

IFC DATA MAPPING BASED ON A PARAMETRIC BIM CODING FOR AN EFFICIENT WORKFLOW IN THE QUANTIFICATION AND MANAGEMENT OF CONSTRUCTION COSTS

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Commission V, WG V/7

KEY WORDS: Building Information Modeling (BIM), IFC, Open BIM, Quantification, Management of Construction Costs.

ABSTRACT:

In recent years there has been a great effort by the agents of the AECO sector aimed at an efficient use of data interoperability between the participating disciplines and the applicability in the specific software. In this context, the BIM (Building Information Modeling) methodology, moves in a collaborative data management environment to monitor and control the design, planning, cost control, construction processes, and building maintenance. But to enjoy the benefits of BIM in its fifth dimension (5D), cost and time savings, it is essential to properly plan each phase of the project and manage the information effectively within the same team.

Therefore, this research aims to validate an effective method for the creation of the information of a constructive entity using codes, disaggregated by budget line items, necessary for the mapping of data in the structure of the IFC file (Industry Foundation Classes) and the confrontation with the filtering rules in quantification programs, in 1 to 1 relationship. Under normal conditions, the item to be measured would have a quality or parameter that distinguishes it from another item. All elements are mapped following an IFC structure using the eCOB standard. This information will be collected in the quantification program to compare it with the information established in the rule corresponding to each item.

The analyzed and tested method, based on a proper structuring and classification of data of the elements that make up the BIM model, has been productive and efficient in avoiding random decision-making by the operator who analyzes the quantifications and that may lead to errors or inaccuracies when applying the metric. The result of the study shows that the combinations of parameters, influences by the possible variables of the constructive element, can be considerably reduced. The percentage of rules would decrease by a ratio of 17/120 in the IFC information mapping process to be validated in quantification and valuation software, improving data exchange and interoperability in an international environment.

1. INTRODUCTION

1.1 Background

The approach to efficient and sustainable construction involves eliminating barriers inherited from past methodologies. These methodologies have become inadequate and obsolete, because the AECO sector has assumed them, through its managers, as accepted practices. The scientific community continues to intensify its studies in the last decade focused on an effective and productive BIM Methodology implementation, achieving better solutions that mainly overcome interoperability barriers. The structuring of the virtual construction process of the building or construction event must be perfected - 3D BIM modeling - and that, in turn, can incorporate the associated data depending on the specific category that it must satisfy; but without forgetting that it must flow adequately between the digital systems involved. In this way, the workflow in its collaborative component is reinforced, which in the case of the fifth dimension BIM -5D-, will facilitate the modeling process for the automatic generation of quantities and the obtaining of real costs. It is necessary to reduce distances due to a lack of BIM software compatibility, disagreement in encoding protocols for elements inserted in the construction information models; as well as improving the IFC standard digital file to adequately encode elements and systems in a collaborative BIM environment. These factors, together with the lack of truly integrated models, are the challenges that we must overcome to

achieve full interoperability and, therefore, efficient collaborative work in the industry (Stanley and Thurnell, 2014).

Building information modeling in its fifth dimension (BIM 5D) integrates all the information from the design to the final construction stage, where quality, time, and cost are the three most important factors (Lee et al., 2016). As construction is increasingly complex, BIM models develop a role for project cost managers (Smith, 2016) in order to adapt to the more sophisticated services of models in their 4D and 5D dimensions. The importance of adjusting the budget of a project is essential for clients, and therefore the adoption of this fifth dimension makes BIM an essential facilitator and thus exposes it (Mitchell, 2012).

Obtaining quantities based on a BIM model is one of the potentially most important specialties within the BIM methodology, as it substantially influences the profitability of the entire construction process. Modeling should be considered as a container of construction systems to be used or existing (in the case of remodeling or rehabilitation), in its 3D representation component, but looking for the most appropriate way to incorporate data and structure them. The dimensional parameters are those that define the geometry of the object and are those that later make up the construction system as a whole. But these values must be organized for an output of appropriate quantities to adapt to the existing specifications in the market, be it of the area, region, or country. It is therefore important to define modeling guidelines that allow the user to extract

adequate quantities for the processes and facilitate data interoperability between specialists. Some authors such as (Monteiro and Poças Martins, 2013) conclude that it is feasible to adapt the model to extract quantities according to specifications for established manual measurements, although the adjustments are not without implications in other applications of the model, such as visualization or drawings.

1.2 The IFC format

The BIM methodology, established based on a 3D modeling of the construction process, moves in a collaborative data management environment to monitor and control the processes of design, planning, cost control, construction, and maintenance of buildings. And this collaborative data management is done through the exchange of information by IFC files (Industry Foundation Classes) that allows obtaining data without alterations or loss of information. The IFC structure is made up of entities, that is, by geometric, constructive, and basic elements (Colucci et al., 2020) that the modeling software manages in layers and subsequent transformation into parametric objects. It is an open, neutral, and generated format to facilitate the exchange of information.

1.3 The 5D BIM applications

Implementation in projects managed through BIM is currently one of the most interesting fields of research. The technology that underpins BIM currently offers opportunities and new challenges for the agents of the AECO sector agents. For this reason, project cost management involves improvement strategies in the organization of construction planning. They solve factors such as interpretation of the units of measurement, human errors in direct measurements, omissions of the constructive units and eliminate the criteria of percentages that may occur when measuring. Therefore, it is necessary that the project manager in turn is a BIM operator. In the United States, associations related to cost engineering (AACE, ASPE) set up a work team to solve these problems. The goal was to develop systems and protocols for the collaboration and coordination of cost engineering (Smith, 2016). Recent work focuses its attention on the practical and theoretical advantages of using BIM 5D, such as cost control, automatic adjustments, savings in construction values (Vigneault et al., 2020). However, the development of the capabilities and applications of BIM 5D is closely related to the applicability of its technology. In the first place, the operability of the system, in which the combination of 3D views with the entities improves the accuracy of interpretation (Nadeem et al., 2015). Moreover, the cost estimate in terms of comprehensive improvement. The linking of external software to the BIM system technology itself, as is the case of Open BIM Quantities (CYPE Ingenieros, 2021), and the analysis throughout the life cycle of the project through a dynamic link between the model and the information of the Project Manager.

1.4 Open BIM 5D workflow

From the outset, it was decided to work through an Open BIM workflow for time and cost management (5D), choosing CYPE's Quantities software to support the amounts provided by ArchiCAD's BIM model. "Open BIM Quantities" is created for reading and managing the quantity measurement of BIM elements, based on the definitions (properties) of the received IFC standard file, and the subsequent generation of the budget. Although there are different software dedicated to measurements and budgets such as Arquimedes CYPE, Gest

Arktec, and Presto, their use would imply a workflow based on the interoperability of the price database following standards, such as FIEBDC-3 (.bc3) (Lucena González et al., 2021) applied in Spain, without taking into account the parametric elements of the BIM model. In Open BIM 5D, the specialist establishes the measurement criteria using intelligent "rules" for filtering elements based on their properties and selects the precise quantities in the measurement. On import, the work units previously extracted from the BIM model will be automatically linked to concepts from the official price bank to generate the budget.

2. OBJECTIVES

2.1 General Instructions

The objective of this research is to validate an effective method for the creation of the information of a constructive entity through codes, disaggregated by budget lines, necessary for the mapping of data in the structure of the IFC file and the confrontation with the filtering rules in programs of quantification, in 1 to 1 relationship. Specifically, it is about defining the entity of the constructive elements of the model by creating a coding and parametric description of the budget items. Under normal conditions, the element or item to be measured would have a quality or parameter that distinguishes it from another element (item). Thus, in the case of a structural basement wall in contact with the ground on the outside, it must contain, in addition to the section and height of the element: one-sided formwork, type of concrete, reinforcement, and quantity according to the characteristics of the materials. The established national and international standards will be followed, so all elements will be mapped following an IFC structure and using the eCOB® standard to generate the BIM objects. In this way, they are endowed with a consistent and technically rigorous data structure, which facilitates interoperability between BIM programs. At present, it is adapted to the Spanish regulations (Technical Building Code). Finally, this information will be collected in the specific quantification program to compare it with the information established in the rule corresponding to each item.

3. METHODOLOGY

At present, a considerable number of applications for the evaluation of construction costs coexist in the market -BIM 5D-, it is working in an Open BIM environment, reinforcing the collaborative workflow based on an IFC file connection. Although the way to manage these files varies depending on the specific software. The work process on the modeling platforms is coincident, generally based on the mapping of information, and the subsequent elaboration of "rules" to filter the parametric data associated with the 3D elements of the IFC file. These "rules" will be defined in the cost evaluation and quantification programs.

But one of the problems involved in the elaboration of the information filtering rules is that in order to generate a database as extensive as possible, it is necessary to generate a large number of rules for a specific element, which is defined by different budget items, combining the different variables. As a work methodology, a procedure is established based on a first organization of the information, which involves structuring the geometric data and the classification of the elements that make up the BIM model. The operator analyzes the data to avoid unpredictability in determining the quantifications.

3.1 Case study

A building with four floors above ground and one at the basement level is chosen. To generate an accurate measurement of the structural model, we proceed to modeling in ArchiCAD. The CYPE Quantities software is used to generate the budget by linking IFC files.

3.2 Parametric modeling

In the BIM ArchiCAD platform, the reinforced concrete structure of the building is modeled, made up of slabs, walls, and columns. To create a twin information to the budget database, specific parameters are created that serve as pre-established variables: material (type of concrete) and amount of steel. And other parameters (section and height) are given by the same BIM platform (Figure 1).

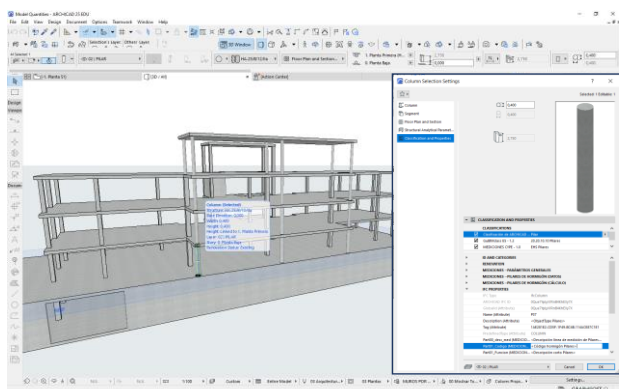


Figure 1. a. Structural model of the building; b. Definitions of the selected parametric object (IFC parameters).

3.3 Classification

In an initial phase, the database is created using the CYPE program, in which the different budget items for columns and reinforced concrete walls will be organized. Items are coded according to variables: type of concrete, element height, formwork section, amount of corrugated steel, among other information (Figure 2).

Figure 2. Cype DB (prices in Spain) of formwork items (a) and reinforced concrete pillars (b).

Various classification systems have been used for the elements of the BIM model, Classification ArchiCAD v2.0, GuBIMclass and CYPE v1.0, the latter being essential for interoperability with Quantities. The image below shows the classification of the circular concrete column P37 (Figure 3).

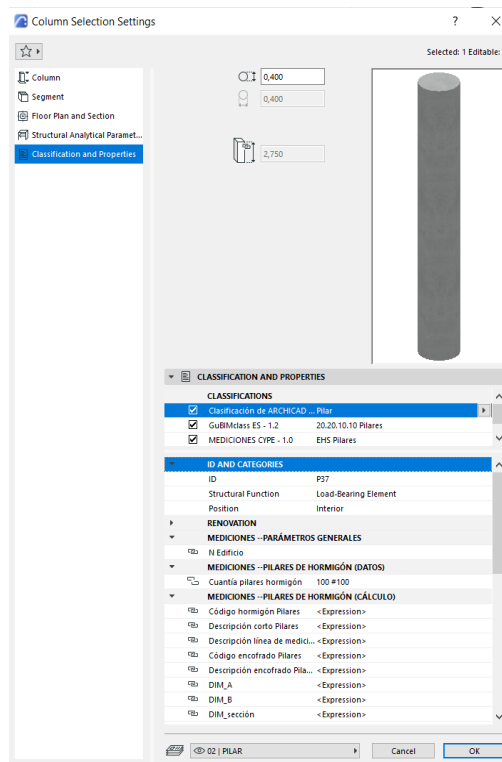


Figure 3. Classification and Properties of column P37. Archicad

3.4 Properties for quantities

In the ArchiCAD Properties Manager, the data are parameterized for the creation of codes and descriptions, among other data. The property "Code Reinforced concrete column" is generated by concatenating data: "Fixed code" + "Code according to concrete" + "Code according to quantity." The property "Description Reinforced concrete column" is generated by concatenating data: "Fixed text: (Section column)" + "Column section parameter" + "Fixed text: (reinforced concrete)" + "Material parameter" + Fixed text: (manufactured in central, poured with bucket and B500S steel with an amount of)" + "Parameter amount of steel" + "Fixed text: (kg / m3). "

In the list in the Property Manager section, specific groups (categories) have been created to contain the properties of quantities (measurements); in this way, each parametric element inserted into the BIM model, depending on its classification, is automatically assigned the appropriate types of property quantity. In the case of EHS columns: Concrete code, Description of the concrete column measurement line, Code formwork, Formwork description... (Figure 3). The following image of the Property Manager (Figure 4) shows the properties related to the characteristics of the element (Data and Calculation), and its assigned "Value Definition" to make the



headings of the work units of concrete structural systems: Slabs of Foundations, Walls, and Pillars.

The result of these parameters is the creation of a code and an automatic description dependent on the variables mentioned above. In this way, a hyperlinked “Scheme” is made in ArchiCAD to list the elements classified according to variables (Figure 5).

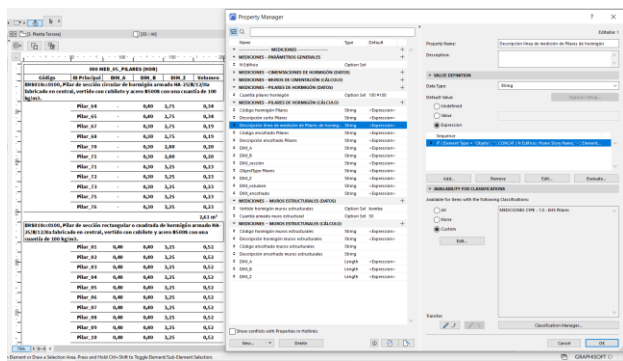


Figure 4. Property Manager

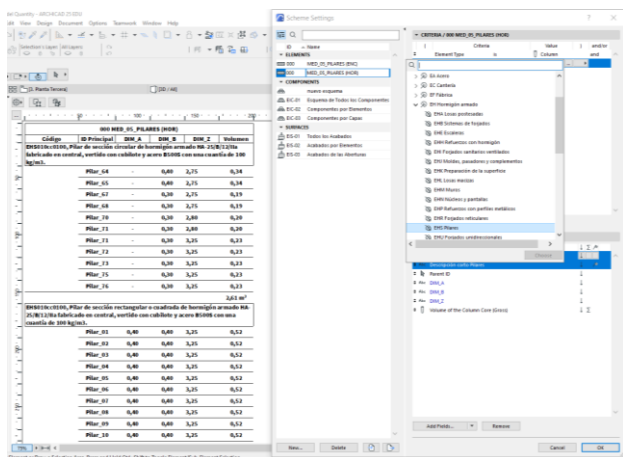


Figure 5. Scheme Settings for extraction of quantifications

3.5 IFC mapping

Once the code and description parameters of the construction elements have been generated, the next step is to structure the information for its IFC export. In ArchiCAD's “Translators - IFC Property Mapping for Export” section, an organization structure for items is established, similar to the eCOB system (eCOB, 2021). From the “IfcBuildingElement” section we will create a Pset and the parameters (Part01_Codigo, Part01_Funcion, Part02_Codigo, Part02_Funcion, Part03...). This organization will be present for all IFC elements of the scheme. The PartXX_Code parameters will refer to the item's budget line codes. The PartXX_Funcion parameters refer to the descriptions of those games.

The following data organization is established in the PartXX parameters: Part01 was assigned to items related to concrete material; Item02 for items related to formwork; and Part03 for those related to steel (Figure 6).

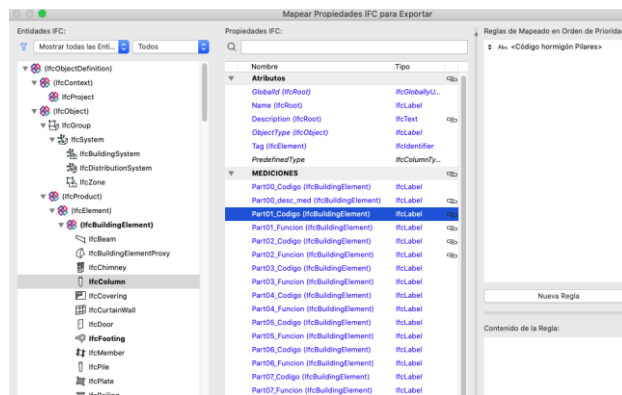


Figure 6. IFC Project Manager: Properties mapped for export of columns in IFC file

Another option is to generate parameters in the IFC mapping structure that refer to the dimensions of the objects. Although these data are available in the ArchiCAD Quantities Pset, there are parameters that are not exported automatically, and it would have to be organized using IFC mapping. If an organization of dimension data is established in the BIM 3D software, the information will have been structured correctly, facilitating identification in the BIM 5D application.

Before exporting the BIM model, a specific IFC translator is made in ArchiCAD, activating the geometric preferences and associated data that you want to select. An IFC Translator defines the rules for deciding which elements should be converted and how they should be interpreted. Here you control the Settings, such as the IFC Schema Type (IFC2x3, IFC4) and the conversion presets (Model Filter, Type Mapping, Geometry Conversion, Property Mapping, Data Conversion, Unit conversion (Figure 7).

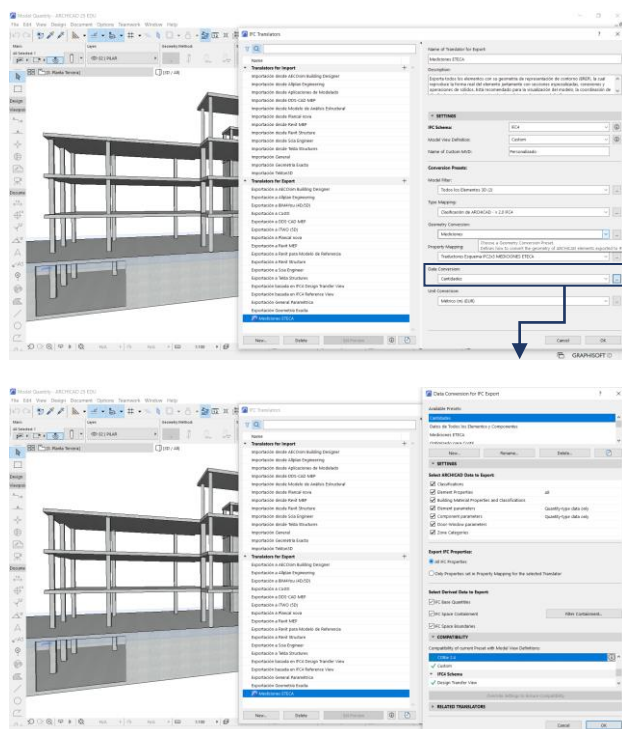


Figure 7. Preparation of the IFC Translator, specific to export quantities: a. Geometry Conversion; b. Data Conversion (ArchiCAD 25)

Once the translator has been prepared, the model is exported in an IFC file, and from any IFC viewer on the market it is possible to review the elements of the model and the structured data in the Measurements Pset. Figure 8 shows the model in the BimCollab viewer, where a filter criterion has been established to analyze the types of formwork depending on the code or description of the parameter (Part02_Codigo or Part02_Funcion).

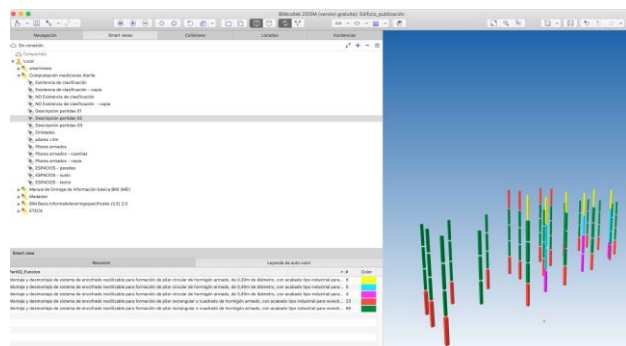


Figure 8. Review of the IFC file in BIMcollab ZOOM. Colours define types of column formwork

3.6 Interoperability of quantities

In the market today, there are a variety of measurement and budget programs that work by extracting information from IFC files. Not all work in the same way, so it is important to establish the correct strategy from modeling, classification, parameterization, to import. CYPE Quantities has been used for this case study. This program, like others, has a data collection system that is filtered through "rules" to identify an element depending on certain characteristics (IFC classification, element name, material, geometry,) and relate them to one or more item budgets from a price base file (standard format. BC3 or proprietary. CYP, .PZH, .TCQ,...). With these rules, we can create a database that is stored in the program for later use in other projects (Table 1).

	Filtering condition	Part01_Code	Budget item. (BD)
RULE 1	SI PART01_CODIGO = EHS010CC0100	EHS010CC0100	EHS010CC0100 - m3 - Hormi....
RULE 2	SI PART02_CODIGO = EHS01203	EHS01203	EHS01203 -m2 - Encofrado...
RULE N	SI PARTON_CODIGO = EHXXXXXX	EHXXXXXX	EHXXXXXX -ud - Dddddd dddd...

Table 1. Rules established for the relationship of the IFC Code parameter and Budgetary BD.

In this case, in the "Measurement criteria" section of CYPE Quantities, a direct relationship has been established for the parameter (p.e., Part01_Codigo) that meets a code in the budget database. If it is true, we will cross that information with the corresponding budget line, and the export will be automatic (Figure 9).

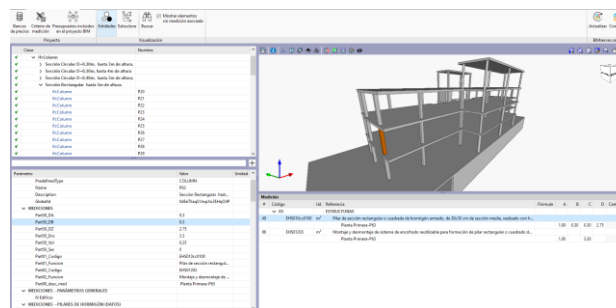


Figure 9. The quantities of the Pilar entity (IFC file) are automatically associated with the work items in Quantities Cype.

By separating the rules, we are able to establish a direct relationship between the structured parameter of the element and the budget line. The way of working on the element according to certain characteristics and relating it to various budget items would generate a greater number of rules by depending on the combinations of variables. For example, we have the column element defined by its material, height, section, and quantity of steel. If the information doesn't structuring the information, we would have the following combination by type (Table 2):

Concrete	Height	Section	Amount
HA-25/B/12/I	< 3m	Square/Rectang.	90 kg/m3
HA-25/B/12/Ia	> 3m	Diameter 30cm	100 kg/m3
HA-25/B/20/I		Diameter 35cm	110 kg/m3
HA-25/B/20/Ia		Diameter 40cm	
		Diameter 45cm	

Table 2. Variables that establish the type of pillar.

For the above case, the combinations to create a rule base with the different budget items are 120. But applying the proposed system reduces the number of combinations, considering the same initial variables, reaching 22 in this case since the base. The data set combines the type of concrete with the amount of steel. But if we separated these two variables, the combination of rules would be reduced to the number of 17 rules (Table 3).

	Filtering condition	Budget line (BD)
RULE 1	If Material = HA-25/B/12/I	Concrete item for HA-25/B/12/I
	If Height < 3m	Item for square or rectangular formwork < 3m
	If Square or Rectangular Section	Item for corrugated steel
	If Amount = 90 kg/m3	
RULE N	If Material =	Concrete item for N
	If Height <>	Formwork item according to section and height
	If Section =	Item for corrugated steel
	If Amount =	

Table 3. Preparation of Rules for the fulfilment of conditions of filtering of characteristics and relationship with the DB

4. CONCLUSIONS

The method analyzed and tested, based on an adequate structuring and classification of the data of the elements that make up the BIM model, has been productive and efficient in

avoiding random decision making by the operator who analyzes the quantifications and that may lead to errors or inaccuracies when applying the metric. The result of the study shows that the combinations of parameters, influences of the possible variables of the constructive element, can be considerably reduced. The percentage of rules would decrease to a ratio of 17/120, in an IFC information mapping process to be validated in software of quantification and valuation, improving data exchange and interoperability in an international environment.

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