CONSERVATION PROCESS MODEL (CPM): A TWOFOLD SCIENTIFIC RESEARCH SCOPE IN THE INFORMATION MODELLING FOR CULTURAL HERITAGE

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ABSTRACT:

The aim of the present research is to develop an instrument able to adequately support the conservation process by means of a twofold approach, based on both BIM environment and ontology formalisation. Although BIM has been successfully experimented within AEC (Architecture Engineering Construction) field, it has showed many drawbacks for architectural heritage. To cope with unicity and more generally complexity of ancient buildings, applications so far developed have shown to poorly adapt BIM to conservation design with unsatisfactory results (Dore, Murphy 2013; Carrara 2014). In order to combine achievements reached within AEC through BIM environment (design control and management) with an appropriate, semantically enriched and flexible The presented model has at its core a knowledge base developed through information ontologies and oriented around the formalization and computability of all the knowledge necessary for the full comprehension of the object of architectural heritage an its conservation. Such a knowledge representation is worked out upon conceptual categories defined above all within architectural criticism and conservation scope. The present paper aims at further extending the scope of conceptual modelling within cultural heritage conservation already formalized by the model. A special focus is directed on decay analysis and surfaces conservation project.

1. INTRODUCTION

The research has focused on architectural modelling developed by means of ontologies; this model is not a simple data repository on existing architecture, but has to support heritage conservation process. Within this methodology, concepts are represented through entities and properties. Entities are set up into hierarchic taxonomies by means of an analytic process. Different classes - declined into super-classes and sub-classes according to the relationship existing between them – organise different meaning in architecture. Every meaning is associated to single concepts, specified through definitions and integrated by properties describing relationship with the context.

This methodology, defined as the “formalization of a conceptualization” (Gruber 2009), makes it possible to hook modelling to a logic framework that grants the reliability of representation. In addition, it permits to establish relationships between concepts, enabling the description of hermeneutic processes, such as historical critics, not static but flexible and always open to new developments.

However, rigour required by the ontology formalisation (formal modelling), on the one hand makes it possible to sharpen the analysis and to articulate the research upon more appropriate definitions (Ciotti 2014, Gigliozzi *et al.* 2003, Mc Carty 2005, Orlandi 2010); on the other hand, to avoid to fall in contradiction, it may lead to simplified representation. A special focus on the participation of specialists within the formalization process can help to avoid that kind of risk.

Starting by cultural heritage description already been developed by means of ontologies (Crofts *et al*. 2010; http://www.cidoc-crm.org/sites/default/files/cidoc_crm_version_6.2.pdf [14.04.2017]), the research aims at encompassing other domains involved in historical architecture investigation process and conservation design. All information required for the exchange and integration of heterogeneous scientific documentation developed within cultural heritage process establishes the intended scope of the proposed ontology. Such a model should convey the requirement that the depth and the quality of descriptive information that can be handled should be sufficient either for academic research or for professional activity.

This ambition arises from the fact that conservation project advocates a special knowledge process. This process developed upon the building has to work out a critical assessment that gives direction to conservation project. Therefore, an important focus of the model must be oriented to scientific reliability.

2. THE CONSERVATION PROCESS MODEL

The proposed model has a twofold aim, it intends to capture and represent the semantic contents of cultural heritage conservation process and to point at working up a model that may achieve integration, mediation and interchange of information in the midst of cultural heritage conservation discipline. Such a model may become an advisable instrument able to support historical architecture conservation research. This kind of modelling has tried to follow existing major ontologies such as Cidoc CRm and FRBRoo adapting and integrating their structure to the considered discipline. Beyond technical items, a particular attention has focused conceptual issues, particularly aroused within architectural project modelling, considering that the scopes addressed to by Cidoc and FRPRoo are library and museum communities. In this direction, interesting researches have been developed (Noardo 2015; Noardo 2016; Felicetti et al. 2013, Ronzino et al. 2013, Ronzino et al. 2015, Guillem) although not especially focused on cultural heritage conservation process. Within Conservation Process Model (CPM), some existing classes have been introduced from scratch; others have been adapted to the context. Some classes are perfectly fitting conservation issues, while some contents needed an *ad hoc* formalization, either for technical requirements or for theoretical implications. The prefixes 'E' (for classes) and 'P' (for properties), followed by the subscript CPM and a progressive number, encode new declared classes and properties.

2.1 Modelling knowledge for conservation process

So far, five principal domains have been defined: *artefact*, *investigation process*, *actors*, *lifecycle* 1 *and lifecycle 2* (Acierno *et al.* 2017). The *artefact* domain focuses on the architectural organism description. *Actors* domain refers to people concerned with the building existence or studies; *cultural heritage process* is addressed to the description of all the analysis worked out on the building and the information gathered; lifecycle 1 focuses on the transformation process description and lifecycle 2 is conceived for design and managing processes (Fig. 1).

The structure itself follows the CIDOC scheme. Moreover, other two existing models have been important benchmarks for the formalization, actually CIDOC extension: FRBRoo (Functional Requirements for Bibliographic Records, http://www.cidoc-crm.org/frbroo/ModelVersion/version-2.4) and AR model developed by Guillelm *et al*. 2016.
Inside the model, classes and properties hierarchies have been extended within the domains, while entities and properties are defined through default specifications. In particular, *class identification* (Superclass of/ subclass of); *scope note*; *order logic* and *properties* identified different entities. Furthermore, the description of entity properties needs to specify: *domain, range, scope note and quantification.*
Finally, the model, developed by means of ontology, will integrate BIM modelling. Highlighted by the existing literature (Pauwels *et al.* 2013), the work focusses on the possibility of achieving a satisfactory representation by enhancing interoperability between these two different applications. The main attention concerns the consistency between the two reference structures, in order to facilitate mapping activity. Each BIM element will correspond to an ontology entity that will provide a complete definition of its underlying semantics. A specific instrument, a 'BIM Semantic Bridge', ensures the connection between BIM database and the knowledge base (Acierno *et al.* 2017).

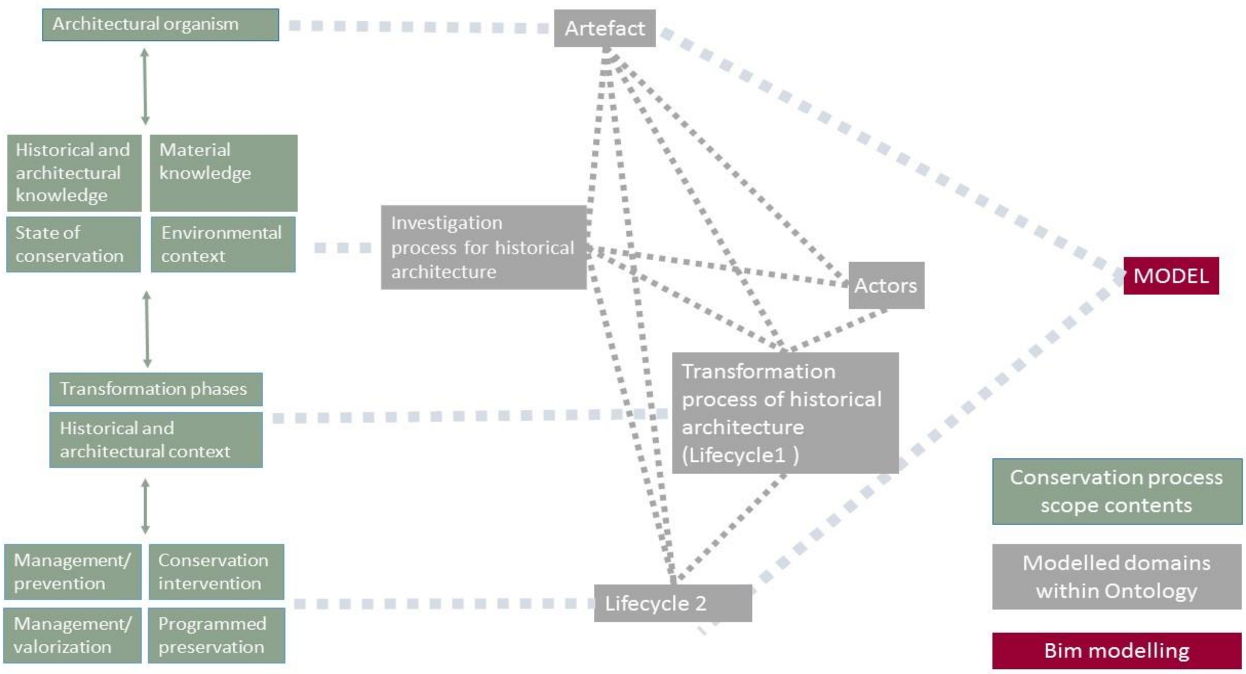

Figure 1. The Conservation process Model

2.1 Modelling decay analysis

As far as ontologies are concerned for decay analysis, some studies have already proposed a dedicated model (Caciotti 2015, Noardo 2014) that deals specifically with the professional edge of the process. However, we focus here the challenge to develop a model that may play a twofold role coping with both research and operational facet.

Decay analysis has been modelled within the template already proposed for the other types of investigation described by the model (Acierno *et al.* 2016). In CPM each analysis is described through the resources needed to be developed - as investigation methods, tools and samples-, the actors who carry out the job, the inputs needed and the information provided (fig.2).

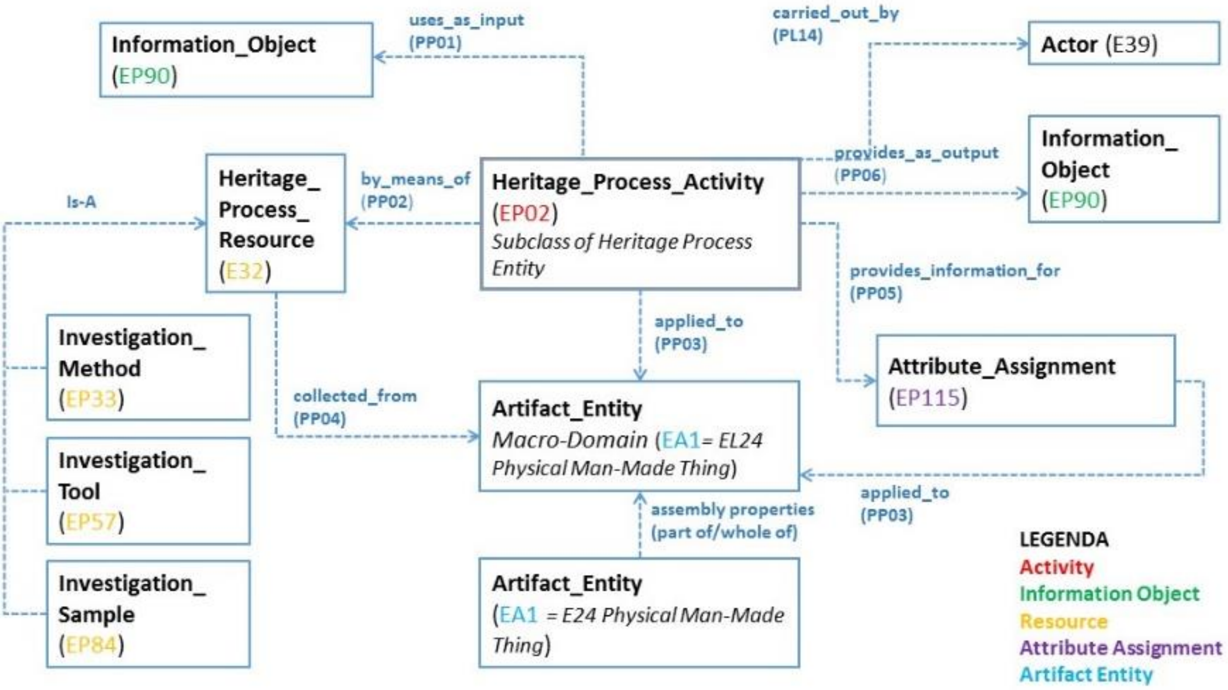

Figure 2. Heritage process: investigation model

Investigation methods are manifold, spreading from the simple direct observation to more sophisticated techniques such as thermography or chemical analysis. Tools are also rather diversified, as decay may be surveyed through cameras, videos, thermal imagery etc. Finally, samples may be needed in case of more specialized analysis. The actors who run the survey may be architects, engineers, diagnosticians, all of them described within a specific domain. Differently, inputs needed to develop the analysis are described within the cultural heritage investigation domain. These inputs range from the geometric survey to the materials survey and the existing lexicons, provided by the Institutions concerned by cultural heritage protection (i.e.*Illustrated glossary on stone deterioration patterns* published by Icomos).

Formalization of decay analysis results deserves however a special attention. Albeit its nature as activity that aims at identifying building state of conservation, hence pertaining to the *Cultural heritage process domain*, it necessarily deals with the changing nature of architecture, coping therefore with the transformation process domain called lifecycle 1. Although the content of the investigation refers quite clearly to the changing of physical conditions, 'decay' encoding is not a foregone job. Actually, two Cidoc classes may present the right content: modification and condition state. The former, previously adopted, may certainly well describe the fact that something arose to change the primary consistency; nevertheless this statement may prove to be quite inappropriate when referring to historical architecture decay. As a matter of facts, the main attention within the scope of the decay analysis must focus on the building physical consistency in relation to its current state of conservation and not to the presumed primary state or to any other previous condition, actually out of our knowledge.

Assuming this stance, the best class to represent decay analysis proved to be condition assessment, in turn a subclass of condition state. Cidoc System has formalized the former (encoded as E14) as "the act of assessing the state of preservation of an object during a particular period." In addition, Cidoc definition refers to the operational context of condition assessment further clarifying the conceptual frame of the class: "The condition assessment may be carried out by inspection, measurement or through historical research. This class is used to document circumstances of the respective assessment that may be relevant to interpret its quality at a later stage, or to continue research on related documents."

In conclusion, decay analysis is formalized as a sub class of 'condition assessment', and in a first order logic it is expressed as follows:

$$E_{cpm}1(x) \supset E14\ (x).$$

The results of decay analysis are described through the property identifies and by the classes condition state and type. Therefore the statement will be: decay analysis ($E_{cpm}1$) has identified (PP35) condition state (E4) that has type (P2): decay phenomenon (E_{cpm} 2). Decay phenomena will be described according to the existing lexicons as *ICOMOS Illustrated glossary on stone deterioration patterns*, *Normal 1/88, UNI* 11182 and will be articulated into two main classes, superficial and structural decay. Each phenomenon identified will be then related to the surfaces concerned through the property is extended to ($P_{cpm}1$) and finally to the building (artefact). Therefore, instances, representing the particular area or areas interested by decay will be created. The single areas are referred to the artefact through the well-known assembly properties such as 'part of'/whole of' and are modelled as information objects that will provide information for the surfaces conservation project (fig. 3).

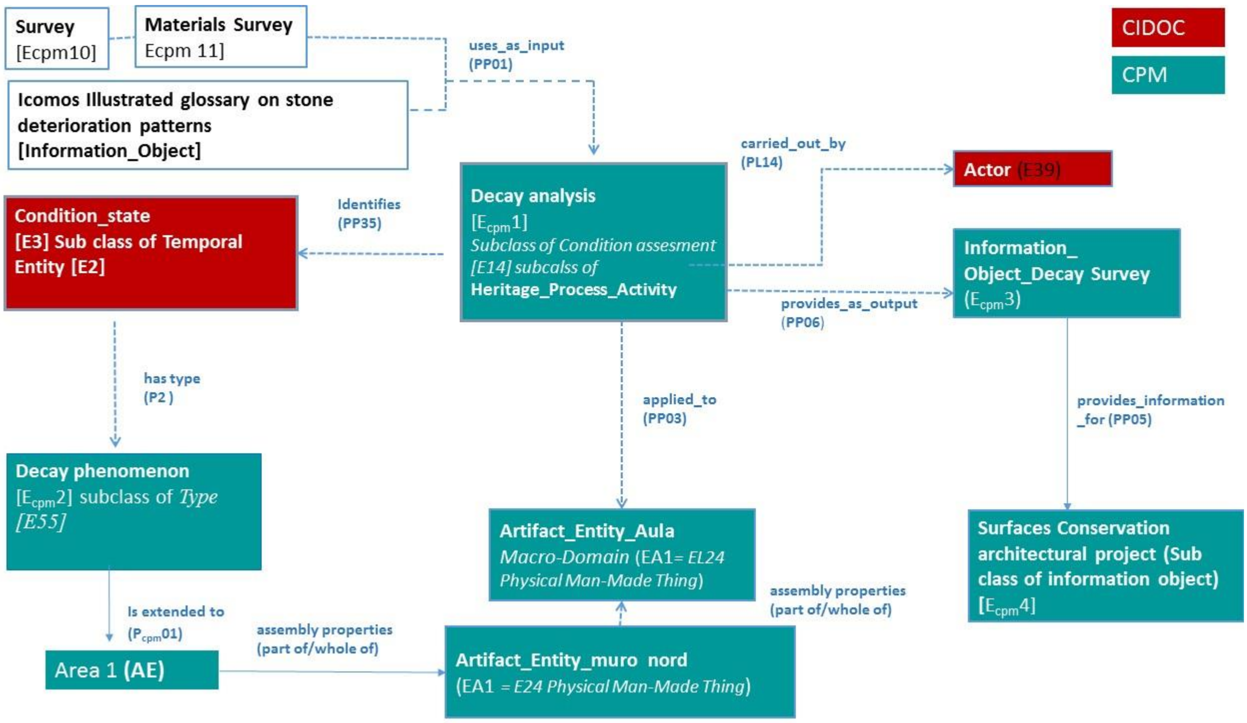

Figure 3. Decay analysis model

2.2 Architectural conservation project

A very interesting starting point for the formalization of conservation design is the work developed by Guillem *et al.* 2016 on the architectural modelling. The study points the attention on the particular nature of architecture design. Starting from the existing Cidoc class Design or Procedure (encoded E29), they argued that the definition scope of this class, although rather wide, disregarded the intellectual and expressive component of architecture. CIDOC describes this class as follows: "This class comprises documented plans for the execution of actions in order to achieve a result of a specific quality, form or contents. In particular, it comprises plans for deliberate human activities that may result in the modification or production of instances of E24 Physical Thing. ". Therefore they have examined more closely the apparently neglected component, considering FRBRoo class expression (encoded F2), which well expresses the concept but overlooks the technical facet. This class is formalized as a subclass of Cidoc Infomation object (encoded E29) whose scope is defined as follows: "This class comprises the intellectual or artistic realisations of works in the form of identifiable immaterial objects, […] that have objectively recognisable structures…". Inasmuch as they introduce a new class architectural model (encoded AR1) that merges both components. To further develop architectural project they needed to declare several subclasses that intend to represent the constructive technical steps: Construction project [AR 3] and Construction plan [AR 4]. Highlighted by this research CPM introduces new classes that better fit conservation process but takes advantage from the whole structure. (Fig. 4).

Formalization of conservation design must necessarily consider the twofold nature of architecture design, as intellectual expression and processing of plans for creating a building. Actually, the design itself has to be considered a document that refers both to a 'propositional object' and to a 'procedure' giving direction for construction. This issue has been already worked out within AR model developed by Guillem1 *et al.*2016 through the declaration of a new class: architectural model. This class, conceived to merge contents of expression (encoded F2 within FRBRoo model) and design or procedure (encoded E29 within Cidoc) encompasses documents that are both results of architectural design processes and realisations of the propositional content of some architectural work. Albeit the contents of the declaration prove to be extremely appropriate for conservation project description, the lexicon proposed: "Architectural model" could be misleading. While within AR modelling its very sense leads to the abstract dimension of an architectural project, the word 'model', in AEC contexts, calls forth a representation or a simulation of construction. Moreover, besides expression and procedure a third major component must be considered within conservation project and this pertains to the appraisal process developing upon the architecture to conserve. Hence, CPM introduces a new class, combining this latter issue to Architectural model contents, declaring thus the Architectural Conservation project class [E_{cpm} 4].

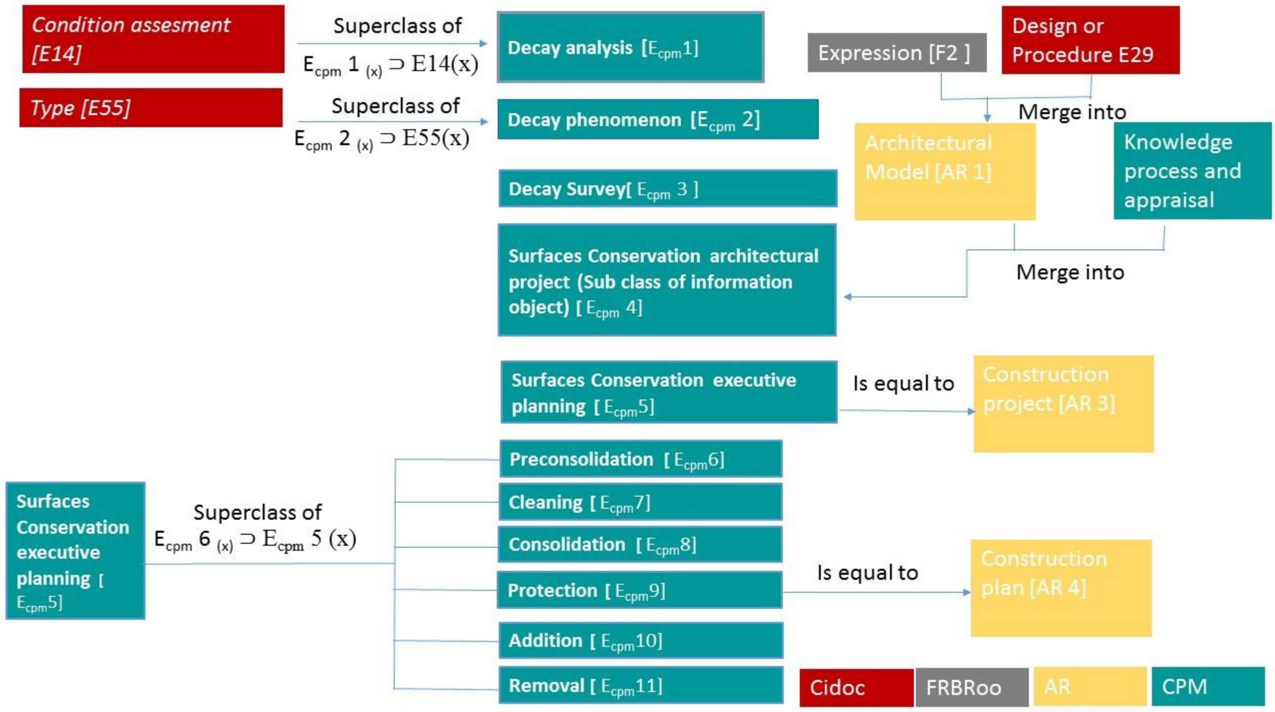

Figure 4. Classes formalization and integration within existing models

In order to clarify the content of this class, it is important to observe that although architectural conservation project requires several inputs to be planned, provided by geometrical and material survey, historical investigation, diagnostics, there are no bi-univocal relations linking these inputs to the actions required to realize the project. Indeed the project is not worked out upon each single result, but springs from their overall critical assessment. Therefore, the model will not foresee a direct link between a decay phenomenon and the intervention to fix it, as the project – to be effective - has always to mediate this relation with other contents. For instance: if the decay phenomenon is related to an event that has an historical importance – as in the coats of arms on the palaces in Feltre (Bl) erased by Venetians – probably filling the gaps will not have any sense. Again, cracks due to the simple juxtaposition of two different walls cannot implicate the destruction of the archaeological evidence and the reconstruction of the whole masonry, and so on and so forth. Undoubtedly, only a-critical approach may conceive a set-up procedure, actually highly undesirable within the scope of cultural heritage conservation. The special feature of unicity of historical architecture entails singularity of intervention. Moreover, some conservation interventions do not concern just decayed areas. As an example, limewater is generally applied to the whole surface of a building to harmonize lacking parts with integer ones. A model developed just on the correspondence between decay phenomenon and intervention would miss to represent that situation.

Further modelling follows AR development adapting its structure to conservation process. As to translate the architect idea - developed within an in depth knowledge process and appraisal - to documents that give direction to operational activities, many planning steps are required, the model foresees a number of subclasses that follows the construction process. Moreover, the law also prescribes planning activity. In Italy, a project has developed in three main work phases: feasibility planning, definitive planning and executive planning[1]. Then, the model has to follow the same scheme.

Starting from the main class Architectural Conservation project, that will represent the whole project, several subclasses will further specify the intervention activity (fig. 5).

Thus far, the research has focussed on surface conservation design, but the full ontology in its future developments will consider all the other issues.

Thereby Surfaces Conservation architectural project (encoded $E_{pcm}4$) will present the subclass Surfaces Conservation executive planning (encoded $E_{pcm}5$), that is equal to AR class, Construction project. Following the first order logic representation, this will be expressed as follows:

$$E_{pcm}5\ (x) \supset E_{pcm}4\ (x).$$

Going further, the model reflects the workflow structure and each phase of surfaces conservation project, such as pre-consolidation ($E_{pcm}6$), cleaning ($E_{pcm}7$), consolidation ($E_{pcm}8$), protection ($E_{pcm}9$), addition ($E_{cpm}10$) and removal (E_{cpm} 11) will correspond to a class. These classes are actually equal to AR class Construction plan [encoded AR 4]. Once defined the specific intervention, the model will specify the materials employed and finally the link to the peculiar activity described in the Institutional prices lists (fig.6).

[1] The planning procedure is prescribed, by the Italian law, with D.Lgs. 50/2016.

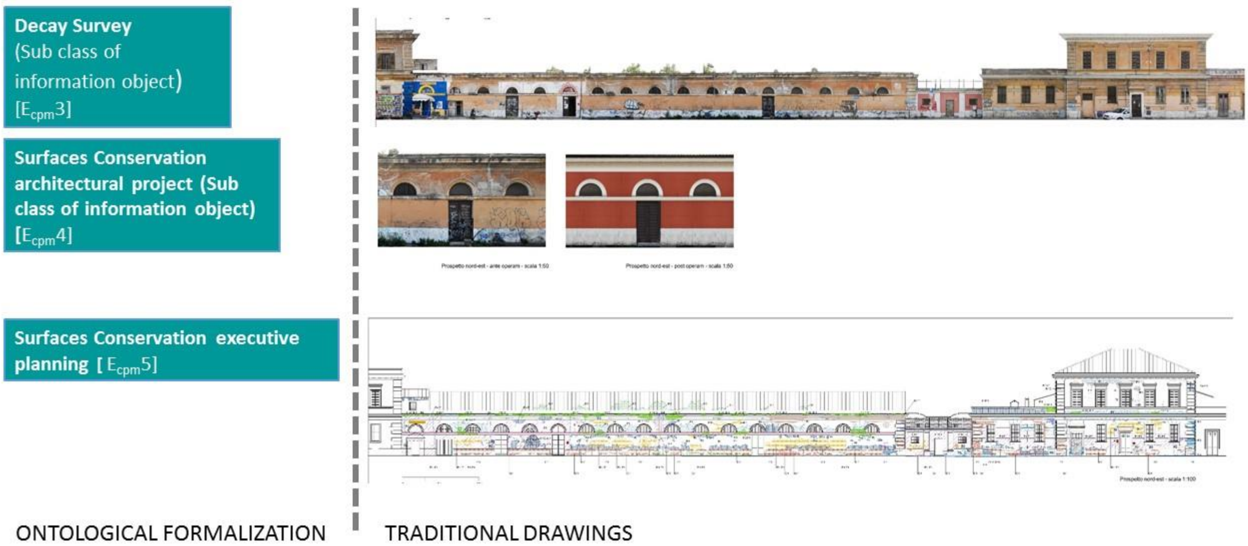

Figure 5. Comparison between model classes and traditional representation of the surfaces conservation project.

The instances that bridge the ontology to the BIM modelling and are represented in a BIM environment are either the decayed areas or the interventions. Specific efforts been addressed to conceive a structure that allows an easy mapping between the two environments. Integrating ontology modelling with BIM environment makes it possible to verify the correspondence to geometrical representation, to facilitate visualization and to extend the possibility of interaction to a wider community of actors and traditionally involved in cultural heritage conservation and managing process. The combined use of the two instruments, BIM and ontology may provide an interesting enhancement of the managing potential of the whole process.

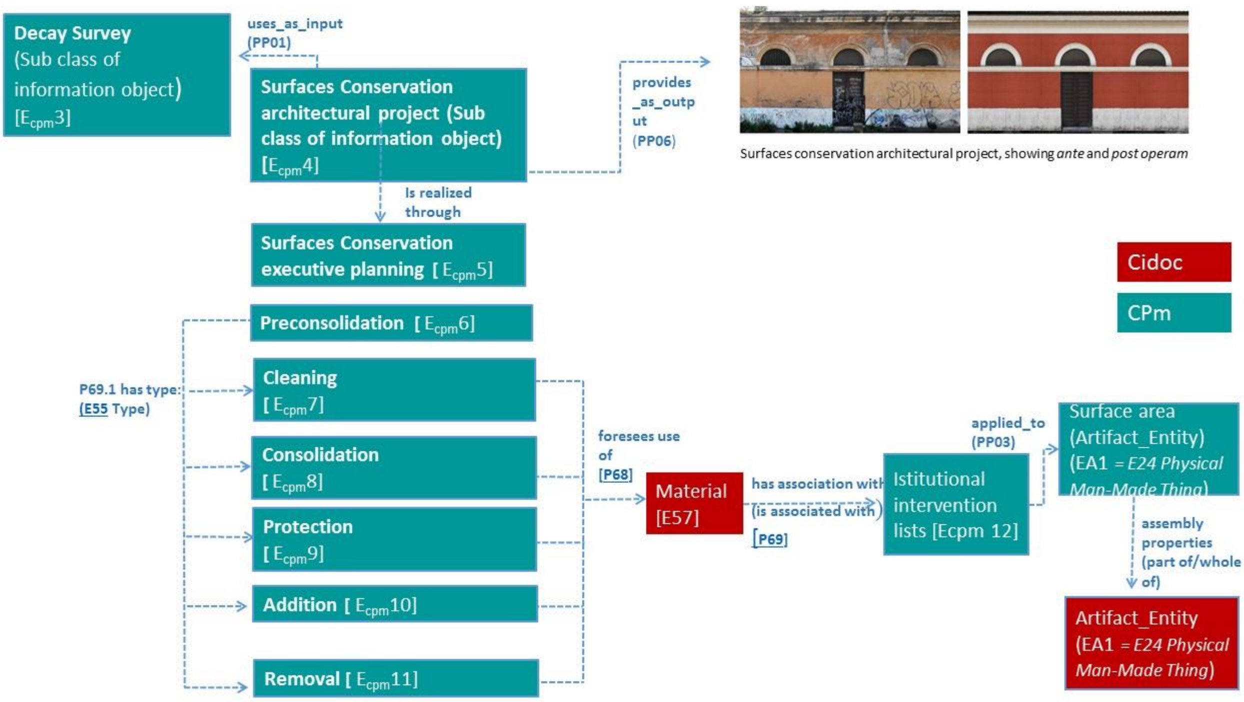

Figure 6. Surfaces conservation project model

3. CONCLUSIONS

This work focuses on the overcoming of a specific drawback of BIM current use within cultural heritage conservation scope- the low level of semantics in the representation- integrating BIM and semantic web methodologies. As the conservation design moves from a hermeneutical process enhanced from building knowledge, each ICT (Information Communication Technology) instrument addressed to cultural heritage protection may not provide adequate knowledge representation. The use of ontologies, as well as their integration with a Building Information Modelling environment, allows a homogeneous, accessible and computable structured formalization of both direct and indirect knowledge necessary for the full comprehension of an architectural artefact. As a matter of facts, the proposed model intends to merge potentialities of new technologies, concerning strictness and capability of managing complex data systems, with humanistic issues that characterize each activity addressed to cultural heritage.

REFERENCES

Acierno, M., *et al.*2017: Acierno M., Cursi S., S. Davide, F. Donatella, Architectural Heritage Knowledge Modelling: An Ontology-Based Framework for Conservation Process, *Journal of Architectural Heritage*, 24(2017), 124-133.

Bekiari, C., *et al.* 2015. Bekiari C. Doerr M. Le Bœuf P. Riva P., (eds), FRBR object-oriented definition and mapping from FRBRER, FRAD and FRSAD (version 2.2), 2015 http://www.cidoc-crm.org/frbroo/ModelVersion/version-2.4 [14/04/2017].

Carrara, G., 2014: *Conoscere collaborare progettare. Teoria tecniche e applicazioni per la collaborazione in architettura*. Roma: Gangemi.

Cacciotti *et al*. 2015. Cacciotti, R. Blasko, M., Valach J., A diagnostic ontological model for damages to historical constructions, *Journal of Cultural Heritage*, 16 (1) (2015) 40-48.

Ciotti, F., 2014. *Tematologia e metodi digitali: dal markup alle ontologie*, in Alfonzetti, B. Baldassarri G. e Tomasi F. (ed), *I cantieri dell'italianistica. Ricerca, didattica e organizzazione agli inizi del XXI secolo*. Atti del XVII congresso dell'ADI – Associazione degli Italianisti;Roma 18-21 settembre 2013. Roma: Adi editore.

Crofts, N., *et al.* 2010: Crofts, N., Doerr, M., Gill, T., Stead S., Stiff, M., Definition of the CIDOC Conceptual Reference Model, ICOM/CIDOC Documentation Standards Group e CIDOC CRM Special Interest Group, January 2010 http://www.cidoc- crm.org/docs/cidoc_crm_version_5.0.2.pdf [14/4/2017].

Dore,C., Murphy, M., 2013. Integration of Historic Building Information Modeling and 3D GIS for Recording and Managing Cultural Heritage Sites, in Guidi G., Addison A. C. (eds), Virtual Systems in the Information Society, Proceedings of the 18th International Conference on Virtual Systems and Multimedia (Milan, 2-5 September 2012), Piscataway, NJ, IEEE, pp. 369-376.

Felicetti, A., et al. 2013. Felicetti, A., Scarselli, T., Mancinelli, M. L., Niccolucci, F., Mapping ICCD Archaeological Data to CIDOC-CRM: the RA Schema in Alexiev, V., Ivanov, V., Grinberg, M., (eds), CRMEX 2013 Practical Experiences with CIDOC CRM and its Extensions, Valetta, Malta, September 26, 2013

Fiorani, Acierno 2016: Fiorani, D., Acierno, M., *Drawing, information and design: tools and perspective for conservation*, in Ippolito Alfonso (ed.), *Handbook of Research on Emerging Technologies for Architectural and Archaeological Heritage*, IGI Global, Hershey (Pennsylvania), pp. 355-386.

Gigliozzi, Ciotti 2003: Gigliozzi, G.e, Ciotti, F., Introduzione all'uso del computer negli studi letterari, Bruno Mondadori. Milano.

Gruber, T., 2009. Ontology, in Liu, Ling, Özsu M. Tamer (eds), Encyclopedia of Database Systems, Springer-Verlag, Berlin: <http://tomgruber.org/writing/ontology-definition-2007.htm> [9.01.2017].

Mc Carty 2005: Mc Carty, Willard, *Humanities Computing*, Basingstoke: Palgrave Macmillan.

Oldman, Kurtz 2014: Oldman, Dominic. Kurtz, Donna , The CIDOC Conceptual Reference Model (CIDOC-CRM): PRIMER. http://cidoc-crm.org/docs/CRMPrimer_v1.1.pdf [30.12.2006].

Orlandi 2010: Orlandi, *Informatica testuale: teoria e prassi*, Roma-Bari: Laterza.

Pauwels *et al.* 2013: Pauwels, Pieter, Bod, Rens, Di Mascio, Danilo, De Meyer, Ronald, *Integrating building information modelling and semantic web technologies for the management of built heritage information*, in Addison, A.C., De Luca L., Guidi G., Pescarin S., *Digital Heritage*; Proceedings of the1st International Congress on Digital Heritage, Marseille, 28 Oct-1 Nov 2013. Piscataway, NJ: Ieee XploreDigital Library.

Fonseca, F., Egenhofer, M., Davis, C., Camara, G., 2002. Semantic granularity. In Ontology-driven geographic information systems. AMAI Annals of Mathematics and Artificial Intelligence, 36 (1-2). pp. 121-151.

Anais Guillem, George Bruseker, Paola Ronzino, Process, concept or thing? Some initial considerations in the ontological modelling of architecture, *International Journal on Digital Libraries*, 2016, pp 1-11

Noardo, F., 2014. Strutturazione dei dati di un GIS in ontologia: applicazione per la mappatura del degrado di un caso studio in Asita, pp. 899-906.

Noardo, F.2016. Architectural Heritage Ontology - Concepts and Some Practical Issues. In Proceedings of the 2nd International Conference on Geographical Information Systems Theory, Applications and Management (GISTAM 2016), pages 168-179 ISBN: 978-989-758-188-5

Noardo, F. 2015. Ontologie e modelli di dati per l'informazione spaziale dei Beni Architettonici, in ASITA, Lecco, 29 settembre – 1 ottobre 2015. pp. 893-900

Ronzino, P., Niccolucci, F., Felicetti, A., Doerr, M., 2015. CRMba a CRM extension for the documentation of standing buildings. In *International Journal on Digital Libraries.* p.1-8.

Ronzino, P.et al. 2013. Ronzino, P., Niccolucci, F., D'Andrea, A., Built Heritage metadata schemas and the integration of architectural datasets using CIDOC-CRM in Built Heritage 2013 Monitoring Conservation Management

Tzompanaki K., *et al*., 2013. Tzompanaki K., Doerr M., Theodoridou M., Fundulaki Reasoning based on property propagation on CIDOC-CRM and CRMdig based repositories in CRMEX 2013 Practical Experiences with CIDOC CRM and its Extensions, Valetta, Malta, September 26, 2013 Vladimir Alexiev, Vladimir Ivanov, Maurice Grinberg (editors)