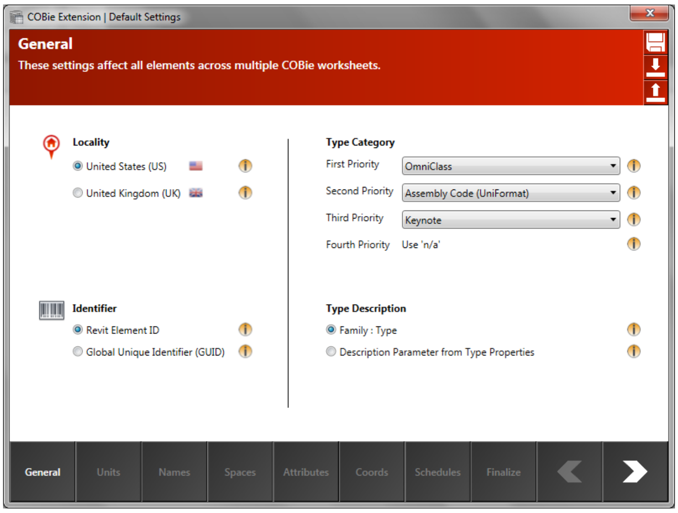


Figure 4-2 – Setup configurations in Revit

In Type Category aim is to define how will be filled COBie information corresponding to the category, which, as previously stated, there in almost all the tabs of COBie. There is an order of priority of how the information should be collected. In this case, first information is obtained from OmniClass after Assembly Code, followed by Keynote and finally is used a term "n / a" in the absence of any preceding classification. The remaining settings relate to the units, names, places, attributes, coordinate and schedules.

Modify

Modify is intended to manage the spaces, select elements to be exported and other parameters that must be mapped in the fields of COBie. To assign COBie Zones, the application uses the Revit Rooms, Revit Spaces or a combination of both. Generally the rooms are used by architects and spaces by engineers Spaces. The COBie file to be created needs information about the location of the object in order to avoid any duplication of information about which of the two locations to use, this is defined previously in setup, Figure 4-2 in the spaces configurations.

For the correct application of a Revit Room the elements must form an enclosed area. This did not happen in the case study of the file and it was necessary to resort to the use of Revit tool that allows the delimitation of the manual form of Room.

Afterwards the elements to be exported are selected in a appropriated window. Here it is possible to see all the families that are in the model and select a family to be exported. The selection does not imply that the whole family is exported, since there is still a division into types and then elements, and it is selected which type or element it is chosen.

Export

Finally, the Export option will generate COBie file as a document that can be later viewed in Excel. This step is quite simple since all the necessary settings have been carried out previously serving only to the definition of what spreadsheets to be filled. There are two options that simply choose if a new file is created or an existing one is updated. As most programs there is also the possibility to choose the file destination.

4.2. Results

In this subchapter it will be analyzed the COBie file created. The objective of this analysis involves checking whether the information in the various spreadsheets is properly filled. Thus it will be made a comparison with the desired information on the date drop 4 and last phase of operation and maintenance, Space Condition from the Deliverable Requirements matrix.

It is observed that in COBie file, the information that comes directly from Revit (purple cells) is always filled. This information is related with software used, the object name in the software and the identification code generated by the software. Thus the great relevance is not given to these columns due to their simplicity and automatic creation by the program.

To check the correct completion of the spreadsheet cells it will be held a comparison between COBie file obtained and the expected information presented at the Deliverable Requirements matrix.

Table 4-1 –
Color code used to verify the file obtained COBie

Color	Designation	Quantity
	Correct information	91
	Lack of information	57
	Parcial information	4
	No information	125
		277

As can be seen, much of the information is missing or is incorrectly entered. The study will be initiated to correct the worksheets that do not have any information, code black. The sheets that are not completed are: Assembly, Connection, Spare, Resource, Job, Impact, Document, Attribute and Issue. It can be considered that there is a lot of missing information but be aware that the development of the model did not take into account a later export of COBie file and that there was no special care in exporting to minimize possible failures.

Another aspect which considerably limits the amount of information is exported the fact that the objects do not contain all the fields filled, inside the Revit model. The method to correct the errors will be to select one object and enter as much information as possible. Subsequently it will be verified the improvements achieved.

The creation of these new parameters associated with an object was not in vain, as those appear on the tab on the Attributes of COBie. Also in Setup (first step of COBie configuration), shown in Figure 4-2, in Attributes you can select the type parameters or instance to be exported to the respective sheet Attribute of COBie. So the information to export can be chosen, despite being conditioned to manual input by the user in the Revit program. The results in the COBie file are presented in Figure 4.3.

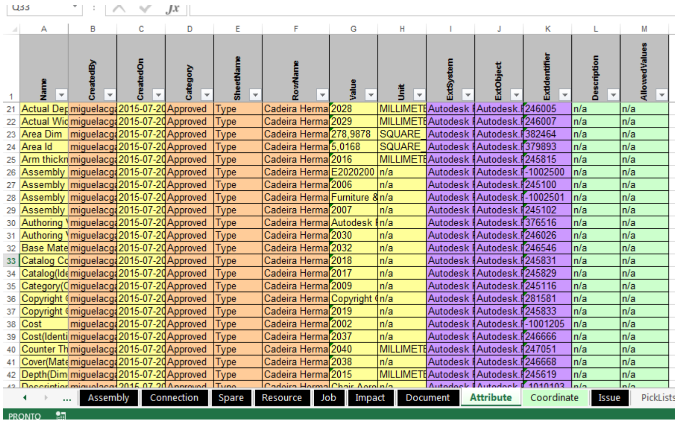


Figure 4-3 – Attribute sheet of the selected object

Having new information been introduced on the attributes sheet, it is important to make a new assessment of the fields that are unfilled at COBie file. The new result are presented in table 4-2.

Table 4-2 – Final results

Color	Designation	1st version	2nd version
(green)	Correct information	91	104
(red)	Lack of information	57	56
(blue)	Parcial information	4	5
(black)	No information	125	112
		277	277

The main difference between Table 4-1 and Table 4-2 relates to the worksheet on the project information and attributes of objects. This result was expected, since these were the fields that it were possible to edit. Thus the number of cells filled with information properly increased and consequently no information cells decreased.

5. Conclusions

5.1. Evaluation of proposed objectives

Internationally there are several standards intended to structure the BIM methodology, from the simple definition of an object, ISO 12006-2 up to the designation of an object with the classification systems.

With regard to information exchanges there is ISOs, IFC, IFD, IDM and MVD standards. Its correct application and use allow the transfer of information between stakeholders involved in the lifecycle of an asset, as they represent a universal structure that serves as the basis for new methods of exchange and storage of information such as COBie.
In Portugal the lack of a National BIM standard that structure the methodology to be followed makes it even harder a national analysis of COBie, which is the major objective of this thesis, serve as a basis for evaluation of a possible use. The importance of COBie is related to the way the information can be stored and extracted from a structured BIM.

After an analysis of the structure and qualitative and quantitative control methods to COBie, it was applied to case study. The analysis of the structure was based on several articles and international publications and analysis of information extracted quality was based mainly on COBie Responsibility Matrix.

We can thus conclude that the proposed objectives were achieved.

5.2. General conclusions

Objects have a problem in his introduction in the BIM model, to run properly is quite time consuming and complex. This is because the objects that are imported into the model does not have all the physical and mechanical information of the material or component. The databases available online only allow to obtain objects that are later modified to resemble what will be installed. Ideally the manufacturers themselves should provide the objects in IFC format, so all the features would be given by manufacturer, like tests and provides. Obviously this solution would increase costs for the manufacturer, a key aspect to be taken into account.

The use of XML Spreadsheet format may seem a throwback to the BIM methodology since the information is being extracted from the 3D model to an Excel file. The use of this format has several advantages that are be listed:

- In the UK the use of COBie purpose is to serve as an intermediate point to be a useful implementation support BIM since it enables the connection between the 3D model and the IFC;
- The storage of information in a format that can be open in several software, the most usual Excel, allows it to be accessible to everyone involved, no longer be a need to have a program leading to the model preview.
- It is expected that a file in XMLSpreadsheet format can be opened in the coming years, net existing a discontinuity of programs that can open it.

The information to be submitted in each project phase is referred to in the Data Drops, but these are somewhat vague, with only general ideas and the absence of any specification for different types of contracts. The application to Portugal should also be taken into account project phases contained in Portaria 701-H.

5.2. Case study conclusions

The purpose of the case study was to apply the knowledge developed along the thesis and evaluate the results. The Hospital da Luz had already developed a model to which was extracted information to COBie, some problems have been encountered in this procedure. It should again be noted that the model had not been developed taking into account the export of COBie, in other words objects were not in IFC format.

It is presented a simplification of Table 4-2, summarizing the results. As mentioned in COBie file the required cells are filled to yellow, the ones filled are the ones represented in Table 5-1.

Table 5.1 – Required information filling

	Correct	Lack	Parcial	None
Required Information	34	9	3	25

Properly filled cells are approximately half, with a small part missing and only three partially filled. As for the non-existent these cells could only be remedied if all the worksheet was completed, in the case study they could not be completed automatically. It should be noted once again that the fields can always be filled manually, in other words directly in COBie file, always associated time and high costs. Nevertheless, at an early stage of application to Portugal this number of correctly filled cells may be acceptable, as it makes sense a phased deployment of COBie.

5.3. Future studies

A phased implementation of COBie in Portugal is a future study. To this can be used a model similar to BIM maturity diagram (different than the one in Chapter 2) developed by The Computer Integrated Construction Research Program which is presented in Figure 5-1.

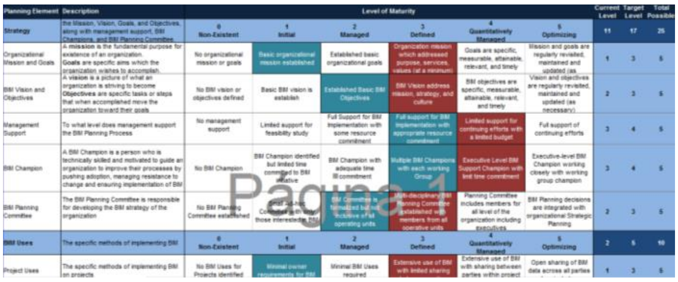


Figure 5.1 – Attribute sheet of the selected object. CIC (2011).

Put simply this diagram can be explained as a detailed description where you can check the current level of an organization in the implementation of BIM. The first column defines the scope to be analyzed, followed by a more detailed explanation of the concept in the next column. The following six columns define the level of implementation for certain context, in other words, in the first column "Organizational Mission and Goals" the current level is 1. The magenta is the level to be achieved in the organization, in this case the level 3. A diagram similar to this could be used to implement the COBie, where each row corresponds to a spreadsheet and COBie levels are associated to detail such information or even the number of cells that must be satisfied. This diagram can become even more complex if it is associated with Data Drops applied to Portugal.

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