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RELIABILITY OF IFC CLASSES IN ONTOLOGY DEFINITION AND COST ESTIMATION OF PUBLIC PROCUREMENT

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Abstract

Cost estimation is one of the most critical tasks in the architecture, engineering, construction, and facilities management industry (AEC/FM). The lack of a standardized support procedure for verifying the association of the cost to geometric objects cause a waste of time, inaccuracy and human errors in the cost estimates. This research investigates how to identify a cost ontology within the Industry Foundation Classes (IFC) database.
The results show that we can consider the cost element no longer as a natural language text string, detached from the digital model, but as a structured class in the IFC data model (*IfcCostItem*).

Introduction

The construction process is dynamic, complex and time consuming. In the AEC industry, all participants have to interact with each other to share different information which are involved and created during the construction phase, such as quantity information of physical building components, schedule plan, resource consumption, cost, site layout, safety management, and quality evaluation (Adeli et al., 2001).
Cost estimation is one of the most critical tasks and includes the calculation of quantities, project cost and the classification of products that constitute a construction project. Moreover, despite the abundance of advanced technologies for quantitative take-off (QTO), scheduling and costing, the integration of all these activities into a single system is still lacking. A system based on modeling technologies related to the scheduling and economic management of a project can provide such integration automatically and effectively (Lu et al., 2016).
Nowadays in the AEC industry the standard format used for information exchange is the IFC.
IFC is an open international standard (ISO 16739-1:2018) developed by BuildingSMART, which is also used for storing information during the entire building lifecycle, from the design phase to operation and maintenance (BuildingSMART, 2022b).
Therefore, to support, verify and improve the quality of cost estimates, in public tendering, and reduce human error-prone, the study proposes both the identification of a structured cost ontology based on IFC and its reliability and applicability. This would make it possible to identify a standardized procedure for storing, exchanging and linking the cost information with that of the objects within the same standard.
This study seeks to lay the foundations for the development of a standardized support procedure aimed at verifying the correspondence between the cost items, contained in the price list of public works (in the present case of the Price List of the Lombardy Region) and their association with objects contained in information models.
To this end an approach was adopted, to consider the cost element as a structured class in the IFC data-model (*IfcCostItem*) that contains a set of attributes in which information can be instantiated and a cost ontology based on structured classes can be identified.
For future validation of the information contained in the two "worlds" (costs and geometry), a structure with defined and standardized fields is necessary for the breakdown of the information of the current price items. In fact, the textual description of the cost is disaggregated and transformed into an ontology resulting more granular. This would allow to:

- place the information in specific fields/attributes;
- ensure validation and comparison between attributes of a certain cost class and the attributes of the object to which it is associated;
- consider cost items no longer only as text strings but as replicable computer classes.

Furthermore, the study carried out cannot be applied on any IFC model but seeks to analyse, evaluate and use the IFC data model to support the economic analysis processes of the projects.
The example of a load-bearing wall consisting of several layers was taken and the corresponding cost structure was created by relating the price elements to each other through the IFC classes. It has been noted that this information can be standardized within the proposed structure, despite some limitations due to the absence of some attributes in the IFC standard. These missing attributes can be implemented through relationships with other IFC entities.
In this paper, it has been studied how to develop a cost domain based on computer classes to support the process with cost estimates and validate the cost information associated with geometric objects.
The paper is developed as follows. First of all is exposed an analysis of the existing literature on cost estimation via

IFC classes and the IFC standard with particular attention to *IfcCostItem* entity (attributes and relations). Currently no BIM authoring software can write this entity so it was decided to rely on the IfcOpenShell library to create the entity through code. The last step was the validation of the data model generated throught IFC viewer and IFC reader and the analysis of the results, limitations of the study and the future developments.

Theoretical background

Many researchers have analyzed the IFC model framework for construction information. Below the main studies in the use of the IFC standard, to support cost estimation, are identified.

Froese T et al., after analyzing the information for project planning and cost estimation, claimed that IFC can be used to represent the information. Various modeling topics were discussed covering topics such as costs, construction processes, resources, products and project documents for work plans and cost estimates. (Froese T et al., 1999). Fu et al. presented the nD model using IFC to describe information related to planning, cost and so on. (Fu et al., 2006). Ma et al. established a framework for BIM-based Construction Cost Estimating (CCE) software based on Chinese standards (Ma et al., 2010). Zhiliang et al. investigated the possibilities and methods of applying the IFC standard, i.e., the mainstream standard of BIM data to the construction cost estimating for tendering in China. Then each aspect of the information was expressed by using the IFC data-model to verify its completeness and to establish the IFC-based information model. They noted that IFC can be used to express the information for the construction cost estimating for tendering in China as a whole, but some extensions in the form of proxy elements and property sets are needed (Zhiliang et al., 2011). Ma et al. discussed the key issues for semi-automatic and specification-compliant Tendering of Building Projects (TBP) cost estimation based on the IFC data of the design model, taking TBP cost estimation for the architectural and structural engineering of the cast-in-place concrete structure projects as an example (Ma et al., 2013). Liao et al. proposed a method to develop a prototype model of collaborative construction on BIM software to improve the efficiency of information sharing (Liao et al., 2014). Xu et al. introduced a new philosophic position for cost estimation to address the development of model-based cost estimation, addressing the importance of contextual information and the need for extension of pricing information according to the general process of cost estimation by using the IFC standard. (Xu et al., 2013). Again, Xu et al. established an innovative means of taking data from the BIM linked to a project and using it to create the necessary items for a bill of quantity that will enable cost estimation to be undertaken for the project. (Xu et al., 2016). Wu et al., (2014), Sacks et al., (2018), Elghaish et al., (2020), and Olatunji et al., (2021) reported on the possibilities of BIM to improve and support cost estimation. Staub-French et al., (2003), Liu et al., (2016), Niknam & Karshenas, (2015) and Lee et al., (2013) investigated the use of semantic web technology in the cost estimation BIM-based. Fürstenberg, Hjelseth, et al., (2021) investigated how semantic web technology can support BIM-based automated cost estimation linked to an IFC property set (Fürstenberg et al., 2021). Moreover, related to the cost estimation, in the literature it emerges that the most currently process is to connect the code, inserted in a specific parameter of the digital objects, as matching keys with various price items. This process, however, implies that for each element that generates distinct articles, the related object must also have a different code (Pavan et al., 2017), (Fürstenberg et al., 2021).

Key Concept

IFC & Construction Management

The IFC, an open and interoperable standard, is developed by buildingSMART. Its mission is "to enable interoperability among industry processes of all different professional domains in civil engineering projects by allowing the computer applications used by all project participants to share and exchange project information". This standard is defined in EXPRESS data specification language or in XML, and describes the actors, processes, controls, resources and product in the construction world. The first release of the IFC standard was published in 1997, and the latest official version is the IFC4 ADD2 TC1 an ISO standard released in 2018 (ISO 16739-1:2018).

The IFC data-model has four conceptual layers (Resource layer, Core layer, Interoperability layer and Domain layer) and is structured hierarchically so that each entity can be related to other entities and described by a set of attributes (BuildingSMART, 2022b). This is possible thanks to the *IfcRelationship* entity, through which related information can reside inside or outside the project data.

The IFC standard plays a very important role in the exchange of information between different participants in the construction or building management project throughout the project lifecycle. IFC is the most prominent vendor-neutral data schema in the AEC industry. With IFC both geometric and semantic information can be exchanged between different stakeholders and software. (Fürstenberg et al., 2021).

IFC provides some entities to represent the information in construction management, including *IfcWorkPlan* (schedule planning), *IfcTask* (construction task), *IfcScheduleTimeControl* (task's time information), *IfcCostSchedule* (cost planning), *IfcCostItem* (unit item of cost estimation) and *IfcResource* (construction resources such as material resource, product resource, labor and equipment resource).

Price list

The process of estimating costs in public tendering differs between States. In Italy the estimation of the prices of public works takes place using a price list. Each region has its own price list, a catalogue containing the price

items, that are the basis for the preparation of the economic offer and regulate payments in public contracts. The determination of the unit prices of the works is based on former Article 32 of the D.P.R. 5 October 2010.
The price items (Figure 1) consist of:

- a unique code for each processing [1];
- a description (declaratory) in natural language describing the work to be carried out [2];
- the unit of measurement of the work, the quantity usually of unit value [3];
- the amount of processing[1] [4];
- the impact of labor, means and materials on the amount carried over [5].

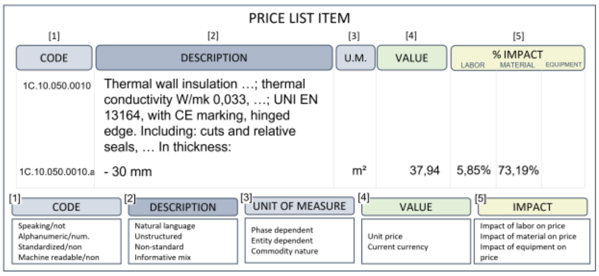


Figure 1 Example of Price List Item

These protocols belong to the Italian context but, the proposed methodology can be implemented according to any other cost estimation approach. In fact, the factors which determine the price of a work deliverable, service or supply are essentially always the same: labor, means and equipment, materials, overheads and profits. These factors, from the perspective of price analysis, constitute the elementary components of the final treatment and allow to determine the total amount of processing.

Methodology

The research aims to identify a cost ontology and a standardized supporting procedure to verify that costs are in line with the model objects. For this, it is necessary to relate the digital model to the cost element described through the structured class in the IFC data model. However, it is not enough to attach an attribute to a geometric entity. In fact, to correctly return the analysis and the processes of economic evaluation, it is necessary to have architectures of computer classes of prices that are configured as more complex systems than a simple attribute associated with a geometric object. The IFC standard, through cost classes, offers the possibility of structuring a cost data model. In function of this it has been deepened as the costs could be transcribed in terms of classes of computer, creating an architecture of the costs, and not simply identifying an attribute associated to the object BIM. Cost classes are available in the IFC standard, but it is unclear how these classes should be related with other IFC entity and for this reason it was decided to deepen this theme.
The methodology is characterized by the following steps also presented in Figure 2.

1. Description of the State of the Art of the current pratices and research connected to cost estimation;
2. Analysis on IFC entities, with which the standard describes the cost (*IfcCostItem*);
3. Implementation of the entity and its relationships in IfcOpenShell[2];
4. Information validation in an IFC Viewer such as FZKViewer or QuickBrowser;
5. Experimental results research.

A way to represent cost information by using IFC was formulated, developed and validated. This could provide the basis for the information exchange resources among information systems. The next sections describe the mechanisms used to implement and test the method.

IfcCostItem definition

IfcCostItem is the entity that represent the cost of assets and services, the execution of works by a process, lifecycle cost, cost estimates, budgets, and more in the IFC standard. It is a non-geometric entity, subclass of *IfcControl*. The abstract entity *IfcCostItem* describes a cost or financial value with descriptive information that describes its context in the form that enables it to be used within a cost schedule (BuildingSMART, 2022a).
Like all entities in the standard, *IfcCostItem* is also described through a set of attributes. Some of them are inherited from the hierarchically superior entities. Name and description are certainly the two fundamental attributes. The Name attribute could be used to provide a common value that enables distinct instances to be brought together in a nesting arrangement, while the Description attribute may contain the text used to describe the item in a cost schedule (BuildingSMART, 2022b). The proprietary attributes of the class are: PredefinedType, CostQuantites and CostValue (Figure 3).

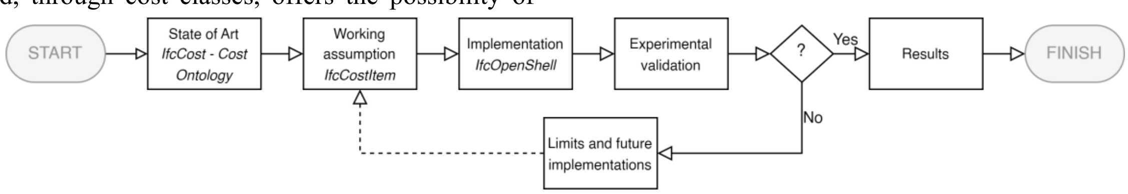


Figure 2 Methodology of the study

[1] Labor amount = unit price (PU) + overheads (SG) ranging from 13% to 17% calculated on the value "PU" + business profit (UI) by law to 10% calculated on the value "PU+SG"

[2] An open-source software library, Lesser General Public License (LPLG), that helps users and software developers to work with the IFC file format

An *IfcCostItem* can link one or many *IfcCostValue's* representing a unit cost, total cost, or a unit cost with one or many quantities used to generate the total cost. The quantities can be given as individual quantities, or those quantities are provided as element quantities by one or many building elements. An *IfcCostValue* may represent an original value or a value derived from formulas. Another key aspect is that *IfcCostItem* can be nested to create cost assemblies through the relation *IfcRelNests*.

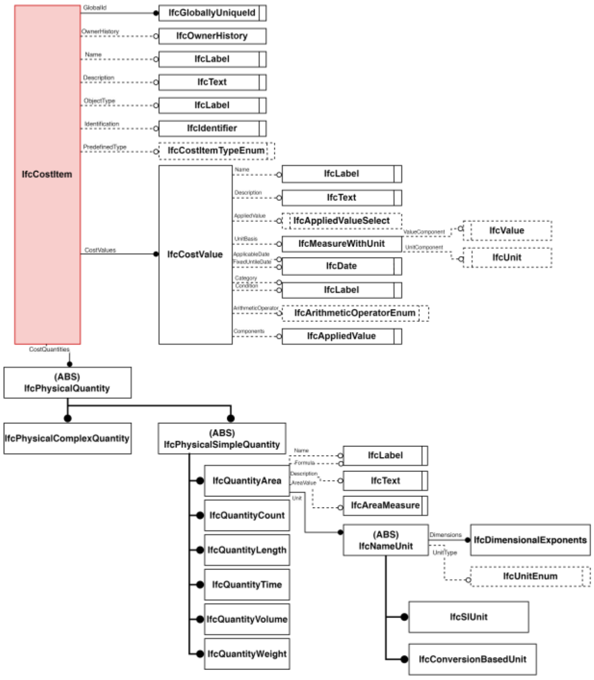


Figure 3 Attributes of IfcCostItem

Break down price items

The cost item has been subdivided into specific fields/attributes. This breakdown will allow to identify the fundamental attributes of the cost items. This process is essential because an initial analysis already shows that the descriptions are not immediately clear, such as in Figure 4. This can create misunderstandings, inaccuracies and errors in the selection and association of the price items to the respective geometric objects during the cost estimation.

PRICE LIST ITEM
Masonry in elevation realized with blocks of alveolar brick of which to standard UNI EN 771, straight or curved and at any height, included burdens and magisteri for the execution of toothing and how much other it becomes necessary to realize the work in workmanlike manner: with blocks 25 x 25 cm, with horizontal holes and a perforation percentage of 60/70%, for infill masonry, counterwalls and partitions: thickness 12.5 cm

Figure 4 Example description of a Price Item in Lombardy Regional price list

PRICE LIST ITEM
Masonry in elevation realized with blocks of alveolar brick of which to standard UNI EN 771, straight or curved and at any height, included burdens and magisteri for the execution of toothing and how much other it becomes necessary to realize the work in workmanlike manner : with blocks 25 x 25 cm, with horizontal holes and a perforation percentage of 60/70%, for infill masonry, counterwalls and partitions: thickness 12.5 cm

Masonry in elevation; for infill masonry, counterwalls and partitions: thickness 12.5 cm

with blocks of alveolar brick of which to standard UNI EN 771; with blocks 25 x 25 cm; a perforation percentage of 60/70%

realized straight or curved and at any height; with horizontal holes

included burdens and magisteri for the execution of toothing and how much other it becomes necessary to realize the work in workmanlike manner

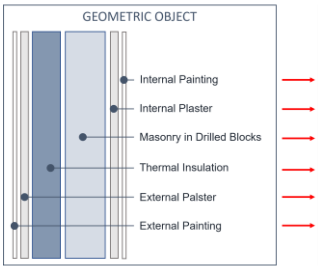
Figure 5 Nonlinear description of a Price Item

As visible in Figure 5 the description is non linear and information about a specific processing object can be found in different parts of the description.

The deconstruction led to the identification of a basic semantics that allows information, contained in a description, to be read and understood by a "machine" and be linked to certain computer classes or attributes. A set of attributes has been defined to compile the information already expressed in the descriptions of price items (Table 1).

Validation and results

Due to the heuristic approach of this paper, the research focused on analyzing an example case of wall. The wall consists of six layers: internal painting, internal plaster, masonry in drilled blocks, thermal insulation, external plaster and external painting (Figure 6).



PRICE LIST ITEM

CODE	DESCRIPTION	UM	VALUE (€)
1C.24.120.0020.a	Two-shot painting, on internal surfaces in civil plaster ...	m²	3,85
1C.07.110.0040	Complete plaster for civil interiors...	m²	20,09
1C.06.050.0300.c	Load-bearing masonry in brick blocks ... thickness 25 cm	m²	59,99
1C.10.300.0020.e	System for thermal insulation with coat ... thickness: 100 mm	m²	75,55
1C.07.120.0040	Exterior civil plaster ...	m²	24,32
1C.24.140.0010.a	Two-shot painting, on external surfaces already ...	m²	6,60

Figure 6 Example layers of masonry and relative price items

The respective items contained in the regional price list (Lombardy Region) have been identified (Figure 6). These price items would be used to estimate a hypothetical cost of this wall. After that, these were broken down into fields explained before to obtain a standardized definition. In the specific case the breakdown was done for the six identified list items, Table 1. This procedure is replicable and implementable on all the items of a price list. The identification of basic semantics allows to structure the description of the price item according to a common logic. Moreover, it will guarantee a series of rules to follow for the correct structuring of the price items. Once the price item was broken down, the relative attributes of the *IfcCostItem* class that could contain this information were identified (Table 2). This is necessary to ensure the identification of cost items no longer based on text strings but on computer classes. The IFC entity allows only some of the information characterizing the price item to be added within its attributes. The remaining ones, that they express information relative to the physical object, cannot be contained directly inside of the entity. For this reason, it is necessary to activate the relationships with certain IFC entities, to identify the sample elements, or specific property sets (PSET) in which to insert these values. This is due to the creation of a price list characterized by computer classes where each price list items will be an independent cost classes that can be associated with the relative model object.

Table 1 Example of breakdown of the price item masonry layer

PRICE ITEM															
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
Class	*Type*	*Function*	*Shape / Geometry*	*Size Parameters*	*Physical Parameters*	*Characterising Product*	*Product Material*	*Accessory Products*	*Performance*	*Standard / Regulation*	*Included*	*Excluded*	*Technical Notes*	*Price Unit*	*Unit of Measure*
LAYER OF MASONRY	-	LOAD BEARING	STRAIGHT	THICKNESS = 25 cm	-	CLAY BLOCK 25 x 30 x 19 cm	CLAY BRICK	CEMENT MORTAR	THERMO ACOUSTIC	-	-	-	1 cm OF MORTAR	59,99 €	m²

Table 2 Matching matrix between price item breakdown attributes and IfcCostItem class attributes

	LAYER OF MASONRY	***PRICE ITEM*** *1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
IFCCOSTITEM	*Name*	√															
	Description		√														
	HasAssignments			IfcWall	IfcWall	IfcWall	IfcWall	IfcResource	IfcResource	IfcResource	IfcWall						
	IsDefinedBy											PSET	PSET	PSET	PSET		
	PredefinedType		√														
	CostValues															√	
	CostQuantities																√
IFCWALL	*Name*	√															
	Description		√														
	IsDefinedBy					Ifc Eelemnt Quantity	Ifc Eelemnt Quantity				PSET						
	PredefinedType			√													

After conceptually verified which information can be contained and transcribed within *IfcCostItem's* attributes and which relations the entity can activate, in accordance with the standard, a code has been implemented and written.

The developed method was implemented using the IFC4_ADD2_TC1 - 4.0.2.1 (currently the official version), IfcOpenShell, an open source library (IfcOpenShell v0.7.0) and Python 3.10 (Paparella Rossana & Zanchetta Carlo, 2021), (IfcOpenShell Contributors, 2020).

The proposed ontology has been tested under real conditions.

The ontology based on the IFC entity was implemented into an IFC step file of a wall, described above. At the operational level, considering the design standards, the wall package was divided into three different parts:

- an external architectural part incorporating the three layers of external painting, external plaster, and thermal insulation. This will be exported with the entity *IfcCovering*;
- a structural part containing the masonry. This will be exported with *IfcWall*;
- an internal architectural part including the last two layers (internal plaster, internal painting). This will be *IfcCovering*.

A cost has been associated with each of the three parts of the wall (Figure 7); the price of the three parts will be given by the unit price of the price list multiplied by the quantity of the model object. The final price of the wall will be given by the sum of six different cost items related to the cost of the six layers (each with its quantity and with its unit price). Every unitary *IfcCostItem* contains specific information and data based on the original description given by the price list and the unitary price.

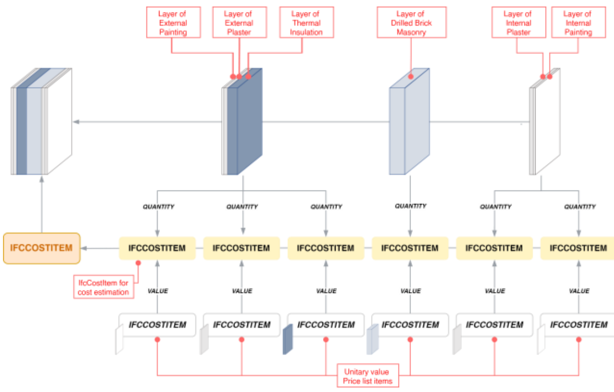


Figure 7 Example wall consists of six layers

Starting from an empty IFC file, a code was written for the creation of some elementary *IfcCostItem* entities. These entities correspond to the individual items of the price list and are nested within a main *IfcCostItem* from which it can be derived the cost value to be included in the cost estimation.

In this way an ontology based on *IfcCostItem* classes was created. Since these entities do not correspond to physical and geometric elements, they are not supported by the main BIM Authoring software. For this reason, it was necessary to edit these entities within the code.

The *IfcCostItem* entities were created with their proprietary attributes (PredefinedType, CostQuantities and CostValues) and inherited attributes (GlobalId, Name, Description and ObjectType. The enumeration of the PredefinedType attribute is set to USERDEFINED), Figure 3.

To enter the information characterizing the price it is then necessary to activate the relationship with a sample element or groups of properties (*IfcPropertySet*). Through HasAssignments attribute, inherited from the *IfcObjectDefinition* class, it is possible to activate the

IfcRelAssignsTo relation and associate the instances of *IfcObject* and its various 1st level subtypes, such as *IfcProduct*, that contains for example, inside the *IfcElement*, the entity *IfcWall*. Through the IsDefinedBy attribute, inherited from the *IfcObjectDefinition* class, it is possible to activate the *IfcRelDefinesBy* relation and associate the *IfcPropertySet*.

The sample element is assigned to the *IfcCostItem* through the *IfcRelAssignsToProduct* relation. It is exactly the unit value in square meters of the masonry layer specified in the price list. The *IfcPropertySet* is assigned via the *IfcRelDefinesByProperty* relation and contain the properties (*IfcComplexProperty* or *IfcSimpleProperty*) holding a set of values (*IfcPropertySingleValue*, *IfcPropertyEnumeratedValue*, *IfcPropertyListValue*, ecc.), Figure 8.

In Figure 9 and Figure 10 the validation of the code is visible both in an IFC text viewer (IfcQuickBrowser) and in an IFC graphic viewer (FZKviewer).

However, *IfcCostItem*, being an abstract entity, will not have a geometry so its graphic representation is not visible in an IFC graphic viewer. Despite that the attributes and relationships activated by the class are visible.

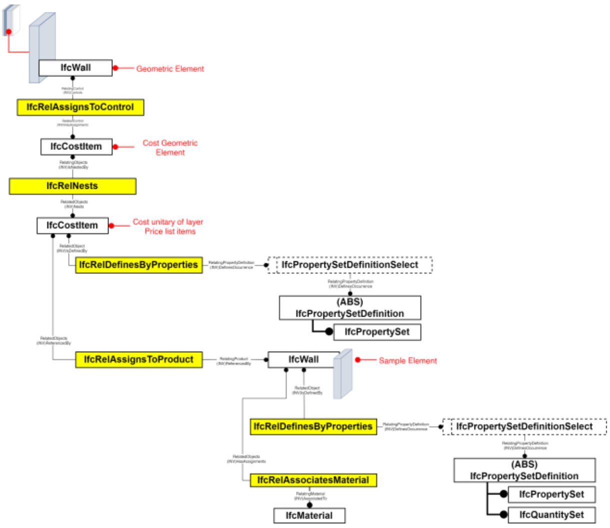


Figure 8 Relationships activated by IfcCostItem

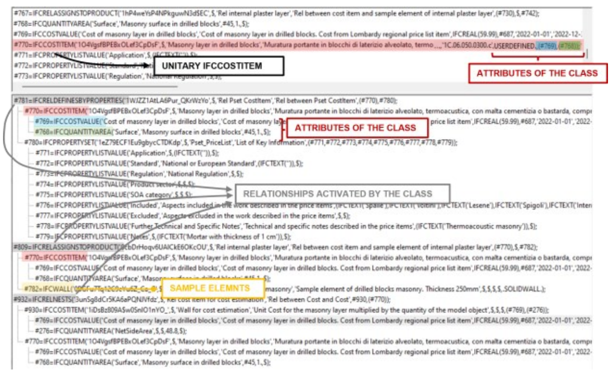


Figure 9 Validation of code script used to create the unitary IfcCostItem (IfcQuickBrowser)

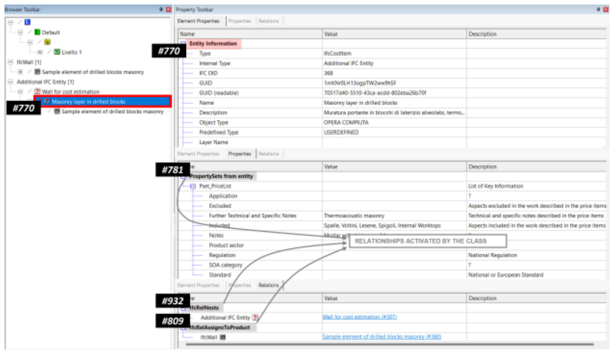


Figure 10 Validation of code script used to create the unitary IfcCostItem (FZKviewer)

Both the sample element and the propertyset therefore contain key information defining this cost item; this information is necessary for the characterization of the cost item and will be useful in the next phase of the study that will foresee the validation of the information contained in both the costs and geometric "world".

This procedure has also been applied to the remaining layers of the wall obtaining standardized cost classes.

At this point there is a need to combine the elementary cost information of the various layers of the wall with the quantities derived from the three parts of the geometric model. Then you get the cost item useful for the realization of the cost estimate.

The new *IfcCostItem* entities correspondent to the final price of the wall layers are created. This entity present, in the attribute CostQuantities, the quantities directly extracted from the *IfcElementQuantity* of the object *IfcWall*, of the geometric model, to which it is associated through the relation *IfcRelAssignsToControl*. While the cost value is contained in the attribute CostValue and obtained from the sum of the single CostValue contained in the elementary *IfcCostItem* (Figure 11, Figure 12 and Figure 13).

Finally, if you want to derive the total price of the wall through the *IfcRelNests* relationship it is possible to nest the various *IfcCostItem* in the total *IfcCostItem* identifying the cost value and the final quantity (Figure 7). This could be useful in the project if it were necessary to know, for example, the total cost of masonry in perforated blocks present in the project.

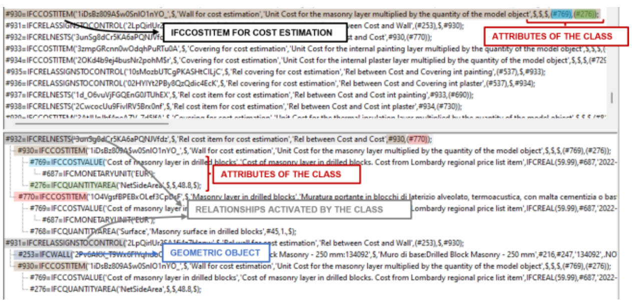


Figure 11 Validation of code script used to create the IfcCostItem (IfcQuickBrowser)

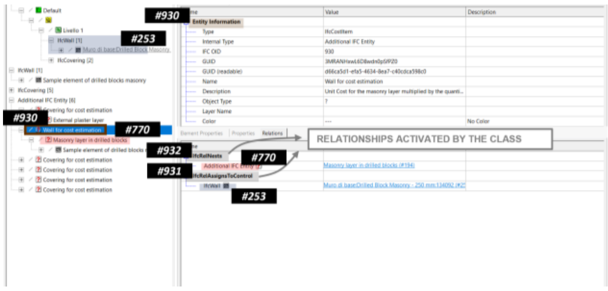


Figure 12 Validation of code script used to create the IfcCostItem (FZKviewer)

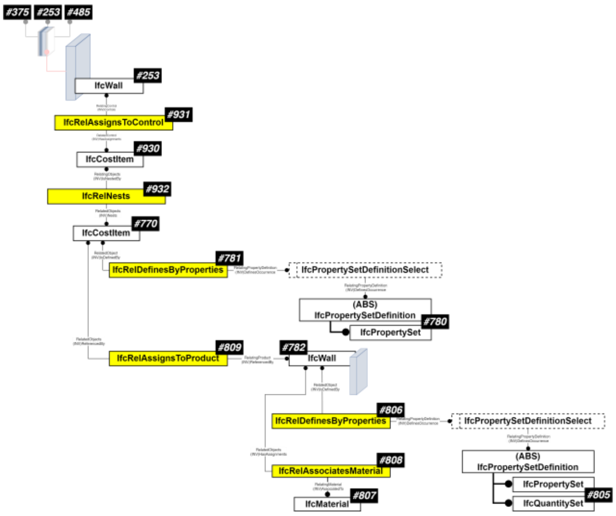


Figure 13 Relationships activated by IfcCostItem with relative identification number

Discussion

This study, still in the first phase of development, presented how the price items can be instantiated as computer classes using IFC entity and not only as a text string. The possibility of creating a new ontology for the price list of the Lombardy Region based on computer classes to standardize and adjust price items and related information has been studied. This is the first part of a larger study that will continue over the next years.

Considering the high uncertainty and inaccuracy of the information during the estimation processes, decomposing the definitions of the price items to arrive at their genetic code, can be considered an operation of ontological definition. This methodological and scientific research has led to technological attempts made through writing in IfcOpenShell with the achievement of results that are actual, effective and scalable. The scalability of the method has been demonstrated as it can also be implemented for other price list items. Currently, however, it is possible to obtain these results only through code because the current commercial applications do not allow user friendly implementations.

To ensure that the approach based on relations between entities (studied approach) results as agile and effective as the approach based on cost assignment via attributes (standard approach) a reliable information base is needed. This process conceptually finds equivalence in the approach of the building ontologies transferred to IFC.

Currently, as seen in the literature, the approaches used are based on the object-attribute relationship and this does not allow a granularity and disaggregation of cost items that is required to ensure greater standardization. In order to guarantee a greater accuracy in the association of the costs there are two practicable ways: to realize detailed geometric models or identify cost ontologies that can be detailed because they use the relationships that entities can create with each other. The goal is not to further breakdown a geometric digital entity, creating more geometric detail and sometimes unnecessary, but to create relationships between the geometric entity and the respective cost architecture, which is richer and more granular.

Conclusions

In this study the proposed architecture can define the new domain of costs through a new ontology and semantics of costs. To create this new cost architecture is necessary to breakdown the actual cost items as much as possible to increase their generality and abstraction and get to have elementary constituent cost elements that ensure order and make a price standardized and replicable in the plurality of contexts. These elementary cost items are nothing more than the classes at the base of a hierarchy of computerized cost classes identified within the IFC standard in the *IfcCostItem* entity. *IfcCostItem* must be independent and ensure the existence of a cost model, but at the same time can be used in any model and any different situation since the cost definition should exist regardless of the model. The next step concerns the validation of information between the cost class and geometric class to assess the consistency of information (it is missing today).

During the study, limits were found in the implementation of a standardized methodology for costs. The first is the market barrier, the lack of a user-friendly tool. A second limitation concerns all the information that cannot be standardized except by imposing rules, such as dimensions (different from object to object and identifiable with different terminologies), but also objects not contained in the geometric model (formwork). It will be necessary to define the rules of calculation but especially the rules for defining the parameters included in the geometric models. However, this approach must allow for exceptions, as it will not be possible to identify all possible cases.

As a future work, there is a need to prototype what is studied on a larger scale, for example to an entire project of the structural discipline, demonstrating how a series of typical costing strategies and economic quantification of projects can easily be implemented in the proposed approach. The next steps involve structuring the *IfcCostItem* entity according to the logic of price analysis; therefore, these elementary entities will be broken down into further *IfcCostItem* relating to the classes of the *IfcConstructionMgmt* domain, the *IfcResources*. This will make it possible to identify a standardized structure for price analysis and to create a price list based on IFC entity.

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