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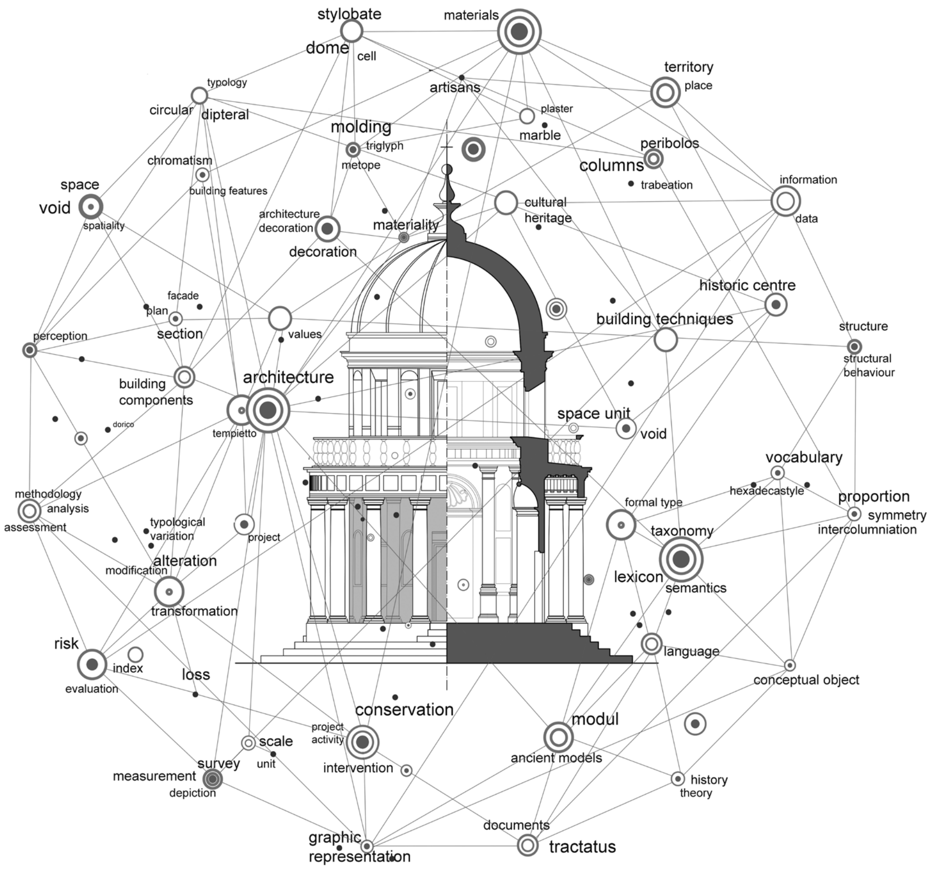
Architettura

Conservation Process Model

An ontology for Conservation in Architecture

Marta Acierno and Donatella Fiorani



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In copertina | *Cover image*: The cover design is by Alessia Vaccariello, and the CPM logo in the following page has been designed by Silvia Cutarelli.

Marta Acierno and *Donatella Fiorani*

Conservation Process Model
An ontology for Conservation in Architecture

With a debate on CIDOC CRM and digital technologies
for architectural heritage

Summary

Presentation

Athanasios Velios

Understanding history is a process of fundamental importance in our society. What happened in the past absolutely shapes our identities and our future. This is of crucial importance now when contested and alternative histories are often presented as co-existing and fluid, leaving scope for arguments that are fuelled by dubious objectives that are not relevant to history. This is why conservation is perhaps one of the most important areas of research and practice. Conservation is the discourse of material evidence and ethics. Material evidence, arguably alongside collective memory, is the way that historical events travel through time. Preserving and documenting that material evidence is the core objective for conservators in their organised effort to help with understanding history. The ethics around what is preserved and how it is preserved is one of the most interesting subjects of discussion. What impact do the choices that conservators make have on material evidence and the historical events this evidence carries? Literature on conservation ethics is simply fascinating. This becomes particularly interesting for built heritage. Historic architecture has accompanied human activity over millennia, and when preserved, it can be a huge pool of evidence for understanding history.

This pool of evidence is observed and analysed by experts. Analyses by different people lead to different conclusions. Evidence is often unclear and the background of each observer means that observations are interpreted depending on existing experience. This initiates discussions among experts and fuels academic discourse. A core exercise in this process is the documentation of material evidence and its safekeeping. Progress in this discourse often requires multiple sets of observations and sets of records being compared and combined. A larger sample often means better conclusions. This is exactly where this book makes a huge contribution: to organise our thoughts, explain and make recommendation on how these records can be combined to fuel academic discourse and to help us understand our history.

I was lucky to follow the development of the work described in this book over the past 10 years. This was only possible because the authors engaged meaningfully with communities and interested parties. Such engagement is necessarily collective. The progression of thinking and articulation of ideas is done through a process of discussion with a positive attitude. This book is the result of countless hours of engagement in a collegiate and supportive manner, in an environment of mutual respect and appreciation for all parties involved. However, this is not co-production, this is the result of deep knowledge of the domain and reaching out to communities around it to test and reform ideas to make them as widely applicable as possible. The authors have shown how experts can engage with communities that lack expertise in a field, make the discussion relevant for everyone, contribute to the community and lead everyone in a journey of discovery. This takes dedication, commitment and patience.

Despite the huge, combined expertise of the authors around material evidence about the environment and architecture, their engagement with the CIDOC CRM Special Interest Group has helped the development of their ideas around knowledge organisation and the articulation of relevant ontological concepts. The CIDOC CRM SIG is a unique place where the understanding of ontology is discussed and debated. It is the slow pace and the inclusive character of the group that makes that understanding accessible to newcomers. Such interaction is typically a long journey, but the SIG has always been welcoming to new members and seeks to support them as much as possible. It is within this environment that the authors developed their ideas and indeed enriched the discussion, while at the same time bringing new members to the group.

Apart from the value of the SIG as a forum for discussing ontologies, the importance of the CIDOC CRM in the organisation of heritage data cannot be overstressed. The CIDOC CRM is a cornerstone in the development of the theory and practice of managing heritage-related data. This is because of its capacity to act as a basis for data integration. The CIDOC CRM articulates a set of rather general classes and properties which describe core concepts in heritage discourses. It also provides methods for adding new classes and properties which extend the existing ones. This is really important for two reasons:

a) not all experts and projects collect data at the same level of detail, and therefore a way to integrate more and less detailed data is needed. This can be achieved through classes and sub-classes, properties and sub-properties of the CIDOC CRM;
b) the heritage discourse is huge and researchers need ways to expand in different areas of research which may not have been considered so far. Having a method to extend the CIDOC CRM means that it can remain applicable and relevant for multiple sub-domains in cultural heritage.

The authors have therefore chosen a solid base to develop their work and that means that any resulting data following their methods can join a huge ecosystem of other integrated datasets. Ultimately this choice reflects the desire for cross-institutional and cross-disciplinary work by the authors with the aim of assisting the development of knowledge and sharing it as widely as possible.

This book is a real achievement by prof. Acierno and prof. Fiorani, on many levels: primarily because it is the first extensive publication on data modelling for architectural conservation, but also because it is a showcase of supportive, respectful and ethical method of developing research that I have always admired.

Closing this short introduction to the main body of the book, I advise the reader to be patient with reading, especially if they are newcomers to the field, as some of the ideas are dense and require revisiting several times before becoming clear. Because of this process, the book also makes an important contribution to training around the development of thinking as well as providing the core practical elements for integrating architectural conservation data.

Athanasios Velios

PART I

The Conservation Process Model

1. The Conservation Process Model

1.1. Introduction: Genesis of the CPM

This book shows the first organic presentation of the Conservation Process Model, a formal ontology[1] we have been developing from 2015 with the goal of formalizing knowledge in the field of architectural conservation. The work that has been done is the result of several experimentation efforts and followed different strategies inspired from time to time by different prerequisites but always with the same aim. This aim is to construct a tool that can help to gather, interchange and manage data about historic (and modern) architectures and the conservation interventions realised on them, as we will better describe below.

Initially, CPM came into being as an autonomous conceptual model, based on the formalisation of entities and processes related to the domain of historic architecture, with reference to the needs of restoration. As such, it started from the definition of classes and properties with their own hierarchy, capable of defining five domains respectively illustrating: 1) the description of the current features of the architecture (the Artefact): 2) the investigation process of the historic building; 3) the Actors involved in the processes of the realization and transformation of the building itself; 4) the so-called "Lifecycle 1", meaning the transformation process for historic architecture; 5) the so-called "Lifecycle 2", regarding the conservation and management activities on it[2].

Of course, the initial beginning of the formalisation was accompanied by an application on real case-studies, with special attention to the underground church of St. Saba in Rome[3].

The interest in CIDOC CRM ontology and then the meeting with the CIDOC CRM Special Interest Group[4] changed the initial premises of the work and definitively convinced us as to the need to homogenize the Conservation Process Modelling for

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1 Early systematic framings of formal ontologies include Gruber 1995; Guarino 1998; for a general overview of major ontologies in the cultural sphere see Biagetti 2016.

2 See Acierno, Fiorani 2017a; Acierno, Fiorani 2017b; Acierno, Fiorani 2017c; Acierno et al. 2017; Fiorani 2017.

3 See Acierno 2017.

4 The CIDOC CRM SIG was created in 2000 and brings together a group of volunteers from all over the world with two-three meetings a year and a non-stop activity of emailing and discussion.

Architecture within the general framework of the wider and shared ontology dedicated to the cultural heritage.

We then started to verify the single classes and properties in the light of the choices made within the CIDOC interest group, and some decisions changed in order to allow the maximum interoperability of the digital systems but also in consideration of the 'philosophical' vision CIDOC expresses. This vision inspires the design principles of the CRM ontology summarized as: search for neutrality that animates the definition of classes (to avoid ambiguity of meanings); use of a bottom-up procedure (going back from a specific case to the abstraction that generalizes its meaning); adoption of a long-term strategy finalized to gain stability of the resultant model through several progressive verifications[5].

The ontology does not seek to explain but to describe reality in terms of a classification as complete as possible that includes all types of entities and their relations, proposing "a taxonomy of the entities in reality at all levels of aggregation"[6]. The idea to summarize the real world in a group of fundamental constituents within the CIDOC balance between 'generativity' and 'descriptiveness'[7] is so far ensured by the combination – as a "family of trees"[8] – of the CIDOC CRM core and its different extensions[9].

With this new orientation, CPM has been structured within the CRM hierarchy and some classes were redefined – among which, significantly, the class dedicated to the historic centre as a subclass of E92 Spacetime Volume (subsequently supplemented by a class expressing the physical components of the city at a given time). Another important work has been developed to match the classes and properties of some extensions of CIDOC, when the content seemed to be similar.

As already discussed, the common acceptance of an ontological system requires its 'neutrality', meaning the need to create and organise a description as uninfluenced as possible by specific theoretical positions[10]. This means that knowledge modelling needs to be aware of the several approaches to the problems dealing with the specific domain and to gather within its data definition and formalisation, the wider spectrum of meanings and intentions. Nevertheless, we can observe the differences existing on data assessment linked to the different scientific approaches, especially when we attempt to apply the wider formalisation in CIDOC CRM and

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5 See DOERR 2003; DOERR, ORE, STEAD 2007; BRUSEKER, CARBONI, GUILLEM 2017.

6 SMITH 2004, p. 3.

7 The generativity of the ontology defines its capacity to produce categories that completely illustrate the domain considered, the descriptiveness expresses the connection between these categories and the real world (*Ibidem*, p. 4).

8 *Ivi*, p. 14

9 The CIDOC CRM ontology represents the most widely shared semantic tool in the field of cultural heritage preservation, also recognised as ISO Standard 21127:2023 (the first ISO Standard CIDOC is dated 2006). The background, method, goals and content of CIDOC are the subject of an extensive literature and are presented in this same volume in Martin Doerr's paper. Further concise overviews include, among others, BRUSEKER, CARBONI, GUILLEM 2017; MORAITOU et al. 2019, while the work produced and ongoing activity are all reported in the CIDOC website <https://www.cidoc-crm.org/>.

10 Of course, the purported neutrality of data is not posited in an actual and definitive philosophical and epistemological sense – an area that has provided quite a few critical arguments against this assumption – but rather as a pragmatic line of approach, aimed at inspiring the greatest possible commitment to the selection of postulates that are as verifiable and logically supportable as possible (see also paragraph 5.1).

its extension to a new specific domain. For this reason, the matching between classes and properties related to different domain ontologies must be sufficiently tested by reasoning and applications.

The development of the incremental process in the definition of CPM has directly experienced this aspect of the problem. The choice of formalising the Risk Map system (Italy's 'Carta del Rischio' of the Italian Ministry of Culture) came about with the aim of verifying the modelling of an existing IT system. Following this strategy, the development and verification of the ontology could be combined with a number of practical descriptive requirements, stemming from the original setup of the data models developed for the digital GIS platform[11]. The long and complex path of this research has led to several choices, some consolidated over time, while others have definitively changed[12]. Among the latter, one of the most important has concerned the change of the initial choice to use the CIDOC extensions CRMba, CRMgeo and CRMsci. Without going into subjects to be discussed further on, we can explain this choice by the general need to find, after a general phase of 'reduction' of the original classes and properties, a more precise adaptation of the conceptualisation related to architecture than that permitted within other domains. These domains, which boasted the presence of already developed ontologies, were chosen in part due to the proximity of the content they dealt with: CRMba, for archaeology, is dedicated, among other things, to the modelling of existing built structures, while CRMsci, developed to enable the conceptualisation of the scientific analysis of cultural objects, concerns, among others, the diagnostic activities on buildings. Another reason for the choice was the similarity of the problems addressed in different domains: in particular, the use of CRMgeo and Geo-SPARQL initially seemed to solve the problems related to the geographical location of the architectures[13].

Continuous verification work, ongoing liaison with the CIDOC CRM SIG, and the progression of formalisation, in particular with the complete definition of the scope notes of the CPM classes and properties, have enabled us to clarify the specificity of the concepts we need for architecture and preservation, suggesting that we should dispense with the initial integrations with CRMba, CRMgeo, and CRMsci, while conversely adding the CRMinf to formalize the process of the inference making.

The work developed for the formalization of the Risk Map has been undertaken also for another purpose as well, looking at the possibility of allowing a future application of the ontology for this GIS platform and the possible interoperability with other kinds of tools in architecture, such us BIM[14].

At the same time, we continued to work on the formalisation of various activities and concepts related to conservation in architecture, considering actions and content useful for the knowledge of historic buildings and their intervention issues, as well

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11 More precisely, the work has been dedicated to the development of the Risk Map for the historic centres, carried out by the same group of researchers within the framework of an agreement between the Department of History, Representation and Restoration of Architecture of Sapienza University of Rome. Specific issues related to the contents and purposes of the Italian Risk Map, and its formalization, are addressed in a dedicated chapter of this volume.

12 See Acierno 2019; Acierno, Fiorani 2019.

13 On the problems in the use of these tools for describing the topological and mereological aspects in architecture see Colucci, Spanò 2020; Guillem et al. 2023.

14 See Fiorani, Acierno in press.

as the development of the project and the execution of the restoration, monitoring or planned conservation worksite. One of the case studies considered, with a focus on the problems of material decay and the intervention on the architectural surfaces, has been the façade of the Mattatoio in Testaccio, Rome[15].

As already stated, the CPM ontology is the product of an iterative work, begun with the characterization of domain and aim of the ontology, continued with the experimentation of a new path but soon subjected to the analysis of the existing ontologies, then tested on some case-studies, and lastly refined with the precise definition of classes and properties we present here[16]. Despite the constant revision and rethinking of previously proposed formalisation strategies, it should be emphasised that the work conducted over the past few years has nevertheless been instrumental in refining conceptualisation, thus allowing useful and well-structured convictions to be reached. Although the present version of the CPM thus shows some differences from what has already been published – starting with the naming of classes and properties – it confirms in substance its conceptual approach and basic philosophy.

The definition of an ontology – or of an AI system – is not a one-way process: the proposed system must be constantly revised, passing from conceptual definition to instantiation, from instantiation to evidence of the possible problems, and from there to the revision of the system. This circular process never actually ends, because the human conceptualization never has a conclusion. This is also the reason why web publication is preferred over print edition, in order to represent developments in digitisation. However, the decision was made to present the work in a 'traditional' manner in order to encourage linking the world of restorative architects to that of computer processing.

In fact, we would like to emphasize that the definition of an ontology is not a matter exclusive to computer experts. This finding, entirely obvious to those working on this topic, is less obvious to the majority of those involved in architectural restoration. This implies, on the one hand, a still limited participation of experts in the field in the joint work necessary to achieve a necessary sharing of results, and on the other hand, a greater need than ever to avoid producing "black boxes" that are such as to prevent an understanding of how the system works[17].

1.2. Scope of the CPM

We normally speak about ontology in terms of interoperability of IT system, but we also have to reflect on the effects of this kind of research within the architectural conservation field. The first answer is very factual and maybe banal: the application of ontology to the Artificial Intelligence risks reducing the conservation intervention to a mechanical reaction to individual, specific technical problems. This is mainly the dream of many engineers working in development toward the most advanced automation in identifying of the conservation problem and selecting the more fitting solution[18]. This approach completely destroys the connection between the technical

[15] See Acierno, Fiorani 2017c.

[16] See Noy, McGuinness 2001.

[17] See Foryciarz, Leufer, Szymielewicz 2020.

[18] See Cacciotti, Blasko, Valach 2015.

and the critical interpretation of the phenomenon, reducing the conservation problems to the sole physical analysis of the material deterioration of the architecture. The second question is more structural and deals with the necessity of clarifying the contents and procedures we adopt when working on architectural conservation in a spontaneous and implicit way. As already stated, ontology can be considered as a kind of a generalized chemistry, and the information system, in this sense, can offer a way to perform a chemical experimentation[19]. Properly speaking, ontology allows a specific community of scholars, in this case experts working on conservation in architecture, to express their specific way of looking at reality and the problems to be dealt with[20]. In this sense, the correctness of the process in conservation can be verified in the general framework and in the specific instantiation.

The overall intended scope of the CPM concerns documentation and management of the information for architectural cultural heritage[21]. The model was conceived to describe conservation processes in order to support all the activities involved in historic architecture protection. It was developed through a bottom-up approach with the ambition of providing a stable reference to record and exchange information within architecture conservation processes attempting to achieve an adequate semantic description. The adequacy of the description was built grounding the formalization within concrete and practical circumstances that addressed multiple contexts. The model was developed to deal with both professional and scientific purposes. Conservation discourse has been articulated according to the multiple applications it may deal with ranging from the protection issues, dealing mainly with managing institutional tasks, to conservation and maintenance activities. The bottom-up approach has also allowed the model to be addressed to the different architectural scales from the urban to the constructive. As far as the operational steps of conservation are concerned, the model was developed through four different main domains. The first focuses on the morpho-typological and constructive description of architecture. The second deals with the documentation of the building lifecycle, tackling modification, transformations, conservation interventions and all other activities affecting the building during its existence. The third addresses all those critical assessments required during the conservation process, ranging from historical interpretations to evaluation of the physical condition. Lastly, the fourth concerns the conservation activity, from the definition of the project to the realization of interventions and maintenance.

Beyond the semantic adequacy, compatibility with CIDOC CRM is seen as a main issue, as the aim is to build up a model highly specific for architectural cultural heritage while also being fully interoperable with existing cultural heritage environments. This required the conception of a model whose semantic description ought to be firmly anchored to an existing standard. Being grounded on the reference set of specific, identifiable documentation standards and practice that the CI-

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19 See Smith 2004, p. 85.

20 See Bruseker, Carboni, Guillem 2017, p. 105.

21 A similar objective inspired the proposed ontology of the PARCOURS project, also elaborated in the CIDOC environment, but with different content and not specifically addressed to historic architecture (see Niang et al. 2017). In contrast, the HERACLES ontology, still focused on the domain of cultural heritage protection, presents an approach independent of CIDOC, as the first proposal developed for the CPM but with different contents (see Hellmund et al. 2018 and Hellmund et al. 2019).

DOC CRM describes, the CPM modelling grants a shared conceptual reference. This issue proved to be essential considering that, as far as protection and safeguard are concerned, cultural heritage is supervised mainly by institutional bodies, that generally employ heterogeneous information systems. Therefore, any attempt to support those bodies' activity cannot disregard providing data sets in an interoperable, machine processable manner[22].

While the philosophy, approach and rules of CIDOC CRM remain unchanged, the CPM ontology has some specific features related to the specificities of the application domain. The most important of these is the greater attention paid to the particularities posed by the physical reality of the architecture. As their authors often emphasise, CIDOC CRM constitutes an event-centric model, in the sense that it assigns priority importance to the activities performed by humans in relation to material preservation issues. This type of approach is entirely consistent with the premises underlying the initiation of formalisation, linked to the conservation needs of the artefacts stored in a museum.

The CPM model always aims to allow for the representation of processuality in the realisation of architecture and its conservation, but it must necessarily devote specific attention to the conceptual tools necessary for the representation of the physical reality of architecture. This necessity responds first and foremost to the need to propose an adequate formalisation for the description of the actual complexity of the historic built environment, so as to make possible an appropriately articulated data collection and management. It also facilitates the development of effective interoperability between digital tools that can be used in the field of restoration. In fact, the CPM model is conceived to relate either to cataloguing and documentation institution, like ICCD in Italy, or to protection and conservation bodies. Moreover, the intended scope of the model is also oriented towards professional concerns, allowing information to be shared with GIS and BIM environments.

Another important distinction concerns the temporal projection of the model. As a tool to relate data, CIDOC CRM always considers already encoded information and most modelled properties use the past tense. Again, the perspective in which one normally works with museum objects and historic architecture orients the formalization. A good example may be found, for instance, with the question of use: the CIDOC CRM specifies eight different properties relating to the use of a thing; of these, only one is in the present tense, expressing the relationship between a certain type of activity and the material required to perform this activity – P68 *foresees use of* (*use foreseen by*), from E29 Design or Procedure to E57 Material – mainly concerning the maintenance procedure of an asset. The other properties, conjugated in the past tense, contemplate data related to the description of museum objects, whose use refers to the past. Conversely, the CPM property Pc43 *is used for* (*uses*) has been conceived to link a built entity (CP1) to an activity (E7) through the employment of the verbs 'to be' and 'to use' conjugated in the present tense. As we can expect, the current function of the object is not contemplated in CIDOC CRM, consistent with the fact that data related to the description of museum objects, whose use refers to

[22] For example, the model could reach the full interoperability not only with the Risk Map, which was specifically worked on, but also with the other platforms of the Ministry of Culture with which Risk Map operates, through the shared platform 'Vincoli in Rete'.

the past, are predominantly considered. On the contrary, architecture is a physical reality almost always characterised by current use, and this condition has required the adoption of the present tense for a property regarding its use, which relates the building to the activities carried out within it.

1.3. Rules and Conventions

As already mentioned, the CPM model is entirely designed following the CIDOC CRM model with the aim of pursuing maximum interoperability in the broader field of preservation. This entails the adoption of the same rules and conventions to ensure compatibility with the fundamental principles of the source ontology. This means that the CPM uses the same terminology to define: the conceptual items (class, superclass, subclass, properties, superproperty, subproperty, instance, scope note, domain, range); the specificities of classes and properties (intentions, extensions, inverse of, inheritance, disjoint, primitive, complement, property quantifier, universal, transitivity, symmetry, reflexivity); some special way of connecting data (shortcut, monotonic reasoning, query containment, interoperability, semantic interoperability, knowledge creation process)[23].

1.4. Introduction to the CPM basic concepts

The construction of the CPM model on the CIDOC CRM model involves the complete acquisition of its general logic. Since the CPM model aims to be a formalized representation of the architecture conservation process, it is conceived to support both the representation of fact based, analytic discourse about what has happened in the past and the documentation of the current condition of the building and the activities developed during the conservation process. However, a wide part of the model addresses the description of the building whose documentation is supported by the key class CP1 Built Entity and several properties specifying the context. As CIDOC CRM, the CPM model proposes a set of formalised properties (relations) that allow semantically explicit statements to be made by relating different concepts (classes). Classes and properties are made logically explicit by their formal definition. The model therefore enables a formal, logically explicit description of relations between individual, architecture conservation process items, classified under distinct ontological classes. The whole formalisation is conceived as an extension of CIDOC CRM classes and properties and provides a standard representation that allows large sets of data coming from conservation process activities to be uniformly managed.

Based on the hierarchical system of classes and relations that provides the basic ontological distinctions to represent the historical discourse formalised by the CIDOC CRM, the CPM model further extends the formalisation to the description of

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[23] The latest version of CIDOC CRM, in draft form, is n. 7.3.1 and dates from May 2025 (<https://cidoc-crm.org/versions-of-the-cidoc-crm>), the official form, with ISO correspondence, is n. 7.1.3, from February 2024. Rules and conventions are explained in Bekiari et al. 2024, pp. 11-24, while the modelling principles are illustrated on pp. 25-32 and discussed in many articles, some of them already cited in the previous footnotes.

the architecture and the preservation activity related to it. This conservation activity entails, in addition to the correct definition of operational interventions, an in-depth preliminary study of the building, aimed at a complete understanding of its construction methods, phases of transformation and conservation conditions.

Grounding on the top-level concepts of E77 Persistent Item, E2 Temporal Entity and E92 Spacetime Volume, which represent the highest-level distinction in the CIDOC CRM, the physical consistency of architecture is formalized through a hierarchy based on E77 Persistent Item and developed through subclasses of E24 Physical Human Made Thing that represent the multifaced nature of built heritage ranging from the spatial features to the constructive ones.

1.4.1. Temporal Entities

1.4.1.1. Activities on architecture, decay and damage phenomena

The descriptions of the entities that are time-limited are conceived as subclasses of the CIDOC CRM's E2 Temporal Entity class. These include events and historical relations that have involved architecture, but also intellectual activities processed on architecture over time. The whole documentation that involved modifying or transforming interventions is modelled through the CIDOC CRM's E81 Transformation and E11 Modification classes. As CIDOC CRM clarifies, these two classes are deeply different, the former defining a permanent change in the identity of the cultural object – framed by the properties P92 *brought into existence* and P93 *took out of existence* –, and the latter assuming the persistence of the original identity.

When we work on an ancient building in a conservation perspective, we assume that the identity of the building is preserved, so the foreseen activities might be considered specifications of the E11 Modification class. At any rate, the depiction of the construction events of the historic building in the past may involve the definition of phases of real transformations, to be instantiated as E81 Transformation, and, in some respects, further specifiable.

An important result derived from transformation in architecture is the ultimate change in architectural typology. This occurs when a new intervention completely changes the general appearance and internal spatial definition of a building: for example, a three-nave church becoming a single-nave church, or a series of contiguous townhouses transformed into a rental mansion, or a castle reduced to a farmhouse for agricultural use. All these cases can be instantiated as CP26 Typological Variation, E81 Transformation subclass.

Much time has been dedicated to reasoning over defining the very meaning of the activities developed for conserving historic architecture. One of these, CP23 Maintenance, can surely be considered as a E11 Modification subclass, showing all the characteristics assumed for an activity dedicated to altering or modifying human-made physical things. The specific of this subclass is related to the specificity of the application field but also to the particular goal of the activity, which is applied to the extension of the historic architecture's life.

More complex is the definition of CP25 Conservation Intervention: might we consider this one also as a E11 Modification subclass or there is a specificity, especially considering historic buildings? In the end, we opted for the latter hypothesis, due to the much more complicated connection with other activities (mainly CP24 Architecture Conservation Project Activity), the necessity to specify the precise object of application (the whole CP2 Architecture Work or a single CP1 Built Entity) and the strong connection with a special kind of design, represented by the CP33 Conservation Project (Fig. 1.1).

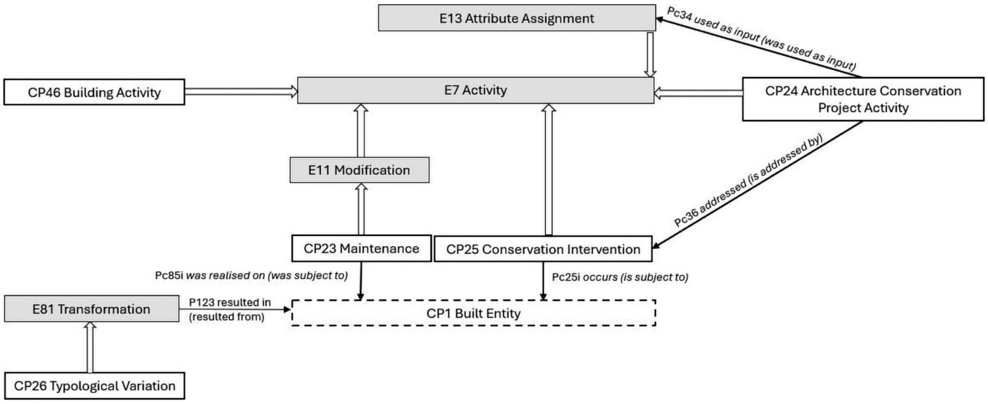

Fig. 1.1. CPM classes for the formalization of activities on architectures.

The distinction between CP25 Conservation Intervention and CP46 Building Activity is important: the former involves intervention on an existing building with the aim of preserving its architectural materiality, and the figurative and constructive qualities that are recognized in it. The latter concerns any kind of construction activity aimed at creating or transforming any kind of building. The former makes it possible to instantiate ongoing interventions (and might be in order to collect the different activities that take place on a construction site), while the latter is mainly used, in conservation, to instantiate building activities conducted in the past.

A final remark concerns the deterioration of buildings: as in the CRMsci, a CIDOC extension, the deterioration of a physical object may be considered by defining the phenomena observed on the object and the materials of which it is composed. These phenomena can be described as subclasses of an E5 Event, being events that bring about changes in the morphology and material composition of the physical reality, in particular of an architecture or part of it.

Similar remarks can then apply to phenomena related to material degradation and the effects of a structural crisis manifested by the building. However, it is necessary to distinguish the phenomenon as an event that determines a change in the body of the building from the material support that undergoes the phenomenon of degradation and instability. The CIDOC CRM has proposed the E26 Physical Feature class to collect, among other things, instances that express material degradation, indicating in this regard the specific example of "damage to the nose of the Great Sphinx of Giza"[24]. The CIDOC CRM proposal is not concerned with the description of the phenomenon, but more with the final effect of the phenomenon on the physical object. It is necessary, however, to emphasise that, from the point of view of the final result, the transformation of the material surface connected to the degradation phenomena is not always expressed as a deteriorated surface "integrally attached" to the material

[24] Bekiari et al. 2024, p. 76.

as CIDOC CRM affirms: new elements are sometimes simply located on the material itself (e.g. deposits, biological presences), and sometimes the degradation involves an unstable pulverisation, and sometimes the decay refers to a distinct component characterised by a composition different from the support and separable from the object.

In a different way, the CIDOC CRMsci extension looks at the phenomenon of material decay as a topic in its own right through the definition of the S18 Alteration class. But we must consider that classification of degradation, standardised in Italy as UNI 11182/2006 and by an international document ICOMOS-ISCS, lists and defines the degradation phenomena, considering alteration as a non-pathological state of the material.

We therefore find ourselves having to propose a formalisation of degradation that differs from what is proposed by both CIDOC CRM and its extension CRMsci: referring to the official catalogues of types of material deterioration, we have defined the CP42 Material Decay class, of E5 Event subclass.

Assessments of the same type have been made on phenomena induced by structural damage, mostly consisting of deformations, cracks, deformations, out-of-plumbness, etc. We can hardly consider all these phenomena as traits physically attached to the physical object: this may indeed be the case for some wall deformations (bulges, out-of-plumb), but not for others that express changes in the physical-geometrical and not the physical-material structure of the object. Even in this case, the definition of a specialised CP43 Structural Damage class, E5 Event subclass, appears more appropriate to express information related to the phenomena of structural instability of a building (Fig. 1.2).

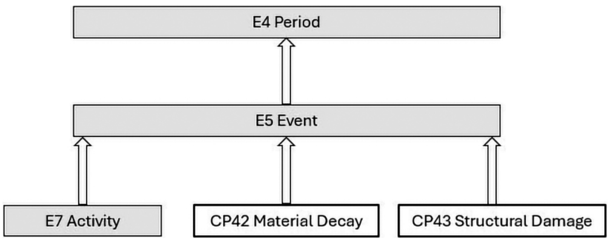

Fig. 1.2. CPM classes for formalizing material decay and structural damage with their hierarchical position with respect to CIDOC CRM classes.

1.4.1.2. Attribute assignments: assessments related to construction evidence and deterioration in architecture

As everyone working in the field of architectural conservation knows, defining the intervention in its general development and specific details requires a complex activity, which is represented in CPM ontology by the CP24 Architecture Conservation Project Activity class. The most particular content of the work produced to define a conservation project, which distinguishes this project from others, concerns the primary role played by knowledge of the existing building. This knowledge is the product of a collection of data subjected, individually and as a whole, and a series of evaluations about them. The activities conducted for the implementation of the different analysis modes are represented by the CP32 Architecture Features Analysis class. However, the more important role is given to the evaluative activity and, also to facilitate the extraction of targeted data, it has to be articulated in specific E13 Attribute Assignment subclasses (Fig. 1.3).

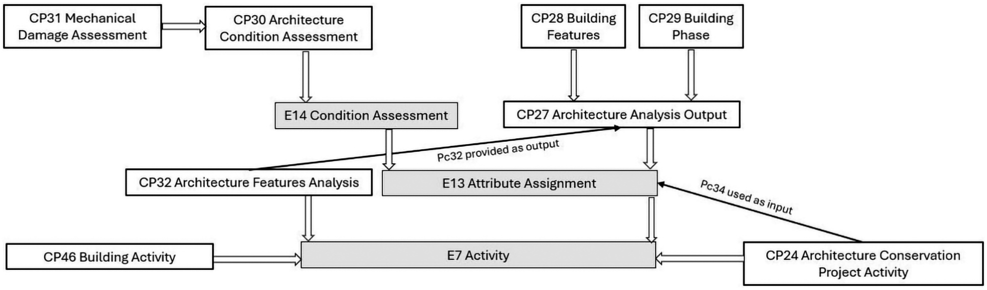

Fig. 1.3. CPM classes dedicated to the formalization of different assessments used in architecture conservation.

Among the different types of assessment, data related to the study of material and structural degradation, on the one hand, and architectural, constructive, and historical features, on the other, are of particular importance and could be extracted and combined for queries and reasoning. A specialization of the CIDOC CRM's E13 Attribute Assignment and E14 Condition Assessment core classes allows this goal to be achieved. E14 Condition Assessment has already been defined as a subclass of E13 Attribute Assignment dedicated to defining the state of preservation of an artifact, especially understood as a museum object. The different scale and complexity of historic buildings and the specialized methodologies and types of assessment have led to the identification of a new specific class to collect related instantiations. This CP30 Architecture Condition Assessment class is further specified with its CP31 Mechanical Damage Assessment subclass, which can clarify the interpretation of structural problems through the analysis of recognized effects on the building in terms of damage or deformation.

The CP27 Architecture Analysis Output class collects evaluations on historic buildings, constituting a specialized perspective dedicated to the architecture of the assessment activity; in its CP28 Building Features and CP29 Building Phases subclasses, data related to the construction characteristics and the historical transformations of the architectures can be respectively instantiated. These are identified through the critical systematization of the results derived from each different path of research carried out on the building, from those related to the different documentary supports to those allowed by direct inspection of the wall stratigraphy.

1.4.1.3. Spacetime volumes: historic centre, space unit and space component

Architecture design and construction together with conservation process can all be described as interrelating instances of E77 Persistent Item, perdurant objects, with E2 Temporal Entity, endurant ones[25], without needing to refer to the interaction between space and time. The former class, as it has been said, makes it possible to represent, through the CPM subclasses, urban and architectural heritage in their physical, perduring nature.

The whole system of E77 Persistent Item subclasses that CPM proposes and the related properties' structure provide the identification of three main groups of con-

[25] To explain the meaning of the terms 'perdurant' and 'endurant' we refer to Bekiari et al. 2024, p.16: "The difference between enduring and perduring entities […] is related to their behaviour in time. Endurants are wholly present (i.e., all their proper parts are present) at any time they are present. Perdurants, on the other hand, just extend in time by accumulating different temporal parts, so that, at any time they are present, they are only partially present, in the sense that some of their proper temporal parts (e.g., their previous or future phases) may be not present".

cepts that allow the cultural heritage domain to be described: urban and architecture physical consistency, planning or conservation designs and types specification that enables the link with every existing vocabulary within a specific domain.

The E2 Temporal Entity class makes it possible, through the CPM subclasses, to refer to the concepts that show an endurant nature such as activities and events to which architecture is subject, in particular, tackling processes of either modification and transformation or protection. It allows to describe the phenomena that determine architecture or urban areas condition and all the activities developed to assess and design conservation or maintenance interventions.

Notwithstanding this, dealing with architecture and urban scope, may entail the interaction between space and time making it necessary to refer to the CIDOC CRM's E92 Spacetime Volume class. For an example, the description of city boundaries, or architecture spatial features, that change over time needs to refer to both time and space references. More generally, tackling the relationship between historical and geographical contexts requires spacetime considerations. In fact, every theoretical or historical approach to architecture actually deals with the spacetime nature of architecture while conservation, at least conceived in its contemporary broadest sense deals solely with the material component of architectural space and is always occurring in the present time, defining a clear distance with the past or the 'times' of the object. Therefore, the whole model, conceived for the conservation process model, actually allows knowledge related to cultural heritage domain without referring to E92 Spacetime Volume to be formalized.

Nonetheless, the model allows spatial features to be described as they change over time, thanks to three classes that are conceived as E92 Spacetime Volume subclasses: following a hierarchical order, CP18 Space Entity is a key class that refers to any architectural or urban space considered in a specific time span. The description of the instances of this class is made possible through different properties that express the vocation, the property, the visual relation with other instances of CP18 Space Entity, along with the characterizing physical element and the attribution to a particular building phase (Fig. 1.4). Aside from the relation that describes the visual connection between two entities of E92 Spacetime Volume, the other properties combine CP18 Space Entity with ranges that pertain to the two principal classes E77 Persistent Item and E2 Temporal Entities.

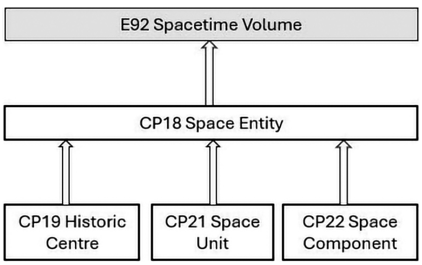

Fig. 1.4. CPM spacetime classes.

Subclasses of CP18 Space Entity are CP19 Historic centre, C21 Space Unit, CP22 Space Component. They allow the description of the urban and architecture volumes in physical spacetime to be specified regardless of their true geometric forms. CP19

Historic centre is referred to the urban scale and allows "agglomeration composed by the historic buildings and the open spaces which formerly constituted the town during all the time of its existence" to be represented. Its properties enable the description of demographic issues through Pc5 *is inhabited by (inhabits)* with range E74 Group and regulation condition through Pc14 *is regulated by (regulates)* E32 Authority Document.

CP21 Space Unit and CP22 Space Component both refer to the urban and architectural scale representing two different kinds of volumes in physical spacetime. The first class, CP21 Space Unit allows instances that show a functional identity and a spatial continuity to be modelled, such as for example the space of a chapel or a square in different time spans, while CP22 Space Component may be referred to as a part of CP21 Space Unit, as for example the bay of a nave in a church or the central garden of a square in different time span.

These three classes are independent of each other and inherit the CP18 Space Entity class properties that allows their relationship with the cultural and social context to be specified. Nonetheless they are connected by mereological relationships. As far as the CP19 Historic Centre is concerned, it inherits the property from the CIDOC CRM E92 Spacetime Volume, P10 *falls within (contains)*. Meanwhile the whole-part structure within the classes CP 21 Space Unit and CP22 Space Component is expressed through the property Pc77 *has as space component (is space component of)* that describes the fact that a space unit might be thought of as a whole made of several space components.

1.4.2. Persistent Items

1.4.2.1. Physical things in architectural and urban context

The central attention to the physical entities expressed by the CPM ontology is the natural effect of a formalization dedicated to the necessity to describe the ancient architectures and the possible interventions on them.

First of all, a distinction must be made between the physical reality consisting of the architectures, their components and the context. This latter is also broad, made up of physical elements that do not constitute proper building entities per se but nevertheless participate in characterizing the actual architectural and urban texture.

The entities properly considered as architecture elements are subclasses of E24 Physical Human-Made Thing, while the others are direct subclasses or sub-subclasses of E18 Physical Thing (Fig. 1.5).

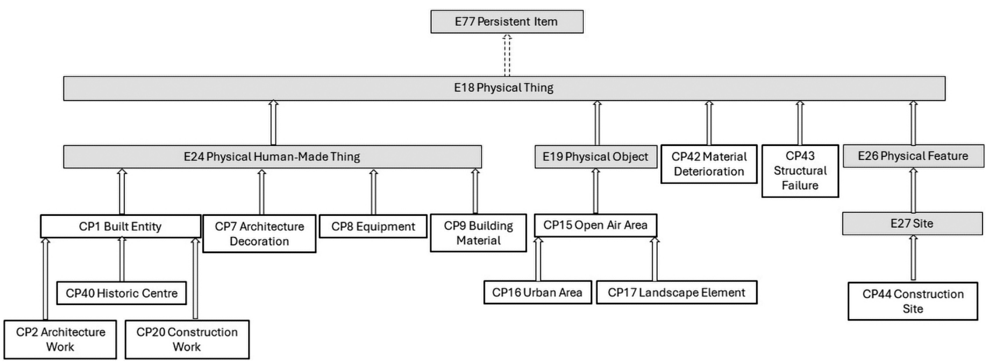

Fig. 1.5. CPM classes for the formalization of physical objects related to architectures and urban sites.

The basic subclasses of E24 Physical Human-Made Thing that describe the built world are CP1 Built Entity, CP7 Architecture Decoration, CP8 Equipment, and CP9 Building Material. The former collect any information pertaining to constructed things, and the latter data concerning elements that are not properly considerable as building components but nevertheless essential to make architecture pleasing (all kinds of permanent decorations), livable (the different types of equipment), and even realizable (materials).

Much thought was given to whether we should adopt some existing classes of the core CIDOC CRM (E57 Material) or its extension CRMsci (S10 Material Substantial) to collect material data. In the end, the over-abstraction of the CIDOC CRM concept and the overly laboratory-oriented specificity of the CRMsci concept convinced us of the desirability of adopting a special class to adequately express the particular features of materials that have been produced, processed or simply selected to build a construction.

The role of the CP1 Built Entity class is fundamental to the description of an architecture.

The physical things involved in defining a built context can consist, at a larger scale, of some physical components of the landscape and, at a smaller scale, of some physical features of built entities.

The former are formalized as a subclass of E19 Physical Object, the CP15 Open Area, and consist of open spaces containing both built and natural elements, further specialized as classes dedicated to open spaces in historic centres – squares or streets – (CP16 Urban Area) or to particular landscape elements that can be relevant for the characterization of a historic urban site (CP17 Landscape Element).

The formalization of the other classes has been particularly debated. At first, we considered CIDOC CRM's E26 Physical Feature class as the ideal class to model the physical features we wanted to describe. For the definition of CP44 Construction Site, a specialization of E27 Site, itself a E26 Physical Feature subclass, the choice was indeed permanent, the construction area being in fact a physical feature "attached in an integral way"[26] to the land (or sometimes even to the sea).

The class CP1 Built Entity, has made it possible to formalise every entity in the built environment, considered from an architectural or constructive perspective. This distinction helps to distinguish considerations of architectures as unitary and coherent elements, defined by their own typological and formal criteria, and information regarding the organisation and constructive specificity of the building. In the first case, the CP2 Architecture Work subclass helps to model the overall morphological, spatial and figurative characteristics; in the second, the CP20 Construction Work subclass allows the architecture itself to be formalised by describing the internal construction relationships (Fig. 1.6).

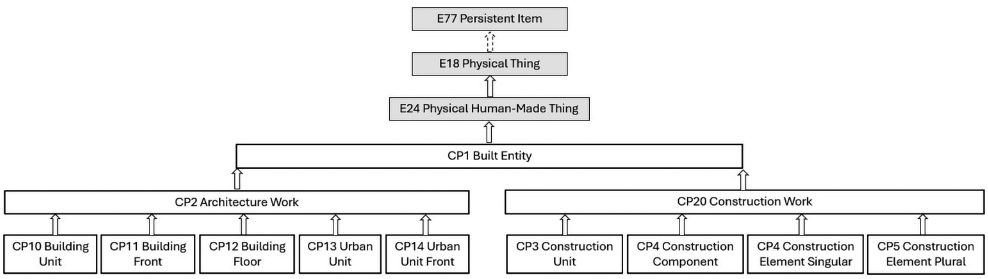

Fig. 1.6. CPM classes for the formalization of architecture and building elements.

[26] BEKIARI et al. 2024, p. 76.

Subclasses of CP2 Architecture Work have been defined for the modelling of individual buildings (CP10 Building Units) and their main vertical and horizontal architectural components, consisting of façades (CP11 Building Front) and floors (CP12 Building Floor), or for the formalising urban components (CP13 Urban Unit) with their façades, considered to be the interfaces between private and public spaces (CP14 urban Unit Front). The instantiation of these classes can be linked to data from websites and also to some specific digital system, such as the "Carta del Rischio" (Risk Map).

The subclasses of CP20 Construction Work are useful for describing the construction system, considering the technological packages of the building, such as the roof systems (CP3 Construction Unit), their homogenous components, such as the layering of a roof pitch (CP4 Construction Component), and the elements that, individually, such as a floor beam (CP6 Construction Element Singular), or in collective form, such as for a tile floor (CP5 Construction Element Plural) allow for the constructive realisation of an architecture. These four subclasses can be considered the cornerstone for linking with the data contained in digital programmes such as Building Information Modelling (BIM), constituting the basic link with a future ontology strictly dedicated to tools aimed at restoration design and conservation management of historic buildings.

Class CP1 Built Entity inherits many properties from its CIDOC CRM superclasses, mostly related to the connection with temporal entities (and among these are the various possible activities); some of these have as ranges the classes related to symbolic objects and the classes and subclasses relevant to the spacetime volume (Fig. 1.7). The only properties linking CIDOC CRM classes relating to persistent objects are P46 *is composed of* and P198 *holds or supports*: these establish the only physical relations available in the core. They may be considered sufficient for museum objects, but certainly not for architectures, where physical connections are fundamental to describing relationships between parts.

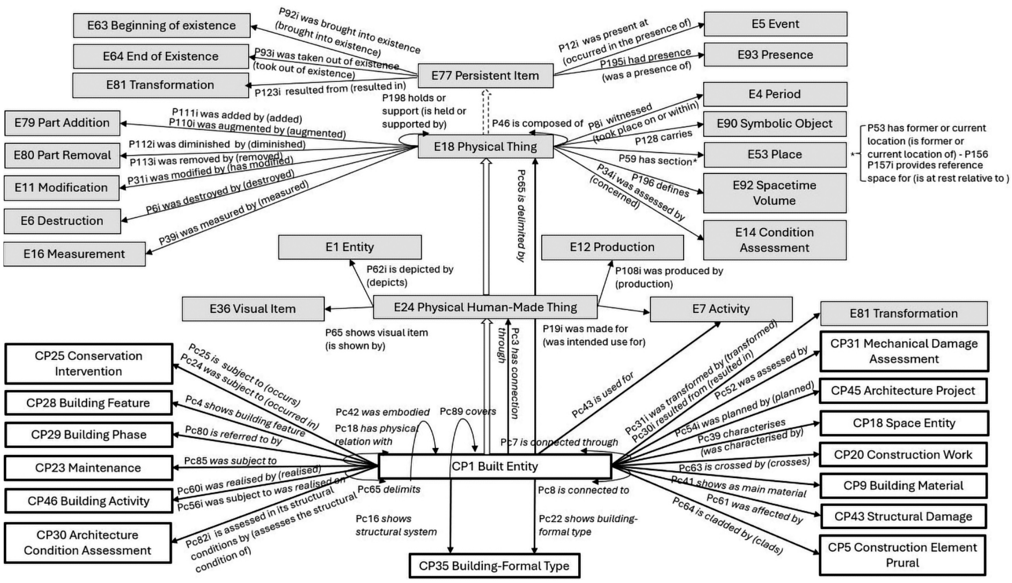

Fig. 1.7. The CPM class CP1 Built Entity with its hierarchy related to CIDOC CRM classes, the main properties inherited by CRM superclasses and the new CPM properties (missing properties related to legal and administrative issues).

1.4.2.2. Symbolic objects and human-made things for conservation

As CIDOC CRM well formalised, humans produce physical things and conceptual objects, the former having different aims and shapes, the latter consisting of immaterial elements, expressing ideas, information, plans and so on.

The description and design elaboration of an architecture or an urban centre are conveyed by conceptual tools that can be defined as the last subclasses in a long chain of derivations that, starting from the CIDOC CRM E28 Conceptual Object, then its E90 Symbolic Object and E55 Type subclasses.

The conceptual line derived from the E90 Symbolic Object class and its E73 Information Object subclass opens up to the two parallel E29 Design or Procedure and E31 Documents classes, the former comprising "documented plans for the execution of actions"[27] in terms of the production of objects or realisation of activities, and the latter collecting "identifiable intangible elements that make propositions about reality"[28].

The main tools that address the execution of action in architecture are architectural designs and urban plans; these can be formalised as specialised classes of E29 Design or Procedure and be distinguished from each other by their scale of application, design content, and reference to individual architectures or urban sites that already exist or are to be realised. These different modelling characteristics correspond to the CP33 Architecture Conservation Project, CP45 Architecture Project, CP49 Conservation Plan and CP50 Urban Conservation Plan classes.

On the other hand, the subclass of E73 Information Object, E31 Document, has been further specified through the creation of subclass CP34 Architecture Depiction, which complements the CIDOC CRM's E32 Authority Document class (Fig. 1.8).

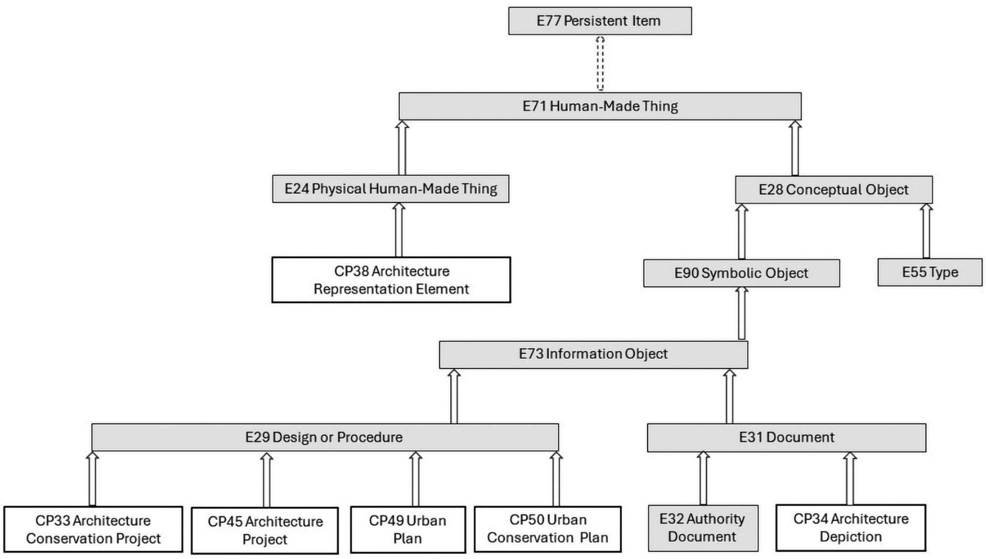

Fig. 1.8. CPM classes formalising specific symbolic objects and human-made things for conservation.

27 *Ivi*, p. 78.

28 *Ivi*, p. 79.

The new CPM class allows for the better formalisation of any type of documentation dedicated to the description of the existing architecture, derived from direct observation or any type of analysis undertaken on the building.

We have already analysed in the previous paragraph most of the CPM classes formalized as subclasses of the E24 Physical Human-Made Thing, which describe the physical entities conceived as architectures or architectural building components. We add here an additional class, dedicated to modelling the physical medium that houses the various information objects related to the architectural and/or urban study and design that we have outlined above.

The relationship between the main phases in the study and in the conservation project in architecture, connected with the CPM subclasses of physical human made thing (built entity and physical support of documents), information objects and conservation activities are summarised in the following graph and discussed in section 4.3 (Fig. 1.9).

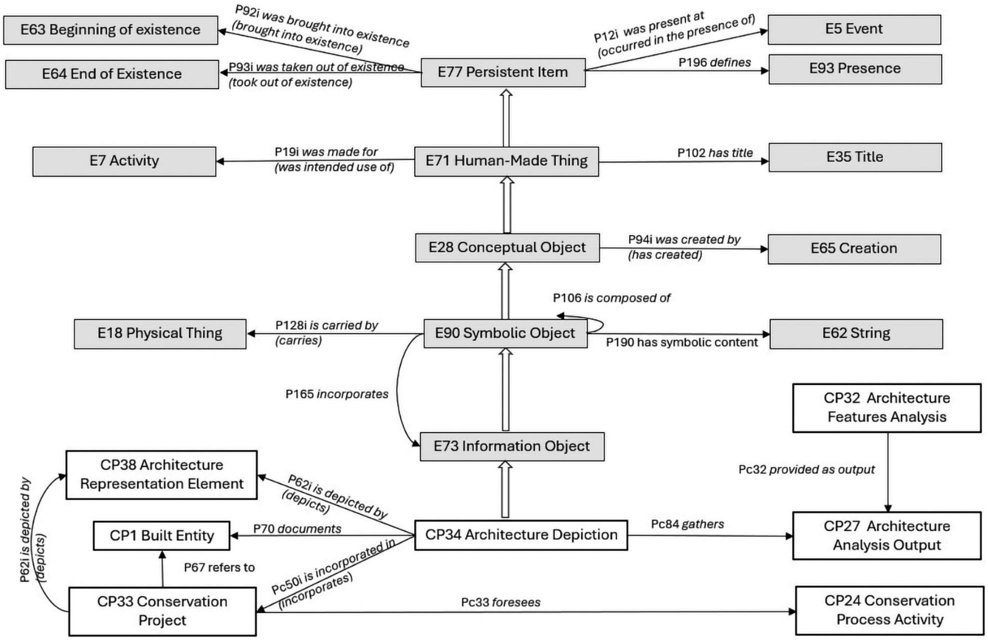

Fig. 1.9. Classes and properties from CIDOC CRM and CPM formalising the relation between the main phases in the study and in the conservation project in architecture.

1.4.2.3. Types for architectures and urban sites

A useful aid for the identification and formalisation of distinctive architecture features is offered by the specialisation of certain subclasses of the CIDOC CRM E55 Type class (Fig. 1.10). In fact, these make it possible to accommodate vocabularies suitable for the description of recognisable constructive and figurative modes (CP35 Building Formal Type), architectural types (CP36 Architecture Type), decorative types (CP47 Decoration) and installations (CP48 Equipment). It is also possible in this way to specify the different types of graphic or alphanumeric representation existing or to be elaborated (CP37 Architecture Graphic Representation Type and CP39 Architecture Alpha Numerical Representation Type).

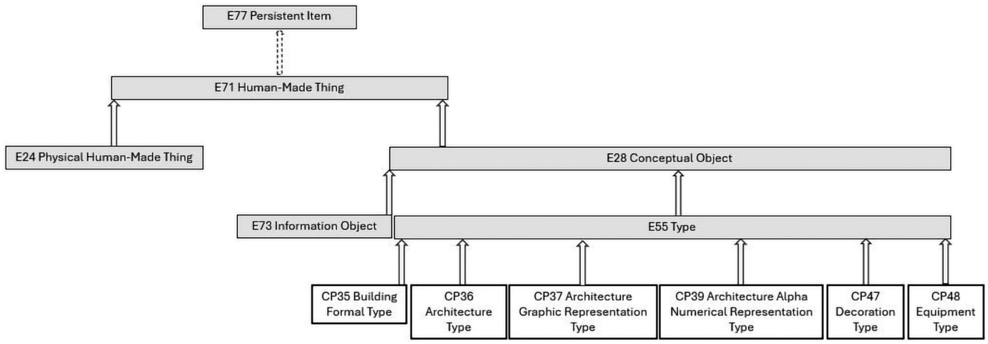

Fig. 1.10. CPM classes as specialisation of subclasses of the CIDOC CRM E55 Type class and their general hierarchy.

1.4.3. Relations System

1.4.3.1. Relations with events

The knowledge CPM aims to formalize, as it has been stated, focusses on both urban or architectural built entities, documenting either the description of their physical features or the processes they may be involved in. Besides the classes that have already been described, the representation system relies on 87 properties that allow built heritage knowledge to be specified either by dealing with the physical condition or with all the activities that it may be subject to. Although the model is compatible with CIDOC CRM core, it was necessary to introduce some properties that allowed the activities developed on built entities thanks to several relations introduced with instances of E5 Event to be specified. As we have seen, these relations first make it possible to refer to the function hosted by the building or part of it through Pc43 *is used for*, that relates the built entity with an instance of the class E7 Activity from CIDOC CRM core. As to the interventions that may involve an instance of CP1 Built Entity, either focussing on the result or just on the activity developed, a set of properties was proposed. Addressed to building activities in a broader sense, the property Pc56 *was realized on* allows it to be documented that an instance of CP46 Building Activity was related to an instance of CP1 Built Entity. Aimed at specifying the documentation of the conservation intervention, described through instances of the CP25 Conservation Intervention class, the property Pc25 *is subject to* relates the building to the intervention, while Pc27 *entails* makes it possible to describe whether the intervention has resulted in a modification. The description of the conservation intervention may also be done relating the building to past intervention with the property Pc24 *was subject to*.

Moreover, when aiming to identifying a transformation intervention, it is possible to employ Pc30 *resulted from*, or Pc31 *was transformed by*, with domain CP1 Built Entity and range E81 Transformation. To further specify the intervention, the employed material can also be documented through the property Pc29 *was adopted by* with domain CP9 Building Material and range E81 Transformation.

When wishing to document decay phenomena affecting built heritage, it is possible to specify through two properties whether the decay is merely addressing architecture surfaces or whether it involves the whole building. In the first situation, the property Pc51 *is affected by* refers to the building material connecting the domain CP9 Building Material to the range CP42 Material Decay. Moreover, when wishing to document structural decay, the property Pc61 *was affected by* makes it possible to describe what kind of damage has acted on the building. To complete the discourse on damage survey, the model allows the causes of structural damage to be documented by referring either to specific events, as for example an earthquake, or to a specific physical condition of the building, as it may have fostered a decay phenomenon. The event triggering the damage is described through the property Pc62 *was caused by*, with range E5 Event, while the documentation of the condition state fostering a particular damage is described through Pc49 *was fostered by*, with range E3 Condition State (Fig. 1.11).

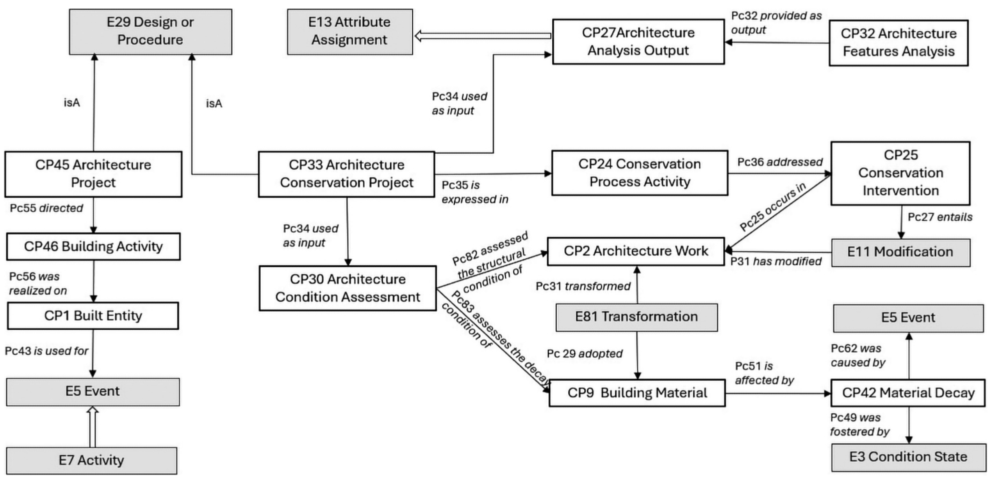

Fig. 1.11. CPM properties and classes for reasoning about architecture design.

The CP24 Architecture Conservation Project Activity is documented through several properties that specify both the physical and the intellectual components as well as the interpretative process that underlies it. The physical result of the project activity is described through Pc36 *addressed* and Pc55 *directed*, the first with range CP25 Conservation Intervention, the latter, with range CP46 Building Activity, allows both the architecture project and the architecture conservation project to be referred to. In the meantime, the conceptual result of the design activity is formalised through Pc35 *is expressed in* with range CP33 Architecture Conservation Project. The interpretative process that triggers the conservation project is documented thanks to the property Pc34 *used as input* with the CIDOC CRM range E13 Attribute Assignment. A further specification of the analysis process is made possible by the property Pc32 *provided as output* that allows the relationship between analytic and interpretative evaluations developed within conservation process to be specified. Lastly, the conservation project assessing process implies two properties: Pc82 *assessed the structural condition of* and Pc83 *assessed the decay condition of*. These properties allow to document respectively structural condition of the building or decay conditions of the construction material that constitutes the edifice (Fig. 1.12).

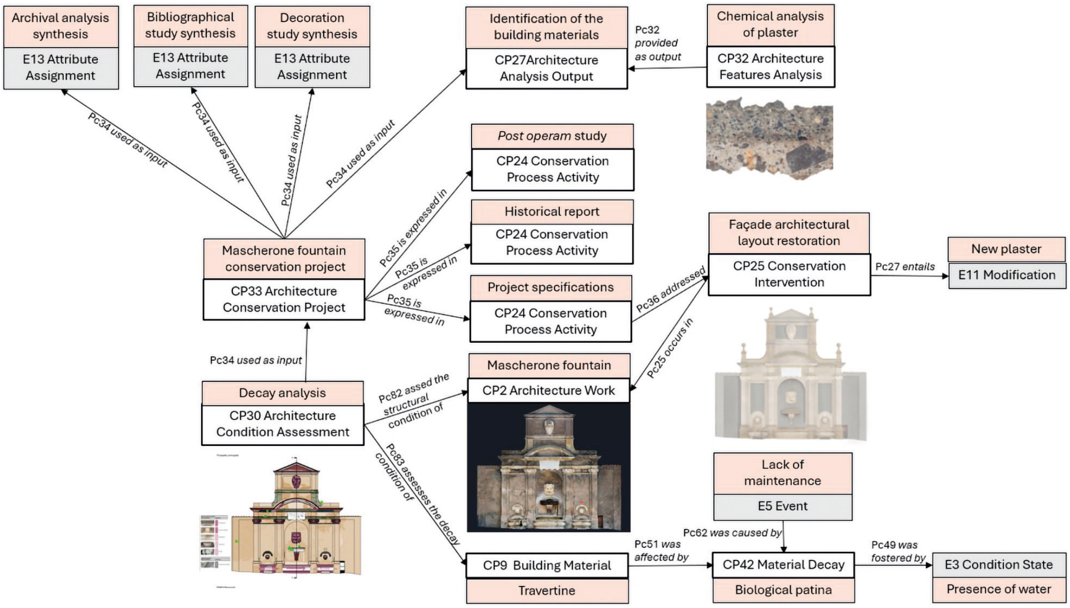

Fig. 1.12. CPM encoding example: conservation project of the Mascherone fountain at Monteromano (Viterbo, Italy).

1.4.3.2. Spatial-topological relations

Positioning in space urban settlements and architecture, together with the events they may have been involved in, is a problematic issue in cultural heritage documentation. CIDOC CRM provides a key class E53 Place and a set of properties to model information as relations between places; recording the geometric expressions, tracing the history of locations of a physical object; identifying places on a physical object and the spatial extent of certain temporal entities. Nonetheless, documentation within conservation process requires a sharper specification on some relations. CPM therefore proposes properties allowing the boundaries of certain urban or architecture elements and their visual relation to be described. In particular, boundaries, intended as physical limits of an urban area, are specified through Pc11 *is bounded by*, with range CP14 Urban Front. On the other hand, when referring to historic centre, the property Pc65 *is delimited by* allows town walls or whatever physical boundary is encircling the urban agglomeration to be described. Another specific topic dealing with architecture concerns the relationship between private and public space, both inside and outside. This relationship is incorporated by architecture façades that act as thresholds between the two spheres. A key property Pc12 *is related to public area through* allows the façade to the building to be referred. When wishing to describe the areas a building is facing onto, the model makes it possible to specify whether it is an urban area or an open-air area through two properties Pc40 *is facing onto*, and Pc73 *is facing onto*, both having as domain CP2 Architecture Work and with range respectively CP16 Urban Area and CP15 Open Air Area (Fig. 1.13).

1.4.3.3. Temporal relations

The conservation process deals with temporal relations in a twofold scope. On the one hand it refers to historical research to substantiate the evaluation that underpins the

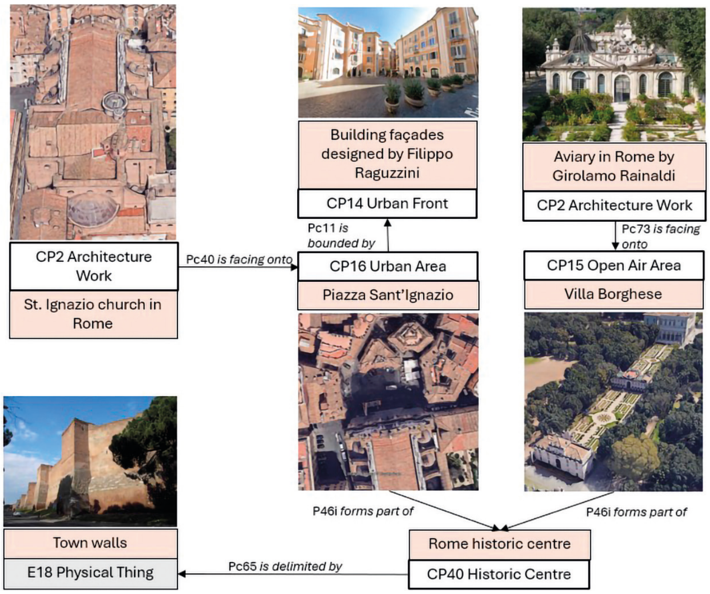

Fig. 1.13. CPM encoding example: documenting spatial topological relations of the church of St. Ignazio in Rome.

conservation project. On the other hand, it has to deal with a set of temporal indications that are to mark the conservation intervention in time. As far as historical studies are concerned, the documentation requirement of urban and architecture research is widely supported by the CIDOC CRM model as it allows temporality to be documented both with regard to known dates but also according to relative positioning within a historical period. However, the historical studies developed to orient conservation project require also the assessment process to be documented. Therefore, the dating of urban settlements or architecture refers to building phases that are the result of the knowledge process preliminary to design. Building phases are identified through reliance on chronological data but also on the comprehension of the relative chronology that put the different parts of the building into temporal relationship. To support the documentation of that issue, the property Pc80 *is referred to* with domain CP29 Building Phase (subclass of E13 Attribute Assignment) allows the building or part of it to be referred to in the assessment process that has been developed within the conservation project activity (Fig. 1.14). In addition, as regards to the time punctuation of specific intervention, like maintenance, that conservators are supposed to provide, the property Pc28 *requires to be repeated within* the range E52 Time Span has been proposed.

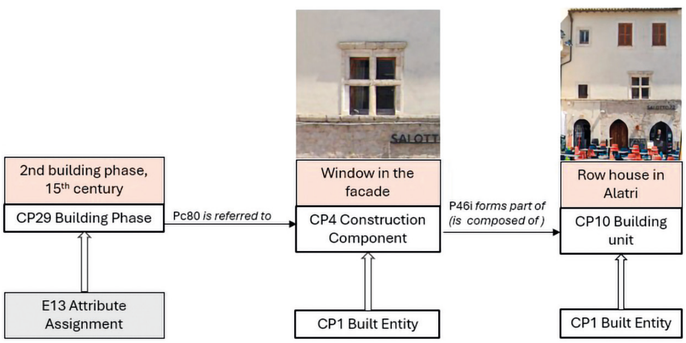

Fig. 1.14. CPM encoding example: documenting medieval row house in Alatri transformation.

1.4.3.4. Spacetime relations

The conservation process needs to refer to the historical and geographical contexts of architecture and urban settlements that change over time. Therefore, also when dealing with space and time as separate entities is normally adequate for describing cultural heritage events and locations, spacetime relations are also considered. To support the documentation of architecture or urban space's structure and visual context, the properties Pc77 *has as space component* or Pc78 *is visually related to* with range subclasses of E92 Spacetime Volume are introduced. Moreover, to describe the ownership, the functional vocation and the specific features that characterize built heritage spaces, the model proposes the properties. Pc9 *belongs to* with range E39 Actor, Pc2 *has as general vocation* with range E7 Activity and Pc39i *is characterized by* with range CP1 Built Entity. Among the spacetime relations, it bears keeping in mind that the class CP18 Space Entity inherits from the CIDOC CRM's E92 Spacetime Volume class all the properties that allow instances of CP18 Space Entity to refer to their physical presence in space and time – P196 *is defined by* –, to the place they are relative to – P161 *has spatial projection (is spatial projection of)* – or to a specific time span – P160 *has temporal projection (is temporal projection of)* (Figs. 1.15, 1.16).

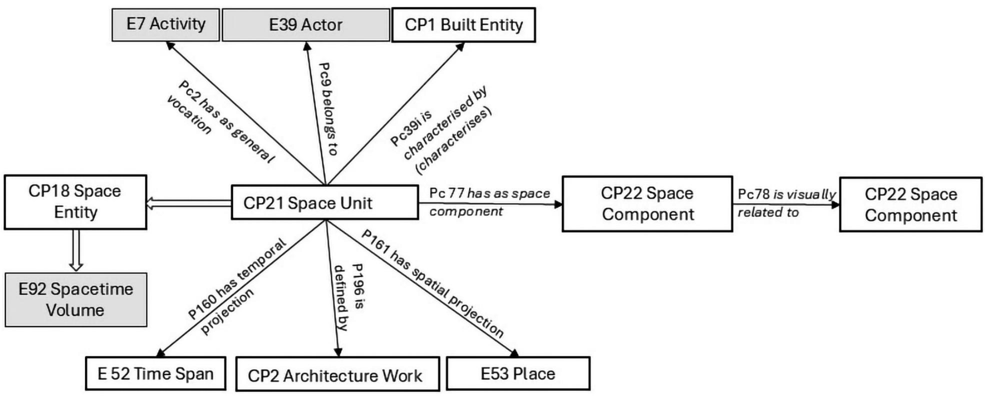

Fig. 1.15. CPM Properties and Classes for reasoning about spacetime information.

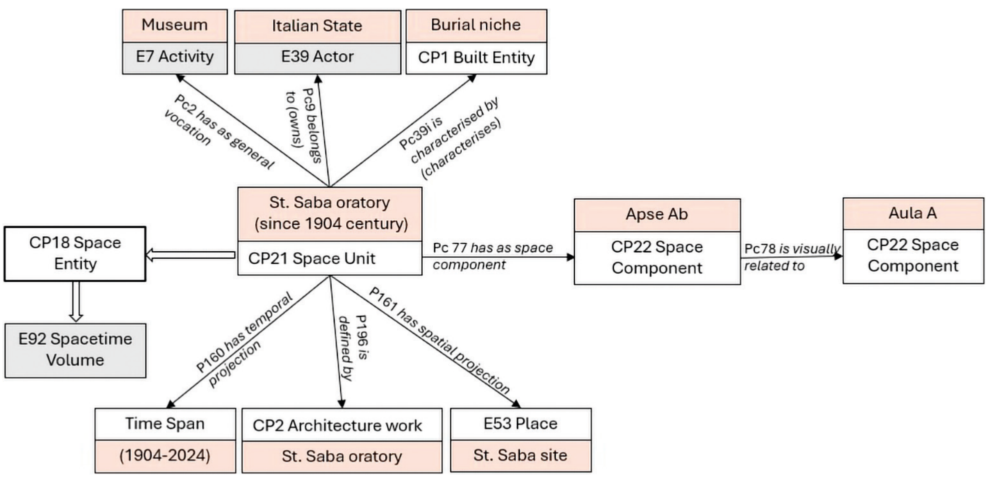

Fig. 1.16. CPM spacetime relations, encoding example of St. Saba oratory in Rome documentation.

A specific set of properties has been conceived to model the description of historic centres, documenting the kind of administrative regulation, the demographic characteristics and the existing landscape elements that are important for the depiction of the urban site and that can be possibly considered cultural landmarks through a specific assessment. The properties supporting the description of these issues are Pc14 *is regulated by* with range E32 Authority Document, Pc15 *is inhabited by*, with range E74 Group, Pc76 *is marked by*, with range CP17 Landscape Element (Fig. 1.17).

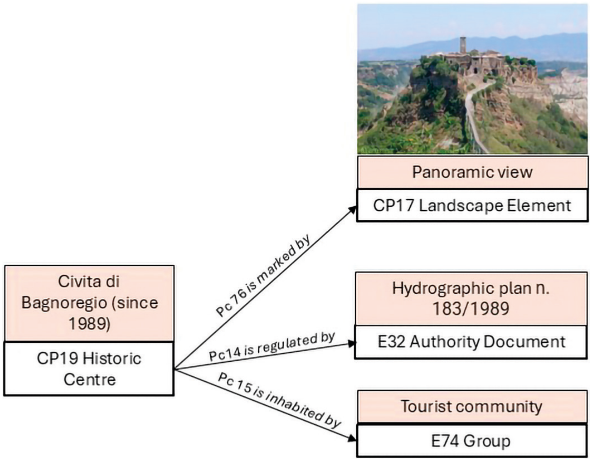

Fig. 1.17. CPM spacetime relations, encoding example: documentation of the condition of Civita di Bagnoregio (Viterbo, Italy) since 1989.

1.4.3.5. Relation with physical human made things

A major area of architecture documentation centres on the relations with physical human-made things expressed through the two principal E24 Physical Human-Made Thing and E73 Information Object classes. The former covers issues related to the description of constructive and architectural features, while the latter allows the modelling of architectural designs

The description of the built work is manly conceived to support the documentation of the part-whole relationship, or the connections and intersections that may occur between building elements. In fact, those issues, although already addressed by CIDOC CRM through the properties P46 *is composed of* and P198 *holds or supports*, both with domain and range E18 Physical Thing, require, as it has already stated, a more specific documentation within architecture and urban cultural heritage.

The part-whole relations are addressed to the constructive features and developed within domains and ranges belonging to subclasses of CP20 Construction Work. They are described through the properties Pc67 *shows as construction component,* relating CP3 Construction Unit with CP4 Construction Component, Pc68 *shows as construction element plural*, relating CP4 Construction Component with CP5 Construction Element Plural, Pc69 *shows as construction element singular*, relating CP5 Construction Element Plural with CP6 Construction Element Singular. Further specifications concern the cladding of the building, it is possible through the property Pc64 *is cladded by* with range CP5 Construction Element Plural (Fig. 1.18), or the roofing of CP1 Built Entity, through the property P89 *covers*.

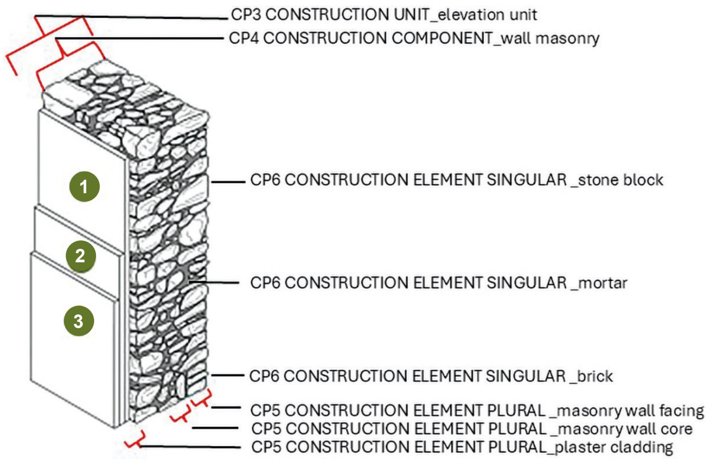

Fig. 1.18. CPM classes conceived to document architecture construction elements.

Although not specifically addressing a physical relationship but deriving from it, another property has been included in this set. It concerns the constructive homogeneity of contiguous buildings that may have a relevant effect on the structural behaviour. This issue is documented through the property Pc20 *shows building homogeneity with* that has both domain and range referring to CP2 Architecture Work.

The documentation of the connections existing between different buildings or parts of it is supported by the model specifying whether they do exist and through which element they have been realized. The properties Pc7 *is connected through* and Pc8 *is connected to* are defined by domain and range both pertaining to the CP1 Built Entity class. In addition, a specific feature concerning the building floors connection is also documented by the model through the property Pc71 *is intrinsically connected to.* A specific kind of connection, within the architecture conservation process, arises when dealing with the analysis of masonry building that requires specific descriptions. To support this kind of documentation, the model proposes the property Pc18 *has physical relation with* that describes the physical relationship between different types of masonries. The description may be further specified though the subproperty Pc18.1 *has type* that makes it possible to specify the kind of physical relation referring to a specific vocabulary.

The intersection between building elements is documented either to describe the construction work or to specify the equipment's position within the building, and it is made possible through the properties Pc63 *is crossed by*, referring to the building (CP1 Built Entity), and Pc70 *passes through* referring to the equipment (CP8 Equipment); both properties have range CP20 Construction Work.

Along with the description of the relationships between the multiple parts of the building, another specification is made possible with regard to the identification of the construction elements defining a building component, such as the nave of a church or the room of a house. The property Pc66 *is defined by,* introduced to document this issue, relates instances of the CP51 Building Component class with instances of the class CP20 Construction Work. For example, the apse (CP51 Building Component) of a church *is defined by* the circular wall (CP20 Construction Work) and the apsidal basin (CP20 Construction Work).

The description of a building or of a part of it may be further specified addressing to material issues, such as, for example, the building material or the type of masonry that constitutes it. This is made possible through the properties Pc41 *shows as main material,* relating CP1 Built Entity to CP9 Building Material and Pc1 *shows masonry feature,* relating CP5 Construction Element Plural, to CP28 Building Feature. The former supports the specification of the material which the building is made of. The latter allows all the possible features that masonry may show, such as the shape of the stone elements, the kind of laying, the type of masonry to be specified.

Example: To better describe the model, we have referred the formalization to the St. Saba oratory in Rome. It is a building that was subjected to several transformations: the first roman aula, built in the 3rd century, was turned into a monastic oratory in the 8th century, and was buried some centuries later to make the foundations for the medieval church raised above it. Lastly, at the beginning of the 20th century, it was excavated and consolidated through reinforced concrete structures (Figs. 1.19-1.22).

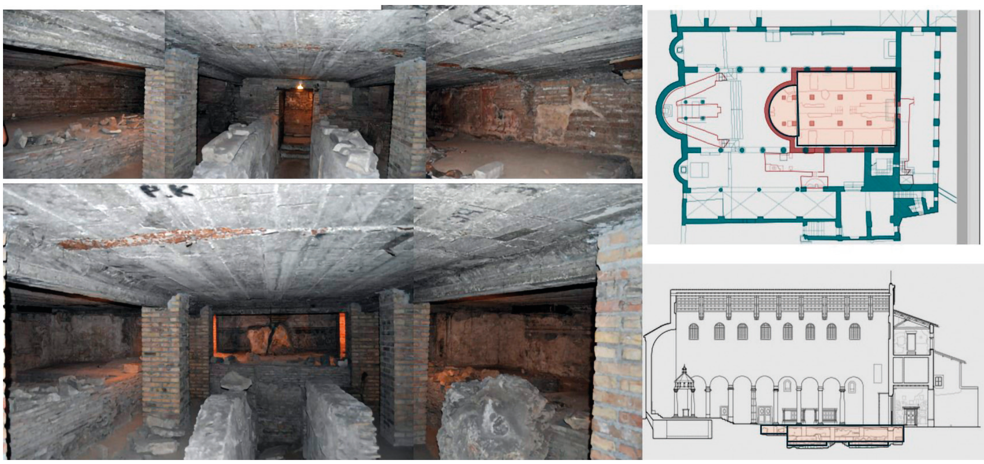

Fig. 1.19. St. Saba oratory in Rome. Documented area is coloured in light pink. The first picture is taken from the apse, the second from the entrance (Drawings by Silvia Cutarelli).

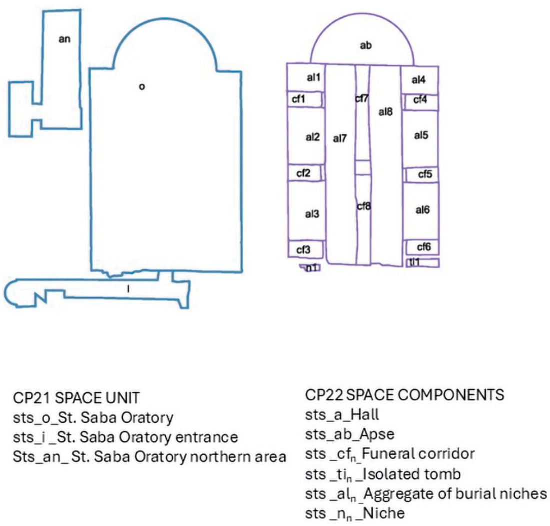

Fig. 1.20. St. Saba oratory formalization: instances of the classes CP21 Space Unit, CP22 Space Component (Acierno 2017).

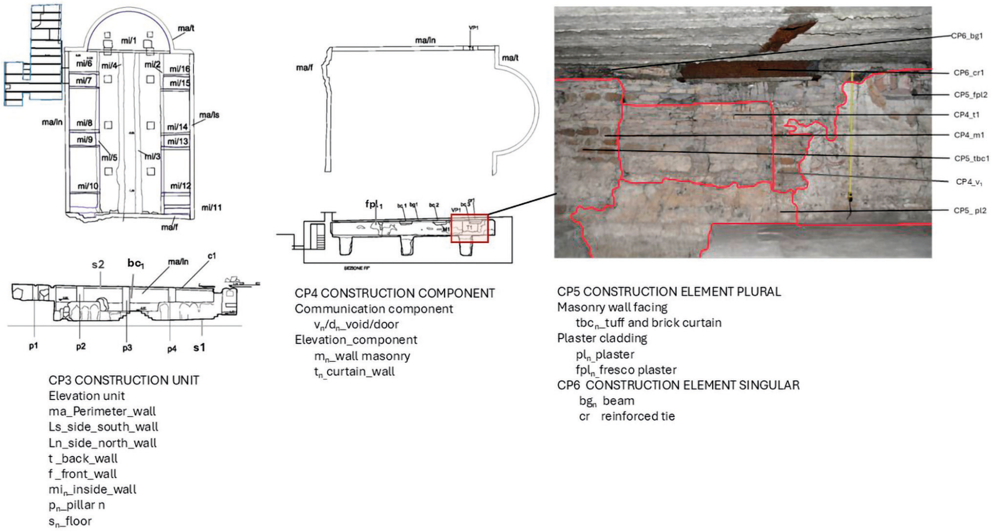

Fig. 1.21. St. Saba oratory formalization: instances of the classes CP3 Construction Unit, CP4 Construction Component, CP5 Construction Element Plural, CP6 Construction Element Singular (Acierno 2017).

When dealing with architecture design modelling, it bears noting that the conservation process is conceived as a managing activity taking into account several contributions often also originating from different disciplines. Therefore, to support the documentation of that specificity, it was necessary to formalize the relationship between design and all the documents that are produced to address it. The property that allows that issue to be documented is Pc50 *incorporates*, which relates an instance of CP33 Architecture Conservation Project with an instance of CP34 Architecture Depiction. Moreover, the role of the multiple instances of the CP34 Architecture Depiction class is specified through the property Pc84 *gathers* that connects the domain to the range CP27 Architecture Analysis Output. In addition, the hierarchy between the different scales of planning is described through the properties Pc86 *addressed*, which specifies the relationship between urban conservation planning and architecture conservation project as the latter is oriented by the former. Meanwhile the property Pc87 *specified* allows it to be documented that the urban conservation project details the urban plan (Fig. 1.9).

1.5. Meaning of a conceptual representation for architectural heritage

1.5.1. Neutrality and exhaustivity in the ontological model

The principle of viewpoint neutrality is one of the main assumptions underlying the formalisation of knowledge in an ontology. In fact, the proposed models aim to describe reality as objectively as possible, providing a detailed representation that excludes the possibility of contradiction so as to favour the maximum sharing of input data. The concept of neutrality is posited in an almost axiomatic manner in the specific field of computer science, whereas it is particularly discussed in the field of digital humanities, where the definition of standards risks levelling out the complexity and multiplicity of cultural topics[29].

[29] Tomasi 2022.

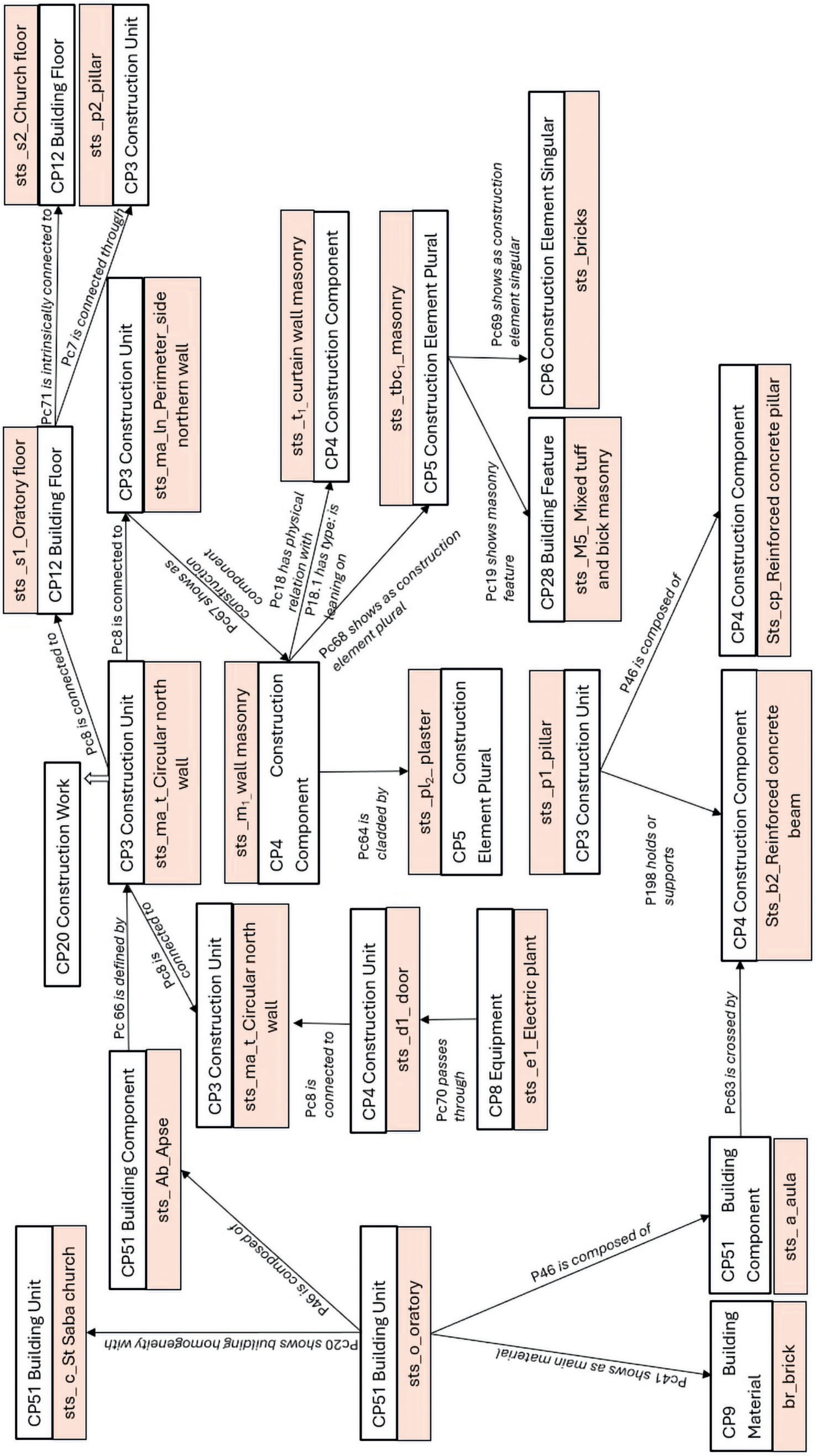

Fig. 1.22. Encoding example of the documentation of St. Saba oratory in Rome.

What may appear to be an argument, albeit a fundamental one of a philosophical nature is perhaps the real crux behind the possibility of effective dissemination of ontologies in general and, in particular, in the field of architectural restoration. As we have been able to verify during the long work of formalising the CPM in adherence to the CIDOC CRM model, some choices have been modified over time in an attempt to find the solution that best reconciles the need to work in continuity and coherence with the conceptual path already traced and that of not dispersing the legacy of the culture of conservation in architecture.

The impossibility of completely eliminating the visual angle from which phenomena are observed has already been pointed out in reference to material degradation. This reality is seen in the core as a visually perceptible result on the surface of the artifact, while in the CIDOC CRMsci extension it is rather a phenomenon to be analysed instrumentally. In architectural restoration, degradation is rather seen as a phenomenon to be identified according to pre-established typologies, to be observed above the building materials and to be treated with particular interventions. These are different modes of evaluation that refer to the same subject and require different conceptual tools. Similarly, after arguing for a long time for the four-dimensional nature of the historic centre, as suggested by the CIDOC CRM, and then defining a special subclass of E92 Spacetime Volume for it, we realised that this type of formalisation could work for all conceptual relations that looked at the historic centre as a place where events take place. On the other hand, it was cumbersome and complicated to use in reference to the physical contents that characterise the architectural and constructive reality of human settlements. The consequence of this finding was the creation of a new class dedicated to the representation of these physical contents.

However, the CIDOC model provides a core and extensions that are semantically aligned with it. The sense of the work done in the creation of the CPM was to ensure an overall consistency of the modelling while respecting the specificity of the architecture. This specificity must in fact be carefully safeguarded from within the cultural heritage sector, because only in this way is it possible to guarantee proper respect for the historic building, otherwise exposed to the logic of mere functionalisation and economic evaluation.

The proposed approach also helps toward the aspiration to the exhaustiveness of the ontological model that appears implicitly or explicitly linked to the goals of formalisation. In the ideal proceeding from the maximum abstraction of the core to the specificities of the domains linked to it, a conceptual hierarchy is created that is both a reduction in scale and a specification of the visual angle. This mode thus allows several planes of relationship to be held together, increasing the efficiency and effective representation capacity of the entire system.

1.5.2. CPM and standardisation within architecture conservation

The development of Information and Communication Technology (ICT) for the architecture heritage conservation process has suffered from a deep bias triggered by conservation architects' scepticism in their concern over the potential conflict between the heterogeneity of historic architecture, to which conservation is addressed, and the simplification process that software programs are subjected to for its representation. Nonetheless, such a position is often jeopardised by a limited view that disregards both the relationship between technology and the scientific and cultural purpose it is intended to support, and the role played in the development of technological tools by domain experts. Within this framework, CPM intends to foster a detailed representation of historic architecture and the complex interrelations between different aspects of cultural heritage, seeing to the nuanced differences between concepts but also attempting to keep it compatible with CIDOC CRM. In such a perspective, without involving the philosophical debate on the opposition between monism and pluralism but maintaining it as a theoretical framework, attention was focussed both on the aim of allowing a specialized documentation and referring to a common and shared standard[30]. This twofold attention has helped on the one hand to avoid the oversimplification of complex, context-specific heritage attributes, potentially disregarding the unique historical, cultural, and architectural values of individual sites, and on the other to avoid the proliferation of multiple ontologies potentially superimposed upon others or not interoperable.

The creation of a tailored ontological model for architectural cultural heritage conservation makes it possible to leverage a standard keeping documentation within the disciplinary scope. Adequacy to the discipline and semantic accuracy is particularly entrusted to the architecture of the ontology that relies on a hierarchical classification and a wide articulation of properties, allowing the specialization of descriptions and enabling the expression of different perspectives. Such a structure is articulated through classes and properties conceived within the so-called AEC (Architecture, Engineering and Construction) scope, providing an interface that appears familiar to architects also from the linguistic perspective, hopefully overcoming experts' scepticism. However, the possibility to refer to CIDOC CRM makes it possible to rely on a standard. This allows knowledge to be shared ensuring that the meaning of data, processes and concepts is consistently interpreted although originated from distinct domains with their unique terminologies and ontologies[31]. The nature of the ontology itself allows standardization to be conceived not as a streamlined process that may result in a loss of local expertise and the homogenization of conservation practices, undermining the authenticity and integrity of heritage sites, but as a real opportunity to align different viewpoints and incorporate unique characteristics into a common framework[32]. By averting the risk of prioritizing efficiency and compatibility over the nuanced needs of specific conservation projects, the alignment is conceived to provide a structure enhancing collaboration and innovation across fields, enabling differences to coexist and be understood in a multidisciplinary field as architectural cultural heritage conservation requires[33].

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30 To focus on the philosophical framework of the discourse refer to David et al. 2024.

31 For an exhaustive focus on potentiality and specificity of ontologies refer to Doerr 2005 and Doerr 2009.

32 An interesting reference to data crossing between different contexts may be found in Castelli et al. 2021.

33 An interesting application of ontologies in a specific scientific domain is described in Galera-Rodriguez, Guéna, Algarín-Comino 2024.

1.5.3. CPM and vocabularies

Vocabularies are in a sense the distillation of domain culture and, at the same time, the basic standard component on which the interoperability of digital systems is built. The issue is particularly complex in architectural conservation, due to the multidisciplinary aspects involved in the characterisation of historic architecture and its conservation problems.

The CPM model foresees some classes and properties related to E55 Type, the CIDOC CRM class for the instantiation of data expressed by controlled vocabularies. Some of these vocabularies are instead defined through official documents or by standards elaborated by the Istituto Centrale per il Catalogo e la Documentazione (Central Institute for Catalogue and Documentation), a special institute of the Italian Ministry of Culture. Unfortunately, Italian vocabularies are poorly supported in international standards, even though the Italian language in the field of architecture is particularly rich[34].

Some controlled vocabularies useful for the description of architecture and urban centre (in Italian) have been selected and tested for the realization of the Risk Map[35], but much work still needs to be done to make knowledge organisation tools complete and efficient, also with reference to the international panorama to which the semantic web inevitably refers.

Considerable work is being done on these issues internationally in the field of cultural heritage, thanks to networks such as Linked Conservation Data[36] and semantic tools such as the Simple Knowledge Organisation System (SKOS)[37]. Lastly, we must mention the great effort made to standardise vocabularies for individual digital knowledge management applications needed to conduct major restorations, such as for the Notre Dame cathedral[38].

1.5.4. Domains and scopes of knowledge

Remaining anchored to the CIDOC CRM standard, CPM has been conceived by taking from architecture heritage conservation the semantic structure traditionally developed through survey, historical study, physical condition study and design. As we have anticipated, four major macrodomains have been modelled within the conceptual structure of CIDOC CRM core model (Fig. 1.23). The first addresses the morpho-typological and constructive features of architecture, the second focuses on transformations and more broadly to the building life cycle, the third is centred on architecture condition and historical assessment, and the fourth takes on conservation design modelling.

The first macrodomain is centred around the description of the artefact and refers to pivot classes CP1 Built Entity and CP18 Space Entity, conceived as subclasses

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34 See the most important online thesaurus on cultural heritage, Art & Architecture Thesaurus® Online <https://www.getty.edu/research/tools/vocabularies/aat/>, which does not have Italian among the selected languages.

35 See FIORANI 2019, pp. 75-96; ACIERNO 2022; ACIERNO 2023.

36 <https://www.ligatus.org.uk/lcd/>.

37 <https://www.w3.org/2004/02/skos/>.

38 <https://opentheso.hypotheses.org/>.

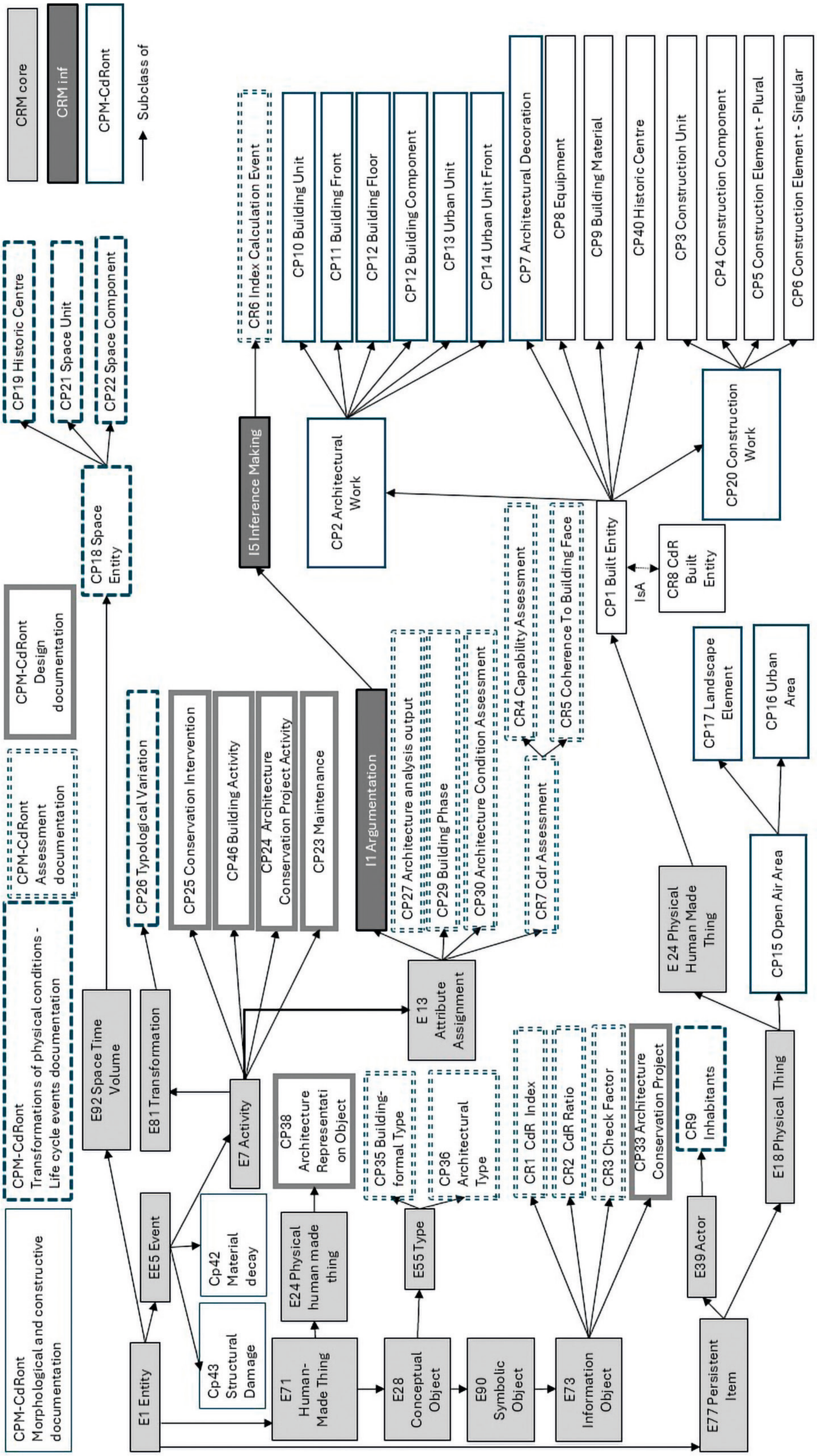

Fig. 1.23. CPM knowledge scopes. The boxes represent the CPM Classes, the line-type of their perimeter is differentiated according to the knowledge scope they refer to, while the inside colour represent the model they pertain to.

respectively of E24 Physical Human Made Thing and E92 Spacetime Volume. The former addresses the physical dimension of architecture, while the latter deals with the spacetime nature of built heritage. The concepts represented by these classes are further specified through an articulated hierarchy that allows a sharper description of cultural heritage to be reached moving from the urban to the construction scale.

The second, focussing on building lifecycle, is centred on the CIDOC CRM class E7 Activity and is aimed at documenting past transformation and all kinds of intervention involving the building. Among these, we also include previous conservation interventions that may have occurred over time, therefore the class CP25 Conservation Intervention pertains to two different macrodomains, as it necessarily relates also to the design scope of knowledge. Within the scope of knowledge, the properties are conjugated either in the past or present tense, allowing results concerning to past interventions or orienting current interventions to be documented.

The fourth macrodomain deals with conservation design modelling. It is developed upon three main subclasses of E7 Activity that allow different phases of conservation (design, design activity and intervention) to be documented. These subclasses are further specified through a series of properties conjugated in the present tense.

1.5.5. CPM and architecture conservation

Potentialities of ontologies for architecture and in particular for the conservation process in terms of allowing both specialized description and standard modelling have been widely described in the previous paragraphs and in our previous studies[39] Moreover, the application within operational context has been widely addressed by the scientific literature[40].

It is worth dedicating some thoughts to the specific advantages that conceptual modelling shows for conservation process as most of the proposals generally present study cases addressing substantially operational criticalities triggered by the interoperability issue[41].

This enables the possibility of comparing data either to enhance scientific architecture research or to match results highlighting previous mistakes or virtuosities to be repeated. As related to scientific research, it is particularly interesting as it allows results to be connected to professional activities often developed by different experts, making it possible to share data between scholars and professionals both belonging to multiple disciplines. Such an opportunity certainly triggers the building of a virtuous community used to work on a participated platform, thereby enhancing aware and respectful behaviour.[42]

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39 See ACIERNO et al. 2017; ACIERNO, FIORANI 2017a; SIMEONE et al. 2019.

40 Literature referring to application examples is wide, we refer here only to a few interesting case studies presented in PREVITALI 2020; MOYANO et al. 2022. A synthetic view of the evolution of ontology for the purposes of architecture is reported in FARGHALY, SOMAN, ZHOU 2023, while an exhaustive state of the art concerning documentation of architecture culture heritage conservation is reported in CURSI et al. 2022.

41 For a broad idea of the current scientific debate, see YANG et al. 2020; JIMENEZ RIOS et al. 2024.

42 The opportunity to share data consistently make it possible to cross information within environment that pertains to different disciplines but gathers in operation contexts (CONSOLI et al. 2023; NOVAA et al. 2023; PINTO et al. 2020).

Moreover, each activity of the operational process, often carried out automatically, being embodied in the conceptual structure that implies relationships between domain and ranges and positioning in the properties and class hierarchies is naturally subjected to a consistency check both from a scientific and operational point of view. By referring to a conceptual model, each intervention is not only afforded as simply required by an operational sequence but is also derived from a scientifically aware perspective. This is useful not only 'for the sake' of academic perspective but also to endorse transparency within the process, as the model necessarily requires explicating relationships between analysis and outputs gathered in conservation design. Such a structure contributes to sustainable and ethical practice of conservation as it makes it difficult, for example, to develop diagnostic activities that are not conveyed consistently in the project, thus highlighting any specious solutions. Within this framework, another important issue is that the model makes it possible to enhance in-depth focusses on the theoretical perspective that might otherwise be neglected. For example, the reasoning on the outcome of a conservation intervention, whether it has entailed a transformation or a modification on a building, is not always obvious or easily understandable, and implies an in-depth analysis that can be sometimes quite fruitful for the broad cultural heritage protection process.

1.5.6. CPM and possible applications

CPM is a domain ontology related to the CIDOC CRM top-level ontology. Within the CIDOC family, our ontology finds the necessary support to link data specifically connecting to architecture with other information of a multidisciplinary nature. These relate to other domains of a different nature, such as archaeology, scientific investigations, geography, informatics, library, etc. With this structure, there is a concrete possibility to share data on architectural heritage via semantic web in different fields and for different purposes, enriching knowledge of heritage from many different cultural perspectives.

In addition, the CPM also aims to improve the possibility of sharing data between computer platforms that are routinely used in architecture, with specific reference to conservation issues and interventions. These computer platforms can be dedicated to linking data to graphical representations of architecture[43] or to creating new information about the historic built environment through data processing.

This objective requires the integration of the CPM with other ontologies developed to enable the complete formalisation of the specific information system under consideration (application ontologies). These types of ontologies are less important from the interoperability point of view but are fundamental to making the entire system work.

Among the main current IT systems used today in architecture conservation are some special kinds of Geographic Information System specially designed for managing and processing data in conservation, such as the Risk Map of the Italian Ministry of Culture.

In order to decide to proceed with the complete formalisation of the Risk Map through the use of the CPM, an applied ontology was purposely designed to integrate

[43] Data and graphic depiction can be referred to the current or a future condition induced by the conservation interventions of architecture.

the CPM. The new classes and properties specifically created to allow the instantiation of particular data foreseen by the system pertain to the CdRont (Carta del Rischio ontology), which will be illustrated in the chapter 2.5.

The Building Information System for the realisation of new architecture projects has become very popular over the past two decades in the field of AEC. Since the beginning of the last decade, many studies have been developed to facilitate the use of BIM for intervention in historic buildings (HBIM), although the problem of the suitability of the available systems to conservation needs is still far from being solved.

From a data management point of view, the optimal use of the BIM system in the historic building is hampered by the type of data that can be recorded in it and the way in which these data can be related to each other. These characteristics are specifically expressed by the Industry Foundation Classes (IFC) standards, which have been defined with reference to contemporary buildings[44].

The idea of combining IFC model with semantic web ontologies is not new and some proposals have been done in this direction[45]. As predicted from the beginning "as the interoperability problem has not been solved after a number of decades of intensive research in AEC domain, we do not expect this issue to disappear in the near future for the documentation of cultural heritage artefacts"[46].

We consider the work done with CPM to be a step in this direction. The greater emphasis on the definition of built entity makes this ontology the link between the broader world of web semantics and the specialised field of architectural preservation design expressed by the practically usable IT tools. This emphasis is expressed by the modelling of certain specific classes that are distinguished by allowing for the more detailed instantiation of constructed elements and the creation of new properties capable of establishing more precise and correct relationships.

Specifically, the CPM adds six new properties to CIDOC that allow for a better definition of physical relationships between built elements. Probably, further classes and properties will have to be added in a more specific HBIM-related application ontology, as indicated by some already published proposals[47].

It is also possible, and to some extent desirable, that in the future new IT tools, alternative to HBIM, will be used that are able to link the graphic representation with information about a historic building. A good example of research into these possible alternative avenues, which does not neglect the use of computerised ontologies, was recently offered developed in parallel with the restoration site of Notre-Dame de Paris after the fire of 2019[48].

The hope is to find ways to share the interoperable development of systems as much as possible by sharing controlled multilingual architecture-related vocabularies and consolidating CIDOC CRM-related domain ontologies such as CPM.

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44 A brief review of IFC is provided in Laakso, Kiviniemi 2012.

45 One of the first proposals in this sense is in Pawels, De Meyer, Van Campenhout 2011, focusing mainly on contemporary architecture. An experiment of application to historic buildings combining a 'progenitor' ontology of CPM and the ontology of IFC was proposed, as already mentioned, in Acierno et al. 2017, for historical buildings.

46 Pawels, De Meyer, Van Campenhout 2011, p. 487.

47 See, among others, Previtali et al 2020.

48 See De Luca 2023.

1.6. CPM Class and property hierarchy

CPM Class Hierarchy

E1 CRM Entity
CP41 - Environmental Observable Entity
E2 - Temporal Entity
E3 - - Condition State
E4 - - Period
E5 - - - Event
CP42 - - - - Material Decay
CP43 - - - - Structural Damage
E7 - - - - Activity
E11 - - - - - Modification
CP23 - - - - - - Maintenance
E79 - - - - - - Part Addition
E80 - - - - - - Part Removal
CP24 - - - - - Architecture Conservation Project Activity
CP25 - - - - - Conservation Intervention
CP46 - - - - - Building Activity
CP32 - - - - - Architecture Features Analysis
E13 - - - - - Attribute Assignment
CP27 - - - - - - Architecture Analysis Output
CP28 - - - - - - - Building Feature
CP29 - - - - - - - Building Phase
E14 - - - - - - Condition Assessment
CP30 - - - - - - - Architecture Condition Assessment
CP31 - - - - - - - - Mechanical Damage Assessment
E15 - - - - - - Identifier Assignment
E16 - - - - - - Measurement
E17 - - - - - - Type Assignment
E65 - - - - - Creation
E63 - - - - Beginning of Existence
E67 - - - - - Birth
E81 - - - - - Transformation
CP26 - - - - - - Typological Variation
E12 - - - - - Production
E65 - - - - - *Creation*
E66 - - - - - Formation
E64 - - - - End of Existence
E6 - - - - - Destruction
E68 - - - - - Dissolution
E81 - - - - - Transformation
E77 - Persistent Item
E70 - - Thing
E72 - - - Legal Object
E18 - - - - Physical Thing
E19 - - - - - Physical Object
CP15 - - - - - - - Open Air Area
CP16 - - - - - - - - Urban Area
CP17 - - - - - - - - Landscape Element
E21 - - - - - - - Person
E22 - - - - - - Human-Made Object
E24 - - - - - Physical Human-Made Thing

CP1 - - - - - - Built Entity
CP2 - - - - - - - Architecture Work
CP10 - - - - - - - - Building Unit
CP11 - - - - - - - - Building Front
CP12 - - - - - - - - Building Floor
CP51 - - - - - - - - Building Component
CP13 - - - - - - - - Urban Unit
CP14 - - - - - - - - Urban Unit Front
CP20 - - - - - - - Construction Work
CP3 - - - - - - - - Construction Unit
CP4 - - - - - - - - Construction Component
CP5 - - - - - - - - Construction Element-Plural
CP6 - - - - - - - - Construction Element-Singular
CP7 - - - - - - Architecture Decoration
CP8 - - - - - - Equipment
CP9 - - - - - - Building Material
CP40 - - - - - - Historic Centre
E26 - - - - - Physical Feature
E25 - - - - - - Human-Made Feature
E27 - - - - - - Site
CP44 - - - - - - - Construction Site
E90 - - - - Symbolic Object
E73 - - - - - Information Object
E71 - - - *Human-Made Thing*
E24 - - - - *Physical Human-Made Thing*
CP38 - - - - - Architecture Representation Object
E22 - - - - - *Human-Made Object*
E25 - - - - - *Human-Made Feature*
E78 - - - - - Curated Holding
E28 - - - - Conceptual Object
E90 - - - - - *Symbolic Object*
E73 - - - - - - *Information Object*
E29 - - - - - - - Design or Procedure
CP33 - - - - - - - - Architecture Conservation Project
CP45 - - - - - - - - Architecture Project
CP49 - - - - - - - - Urban Plan
CP50 - - - - - - - - Urban Conservation Plan
E31 - - - - - - - Document
E32 - - - - - - - - Authority Document
CP34 - - - - - - - - Architecture Depiction
E33 - - - - - - Linguistic Object
E34 - - - - - - - - - Inscription
E35 - - - - - - - - Title
E36 - - - - - - - - Visual Item
E37 - - - - - - - - - Mark
E34 - - - - - - - - - - Inscription
E41 - - - - - - Appellation
E42 - - - - - - - Identifier
E35 - - - - - - - Title
E95 - - - - - - - Spacetime Primitive
E94 - - - - - - - Space Primitive
E61 - - - - - - - Time Primitive
E89 - - - - - Propositional Object
E30 - - - - - - Right
E55 - - - - - Type
E56 - - - - - - Language

E57	- - - - - - Material
E58	- - - - - - Measurement Unit
CP35	- - - - - - Building-Formal Type
CP36	- - - - - - Architecture Type
CP37	- - - - - - Architecture Graphic Representation Type
CP39	- - - - - - Architecture Alpha Numerical Representation Type
CP47	- - - - - - Decoration Type
CP48	- - - - - - Equipment Type
E39	- - Actor
E74	- - - Group
E21	- - - Person
E52	- Time-Span
E53	- Place
E54	- Dimension
E92	- Spacetime Volume
CP18	- - Space Entity
CP19	- - - Historic Centre
CP21	- - - Space Unit
CP22	- - - Space Component

CPM Property Hierarchy

Property ID	Property Name	Entity – Domain	Entity – Range
Pc1	affects (is subject to)	CP41 Environmental Observable Entity	E1 CRM Entity
Pc3	has connection through (connects)	CP40 Historic Centre	E24 Physical Human Made Thing
Pc5	is inhabited by (inhabits)	CP19 Historic Centre	E74 Group
Pc6	was fostered by (fostered)	CP42 Material Decay	E3 Condition State
Pc25	is subject to (occurs in)	CP1 Built Entity	CP25 Conservation Intervention
Pc43	is used for (uses)	CP1 Built Entity	E7 Activity
Pc49	was fostered by (fostered)	CP43 Structural Damage	E3 Condition State
Pc51	is affected by (is generated on)	CP9 Building Material	CP42 Material Decay
Pc62	was caused by (caused)	CP43 Structural Damage	E5 Event
Pc74	was caused by (caused)	CP42 Material Decay	E5 Event
Pc18	has physical relation with	CP1 Built Entity	CP1 Built Entity
Pc7	- is connected through (connects)	CP1 Bult Entity	CP1 Built Entity
Pc8	- is connected to	CP1 Built Entity	CP1 Built Entity
Pc12	- is related to public area through (allows the relationship to the public area of)	CP10 Building Unit	CP11 Building Front
Pc42	- was embodied by (embodied)	CP1 Built Entity	CP1 Built Entity
Pc63	- is crossed by (crosses)	CP1 Built Entity	CP20 Construction Work
Pc64	- is cladded by (clads)	CP1 Built Entity	CP5 Construction Element Plural
Pc71	- is intrinsically connected to	CP12 Building Floor	CP12 Building Floor
Pc89	- covers (is covered by)	CP1 Built Entity	CP1 Built Entity
Pc70	passes through (is crossed by)	CP8 Equipment	CP20 Construction Work
Pc73	is facing onto (is the overlook of)	CP2 Architecture Work	CP15 Open Air Area
Pc11i	- bounds (is bounded by)	CP14 Urban Unit Front	CP16 Urban Area

PROPERTY ID	PROPERTY NAME	ENTITY – DOMAIN	ENTITY – RANGE
Pc40	- is facing onto (is the overlook of)	CP2 Architecture Work	CP16 Urban Area
Pc78	is visually related to	CP18 Space Entity	CP18 Space Entity
P130	shows features of (features are also found on)	E70 Thing	E70 Thing
Pc4	- shows building features (is shown in)	CP1 Built Entity	CP28 Building Feature
Pc19	- - shows masonry feature (masonry feature is shown in)	CP5 Construction Element Plural	CP28 Building Feature
Pc20	- shows building homogeneity with	CP2 Architecture Work	CP2 Architecture Work
P52	has current owner (is current owner of)	E18 Physical Thing	E39 Actor
Pc9	- belongs to (owns)	CP18 Space Entity	E39 Actor
Pc10	- belongs to (owns)	CP2 Architecture Work	E39 Actor
P67i	refers to (is referred to by)	E89 Propositional Object	E1 CRM Entity
Pc48	- planned (was planned by)	CP49 Urban Plan	CP16 Urban Area
Pc54	- planned (was planned by	CP45 Architecture Project	CP1 Built Entity
Pc55	- directed (was directed by)	CP45 Architecture Project	CP46 Building Activity
Pc81	- planned the conservation of (was planned by)	CP50 Urban Conservation Plan	CP16 Urban Area
P70i	is documented in (documents)	E1 CRM Entity	E31 Document
Pc13	- is regulated by (regulates)	CP2 Architecture Work	E32 Authority Document
Pc14	- is regulated by (regulates)	CP19 Historic Centre	E32 Authority Document
Pc17	had performance efficiency documented in (documented performance efficiency of)	CP2 Architecture Work	E73 Information Object
Pc21	- addressed (was addressed by)	CP49 Urban Plan	CP45 Architecture Project
Pc26	- is illustrated by (illustrates)	CP33 Architecture Conservation Project	CP38 Architecture Representation Object
Pc33	- foresees (is foreseen by)	CP33 Architecture Conservation Project	CP25 Conservation Intervention
Pc35	- is expressed in (expresses)	CP24 Architecture Conservation Project Activity	CP33 Architecture Conservation Project
Pc37	- complies with (binds)	CP33 Architecture Conservation Project	E32 Authority Document
Pc44	- illustrates (is illustrated by)	CP38 Architecture Representation Object	CP34 Architecture Depiction
Pc84i	- is gathered by (gathers)	CP27 Architecture Analysis Output	CP34 Architecture Depiction
Pc88	- is regulated by (regulates)	CP16 Urban Area	E32 Authority Document
P2	has type (is type of)	E1 CRM Entity	E55 Type
Pc15	- shows plan configuration type (is configuration type of)	CP10 Building Unit	E55 Type
Pc16	- shows structural system (structural system is shown in)	CP1 Built Entity	CP35 Building-Formal Type
Pc22	- shows building-formal type (building formal type is shown on)	CP2 Architecture Work	CP35 Building-Formal Type
Pc45	- has morphology type	CP44 Construction Site	E55 Type
Pc46	- has geology type	CP44 Construction Site	E55 Type
Pc57	- shows decoration type (is decoration type of)	CP7 Architecture Decoration	CP47 Decoration Type
Pc59	- shows equipment type (is equipment type of)	CP8 Equipment	CP48 Equipment Type

Property ID	Property Name	Entity – Domain	Entity – Range
Pc72	- shows geometry plan type (is geometry plan type of)	CP13 Urban Unit	E55 Type
Pc75	- can be referred to landscape element type (landscape element type can be referred to by)	CP17 Landscape Element	E55 Type
P10i	contains (falls within)	E92 Spacetime Volume	E92 Spacetime Volume
Pc77	- has as space component (is space component of)	CP21 Space Unit	CP22 Space Component
P46	is composed of (forms part of)	E18 Physical Thing	E18 Physical Thing
Pc65	- is delimited by (delimits)	CP40 Historic Centre	E18 Physical Thing
Pc66	- is defined by (defines)	CP51 Building Component	CP20 Construction Work
Pc67	- shows as construction component (is construction component of)	CP3 Construction Unit	CP4 Construction Component
Pc68	- shows as construction element plural (is construction element plural of)	CP4 Construction Component	CP5 Construction Element Plural
Pc69	- shows as construction element singular (is construction element singular of)	CP5 Construction Element Plural	CP6 Construction Element Singular
Pc76	- is marked by (marks)	CP40 Historic Centre	CP17 Landscape Element
P45	consists of (is incorporated in)	E18 Physical Thing	E57 Material
Pc41	- shows as main material (is shown as main material)	CP1 Built Entity	CP9 Building Material
P126i	was employed in (employed)	E57 Material	E11 Modification
Pc23	- was used by (made use of)	CP 9 Building Material	E11 Modification
P4	has time-span (is time-span of)	E2 Temporal Entity	E52 Time-Span
Pc28	- requires to be repeated within (temporally specifies the repetition of)	CP 23 Maintenance	E52 Time-Span
P15	was influenced by (influenced)	E7 Activity	E1 CRM Entity
Pc2i	- is the general vocation of (has as general vocation)	E7 Activity	CP18 Space Entity
Pc38	- specifies (is specified by)	CP27 Architecture Analysis Output	CP9 Building Material
Pc56	- was realised on (was subject to)	CP46 Building Activity	CP1 Built Entity
Pc60	- realised (was realised by)	CP46 Building Activity	CP1 Built Entity
P17	motivated (was motivated by)	E7 Activity	E1 CRM Entity
Pc27	- entails (is entailed by)	CP25 Conservation Intervention	E11 Modification
P16i	was used for (used specific object)	E70 Thing	E7 Activity
Pc24	- was subject to (occurred in)	CP1 Built Entity	CP25 Conservation Intervention
Pc29	- was adopted by (adopted)	CP9 Building Material	E81 Transformation
Pc85	- was subject to (was realised on)	CP1 Built Entity	CP23 Maintenance
P123i	resulted from (resulted in)	E77 Persistent Item	E81 Transformation
Pc30	- resulted from (resulted in)	CP1 Built Entity	E81 Transformation
Pc31	- was transformed by (transformed):	CP1 Built Entity	E81 Transformation
Pc79i	- - transformed (was transformed by)	CP2 Architecture Work	CP26 Typological Variation
P20i	had specific purpose (was purpose of)	E7 Activity	E5 Event

PROPERTY ID	PROPERTY NAME	ENTITY – DOMAIN	ENTITY – RANGE
Pc32	- provided as output (was output for)	CP32 Architecture Features Analysis	CP27Architecture Analysis Output
Pc34i	- was input for (used as input)	E13 Attribute Assignment	CP24 Architecture Conservation Project activity
Pc36	- addressed (was addressed by)	CP24 Architecture Conservation Project Activity	CP25 Conservation Intervention
P69	has association with (is associated with)	E29 Design or Procedure	E29 Design or Procedure
Pc47	- has modified (was modified by)	CP49 Urban Plan	CP49 Urban Plan
Pc53	- has modified	CP45 Architecture Project	CP45 Architecture Project
Pc86	- addressed (was addressed by)	CP50 Urban Conservation Plan	CP33 Architecture Conservation Project
Pc87	- specified (was specified by)	CP50 Urban Conservation Plan	CP49 Urban Plan
P148	has component (is component of)	E89 Propositional Object	E89 Propositional Object
Pc50	- incorporates (is incorporated in)	CP33 Architecture Conservation Project	CP34 Architecture Depiction [doc(io]
P141i	was assigned by (assigned)	E1 CRM Entity	E13 Attribute Assignment
Pc52	- was assessed by (assessed)	CP1 Built Entity	CP31 Mechanical Damage Assessment
P62	depicts (is depicted by)	E24 Physical Human-Made Thing	E1 CRM Entity
Pc58	- represents (is representation by)	CP7 Architecture Decoration	E1 CRM Entity
P12i	was present at (occurred in the presence of)	E77 Persistent Item	E5 Event
Pc61	- was affected by (was generated on)	CP1 Built Entity	CP43 Structural Damage
P34	concerned (was assessed by)	E14 Condition Assessment	E18 Physical Thing
Pc80	- is referred to (is referred to by)	CP29 Building Phase	CP1 Built Entity
Pc82	- assessed the structural condition of (was assessed in its structural condition by)	CP30 Architecture Condition Assessment	CP2 Architecture Work
Pc83	- assessed the decay condition of (is assessed in its decay condition by)	CP30 Architecture Condition Assessment	CP9 Building Material

PROPERTY ID	PROPERTY NAME	PROPERTY – DOMAIN	ENTITY – RANGE
Pc4.1	has colour	CP1 Built Entity Pc 4 *shows building feature*: (CP28 Building Feature)	E55 Type
Pc18.1	has type	CP1 Built Entity Pc 18 *has physical relation with* CP1 Built Entity	E55 Type
Pc19.1	has type feature	CP1 Built Entity Pc 19 *shows masonry feature* (CP28 Building Feature)	E55 Type

1.7. CPM Class declarations

CP1 Built Entity

Subclass of:

E24 Physical Human-Made Thing

Superclass of:

CP2 Architecture Work; CP20 Construction Work

Scope note:

This class comprises instances of human-made things such as freestanding buildings, construction units, construction components, construction elements, and complexes of buildings. It refers to human-made environments serving a practical purpose, being relatively permanent and stable. Instances of CP1 Built Entity consist of parts that perform a specific constructive or architectural function. Natural components, such as caves or rocky outcrops, even unworked ones, that are constructively and/or functionally integrated with existing architecture are also instances of CP1 Built Entity.

Examples:

- the Pisa tower (Pierotti 2003)
- the underground basilica of Porta Maggiore in Rome (Aurigemma 1961)
- the façade of the St. Salvatore Maggiore monastic church in Concerviano (Rieti) (Fiorani 1995)
- the painted wooden beams of the Carli Benedetti palace in L'Aquila (Bartolomucci 2011)

In first-order logic:

$CP1(x) \Rightarrow E24(x)$

Properties:

Pc4 shows building feature (building feature is shown in): CP28 Building Features

Pc7 is connected through: CP1 Built Entity

Pc8 is connected to: CP1 Built Entity

Pc16 shows structural system (structural system is shown in): CP35 Building-Formal Type

Pc18 has physical relation with: CP1 Built Entity

Pc24 was subject to (occurred in): CP25 Conservation Intervention

Pc25 is subject to (occurs): CP25 Conservation Intervention

Pc30 resulted from (resulted in): E81 Transformation

Pc31 was transformed by (transformed): E81 Transformation

Pc39 characterises (was characterised by): CP18 Space Entity

Pc41 shows as main material (is shown as main material of): CP9 Building Material

Pc42 was embodied by (embodied): CP1 Built Entity

Pc43 is used for (uses): E7 Activity

Pc52 was assessed by (assessed): CP31 Mechanical Damage Assessment

Pc54i was planned by (planned): CP45 Architecture Project

Pc56i was subject to (was realised on): CP46 Building Activity

Pc60i was realised by (realised): CP46 Building Activity

Pc61 was affected by (was generated on): CP43 Structural Damage

Pc63 is crossed by (crosses): CP20 Construction Work

Pc64 is cladded by (clads): CP5 Construction Element Plural

Pc80i is referred to by (is referred to): CP29 Building Phase

Pc85 was subject to (was realised on): CP23 Maintenance

Pc89 covers (is covered by): CP1 Built Entity

CP2 Architecture Work

Subclass of:

CP1 Built Entity

Superclass of:

CP10 Building Unit; CP11 Building Front; CP12 Building Floor; CP13 Urban Unit; CP14 Urban Unit Front; CP51 Building Component

Scope note:

This class comprises instances of Physical Human-Made Thing such as freestanding buildings and complexes of buildings, created for hosting or supporting every kind of human activity. Other instances can be urban or rural constructions realised to protect humans or to host different functions also with a symbolic meaning, as with triumphal arches and for funeral chapels. In addition, instances can be terminals of infrastructures, such as monumental fountains, as well as rooms created by excavating and modelling a rock for residential or religious purposes. CP2 Architecture Work may also comprise components of buildings when they maintain a recognisable formal identity, such as for a renaissance chapel built in a medieval basilica or a façade of a building, with its proper formal, constructive and material features. It refers to human-made environments, built for human needs, either practical, aesthetic or symbolic, being relatively permanent and stable and with a size and scale appropriate for – but not limited to – habitable buildings.

Examples:

- the Pisa tower (Pierotti 2003)
- the Colosseum (Luciani 1993)

- the Trevi Fountain in Rome (Cardilli Alloisi 1991)
- the underground basilica of Porta Maggiore in Rome (Aurigemma 1961)
- the building unit of the Palazzo Pubblico in Siena (Bartalini 2020)
- the main façade the Palais Garnier (Opéra Garnier) in Paris (Fontaine 2001)

In first-order logic:

CP2(x) ⇒ CP1(x)

Properties:

Pc10 belongs to (own): E39 Actor

Pc13 is regulated by (regulates): E32 Authority Document

Pc17 had performance efficiency documented in (documented performance efficiency of): E73 Information Object

Pc20 shows building homogeneity with: CP2 Architecture Work

Pc22 shows building-formal type (building-formal type is shown on): CP35 Building-Formal Type

Pc40 is facing onto (is the overlook of): CP16 Urban Area

Pc73 is facing onto (is the overlook of): CP15 Open Air Area

Pc79i was transformed by (transformed): CP26 Typological Variation

Pc82i was assessed in its structural conditions by (assessed the structural condition of): CP30 Architecture Condition Assessment

CP3 Construction Unit

Subclass of:

CP20 Construction Work

Scope note:

This class includes instances of composite portions of a building that have specific functions from a constructional point of view or that delimit and/or support the building or parts of it. Such instances may consist of the network of empty channels within the walls for smoke evacuation, the construction system of a wall (e.g., the two opposing faces and the intermediate core, with any stone or plaster cladding), the construction system of a floor (e.g., consisting of main beams, secondary frames and wood planking, a layer of bedding mortar, and flooring).

Examples:

- the construction system of the 'roof-garden' coverage of Ville Savoye (Benton 2008)
- the construction system of the Bernini's stair in Palazzo Barberini (Gallo Curcio 2009)
- the construction system of the medieval house in Cluny 6, rue d'Avril (Garrigou Grandschamp et al. 1997)

In first-order logic:

CP3(x) ⇒ CP20(x)

Properties:

Pc67 shows as construction component (is construction component of): CP4 Construction Component

CP4 Construction Component

Subclass of:

CP20 Construction Work

Scope note:

This class includes instances of a part of the building unit which is consistent from the structural or technological viewpoint. Such instances may consist of the structural component of a floor or of a vault, excluding finishings such as flooring and plastering, the construction part of a wall (e.g., the two opposing faces and the intermediate core), as well as the door and window shutters.

Examples:

- the building structure of the golden bay in the Domus Aurea in Rome (BRUNETTI 2020)
- the slope of the roof on a 'gassho' house in Shirakawa-go, Japan (SINGH, FUKUNAGA 2011)
- the building structure of the façade toward rue de la Barré of the medieval house in Cluny 6, rue d'Avril (GARRIGOU GRANDSCHAMP et al. 1997)
- the bronze door of the Pantheon (BELARDI 2006)

In first-order logic:

CP4(x) ⇒ CP20(x)

Properties:

Pc67i is construction component of (shows as construction component) CP3 Construction Unit

Pc68 shows as construction element plural (is construction element plural of): CP5 Construction Element Plural

CP5 Construction Element Plural

Subclass of:

CP20 Construction Work

Scope note:

This class includes instances of the construction component characterised by a technical specificity. Such instances may consist of masonry faces, roofing systems covering the trusses in a wooden roof, coffered ceiling, the window frames, and the plaster cladding a wall.

Examples:

- the plaster over the San Giorgio Palace façade toward via della Mercanzia in Genoa (Martini 2023)
- the Cosmatesque flooring in the Cathedral of Civita Castellana (Viterbo) (Creti 2012)
- the flat stone slab roofing of the staircase of the medieval house in Cluny 6, rue d'Avril (Garrigou Grandschamp et al. 1997)
- the right wing of the Pantheon's bronze door (Belardi 2006)

In first-order logic:

CP5(x) ⇒ CP20(x)

Properties:

Pc19 shows masonry feature (masonry feature is shown in): CP28 Building Features

Pc64i clads (is cladded by): CP1 Built Entity

Pc68i is construction element plural of (shows as construction element plural): CP4 Construction Component

Pc69 shows as construction element singular (is construction element singular of): CP6 Construction Element Singular

CP6 Construction Element Singular

Subclass of:

CP20 Construction Work

Scope note:

This class includes instances of the construction component characterised by a proper material and technical specificity. Such instances may consist of masonry faces elements, roofing elements covering the trusses in a wooden roof, elements composing a coffered ceiling or a window frame, a single layer of a plaster cladding a wall.

Examples:

- the outer layer of the plaster over the San Giorgio Palace façade toward via della Mercanzia in Genoa (Martini 2023)
- a porphyry slab in the Cosmatesque flooring in the Cathedral of Civita Castellana (Viterbo) (Creti 2012)
- a limestone ashlar over the door in the inner wall of the medieval house in Cluny 6, rue d'Avril (Garrigou Grandschamp et al. 1997)
- a wooden beam of the floor at the ground floor of palazzo Carli Benedetti in L'Aquila (Bartolomucci 2018)
- the lower bronze panel in the right wing of the Pantheon gate (Belardi 2006)

In first-order logic:

CP6(x) ⇒ CP20(x)

Properties:

Pc69i is construction element singular of (shows as construction element singular): CP5 Construction Element Plural

CP7 Architecture Decoration

Subclass of:

E24 Physical Human-Made Thing

Scope note:

This class includes instances of decorative apparatus closely related to the composition of the architecture work. Such instances may consist of figurative paintings on the façades of a building or on the inner face of the walls in a church, as well as stuccoes, graffiti, ceramic cladding and sculptures attached to the walls of the building. Unlike instances of CP6 Construction Element Singular, instances of CP7 Architecture Decoration do not usually play a specific role in the construction other than strictly decorative. This means that in the presence of a stone lintel carved in bas-relief, the lintel as a structural element must be considered as an instance of CP6 Construction Element Singular, while its vertical surface with bas-relief can be instantiated as CP7 Architecture Decoration. Similarly, the metal key head should be instantiated as CP6 Construction Element Singular, while the cover stud should be instantiated as CP7 Architecture Decoration. When the constructive and decorative aspects are not separable (e.g. the decorated wrought iron balustrade of a balcony), the element may be instantiated as either CP6 Construction Element Singular or CP7 Architecture Decoration.

Examples:

- the paintings with St. George slaying the dragon over the San Giorgio Palace in Genoa (MARTINI 2023)
- the stucco decorations over the windows of the palace in Valencia, Calle Conde de Montornés 1-5 (MILETO, VEGAS 2016)
- the doomsday on the portal of the façade of Notre Dame de Paris (MIDANT 2002)
- the Bernardinian coat of arms on the ceiling of the church of St. Bernardino in L'Aquila (D'ANTONIO 2020)
- the stars in the bronze door of St John Lateran from the Curia Iulia adapted by Francesco Borromini (ROCA DE AMICIS 1995)

In first-order logic:

CP7(x) ⇒ E24(x)

Properties:

Pc57 shows decoration type (is decoration type of): CP47 Decoration Type

Pc58 represents (is represented by): E1 CRM Entity

CP8 Equipment

Subclass of:

E24 Physical Human-Made Thing

Scope note:

This class includes instances of plant systems pertaining a single architecture work. Such instances can have different nature, regarding the web and the terminals used for the distribution of water, electricity, heating or cooling, etc. in a building.

Examples:

- the equipment in palazzo Altemps in Rome (Scoppola 1996)
- the equipment in the Roma domus in the complex of St. Giulia in Brescia (Brogiolo, Morandini 2005)

In first-order logic:

CP8(x) ⇒ E24(x)

Properties:

Pc59 shows equipment type (is equipment type): CP49 Equipment Type

Pc70 passes through (is crossed by): CP20 Construction Work

CP9 Building Material

Subclass of:

E24 Physical Human-Made Thing

Scope note:

This class includes instances of structural products, manufactured as standard units, intended for use in building construction (definition from Art & Architecture Thesaurus).

Examples:

- the porphyry in the Cosmatesque flooring of the Cathedral of Civita Castellana (Viterbo, Italy) (Creti 2012)
- the sandstone of the mullion arch in the façade of the Hópital Saint-Blaise, rue Filaterie, Cluny (Garrigou Grandschamp et al. 1997)
- the chestnut ceiling beam in the main hall of Palazzo Farnese (D’Amelio 2017)

In first-order logic:

CP9(x) ⇒ E24(x)

Properties:

Pc23 was used by (made use of): E11 Modification
Pc29 was adopted by (adopted): E81 Transformation
Pc38i is specified by (specifies): CP27 Architecture Analysis Output
Pc41i is shown as main material (shows main material): CP1 Built Entity
Pc51 is affected by (is generated on): CP42 Material Decay
Pc83i was assessed in its decay conditions by (assessed the decay condition of): CP30 Architecture Condition Assessment

CP10 Building Unit

Subclass of:

CP2 Architecture Work

Scope note:

This class includes instances of coherent architecture organisms populating an urban historic setting. It consists in a single construction phase or by the merging/recasting of several pre-existing building units. This kind of organism is characterized by the presence of one or more functional units (residential and non-residential) connected to each other through common distribution elements and served by access at the road level; it is bordered by external façades with a generally continuous eaves line and a unitary or composite roof composed of flat and/or inclined parts consistent with all fronts. Instances of CP10 Building Unit differ from instances of CP2 Architecture Work by being related to an edifice that is considered a component of an urban historic setting. This means that instances of CP10 Building Unit are buildings which are components of an urban tissue, where the main characteristics are the relationships established among them.

Examples:

- the building unit of the Palazzo Pubblico in Siena (GALLI 2011)
- the medieval house at the corner of via della Lungaretta and vicolo della Luce in Rome (DE MINICIS, GUIDONI 1996)

In first-order logic:

CP10(x) ⇒ CP2(x)

Properties:

Pc12 is related to public area through (allows the relationship to the public area of): CP11 Building Front
Pc15 shows plan configuration type (is configuration type of): E55 Type

CP11 Building Front

Subclass of:

CP2 Architecture Work

Scope note:

This class includes instances corresponding to the façades of single building unit overlooking on an urban space or, more generally, on a street or a square but also on the natural margin of the town (maritime, river, lake coast, promontory limit, etc.).

Examples:

- the façade toward via della Lungaretta of the medieval house at the corner of via della Lungaretta and vicolo della Luce in Rome (De Minicis, Guidoni 1996)
- the main façade the Palais Garnier (Opéra Garnier) in Paris (Fontaine 2001)

In first-order logic:

CP11(x) ⇒ CP1(x)

Properties:

Pc12i allows the relationship to the public area of (is related to public area through): CP10 Building Unit

CP12 Building Floor

Subclass of:

CP2 Architecture Work

Scope note:

This class includes instances relating to a portion of a CP10 Building Unit between the floor and the ceiling. In residential buildings, instances of CP12 Building Floor normally correspond to the presence of one or more residential units, but in historic buildings, instances of CP12 Building Floor may include only part of a residential unit (such as for a row house, composed of overlapping rooms, or for a noble palace, which housed and may still house a family and its employees on all levels of the building). It is also not uncommon for historic residential buildings to combine a ground floor with commercial functions and residential upper floors or for different functions to overlap with each other. This is often the case in specialised buildings, where instances of CP12 Building Floor may also involve floor-to-ceiling portions with different organisational and functional characteristics (e.g. classrooms and staff offices in a school).

Examples:

- the first floor of Palazzo Barberini in Via delle Quattro Fontane in Rome (GOLZIO 1968)
- the second floor of Villa Medici in Poggio a Caiano (BARDAZZI 1981)

In first-order logic:

CP12(x) ⇒ CP2(x)

Properties:

Pc71 is intrinsically connected to: CP12 Building Floor

CP13 Urban Unit

Subclass of:

CP2 Architecture Work

Scope note:

This class includes instances corresponding to a coherent architecture organism populating an urban historic setting. It consists of a single construction phase or by the merging/recasting of several pre-existing building units and can be described only in its exterior features. This body is characterized by the presence of one or more functional units (residential and non-residential) connected to each other through common distribution elements and served by access at the road level; it is bordered by external façades with a generally continuous eave line and a unitary or composite roof composed of flat and/or inclined parts consistent with all fronts. An urban unit can be constituted by a continuous set of structurally connected but distinguishable building units as organisms that are architecturally coherent populating an urban historic setting and may contain within it places relevant to one or more building units. In this case, it overlooks on urban spaces through fronts that result from the succession of the individual façades of the building units. This specific type of urban unit is called 'aggregate'. Alternatively, the urban unit can be a homogeneous and autonomous unitary element, bordered by urban spaces with which it communicates through accesses to the ground floor and can contain open places inside. It overlooks urban spaces through a variable number of fronts generally figuratively and constructively coherent with each other. This is called 'residential or specialist punctual building unit' and consists of buildings such as villas or cottages (residential building) or complexes as hospitals or schools (specialist building).

Instances of CP13 Urban Unit differ from instances of CP2 Architecture Work by being related to an edifice that is considered a component of an urban historic setting. This means that instances of CP13Urban Unit are buildings which are components of an urban tissue, where the main characteristic are the relationships established among them.

Examples:

- the block in Castelvecchio Calvisio (L'Aquila) bounded by via Catilina, via Borghi Archi Romani, via delle sentinelle (Crisan et al. 2015)
- the Mecca Flat in Chicago (Bluestone 2011)
- the urban unit of the Palazzo Pubblico in Siena (Galli 2011)
- the Palais Garnier (Opéra Garnier) in Paris (Fontaine 2001)

In first-order logic:

CP13(x) ⇒ CP2(x)

Properties:

Pc72 shows geometry plan type (is geometry plan type of): E55 Type

CP14 Urban Unit Front

Subclass of:

CP2 Architecture Work

Scope note:

This class includes instances corresponding to the set of façades on the same urban space – street or square – of the individual building units composing an urban unit.

Examples:

- the façade of the Urban Unit of the Palazzo Pubblico toward piazza del Campo in Siena (Galli 2011)
- the whole façade toward via Catilina of the block in Castelvecchio Calvisio (L'Aquila) bounded by via Catilina, via Borghi Archi Romani, via delle sentinelle (Crisan et al. 2015)

In first-order logic:

CP14(x) ⇒ CP2(x)

Properties:

Pc11i bounds (is bounded by): CP16 Urban Area

CP15 Open Air Area

Subclass of:

E19 Physical Object

Superclass of:

CP16 Urban Area; CP17 Landscape Element

Scope note:

This class includes instances relating to environments and landscapes resulting consistent for natural and anthropic features. Sometimes this consistency is evident from a perceptive viewpoint, and sometimes this consistency is perceivable as homogeneity of constituent features. Instances of CP15 Open Air Area can be squares, streets or gardens of an urban centre, but also parks and open landscapes related to historic architectures or urban centres. Such instances may have a particular cultural value or also constitute elements of local connotation of a specific urban landscape.

Examples:

- Monte Mario in Rome (FAGIOLO, MAZZA 2016)
- the Vigeland Park in Oslo (WIKBORG 1991)
- the Tiergarten Park in Berlin (BARTOLI, STOLLMANN 2019)

In first-order logic:

CP15(x) ⇒ E19(x)

Properties:

Pc73i is the overlook of (is facing onto): CP2 Architecture Work

CP16 Urban Area

Subclass of:

CP15 Open Air Area

Scope note:

This class includes instances relating to the hollows of historic urban settlements, bounded by the fronts pertaining to the urban units facing them and containing pavements, furniture, and possibly public green elements. These instances constitute a unified whole from a perceptual and functional point of view and very often represent particularly connotative elements of historic centres.

Examples:

- Piazza del Campo in Siena (GALLI 2011)
- Piazza Navona in Rome (BERNARD 2014)
- Rue de la Gaîté in Paris (BAUËR 1963)

In first-order logic:

CP16(x) ⇒ CP15(x)

Properties:

Pc11 is bounded by (bounds): CP14 Urban Unit Front

Pc40i is the overlook of (is facing onto): CP2 Architecture Work

Pc48i was planned by (planned): CP49 Urban Plan

Pc80i was subdued to (planned the conservation of): CP50 Urban Conservation Plan

Pc88 is regulated by (regulates): E32 Authority Document

CP17 Landscape Element

Subclass of:

CP15 Open Air Area

Scope note:

This class includes instances of environments that are consistent in terms of natural and anthropic features. Sometimes this consistency is evident from a perceptual point of view other times it is appreciable as homogeneity. Instances of CP17 Landscape Element connote recognisable urban or rural landscapes and often specifically characterise urban centres. In some cases, they may possess a particular cultural value and be defined – through a specific assessment – as elements of outstanding universal value and for this reason be placed on the UNESCO World Heritage List or otherwise subject to spatial and landscape constraints by national conservation bodies or through town planning regulations.

Examples:

- Bomarzo Park (Calvesi 1998)
- Tiergarten Park in Berlin (Bartoli, Stollmann 2019)

In first-order logic:

CP17(x) ⇒ CP15(x)

Properties:

Pc75 can be referred to landscape element type (landscape element type can be referred to by): E55 Type

Pc76i marks (is marked by): CP19 Historic Centre

CP18 Space Entity

Subclass of:

E92 Spacetime Volume

Superclass of:

CP19 Historic Centre; CP21 Space Unit; CP22 Space Component

Scope note:

This class includes instances defined by sets of CP2 Architecture Work together with spaces related to architectural organisms, urban ensembles, or man-made landscapes. These instances represent 4D ensembles and can refer to the set that collects the constructed buildings and the empty spaces between them or to just the footprint of the empty spaces bounded by an urban physical perimeter or an architectural envelope. In either case, these instances are changeable over time, meaning that the shape and extent of the CP18 Space Entity can be changed over time and become precisely defined with the intersection of E53 Place and E52 Time-Span instances.

Examples:

- the extension in space and time defined by the area approximating the historic centre of L'Aquila from its beginning into existence to 1919 (CLEMENTI, PIRODDI 1986)
- the extension in space and time of the set of interior and confined spaces of Palazzo Venezia in Rome from 15th to 19th century (FROMMEL 2006)
- the extension in space and time defined by Piazza del Campo in Siena from 12th to 21st century (GALLI 2011)
- the extension in space and time defined by the central nave of St. Giovanni in Rome produced by the Borromini's intervention in the 17th century (ROCA DE AMICIS 1995)

In first-order logic:

CP18(x) ⇒ E92(x)

Properties:

Pc2 has as general vocation (is general vocation of): E7 Activity

Pc9 belongs to (owns): E39 Actor

Pc39i is characterised by (characterises): CP1 Built Entity

Pc78 is visually related to: CP18 Space Entity

Pc81i is referred to by (is referred to): CP29 Building Phase

CP19 Historic Centre

Subclass of:

CP18 Space Entity

Scope note:

This class includes instances of urban agglomeration composed by the historic buildings and the open spaces which formerly constituted the town during the entire time of its existence. These instances represent 4D ensembles and refer to the set that collects the constructed buildings and the empty spaces between them. These instances are changeable over time, meaning that the shape and extent of the CP19 Historic Centre can be changed over time and become precisely defined with the intersection of E53 Place and E52 Time-Span instances.

Examples:

- the extension in space and time defined by the area approximating the historic centre of L'Aquila from its beginning into existence to 1919 (CLEMENTI, PIRODDI 1986)

- the extension in space and time defined by the area approximating the historic centre of Marseille from its beginning into existence to 2020 (Bajard, Planchenault 2022)

In first-order logic:

CP19(x) ⇒ CP18(x)

Properties:

Pc5 is inhabited by (inhabits): E74 Group

Pc14 is regulated by (regulates): E32 Authority Document

Pc76 is marked by (marks): CP17 Cultural Heritage Landscape Element

CP20 Construction Work

Subclass of:

CP1 Built Entity

Superclass of:

CP3 Construction Unit; CP4 Construction Component; CP5 Construction Element Plural; CP6 Construction Element Singular

Scope note:

This class includes instances of the constructive apparatus that characterizes an architecture. Instances of CP20 Construction Work can gather building units, components and elements that have specific functions from a constructional point of view or that delimit and/or support the building or parts of it.

Examples:

- the construction system of the Bernini's stair in Palazzo Barberini (Gallo Curcio 2009)
- the vault bay of the octagonal room of the Domus Aurea in Rome (Brunetti 2020)
- the floor of the hall in Villa Medici in Poggio a Caiano (Bardazzi 1981)

In first-order logic:

CP20(x) ⇒ CP1(x)

Properties:

Pc63i crosses (is crossed by): CP1 Built Entity

Pc66i defines (is defined by): CP51 Building Component

Pc70i is crossed by (passes through): CP8 Equipment

CP21 Space Unit

Subclass of:

CP18 Space Entity

Scope note:

This class includes instances relating to the substance of the architectural or urban organism uniquely determinable on the basis of the characters of continuity and recognizability referring to the built elements. The instances of CP21 Space Unit are not physical objects but deal with the footprint of empty spaces defined by its changing physical presence over time, representing 4D ensembles.

Examples:

- the extension in space and time defined by Piazza del Campo in Siena from 12th to 21st century (GALLI 2011)
- the extension in space and time defined by the central nave of St. Prassede in Rome from the 9th to the 20th century (CAPERNA 2014)
- the extension in space and time defined by the nave of St. Balbina in Rome from the 6th to the 21st century (KRAUTHEIMER 1937-77)

In first-order logic:

CP21(x) ⇒ CP18(x)

Properties:

Pc77 has as space component (is space component of): CP22 Space Component

CP22 Space Component

Subclass of:

CP18 Space Entity

Scope note:

This class includes instances relating to a part of the architectural organism endowed with a spatial identity that cannot be further subdivided. Instances of CP22 Space Component are identified by their specific traits of homogeneity and recognizability referring to the built elements. They do not involve physical objects, but the footprint of empty space defined by them, subject to change over time, and represent 4D ensembles.

Examples:

- the extension in space and time defined by the second bay of the central nave of St. Prassede in Rome from the 9th to the 20st century (CAPERNA 2014)
- the extension in space and time defined by the Ceremony Hall within the Royal Palace in Milan from the 12th to the 21st century (COLLE, MAZZOCCA 2002)

In first-order logic:

CP22(x) ⇒ CP18(x)

Properties:

Pc77i is space component of (has as space component): CP21 Space Unit

CP23 Maintenance

Subclass of:

E11 Modification

Scope note:

This class comprises instances of E11 Modification undertaken to maintain the form, structure, and construction apparatus of the CP2 Architecture Work. This activity occurs at periodic scheduled intervals or resulting from the detection of local malfunctions in the building system; it is aimed at extending the life of the existing building and may involve the replacement or addition of materials, elements and construction components, while still pursuing a conservative intent. Instances of CP23 Maintenance differ from instances of CP25 Conservation Intervention because of their specific character of repetitiveness and cyclicality and the low conceptual problematic nature of the operations to be performed. In fact, these are carried out using general protocols based on different issues that can be: 1) the expectation of effectiveness of a product (e.g., a stone surface protector); 2) the expectation of effectiveness of a building component (such as the drainage of an eave in a roof); 3) the expectation of effectiveness of a building technique (such as the roofing tile covering of a roof); 4) the potential harmfulness of a climatic event (rain, heavy wind, etc); 5) the expected consequences of a phenomenon (deposition of limestone contained in water, growth of nearby vegetation). These issues can be tackled without having to field special diagnostics and studies and the severity of the problem, as well as the material impact of the intervention are always limited.

It follows that the maintenance plan, as a simple management protocol, can be formalised via the CIDOC CRM. This plan can in fact be instantiated using the class E29 Design or Procedure, related to an instance of CP23 Maintenance via the property P33 *used specific technique* (*was used by*), inherited from its superclass E7 Activity.

Examples:

- the maintenance of the Fontana dei Fiumi in piazza Navona, Rome (Pandolfi 2012)
- the maintenance of the walls of Lucca (Giusti 2005)

In first-order logic:

CP23(x) ⇒ E11(x)

Properties:

Pc28 requires to be repeated within (temporally specifies the repetition of): E52 Time Span

Pc85i was realised on (was subject to): CP1 Built Entity

CP24 Architecture Conservation Project Activity

Subclass of:

E7 Activity

Scope note:

This class comprises instances of E7 Activity intentionally carried out by instances of E39 Actor in order to develop a CP33 Architecture Conservation Project. The aim of this activity is to define technically the best choices for preserving, safeguarding, and using in a compatible way historic architectures, archaeological sites, and high-value modern buildings by developing the appropriate project tools. This activity has a multidisciplinary character and is oriented by the knowledge of the architecture to conserve.

Examples:

- the activity for the development of the architecture conservation project for the Fontana dei Fiumi in piazza Navona, Rome (PANDOLFI 2012)
- the activity for the definition of the monitoring plan of the Patriarchate of Peć-Peje in Kosovo (FIORANI 2010)

In first-order logic:

CP24(x) ⇒ E7(x)

Properties:

Pc34 used as input (was input for): E13 Attribute Assignment

Pc35 is expressed in (expresses): CP33 Architecture Conservation Project

Pc36 addressed (was addressed by): CP25 Conservation Intervention

CP25 Conservation Intervention

Subclass of:

E7 Activity

Scope note:

This class comprises instances of E7 Activity produced to preserve historic architectures following the prescriptions of a CP24 Architecture Conservation Project Activity documented in CP33 Architecture Conservation Project, as restoration project, protocols for planned conservation, and diagnostic plan.

Examples:

- the conservation work for the Greek temples at Paestum (De Palma 2018)
- the monitoring of the Patriarchate of Peć-Peje in Kosovo (Fiorani 2010)
- the restoration of Notre Dame de Paris (<https://rebatirnotredamedeparis.fr/>)

In first-order logic:

CP25(x) ⇒ E7(x)

Properties:

Pc24i occurred in (was subject to): CP1 Built Entity

Pc25i occurs in (is subject to): CP1 Built Entity

Pc27 entails (is entailed by): E11 Modification

Pc33i is foreseen by (foresees): CP33 Architecture Conservation Project

Pc36i was addressed by (addressed): CP24 Architecture Conservation Project Activity

CP26 Typological Variation

Subclass of:

E81 Transformation

Scope note:

This class comprises the event that result in the simultaneous destruction of one or more than one CP2 Architecture Work and the creation of one or more than one CP2 Architecture Work that preserve recognizable substance and structure from the first one(s) but have fundamentally different nature or identity. Instances of CP26 Typological Variation deal with the organization of inner spaces, such as the distribution and connection of interior spaces in a residence or the internal organization of a church. A common example is the recasting of row houses into in-line residential building, with the interrelation of rooms on the same level, the elimination of the original vertical connectives and their replacement by a single staircase that distributes to all levels. Equally frequent was, especially during the late Italian Renaissance, was the transformation of medieval three-nave churches into single-nave churches with chapels to meet post-Tridentine liturgical needs.

Typological variation does not necessarily entail a change in function and may tie in with fairly limited transformations of material substance, but it still brings about a substantial transformation in the way the affected architecture is used and experienced.

Examples:

- the transformation of the medieval row houses in the Communal Palace at Anagni (ACIERNO 2013)
- the transformation of the medieval church of St. Vitale in Rome with three naves in a single nave (KRAUTHEIMER 1937-77)

In first-order logic:

CP26(x) ⇒ E81(x)

Properties:

Pc79 transformed (was transformed by): CP2 Architecture Work

CP27 Architecture Analysis Output

Subclass of:

E13 Attribute Assignment

Superclass of:

CP28 Building Feature; CP29 Building Phase

Scope note:

This class comprises the actions of making assertions about one historic architecture or one or more of its components, also considering any single relationship between various aspects concerning different architectures. These assertions derive from the specialistic study of the historic architecture, concerning different aspects of the discipline.

For example, the class describes the actions of scholars and architects who make propositions and statements during some scientific procedures. These may pertain to the nature and layering of construction techniques present in the building, past units of measurement used to dimension spaces and structures, geometric proportioning criteria underlying the definition of spaces and structures, and lexical and linguistic references adopted as reference for formal choices.

Possible instances of this class describe the results of the CP30 Architecture Condition Assessment or the CP34 Architecture Feature Assessment.

Examples:

- the masonry in the walls of St. Quattro Coronati in Rome from the survey at the beginning of 21st cent. (Barelli 2008)
- the composite capitals of the Zeus Olympic Temple in Athens in the 4th cent. (Tölle-Kastenbein 1994)
- the golden ratio in the plan of Parthenon in Athens (Sala, Cappellato 2003)

In first-order logic:

CP27(x) ⇒ E13(x)

Properties:

Pc32i was output for (provided as output): CP32 Architecture Feature Analysis

Pc38 specifies (is specified by): CP9 Building Material

Pc84i is gathered by (gathers): CP34 Architecture Depiction

CP28 Building Feature

Subclass of:

CP27 Architecture Analysis Output

Scope note:

This class comprises instances related to the constitution of CP2 Architecture Work by a certain condition over a time span; they can be related to the masonry quality under different points of view, concerning the building characteristics, structural capacity, resistance to decay, etc. Instances of CP28 Building Feature are also other characteristics, such as the presence and the nature of transverse connections, vertical inhomogeneities, connections between orthogonal walls and so on.

Examples:

- the connection system of the ashlars in the corners of Parthenon (Korres 2000)
- the scarp wall reinforcement at the left head of the transept of St. Pietro in Vincoli in Rome (Krautheimer 1937-77)

In first-order logic:

CP28(x) ⇒ CP27(x)

Properties:

Pc4i building feature is shown in (shows building feature): CP1 Built Entity

Pc19i masonry feature is shown in (shows masonry feature): CP5 Construction Element Plural

CP29 Building Phase

Subclass of:

CP27 Architecture Analysis Output

Scope note:

This class comprises instances related to a unified construction process carried out over a defined period of time for a CP2 Architecture Work. These instances, related to the restitution of the configuration of a historic building in a given historic period, are the product of in-depth knowledge of the building in its current state and inferential processes that can offer indications as objective as possible of the configuration of the building in a specific era.

Examples:

- the configuration of St. Peter Basilica in Rome in the 16th century (CARPICECI 1987)
- the configuration of the first church of St. Saba in Rome (CUTARELLI 2019)
- the configuration of the building of the Communal Palace at Anagni in the 13th century (ACIERNO 2013)

In first-order logic:

CP29(x) ⇒ CP27(x)

Properties:

Pc80 is referred to (is referred to by): CP1 Built Entity

Pc81 is referred to (is referred to by): CP18 Space Entity

CP30 Architecture Condition Assessment

Subclass of:

E14 Condition Assessment

Superclass of:

CP31 Mechanical Damage Assessment

Scope note:

This class comprises actions of making propositions or statements about architecture conditions based on hypothesis and any form of formal or informal logic. The aim of the CP30 Architecture Condition Assessment is the understanding of material decay and structural damage of CP2 Architecture Work and CP1 Built Work.

Examples:

- the Michele Jamiolkowski's assessment about the structural damage of the Pisa tower in 1990 (JAMIOLKOWSKI, VIGGIANI 2007)

- the restorer's assessment about the material decay of the façade of St. Sebastiano and Rocco in San Vito Romano (Rome) at the beginning of 21st cent. (Fiorani 2003)
- the assessment about the material decay of the façade of St. Sebastiano and Rocco in San Vito Romano (Rome), at the beginning of 21st cent. (Fiorani 2003)

In first-order logic:

CP30(x) ⇒ E14(x)

Properties:

Pc82 assessed the structural condition of (was assessed in its structural conditions by): CP2 Architecture Work

Pc83 assessed the decay condition of (was assessed in its decay condition by): CP9 Building Material

CP31 Mechanical Damage Assessment

Subclass of:

CP30 Architecture Condition Assessment

Scope note:

This class describes the act of assessing the mechanical damage of a structure during a particular period. The mechanical damage assessment may be carried out by the observation (directly or using a sufficient number of photos) of the structural disruptions found on the building (cracks, deformation and so on) and/or through historic research. It indicates the assessment about the manner in which a building is deformed and/or damaged by kinematic stresses, with particular reference to seismic phenomena.

Examples:

- the assessment of the big crack and damages in the wall of the interior staircase of the Carli Benedetti Palace as the effect of the action in the plan of the wall due to the earthquake in 2009 in L'Aquila (Bartolomucci 2018)
- the assessment of the out of plumb in the façade of the church of St. Antonio Abate at Introdacqua (L'Aquila) as the effect of the action off the plan with the earthquake in 2009 (L'Aquila) (Donatelli 2010)

In first-order logic:

CP31(x) ⇒ CP30(x)

Properties:

Pc52i assessed (was assessed by): CP1 Built Entity

CP32 Architecture Features Analysis

Subclass of:

E7 Activity

Scope note:

This class comprises actions investigating instances of CP1 Built Entity, that can be determined by a systematic procedure. The aim of the CP32 Architecture Features Analysis is the understanding of constructive and formal features of CP2 Architecture Work and CP1 Built Entity. This class is used to document the building development, and the technical, figurative and typological references of the architecture.

Examples:

- the analysis of masonry of the walls of St. Quattro Coronati in Rome (BARELLI 2008)
- the study of the composite capitals of the Zeus Olympic Temple in Athen in the 4th cent. (TÖLLE-KASTENBEIN 1994)

In first-order logic:

CP32(x) ⇒ E7(x)

Properties:

Pc32 provided as output (was output for): CP27 Architecture Analysis Output

CP33 Architecture Conservation Project

Subclass of:

E29 Design or Procedure

Scope note:

This class comprises documented plans for the executions of actions in order to achieve the preservation and compatible use or fruition of historic architectures, archaeological sites, high-value modern buildings. These plans are depicted by drawings, protocols, and check lists and they may result in new instances of CP38 Architecture Representation Object. They are used for shaping or guiding the execution of an instance of CP25 Conservation Intervention though the property Pc33 foresees (is foreseen by). The existence of an instance of CP33 Architecture Conservation Project normally implies the intention of any actor to realize it, because it derives from the necessity to hinder any kind of conservation problems.

CP33 Architecture Conservation Project is an architectural project dedicated to an existing building that is recognised as being of particular interest and value. For this reason, the role assumed by the study of the pre-existence takes on a particular importance, since the design choices of both conservative and creative nature are based on it. In fact, the main objective of the project is to preserve the material, historic and figurative values of the historic building, without sacrificing the building's formal and functional effectiveness.

CP33 Architecture Conservation Project differs from ActE2 Activity Plan because of its specific nature that requires special technical tools also prescribed by law which must give information about the final state of the building and the specific techniques of intervention. An instance of an ActE2 Activity Plan, on the other hand, consists of a site implementation plan or a site safety plan, which regulate how the various restoration activities are to be conducted on site, also taking into account workers' clothing, as well as working times and methods.

Examples:

- the monitoring plan of the Patriarchate of Peć-Peje in Kosovo (Fiorani 2010)
- the restoration project of the Neues Museum in Berlin (Hamm 2009)

In first-order logic:

CP33(x) ⇒ E29(x)

Properties:

Pc26 is illustrated by (illustrates): CP38 Architecture Representation Object

Pc33 foresees (is foreseen by): CP25 Conservation Intervention

Pc35i expresses (is expressed in): CP24 Architecture Conservation Project Activity

Pc37 complies with (binds): E32 Authority Document

Pc50 incorporates (is incorporated in): CP34 Architecture Depiction

Pc86i was addressed by (addressed): CP50 Urban Conservation Plan

CP34 Architecture Depiction

Subclass of:

E31 Document

Scope note:

This class allows the study of architecture to be documented through a description in words, orthophotos, drawings, digital models retrieved from an architectural survey. It represents the knowledge expressed through a physical document (E22 Human-Made Object) such as a drawing or a report.

Examples:

- the representation of the Synodal hall of the archdiocese of Sens, west façade, by E.E. Viollet le Duc (Midant 2002)

- the description of Palazzo Ducale by Camillo Boito (BOITO 1893)
- the description of Notre Dame de Paris expressed by the digital model of the cathedral (<https://rebatirnotredamedeparis.fr/>)

In first-order logic:

CP34(x) ⇒ E31(x)

Properties:

Pc44i is illustrated by (illustrates): CP38 Architecture Representation Object

Pc50i is incorporated in (incorporates): CP33 Architecture Conservation Project

Pc84 gathers (is gathered by): CP27 Architecture Analysis Output

CP35 Building-Formal Type

Subclass of:

E55 Type

Scope note:

This class includes types that collect formal or constructive characteristics shared by structures, units, components, and elements of architecture. Instances of CP35 Building-Formal Type may concern the figurative organization of façades (e.g., façades with overlapping orders, with giant order, with regular windows) or the construction characteristics of masonry (e.g., regular row wall in squared ashlars; rubble masonry; reticulated work). Each aspect of architecture that lends itself to being identified according to defined design or construction rules can be instantiated using CP35 Building-Formal Type, according to its own typology of reference.

Examples:

- the three orders façade type as shown on the Colisseum, Rome (REA 2019)
- the reticulate work type of the 1st cent. b.C. as shown in the Teatro di Marcello (COARELLI 1984)
- the continuous load-bearing masonry structural system as shown in the Roman architecture (GIOVANNONI 1928)

In first-order logic:

CP35(x) ⇒ E55(x)

Properties:

Pc16i structural system is shown in (shows structural system): CP1 Built Entity

Pc22i building-formal type is shown on (shows building-formal type): CP2 Architecture Work

CP36 Architecture Type

Subclass of:

E55 Type

Scope note:

This class describes the presence of specific formal invariants related to the inherent organizational, functional and constructive aspects of the building. Instances of CP36 Architecture Type can concern form and relative distribution of spaces in architecture, the nature of which has been codified over time by architectural history. Instances of CP36 Architecture Type are the residential building types of town-houses, courtyard, in-line, etc., or the church types with three naves, central, Greek cross, etc.

Examples:

- the Georgian house type of the building in Edinburgh (Matthew, Reid, Lindsay 1972)
- the ‘mature’ row house type of the 15th century in Italy (Caniggia, Maffei 1979)

In first-order logic:

CP36(x) ⇒ E55(x)

Properties:

CP37 Architecture Graphic Representation Type

Subclass of:

E55 Type

Superclass of:

CP38 Architecture Graphic Object

Scope note:

This class is a specialization of E55 Type and comprises the concepts of architectural representation. Instances of CP37 Architecture Graphic Representation Type can be orthophotos, 3D models, orthographic projections.

Examples:

- the type of drawings in paper used by E.E. Viollet le Duc for representing the west façade of the Synodal hall of the archdiocese of Sens (Midant 2002)
- the type of description of architecture formulated in the pages of Camillo Boito’s book “Questioni Pratiche di Belle Arti” (1893), devoted to Palazzo Ducale (Boito 1893)
- the type of the 3D model as developed for the cathedral of Notre Dame de Paris (https://rebatirnotredamedeparis.fr/)

In first-order logic:

CP37(x) ⇒ E55(x)

Properties:

CP38 Architecture Representation Object

Subclass of:

E24 Physical Human-Made Thing

Scope note:

This class comprises discrete, identifiable human made items created with the purpose of representing every kind of CP1 Built Entity using graphic or alpha-numeric representation, regardless to the scale of representation (from the urban scale to the detailed one). Instances of CP38 Architecture Representation Object can be printed drawings, handmade sketches on paper, maquettes, reports on paper, or even digital models or 2D representation, files with structural or economic calculation, etc.

Examples:

- the drawings of the Synodal hall of the archdiocese of Sens, west façade, by Viollet-le-Duc (Midant 2002)
- the pages of Camillo Boito's book devoted to Palazzo Ducale (Boito 1893)
- the 3D model of the cathedral of Notre Dame de Paris (<https://rebatirnotredamedeparis.fr/>)

In first-order logic:

CP38(x) ⇒ E71(x)

Properties:

Pc26i illustrates (is illustrated by): CP33 Architecture Conservation Project

Pc44 illustrates (is illustrated by): CP34 Architecture Depiction

CP39 Architecture Alpha-Numeric Representation Type

Subclass of:

E55 Type

Scope note:

This class is a specialization of E55 Type and comprises the concepts of architecture that can be expressed by written and/or numerical elaboration. Instances of CP39 Architecture Alpha-Numeric Representation Type can be written reports, calculation reports, sheets and tables.

Examples:

- the type of report about the structural behaviour used for the Pisa tower (Jamiolkowky, Viggiani 2007)
- the type of reports and the type of cataloguing of the masonry used for the study of church of St. Saba (Cutarelli 2019)

In first-order logic:

CP39(x) ⇒ E55(x)

Properties:

CP40 Historic Centre

Subclass of:

E24 Physical Human-Made Thing

Scope note:

This class includes instances of current urban agglomeration composed by the historic buildings and the open spaces which formerly constituted the town. The historic centre is delimited by a perimeter that can sometimes coincide with the boundary of the city walls when they still exist or when they can be identified on the basis of historic records, material evidence, or on natural limits (streams, steep slopes, etc.). The chronological limit of the World War I (1919) normally identifies a part – generally central – of the town, but the contemporary city can also include several historic districts that are in fact disjointed. This threshold can sometimes result from the evident constructive mutation of the building, verified by the comparison with the available cartographic and historic graphic documentation and direct feedback. In terms of CPM ontology, instances of CP40 Historic Centre are composed by instances of CP13 Urban Unit and CP16 Urban Area.

Examples:

- the historic centre of L'Aquila in the 20th cent. (Clementi, Piroddi 1986)
- the historic centre of Marseille at the beginning of the 21st cent. (Bajard, Planchenault 2022)

In first-order logic:

CP40(x) ⇒ CP1(x)

Properties:

Pc3 has connection through: E24 Physical Human Made Thing

Pc65 is delimited by (delimits): E18 Physical Thing

CP41 Observable Environmental Entity

Subclass of:

E1 CRM Entity

Scope note:

This class includes instances of E1 CRM Entity that can be observed by human sensory impression on a global scale. It describes different types of environmental phenomena related to a specific place and affecting the state of preservation of buildings located there. Class CP41 Observable Environmental Entity describes qualitatively – referring to common categories developed by experts in the field – the most relevant environmental conditions of a site, especially in relation to weather and climate conditions.

Examples:

- the prevailing north wind (fictitious)
- the Mediterranean climate (fictitious)

In first-order logic:

$CP41(x) \Rightarrow E1(x)$

Properties:

Pc1 affects (is subject to): E1 CRM Entity

CP42 Material Decay

Subclass of:

E5 Event

Scope note:

This class comprises natural events or human-made processes that create, alter or change physical things, with special reference to building material, by permanently affecting their form or consistency without changing their identity. These phenomena are generally pathological in nature per se or potentially and affect the physical features of a CP1 Built Entity or, more generally, of a E18 Physical Thing.
Instances of CP42 Material Decay refer specifically to the phenomenon of material deterioration as defined in the Italian UNI 11182/2006 or in the Illustrated Glossary on Stone Deterioration Patterns from ICOMOS and ISCS. They collect the effect of addition to the material (surface deposit, efflorescence, crust, biological coating), but also the situations derived from the loss of material (disintegration, detachment, exfoliation, lacuna) or, simply, the change of some original characteristic of the material, such as the colour appearance or the formation of stains, due to deterioration mechanisms.

Examples:

- the black crust on the Bernini's Fontana dei Fiumi (Pandolfi 2012)
- the gap corresponding to the tower to the left of the entrance to the Neues Museum destroyed by bombing (Barndt 2011)

In first-order logic:

CP42(x) ⇒ E5(x)

Properties:

Pc6 was fostered by (fostered): E3 Condition State

Pc51i is generated on (is affected by): CP9 Building Material

Pc74 was caused by (caused): E5 Event

CP43 Structural Damage

Subclass of:

E5 Event

Scope note:

CP43 Structural Damage cases refer specifically to phenomena that cause changes in the structural behaviour of a CP1 Built Entity. These changes are normally due to failure mechanisms that favour the partial or total loss of a building's resistance capacity. Induced failure mechanisms manifest themselves with specific recognisable effects on building structures.
Instances of CP43 Structural Damage thus refer, among others things, to the phenomena of cracking, crushing of materials, deformation or change in the original position of a building structure as a whole or a part thereof.

Examples:

- the diagonal breaks on the façade of Palazzo Carli Benedetti in L'Aquila (Bartolomucci 2018)
- the out-of-plane wall overturning in the Palazzo dei Trecento in Treviso (Forlati 1952)

In first-order logic:

CP43(x) ⇒ E5(x)

Properties:

Pc49 was fostered by (fostered): E3 Condition State

Pc61i was generated on (was affected by): CP1 Built Entity

Pc62 was caused by (caused): E5 Event

CP44 Construction Site

Subclass of:

E27 Site

Scope note:

This class includes pieces of land or sea plan where a single building, a group of buildings, or a historic centre has been placed. The concept of a site is broader than the area exactly occupied by the single architecture and defines the main characteristics of this area and its surroundings; in the presence of a villa, the construction site gathers the area of the entire complex, both built and green.
In contrast to the purely geometric notion of E53 Place, this class describes constellations of matter on the surface of the Earth containing buildings, which can be represented by photographs, paintings, and maps.
Instances of CP44 Construction Site are composed of relatively immobile material items and features with specific morphology and use and a proper geologic composition of the ground.

Examples:

- the submerged harbour of the Minoan settlement of Gournia, Crete (WATROUS et al. 2012)
- the construction site of Villa Torlonia in Rome (CAMPITELLI 1997)

In first-order logic:

CP44(x) ⇒ E27(x)

Properties:

Pc45 has morphology type: E55 Type

Pc46 has geology type: E55 Type

CP45 Architecture Project

Subclass of:

E29 Design or Procedure

Scope note:

This class comprises documented plans for the executions of actions to realise new architectures (in the present or in the past) or to radically transform existing buildings. These plans are depicted by drawings, reports, check lists, bill of quantities, etc., and they may result in new instances of CP1 Built Entity or for shaping or guiding the execution of an instance of E7 Activity.
Instances of CP45 Architecture Project can be related to the different kinds of the project of an architecture (concept plan, final project, executive project, execution variant, etc.). Architecture project can be also

constituted by models, sketches, analytic description, in short, any kind of indication that may have been worked out for the purpose of on-site implementation of the building.

Examples:

- the architectural drawings for the Kölner Dom (Cologne Cathedral) in Cologne, Germany (Wolff 1999)
- the wooden model of the Fontana di Trevi by Carlo Camporese (1733-35) (Liserre 2017)

In first-order logic:

CP45(x) ⇒ E29(x)

Properties:

Pc21i was addressed by (addressed): CP49 Urban Plan

Pc53 has modified (was modified by): CP45 Architecture Project

Pc54 planned (was planned by): CP1 Built Entity

Pc55 directed (was directed by): CP46 Building Activity

CP46 Building Activity

Subclass of:

E7 Activity

Scope note:

This class comprises instances of E7 Activity produced to build a new architecture or to introduce new important transformation in it, normally documented in CP45 Architecture Project. Instances of CP46 Building Activity can also deal with activities carried out without any real design when they are equally significant for the final architectural configuration.

Examples:

- the building activity for the construction of Colosseum in Rome (Cozzo 1971)
- the building activity for the transformation of Pantheon in Rome in the 18th century (Pasquali 1996)

In first-order logic:

CP46(x) ⇒ E7(x)

Properties:

Pc55i was directed by (directed): CP45 Architecture Project

Pc56 was realised on (was subject to): CP1 Built Entity

Pc60 realised (was realised by): CP1 Built Entity

CP47 Decoration Type

Subclass of:

E55 Type

Scope note:

This class specifies the different types of decoration existing in a CP1 Built Entity. Instances of CP47 Decoration Type concern techniques used for decorating architectures, components or elements, such as painting techniques, sculptural treatments of stone or wood, etc.

Examples:

- the stucco decorations type as over the windows of the palace in Valencia, Calle Conde de Montornés 1-5 (MILETO, VEGAS 2016)
- the stone bas-relief type as in the portal of the façade of Notre Dame de Paris (MIDANT 2002)
- a gilded wood bas-relief type as on the ceiling of the church of St. Bernardino in L'Aquila (D'ANTONIO 2020)

In first-order logic:

CP47(x) ⇒ E55(x)

Properties:

Pc57i is decoration type of (shows decoration type): CP7 Architecture Decoration

CP48 Equipment Type

Subclass of:

E55 Type

Scope note:

This class specifies the different types of CP8 Equipment. Instances of CP48 Equipment Type can refer to plumbing, electrical or heating system, etc.

Examples:

- the lighting equipment type as in palazzo Altemps in Rome (Scoppola 1996)
- the water drainage system type as in the Roma domus in the complex of St. Giulia in Brescia (BROGIOLO, MORANDINI 2005)

In first-order logic:

CP48(x) ⇒ E55(x)

Properties:

Pc59i is equipment type of (shows equipment type): CP8 Equipment

CP49 Urban Plan

Subclass of:

E29 Design or Procedure

Scope note:

This class includes urban planning instruments aimed at planning the activities to be carried out on cities; these instruments design and regulate uses of space focused on the physical form, economic functions, and social impacts of the urban environment. Instances of CP49 Urban Plan are urban instruments that identify the architectural, functional and constructive characteristics of existing buildings and sites and envisage the operations to be carried out in terms of the provision of services and infrastructure, new construction, and transformation of existing buildings. They can also contain restrictive constraints on the actions to be taken on the existing building. These plans are depicted by drawings, reports, check lists, and forms address new instances of CP5 Architecture Project. Instances of CP49 Urban Plan can also be related to plans that modify already existing plans.

Examples:

- the Urban Plan for the town of Rome approved in 2016 (<http://www.urbanistica.comune.roma.it/prg.html>)
- the Urban Plan Variant for the city of Naples approved in 2004 (<https://www.comune.napoli.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/102>)

In first-order logic:

CP49(x) ⇒ E29(x)

Properties:

Pc21 addressed (was addressed by): CP45 Architecture Project

Pc47 has modified (was modified by): CP49 Urban Plan

Pc48 planned (was planned by): CP16 Urban Area

Pc87i was specified by (specified): CP50 Urban Conservation Plan

CP50 Urban Conservation Plan

Subclass of:

E29 Design or Procedure

Scope note:

This class includes urban planning instruments aimed at planning the conservation activities to be carried out on historic architecture; these instruments design and regulate interventions focused on the physical form and the construction structure of the historic urban environment.

Instances of CP50 Urban Conservation Plan are urban instruments that identify the architectural, functional and constructive characteristics of existing buildings and sites and envisage the operations to be carried out in terms of conservation and restoration of existing buildings. They contain restrictive constraints on the actions to be taken on the existing building but also the guidelines to orient how to intervene on the historic façades (in terms of colours, materials and constructive solutions), on the inner part of the building (preserving their historic character but also using compatible solutions to allow the introduction of modern equipment and services), and on to the open areas (orienting the choices about materials, techniques and furniture). These plans are depicted by drawings, reports, check lists, and forms addressing new instances of CP33 Architecture Conservation Project. Instances of CP50 Urban Conservation Plan can also be related to plans that modify already existing plans.

Examples:

- the Urban Conservation Plan for the 'Ghetto' in the historic centre of Rome (BENEDETTI 1995)
- the Urban Conservation Plan Variant for the historic centre of Basciano (Teramo) adopted in 2001 (fictitious)

In first-order logic:

CP50(x) ⇒ E29(x)

Properties:

Pc86 addressed (was addressed by): CP33 Architecture Conservation Project

Pc87 specified (was specified by): CP49 Urban Plan

Pc80 planned the conservation of (was subdued to): CP16 Urban Area

CP51 Building Component

Subclass of:

CP2 Architecture Work

Superclass of:

This class includes instances relating to parts of the architectural organism that subtend spaces that cannot be further subdivided. The instances of CP51 Building Component are identified on the basis of their specific characteristics of continuity and recognisability ascribable to a given period of time. These characters refer both to the physical architectural and building components and to the space that is defined by them.

Examples:

- the current second bay of the central nave of St. Prassede in Rome (CAPERNA 2014)

- the current Ceremony Hall within the Royal Palace in Milan (Colle, Mazzocca 2002)

In first-order logic:

CP21(x) ⇒ CP18(x)

Properties:

Pc66 is defined by (defines): CP20 Construction Work

1.8. CPM Property declarations

Pc1 affects (is subject to)

Domain:

CP41 Environmental Observable Entity

Range:

E1 CRM Entity

Quantification:

Many to many, necessary, dependent (1,n:1,n)

Scope note:

This property documents that an instance of CP41 Environmental Observable Entity *Pc1 affects (is subject to)* an instance of class E1 CRM Entity. This property may be used to describe the fact that external factors that can be observed through visual analysis or by the means of special instruments are affecting any instance of E1 Entity. It has been conceived to describe the action of natural phenomenon such as winds, temperature, atmospheric agents on, either, human-made items, such as architecture, or on natural elements, such as caves or cliffs. Man made items may refer to the heterogenous elements themselves that spread from urban areas to the singular building component. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the historic centre of Gaeta (CP40) *is subject to* Grecale wind (CP41)
- the historic centre of Milan (CP40) *is subject to* continental climate (CP41)
- the Coliseum (CP14) *is subject to* the raising groundwater table (CP41)

In first-order logic:

Pc1(x,y) ⇒ CP41(x)

Pc1(x,y) ⇒ E1(y)

Pc2 has as general vocation (is general vocation of)

Domain:

CP18 Space Entity

Range:

E7 Activity

Subproperty of:

E1 CRM Entity. P15i influenced (was influenced by): E7 Activity

Quantification:

Many to many (0,n:0,n)

Scope note:

This property documents that an instance of E7 Activity is mainly performed within an instance of CP18 Space Entity
The property allows the description of the functional vocation of activity mainly performed in an architecture instance of CP21 Space Unit or CP22 Space Component, or urban space instance of CP19 Historic Centre, that are subclasses of CP18 Space Entity. This property mainly refers to conditions revealed by economic and statistical surveys. For example, this property may describe the agricultural vocation of a village or the specific productive activity (industry, fishing, handicrafts, etc.) of a historic centre or the religious vocation of a district.

Examples:

- the historic centre of Gaeta (CP19) *has as general vocation* a touristic activity (E7)
- the historic centre of Manchester (CP19) *has as general vocation* an industrial activity (E7)

In first-order logic:

Pc2(x,y) ⇒ CP18(x)

Pc2(x,y) ⇒ E7(y)

Pc2(x,y) ⇒ P15i(x,y)

Pc3 has connection through (connects)

Domain:

CP40 Historic Centre

Range:

E24 Physical Human-Made Thing

Quantification:

Many to many, necessary (1,n:0,n)

Scope note:

This property documents that an instance of CP40 Historic Centre is joined (connected) to its environment through an instance of E24 Physical Human-Made Thing. The property is mainly conceived to describe which is the main route of communication that connects a historic centre to the territory. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the historic centre of Brindisi (CP40) *has connection through* the Via Appia (E24)
- the historic centre of Rome (CP40) *has connection through* the Via Flaminia (E24)

In first-order logic:

Pc3(x,y) ⇒ CP40(x)

Pc3(x,y) ⇒ E24(y)

Pc4 shows building feature (building feature is shown in)

Domain:

CP1 Built Entity

Range:

CP28 Building Feature

Superproperty of:

CP5 Construction Element Plural. Pc19 shows masonry feature (masonry feature is shown in): CP28 Building Feature

Subproperty of:

E70 Thing. P130 shows features of (features are also found on: E70 Thing

Quantification:

Many to many, necessary (1,n:0,n)

Scope note:

This property documents that an instance of CP1 Built Entity shows building feature which are specified by an instance of CP28 Building Feature.

Examples:

- the eastern wall of St. Balbina complex (CP4) in Rome *shows building feature* transverse connections (CP28) (Bianchi, Coppola, Mutarelli 2014)
- the church of St. Balbina in Rome (CP2) *shows building feature* a roof made of wooden trusses (CP28)

In first-order logic:

Pc4(x,y) ⇒ CP1(x)

Pc4(x,y) ⇒ CP28(y)

Pc4(x,y) ⇒ Pc130(x,y)

Pc5 is inhabited by (inhabits)

Domain:

CP19 Historic Centre

Range:

E74 Group

Quantification:

One to many (0,n: 0,1)

Scope note:

This property documents that an instance of CP19 Historic Centre is related with an instance of E74 Group. The property is conceived to specify properties about the people who live in the area considered either to specify the number or other characteristics such as origin, religion, etc. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- Falconara Albanese (CP19) (Cosenza, Italy) *is inhabited by* Albanian people (E74) (GENOESE 1989)
- Urbino (CP19) (Italy) *is inhabited by* students (E74)

In first-order logic:

Pc5(x,y) ⇒ CP19(x)

Pc5(x,y) ⇒ E74(y)

Pc6 was fostered by (fostered)

Domain:

CP42 Material Decay

Range:

E3 Condition State

Quantification:

Many to many, necessary (1,n:0,n)

Scope note:

This property documents that an instance of CP42 Material Decay was made possible by a specific E3 Condition State. It refers to the need to describe, beyond the causes of a particular state of degradation due to specific factors such as dampness for example, the environmental agents such as climate or exposition that are described through the class condition state. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- The biological patina (CP42) of the globigerina of the northern side of the walls of Birgu in Malta *was fostered by* the exposition towards north (E3) (Acierno, Baratin 2016)
- The weathering (CP42) of the tuff of the eastern front of Rocca Bruna in Villa Adriana *was fostered by* the exposition to prevailing winds (E3)

In first-order logic:

Pc6(x,y) ⇒ CP42(x)

Pc6(x,y) ⇒ E3(y)

Pc7 is connected through (connects)

Domain:

CP1 Built Entity

Range:

CP1 Built Entity

Subproperty of:

CP1 Built Entity. Pc18 has physical relation with: CP1 Built Entity

Quantification:

Many to many (0,n:0,n)

Scope note:

This property documents that an instance of CP1 Built Entity is connected through an instance of CP1 Built Entity to another built element. This circumstance refers mainly to the historic centres' fabric. This property is not transitive, it is asymmetric, irreflexive.

Examples:

- Palazzo Ducale (CP1) *is connected through* The Bridge of Sighs (Ponte dei Sospiri) in Venice (CP1) to the prisons building (Trincanato 1966)
- the chapel of the conservatory of St. Annunziata in Gaeta (Italy) (CP1) *is connected through* a covered bridge (CP1) to the house in Via Annunziata, vico 3 (Locci 2012)

In first-order logic:

Pc7(x,y) ⇒ CP1(x)

Pc7(x,y) ⇒ CP1(y)

Pc7(x,y) ⇒ Pc18(x,y)

Pc8 is connected to

Domain:

CP1 Built Entity

Range:

CP1 Built Entity

Subproperty of:

CP1 Built Entity. Pc18 has physical relation with: CP1 Built Entity

Quantification:

Many to many (0,n:0,n)

Scope note:

This property documents that an instance of CP1 Built Entity is connected to another instance of CP1 Built Entity. This circumstance refers mainly to the historic centres' fabric. This property is not transitive, it is symmetric, irreflexive.

Examples:

- the eastern front of Palazzo Ducale (CP1) in Venice *is connected to* the prisons building (CP1) (TRINCANATO 1966).
- the Casa Grande Barberini (CP1) in Rome *is connected to* the Banco dei pegni (CP1).

In first-order logic:

Pc8(x,y) ⇒ CP1(x)

Pc8(x,y) ⇒ CP1(y)

Pc8(x,y) ⇒ Pc18(x,y)

Pc8(x,y) ⇒ Pc8(y,x).

Pc9 belongs to (owns)

Domain:

CP18 Space Entity

Range:

E39 Actor

Subproperty of:

E18 Physical Thing. P52 has current owner (is current owner of): E39 Actor

Quantification:

One to many (0,n:0,n)

Scope note:

This property documents that an instance CP18 Space Entity belongs to an instance of E39 Actor and allows to document the ownership of a spacetime volume to be documented. The history of architecture is in fact intertwined with the changes of ownership, and therefore their specification is generally required.

Examples:

- Piazza Navona (CP18) in Rome *belongs to* the Italian State since 1870 (E39)
- Palazzo Salviati (CP18), built in Rome in Via della Lungara, *belongs to* Francesco Borghese in 1839 (Bucolo 2007)

In first-order logic:

Pc9(x,y) ⇒ CP18(x)

Pc9(x,y) ⇒ E39(y)

Pc9(x,y) ⇒ P52(x,y)

Pc10 belongs to (owns)

Domain:

CP2 Architecture Work

Range:

E39 Actor

Subproperty of:

E18 Physical Thing. P52 has current owner (is current owner of): E39 Actor

Quantification:

Many to many (0,n:0,n)

Scope note:

This property documents that an instance of CP2 Architecture Work belongs to an instance of E39 Actor it makes it possible to document the ownership of a building.

Examples:

- the Palazzo degli Uffizi (CP2) in Florence *belongs to* the Italian State (E39).
- the house in via Cimarra (CP2) in Rome *belongs to* Rossi family (E39) (fictitious)

In first-order logic:

Pc10(x,y) ⇒ CP2(x)

Pc10(x,y) ⇒ E39(y)

Pc10(x,y) ⇒ P52(x,y)

Pc11 is bounded by (bounds)

Domain:

CP16 Urban Area

Range:

CP14 Urban Unit Front

Quantification:

One to many (1,n:1,1) necessary, dependent

Scope note:

This property documents that an instance of CP16 Urban Area is bounded by an instance of CP14 Urban Unit Front. The property aims to describe the boundaries of an urban area in the cases in which they are constituted by the façades of the buildings. In particular, the property aims to describe not only the geometrical perimeter but the elevations that characterize the area.

Examples:

- the piazza Farnese (CP16) in Rome *is bounded by* Palazzo Farnese façade (CP14).
- the piazza di Santa Annunziata (CP16) *is bounded by* the Ospedale degli Innocenti in Florence (CP14).
- the Institute of Arab World façade (CP14) *bounds* Rue des Fossés Saint-Bernard, 75005 Paris (CP16).

In first-order logic:

Pc11(x,y) ⇒ CP16(x)

Pc11(x,y) ⇒ CP14(y)

Pc12 is related to public area through (allows the relationship to the public area of)

Domain:

CP10 Building Unit

Range:

CP11 Building Front

Subproperty of:

CP1 Built Entity. Pc18 has physical relation with: CP1 Built Entity

Quantification:

One to many, necessary, dependent (1,n:1,1)

Scope note:

This property documents that an instance of CP10 Building Unit is related to public area through an instance of CP11 Building Front.

The property allows the relationship between a building unit and its façade to be described. The property aims at describing both the constructive relation between the building and its façade and the nature of the façade that acts as a threshold between private and public space. The relation between the building and the public area is made possible through at least an opening, a door or a window.

Examples:

- The Palais Garnier (Opéra Garnier) (CP 10) in Paris *is related to public area through* its façade (CP11)
- The façade of Palazzo Farnese (CP11) in Rome *relates to public area* (piazza Farnese) the building (CP10)

In first-order logic:

Pc12(x,y) ⇒ CP10(x)

Pc12(x,y) ⇒ CP11(y)

Pc12(x,y) ⇒ Pc18(x,y)

Pc13 is regulated by (regulates)

Domain:

CP2 Architecture Work

Range:

E32 Authority Document

Quantification:

Many to many (0,n:0,n)

Subproperty of:

E1 CRM Entity. P70 is documented in (documents): E31 Document

Scope note:

This property documents that an instance of CP2 Architecture Work, from the legislative point of view, is regulated by an instance of E32 Authority Document, in the sense that every action performed on the object must follow the prescriptions expressed in the document. The authority document may be a monumental constraint, an urban planning tool, etc. There might be cases of a building not following any legislative constraints.

Examples:

- Palazzo Farnese (CP2) in Rome *is regulated by* the monumental constraint document n.10409/17/01/1951, L.1089/1939 art.21 (E32).
- Row house in 34, via Castello Alessandro (CP2), Monte Romano (Viterbo, Italy) *is regulated by* the ‘building rules document’ (E32) approved by the Municipality in 2018.

In first-order logic:

Pc13(x,y) ⇒ CP2(x)

Pc13(x,y) ⇒ E32(y)

Pc13(x,y) ⇒ P70(x,y)

Pc14 is regulated by (regulates)

Domain:

CP19 Historic Centre

Range:

E32 Authority Document

Subproperty of:

E1 CRM Entity. P70 is documented in (documents): E31 Document

Quantification:

Many to many, necessary (1,n:0,n)

Scope note:

This property makes it possible to relate an instance of the class CP19 Historic Centre with an instance of E32 Authority Document. It specifies which Authority document regulates the building activities to be developed in an instance of CP19 Historic Centre. In the historic centres every action performed must follow the prescriptions expressed by the law. The authority document could be a territorial or an urban planning tool.

Examples:

- the historic centre of Rome (CP19) *is regulated by* the Piano Regolatore Generale di Roma (E32) and by the management plan (E32) required by the inscription in the UNESCO World Heritage List
- the historic centre of Trinidad (CP18) in Cuba *is regulated by* the management plan (E32) required by the inscription in the UNESCO World Heritage List

In first-order logic:

Pc14(x,y) ⇒ CP19(x)

Pc14(x,y) ⇒ E32(y)

Pc14(x,y) ⇒ P70(x,y)

Pc15 shows plan configuration type (is configuration type of)

Domain:

CP10 Building Unit

Range:

E55 Type

Subproperty of:

E1 CRM Entity. has type (is type of): E55 Type

Quantification:

Many to one, necessary (1,1:0,n)

Scope note:

This property documents that an instance of CP2 Architecture Work shows plan configuration by an instance of the class E55 Type.

Examples:

- the Palatine chapel (CP2) in Achen (Germany) *shows plan configuration type* (E55) centralized (Heitz 1980)
- the church of St. Balbina (CP2) in Rome *shows plan configuration type* (E55) basilica (Krautheimer 1937-77)

In first-order logic:

Pc15(x,y) ⇒ CP2(x)

Pc15(x,y) ⇒ E55(y)

Pc15(x,y) ⇒ P2(x,y)

Pc16 shows structural system (structural system is shown in)

Domain:

CP1 Built Entity

Range:

CP35 Building-Formal Type

Subproperty of:

E1 CRM Entity. has type (is type of): E55 Type

Quantification:

Many to many, necessary (1,n:0,n)

Scope note:

This property associates an instance of CP35 Building Formal Type with an instance of CP1 Built Entity. It allows the structural system of a building to be described, relating it to a thesaurus that gathers both formal, constructive and structural features.

Examples:

- the Chapelle de Ronchamps (CP2) *shows structural system* mixed type (CP35) (Petit 1997)

- The Palazzetto dello Sport (CP2) in Rome *shows structural system* reinforced concrete type (CP35)

In first-order logic:

Pc16(x,y) ⇒ CP1(x)

Pc16(x,y) ⇒ CP35(y)

Pc16(x,y) ⇒ P2(x,y)

Pc17 has performance efficiency documented in (documented performance efficiency of)

Domain:

CP2 Architecture work

Range:

E73 Information Object

Subproperty of:

E1 CRM Entity. P70 is documented in (documents): E31 Document

Quantification:

One to many, dependent (0,n:1,1)

Scope note:

This property associates an instance of CP2 Architecture work with an E73 Information Object documenting specifically performance efficiency. This can be required in several different domains such as accessibility, sustainability, or plant efficiency.

Examples:

- the building Aqueduct hamlet (CP2) in Nepi (Viterbo, Italy) *has performance efficiency documented in* Green Building Council certificate (E73)
- the building of the stables of the St. Apollinare Rocca Monastery (CP2) (Perugia, Italy) *has performance efficiency documented in* LEED Gold certificate (E73)

In first-order logic:

Pc17(x,y) ⇒ CP2(x)

Pc17(x,y) ⇒ E73(y)

Pc17(x,y) ⇒ P70(x,y)

Pc18 has physical relation with

Domain:

CP1 Built Entity

Range:

CP1 Built Entity

Superproperty of:

CP1 Bult Entity. Pc7 is connected through (connects): CP1 Built Entity
CP1 Bult Entity. Pc8 is connected to: CP1 Built Entity
CP1 Bult Entity. Pc12 is related to public area through (allows the relationship to the public area of): CP1 Built Entity
CP1 Bult Entity. Pc42 was embodied by (embodied): CP1 Built Entity
CP1 Bult Entity. Pc63 is crossed by (crosses): CP1 Built Entity
CP1 Bult Entity. Pc64 is cladded by (clads): CP1 Built Entity
CP1 Bult Entity. Pc71 is intrinsically connected to: CP1 Built Entity
CP1 Bult Entity. Pc89 covers (is covered by): CP1 Built Entity

Quantification:

Many to many (0,n:0,n)

Scope note:

This property associates an instance of CP1 Built Entity with another instance of CP1 Built Entity documenting the physical relation existing between them. This property allows the constructive layering shown by a building or a part of it to be described. It is generally completed by a property type which specifies the kind of relationship, if, for example, a wall has a physical relation with another wall being built on it or filling one of its windows. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.
Pc18.1 *has type* can be used to specify the type of physical relation the CP1 Built Entity has with another CP1 Built Entity. This property is not transitive, it is symmetric and irreflexive.

Examples:

- the ashlar masonry of the eastern wall of the first courtyard of St. Balbina (CP1) in Rome *has physical relation with* the opus reticulatum pertaining to the domus Cilonis (CP1), leaning on it (Pc18.1 *has type)* (Krautheimer 1937-77)
- the mixed tuff and brick masonry of the northern wall of the hypogeal oratory of the church of St. Saba in Rome (CP1) *has physical relation with* the brick masonry, leaning on it (Pc18.1 *has type)* (Cutarelli 2018, pp. 125, 126).

In first-order logic:

$Pc18(x,y) \Rightarrow CP1(x)$

$Pc18(x,y) \Rightarrow CP1(y)$

$Pc18(x,y,z) \Rightarrow [Pc18(x,y) \wedge E55(z)]$

$Pc18(x,y) \Rightarrow Pc18(y,x)$.

Properties:

Pc18.1 has type: E55 Type

Pc19 shows masonry feature (masonry feature is shown in)

Domain:

CP5 Construction Element Plural

Range:

CP28 Building Feature

Subproperty of:

CP1 Built Entity. Pc4 shows building feature (building feature is shown in): CP28 Building Feature

Quantification:

Many to many, necessary, dependent (1,n:1,n)

Scope note:

This property documents that an instance of CP5 Construction Element Plural shows masonry features specified by an instance of CP28 Building Feature.
Pc19.1 *has type* can be used to specify the type of masonry features the CP5 Construction Element Plural is showing. For example, the eastern wall of the lower courtyard wall of the complex of St. Balbina in Rome (CP5) shows masonry feature that has type: opus reticulatum (E55).

Examples:

- the eastern wall of the church of St. Balbina (CP5) in Rome *shows masonry features* laying on horizontal layers (CP28) (KRAUTHEIMER 1937-77)
- the wall of the apse of the church of St. Balbina (CP5) in Rome *shows masonry features* shaping of the elements in blocks (CP28) (KRAUTHEIMER 1937-77)

In first-order logic:

Pc19(x,y) ⇒ CP5(x)

Pc19(x,y) ⇒ CP28(y)

Properties:

Pc19.1 has type: E55 Type

Pc20 shows building homogeneity with

Domain:

CP2 Architecture Work

Range:

CP2 Architecture Work

Subproperty of:

E70 Thing. P130 shows features of (features are also found on: E70 Thing

Quantification:

Many to many (0,n:0,n)

Scope note:

This property documents that an instance of CP2 Architecture Work shows building homogeneity with another instance of CP2 Architecture Work. Homogeneity may refer to the construction technique. This property is transitive, symmetric and reflexive.

Examples:

- the church of St. Balbina (CP2) in Rome *shows building homogeneity with* the St. Margherita Institute (CP2) (Bianchi, Coppola, Mutarelli 2014)
- Palazzo Comunale in piazza del Campo (CP2) in Siena *shows building homogeneity with* the addition (CP2) raised on the last floor centuries later.

In first-order logic:

Pc20(x,y) ⇒ CP2(x)

Pc20(x,y) ⇒ CP2(y)

Pc20(x,y) ⇒ P130(x,y)

Pc20(x,y) ⇒ Pc20(y,x).

Pc21 addressed (was addressed by)

Domain:

CP49 Urban Plan

Range:

CP45 Architecture Project

Subproperty of:

E1 CRM Entity. P70 is documented in (documents): E31 Document

Quantification:

One to many (0,n:0,1)

Scope note:

This property documents that an instance of CP49 Urban Plan addressed an instance of CP45 Architecture project. It aims to describe the relationship that exists between an urban plan and an architecture project that is normally subject to the former and conceived within the framework that the urban plan describes.

Examples:

- the Cathedral project (CP45) *was addressed by* Bernardo Rossellino urban plan (CP49) of Pienza (Siena, Italy) (Del Sole 2020)

- the Palazzo dei Diamanti project (CP45) *was addressed by* Biagio Rossetti urban plan of Ferrara (CP49) in the 15th century (ZEVI 2006)

In first-order logic:

Pc21(x,y) ⇒ CP49(x)

Pc21(x,y) ⇒ CP45(y)

Pc21(x,y) ⇒ P70(x,y)

Pc22 shows building-formal type (building-formal type is shown on)

Domain:

CP2 Architecture Work

Range:

CP35 Building-Formal Type

Subproperty of:

E1 CRM Entity. has type (is type of): E55 Type

Quantification:

Many to many, necessary, dependent (1,n:1,n)

Scope note:

This property documents that an instance CP2 Architecture Work shows a particular typology. This may be further specified whether the information concerns its distribution or its structural system (e.g. continuous, punctual).

Examples:

- the Ville Savoie (CP2) in Poissy (France) designed by Le Corbusier *shows building-formal type* frame structure (CP35) (TOURNIKIOTIS 2007)
- Palazzo dei Conservatori (CP2) *shows building-formal type* façade with a giant order (CP35) (DE ANGELIS D'OSSAT, PIETRANGELI 1965)

In first-order logic:

Pc22(x,y) ⇒ CP2(x)

Pc22(x,y) ⇒ CP35(y)

Pc22(x,y) ⇒ P2(x,y)

Pc23 was used by (made use of)

Domain:

CP9 Building Material

Range:

E11 Modification

Subproperty of:

E57 Material. P126 was employed in (employed): E11 Modification

Quantification:

Many to many, necessary (1, n:0,n)

Scope note:

This property identifies an instance of CP9 Building Material used by an instance of E11 Modification. E11 Modification commonly foresees the use of particular instances of CP9 Building Material. The modification realized to consolidate lime mortars, for example, requires ethyl silicate. This property enables this to be documented.

Examples:

- Aerial lime (CP9) and fine pozzolan (CP9) *were used by* the modification of the fountain in the Orto Botanico (E11) in Rome made by Ferdinando Fuga (Luzi, Sbardella 2015).
- Marble (CP9) was used by the modification of the terracotta floor of the St. Eufemia Basilica (E11) in Grado (Gorizia, Itay) (Foramitti 2010).

In first-order logic:

Pc23(x,y) ⇒ CP9(x)

Pc23(x,y) ⇒ E11(y)

Pc24 was subject to (occurred in)

Domain:

CP1 Bult Entity

Range:

CP25 Conservation Intervention

Subproperty of:

E70 Thing. P16i was used for (used specific object): E7 Activity

Quantification:

Many to one, necessary (1,1:0,n)

Scope note:

This property specifies the CP1 Built Entity that was subject to an instance CP25 Conservation Intervention. This property enables the documentation of the outcome of a conservation intervention. Conservation intervention realized in a building may also entail the modification of some features such as its internal distribution, the shape of some of its components (windows, roof, etc.), its function, without modifying its identity and with the aim of preserving it for the future.

Examples:

- the single lancet windows of the façade of the church of St. Balbina (CP2) in Rome *was subject to* the conservation intervention (CP25) by Antonio Muñoz in 1927 (BELLANCA 2003)
- the Rivoli Castel (CP1) (Torino, Italy) *was subject to* the conservation intervention (CP25) by Andrea Bruno (BRUNO 2001)

In first-order logic:

Pc24(x,y) ⇒ CP1(x)

Pc24(x,y) ⇒ CP25(y)

Pc24(x,y) ⇒ P16(x,y)

Pc25 is subject to (occurs in)

Domain:

CP1 Built Entity

Range:

CP25 Conservation Intervention

Quantification:

One to one, necessary (1,1:0,1)

Scope note:

This property identifies the building on which the intervention occurs at the moment of the documentation. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the floor of St. Maria delle Fortezze (CP1) in Viterbo (Italy) *is subject to*
- the conservation intervention planned by the Italian Ministry of Culture (CP25)
- the conservation intervention triggered by the fire in the wooden roof (CP25) *occurs in* the wooden roof of the church of Notre Dame (CP1) in Paris

In first-order logic:

Pc25(x,y) ⇒ CP1(x)

Pc25(x,y) ⇒ CP25(y)

Pc26 is illustrated by (illustrates)

Domain:

CP33 Architecture Conservation Project

Range:

CP38 Architecture Representation Object

Subproperty of:

E1 CRM Entity. P70 is documented in (documents): E31 Document

Quantification:

Many to many, necessary (1, n:0,n)

Scope note:

This property associates an instance of CP38 Architecture Representation Object with an instance of CP 33 Architecture Conservation Project and it makes it possible to relate the conservation project to the different levels of representation, that may concern either alphanumeric documents as the project report, bill of quantities or graphic documents.

Examples:

- the figure 22 in Fiorani 2003 (CP38) *illustrates* the conservation project of the façade of the church of St. Sebastiano and Rocco in San Vito Romano (Rome) (CP33)
- the architecture conservation project of the Domus Aurea (CP33) in Rome *is illustrated by* the video representation (CP38) settled in the octagon suite

In first-order logic:

P26(x,y) ⇒ CP33(x)

P26(x,y) ⇒ CP38(y)

Pc26(x,y) ⇒ P70(x,y)

Pc27 entails (is entailed by)

Domain:

CP25 Conservation Intervention

Range:

E11 Modification

Subproperty of:

E7 Activity. P17 motivated (was motivated by): E1 CRM Entity

Quantification:

One to many, necessary (1, n:0,1)

Scope note:

This property documents that a conservation intervention (CP25) has realised a modification (E11) on the building it has involved. It is useful to specify the kind of result obtained by the conservation intervention.

Examples:

- the conservation intervention realized on the façades of Palazzo Falconieri (CP25) in Rome *entails* a modification (E11) since it changed the colour of the plaster.
- the modification of the terracotta floor of the St. Eufemia Basilica (E11) in Grado (Gorizia, Italy) *is entailed by* the conservation intervention (CP25) (FORAMITTI 2010)

In first-order logic:

Pc27(x,y) ⇒ CP25(x)

Pc27(x,y) ⇒ E11(y)

Pc27(x,y) ⇒ Pc17(x,y)

Pc28 requires to be repeated within (temporally specifies the repetition of)

Domain:

CP23 Maintenance

Range:

E52 Time-Span

Subproperty of:

E2 Temporal Entity. P4 has time-span (is time-span of): E52 Time-Span

Quantification:

Many to many, necessary (1, n:0,n)

Scope note:

This property associates an instance of the class CP23 Maintenance with an instance of the E52 Time-Span class. It enables to document the time span that it is foreseen to be observed between two sequential maintenance interventions.

Examples:

- the removal of the biological patina from the Ferdinando Fuga fountain in the Orto Botanico (CP23) in Rome *requires to be repeated within* a year (E52) (MICHLE 2011)
- the close-up view of surfaces and possible dusting in St. Mary of Passion Basilica (CP23) in Milan *requires to be repeated within* six months (E52) (Maintenance plan 2021)

In first-order logic:

Pc28(x,y) ⇒ CP23(x)

Pc28(x,y) ⇒ E52(y)

Pc28(x,y) ⇒ P4(x,y)

Pc29 was adopted by (adopted)

Domain:

CP9 Building Material

Range:

E81 Transformation

Subproperty of:

E70 Thing. P16i was used for (used specific object): E7 Activity

Quantification:

One to many, necessary, dependent (1,n:1,n)

Scope note:

This property relates instances of E81 Transformation with instances of CP9 Building Material. It makes it possible to identify the materials employed within a transformation intervention as E81 Transformation necessarily adopts different materials. This property enables this to be documented.

Examples:

- Carrara marble (CP9) *was adopted by* the transformation intervention on Terme di Diocleziano (E11) in Rome by Michelangelo (Ackerman 1986)
- Bricks (CP9) were *adopted by* the transformation of the roman Domus Cilonis (E11) in Rome, that resulted in the church of St. Balbina (Bianchi, Coppola, Mutarelli 2014)

In first-order logic:

Pc29(x,y) ⇒ CP9(x)

Pc29(x,y) ⇒ E81(y)

Pc29(x,y) ⇒ Pc16i(x,y)

Pc30 resulted from (resulted in):

Domain:

CP1 Built Entity

Range:

E81 Transformation

Subproperty of:

E77 Persistent Item. P123i resulted from (resulted in): E81 Transformation

Quantification:

One to one (1, 1:1,1)

Scope note:

This property associates an instance of E81 Transformation with an instance of CP1 Built Entity. It aims at documenting the result of transformation interventions which may involve either a building or a part of it.

Examples:

- the church of St. Maria degli Angeli (CP1) in Rome *resulted from* The transformation by Michelangelo of the Diocletian Baths (E81) (ACKERMAN 1986)
- the complex of St. Maria Nova in Rome (CP1) *resulted from* the transformation of the western naos of the Venere and Roma Temple (E81) (DANTI 2011)

In first-order logic:

Pc30(x,y) ⇒ CP1(x)

Pc30(x,y) ⇒ E81(y)

Pc30(x,y) ⇒ P123i

Pc31 was transformed by (transformed)

Domain:

CP1 Built Entity

Range:

E81 Transformation

Superproperty of:

CP2 Architecture Work. Pc79i transformed (was transformed by): CP26 Typological Variation

Subproperty of:

E77 Persistent Item. P123i resulted from (resulted in): E81 Transformation

Quantification:

One to many, necessary (1,n:0,1)

Scope note:

This property associates an instance of E81 Transformation with an instance of CP1 Buit Entity. It allows all the interventions occurring on a building or part of it that have modified its identity to be described.

Examples:

- the Roman building (CP1) was *transformed* by the intervention of Michelangelo on the Diocletian Baths (E81) (Ackerman 1986)
- the temple built by Agrippa (CP1) in Rome was *transformed* by the intervention of Adrian on the Pantheon (E81) (Belardi 2006)

In first-order logic:

Pc31(x,y) ⇒ CP1(x)

Pc31(x,y) ⇒ E81(y)

Pc31(x,y) ⇒ P123i

Pc32 provided as output (was output for)

Domain:

CP32 Architecture Features Assessment

Range:

CP27 Architecture Analysis Output

Subproperty of:

E7 Activity. P20i had specific purpose (was purpose of): E5 Event

Quantification:

Many to many, necessary, dependent (1,n:1,n)

Scope note:

This property associates an instance of CP32 Architecture Features Assessment with an instance of CP27 Architecture Analysis Output. The outputs of the architectural analysis result from inferences as the assessments that orient the conservation project are not only based on data collection but require reasoning taking into account the architectural features of the building or the documentary sources existing on it. Inferences elaborated from the observation of architectural features provide as output the result of the architectural analysis.

Examples:

- the study of the masonries of the Palazzo Comunale (CP32) in Anagni (Frosinone, Italy) *provided as output* the masonry analysis output (CP 27) (Acierno 2013)
- the study of the typology of a monument (CP32) *provides as output* the comparative typological study (CP27) (fictitious)

In first-order logic:

Pc32(x,y) ⇒ CP32(x)

Pc32(x,y) ⇒ CP27(y)

Pc32(x,y) ⇒ P20i

Pc33 foresees (is foreseen by)

Domain:

CP33 Architecture Conservation Project

Range:

CP25 Conservation Intervention

Subproperty of:

E1 CRM Entity. P70 is documented in (documents): E31 Document

Quantification:

One to one (1,1:1,1)

Scope note:

This property associates an instance of CP25 Conservation Intervention with an instance of CP33 Architecture Conservation Project and it makes it possible to express the allographic nature of architecture and its conservation. The project itself is a subclass of E29 Design or Procedure while its realisation is conceived as a subclass of E7 Activity.

Examples:

- the conservation project for Neues Museum (CP33) in Berlin *foresees* the conservation intervention of plaster surfaces of the building (CP25) (BARNDT 2011)
- the architecture conservation project of the church of St. Sebastiano and Rocco (CP33) in San Vito Romano (Rome) *foresees* the conservation intervention of the façade (CP25) (FIORANI 2003)

In first-order logic:

Pc33(x,y) ⇒ CP33(x)

Pc33(x,y) ⇒ CP25(y)

Pc33(x,y) ⇒ P70(x,y)

Pc34 used as input (was input for)

Domain:

CP24 Architecture Conservation Project Activity

Range:

E13 Attribute Assignment

Subproperty of:

E7 Activity. P20i had specific purpose (was purpose of): E5 Event

Quantification:

One to many, necessary, dependent (1,n:1,1)

Scope note:

This property associates an instance of CP24 Architecture Conservation Project Activity with instances of E13 Attribute Assignment that act as a guideline for the conservation project. CP33 Architecture Conservation Project is elaborated moving from the CP27 Architecture Analysis Output carried out as during the architecture analysis which is compulsory to intervene on cultural heritage architecture. A use case of this property is to describe what elements, retrieved from the architecture analysis, have oriented the conservation project. As an example, within a conservation project activity the retrieval of an archival document, such an a historic survey, for example, may suggest and orient the reconstruction of a decoration that was totally lost due to the decay condition. In such a situation the architect develops a synthesis of the data emerged from the archival research that can be instantiated as E13 Attribute Assignment; this will be used as input for the conservation project activity that will foresee the reconstruction.

Examples:

- the conservation project activity of the Mascherone fountain in Monte Romano (CP24) *used as input* the synthesis of the results of the archival research (E13) developed at the National Archive in Rome (Archivio di Stato di Roma) (fictitious).
- the conservation project activity of the Ponte Sisto (CP24) in Rome *used as input* the historic report (E13) (Miarelli 1999)

In first-order logic:

Pc34(x,y) ⇒ CP24(x)

Pc34(x,y) ⇒ E13(y)

Pc34(x,y) ⇒ P20i

Pc35 is expressed in (expresses)

Domain:

CP24 Architecture Conservation Project Activity

Range:

CP33 Architecture Conservation Project

Subproperty of:

E1 CRM Entity. P70 is documented in (documents): E31 Document

Quantification:

One to one (1,1:1,1)

Scope note:

This property associates an instance of CP24 Architecture Conservation Project Activity with an instance of CP33 Architecture Conservation

Project and it makes it possible to distinguish between the activity of elaborating the conservation project and the document that represents the result of this activity which is the project itself. An instance of CP24 Architecture Conservation Project Activity in fact creates the condition for an instance of CP33 Architecture Conservation Project to be realised.

Examples:

- the conservation project activity (CP24) developed by the architect *is expressed in* the architecture conservation project (CP33) (fictitious)
- the study of the apartments transformation in Fendi Foundation building (CP24) in Rome *is expressed in* Fendi Foundation architecture conservation project (CP33) (ACIERNO 2020)
- the study of the history of the church of St. Sebastiano e Rocco (CP24) in San Vito Romano (Rome) *is expressed in* its architecture conservation project (CP33) (FIORANI 2003)

In first-order logic:

Pc35(x,y) ⇒ CP24(x)

Pc35(x,y) ⇒ CP33(y)

Pc35(x,y) ⇒ P70(x,y)

Pc36 addressed (was addressed by)

Domain:

CP24 Architecture Conservation Project Activity

Range:

CP25 Conservation Intervention

Subproperty of:

E7 Activity. P20i had specific purpose (was purpose of): E5 Event

Quantification:

One to one (1,1:1,1)

Scope note:

This property associates an instance of CP24 Architecture Conservation Project Activity with an instance of CP25 Conservation Intervention and it makes it possible to distinguish between the activity of elaborating the conservation project and the realisation of it. An instance of CP24 Architecture Conservation Project Activity Pc36 *addressed* an instance of CP25 Conservation Intervention which was realised by the construction company.

Examples:

- the activity for the development of the architecture conservation project on the Fontana dei Fiumi (CP24) *addressed* the conservation in-

tervention on the monument (CP25) in piazza Navona, Rome (Pandolfi 2012)
- the monitoring plan of the Patriarchate of Pec-Peje (CP24) *addressed* the conservation intervention (CP25) on the building (Fiorani 2010)

In first-order logic:

Pc36(x,y) ⇒ CP24(x)

Pc36(x,y) ⇒ CP25(y)

Pc36(x,y) ⇒ P20i

Pc37 complies with (binds)

Domain:

CP33 Architecture Conservation Project

Range:

E32 Authority Document

Subproperty of:

E1 CRM Entity. P70 is documented in (documents): E31 Document

Quantification:

One to many, necessary, dependent (1, n:1,1)

Scope note:

This property associates an instance of CP33 Architecture Conservation Project with an instance of E32 Authority Document and it makes it possible to associate the conservation project activity to the pertaining normative references. The conservation project activity on a listed building in Italy complies necessarily with the Legislative Decree no. 42/2004.

Examples:

- the architecture conservation project of the Pisa tower (CP33) *complies with* the UNESCO management plan (E32).
- the architecture conservation project of the of the church of St. Sebastiano e Rocco (CP33) in San Vito Romano (Rome) *complies with* the Italian Ministry Authorization report (Fiorani 2003).

In first-order logic:

Pc37(x,y) ⇒ CP33(x)

Pc37(x,y) ⇒ E32(y)

Pc37(x,y) ⇒ P70(x,y)

Pc38 specifies (is specified by)

Domain:

CP27 Architecture Analysis Output

Range:

CP9 Building Material

Subproperty of:

E7 Activity. P15 was influenced by (influenced): E1 CRM Entity

Quantification:

Many to many, necessary (1,n:0,n)

Scope note:

This property associates an instance of CP27Architecture Analysis Output with an instance of CP9 Building Material and it makes it possible to express which materials have been identified within the building material analysis. The specification of the material substantial is the result of an assessment and is considered as an output of the analysis process.

Examples:

- the architecture analysis output on the church of St. Ciriaco (CP27) in Ancona *specifies* Istria stone (CP9)
- the architecture analysis output on the façade of the church of St. Sebastiano e Rocco (CP27) in San Vito Romano (Rome) *specifies* different types (E55) of plasters (CP9) (FIORANI 2003)

In first-order logic:

Pc38(x,y) ⇒ CP27(x)

Pc38(x,y) ⇒ CP9(y)

Pc38(x,y) ⇒ Pc15(x,y)

Pc39 characterizes (is characterized by)

Domain:

CP1 Built Entity

Range:

CP18 Space Entity

Quantification:

Many to many (0,n:0, n)

Scope note:

This property associates an instance of CP1 Built Entity with an instance of CP18 Space Entity and makes it possible to describe what the connotative element of a historic centre or an urban area is. Connotative elements may be very heterogeneous, such as built towers or balconies or opus craticium walls.

Examples:

- the high towers (CP1) *characterise* the historic centre of San Gimignano (CP18) (Siena, Italy) since the Middle Ages
- the opus craticium walls (CP1) *characterize* Alsatian region (CP18) in France since the Middle Ages

In first-order logic:

P39(x,y) ⇒ CP1(x)

P39(x,y) ⇒ CP18(y)

Pc40 is facing onto (is the overlook of)

Domain:

CP2 Architecture Work

Range:

CP16 Urban Area

Quantification:

Many to many, dependent (0,n:1,n)

Scope note:

This property associates an instance of CP2 Architecture Work with an instance of CP16 Urban Area describing that a instance of the former class is facing onto an instance of the latter one. This property is necessary to express the physical relation that is established between a building and the space onto which it is facing through its façade. This relationship expresses the threshold role that is accorded to a façade between private and public space. It describes a twofold relationship, referring either to the connection that an observer may have with the outer space through a window looking outside or to the role that the building façade is playing as a backdrop for the urban space.

Examples:

- Palazzo Farnese (CP2) *is facing onto* Piazza Farnese in Rome (CP16)
- Palazzo Farnese (CP2) *is facing onto* via Giulia in Rome (CP16)

In first-order logic:

Pc40(x,y) ⇒ CP2(x)

Pc40(x,y) ⇒ CP16(y)

Pc41 shows as main material (is shown as main material)

Domain:

CP1 Built Entity

Range:

CP9 Building Material

Subproperty of:

E18 Physical Thing. P45 consists of (is incorporated in): E57 Material

Quantification:

Many to one, necessary (1,1:0,n)

Scope note:

This property associates an instance of CP1 Built Entity with an instance of CP9 Building Material and makes it possible to describe what is the principal material that can be observed in a building, or a part of it, aiming not to specify all the materials that have been used to build the edifice, but the one which is prevailing and directly observable by viewing. It refers explicitly to a building material (e.g. concrete, marble, etc.).

Examples:

- Palazzo dei Conservatori (CP2) in Rome *shows as main material* travertine (CP9) (DE ANGELIS D'OSSAT, PIETRANGELI 1965)
- the moulding of the window of Palazzo dei Conservatori (CP1) in Rome *shows as main material* travertine (CP9) (DE ANGELIS D'OSSAT, PIETRANGELI 1965)

In first-order logic

Pc41(x,y) ⇒ CP1(x)

Pc41(x,y) ⇒ CP9(y)

Pc41(x,y) ⇒ P45(x,y)

Pc42 was embodied by (embodied)

Domain:

CP1 Built Entity

Range:

CP1 Built Entity

Subproperty of:

CP1 Built Entity. Pc18 has physical relation with: CP1 Built Entity

Quantification:

Many to many (0,n:0,n)

Scope note:

This property associates an instance of CP1 Built Entity with an instance of CP1 Built Entity and makes it possible to describe the physical result of the modification a building went through. This property allows the physical entity that resulted from the activity of modifying a building or a part of it to be represented. This property is transitive, asymmetric, reflexive.

Examples:

- The Augustus temple (CP1) *was embodied by* St. Proculo Martire Cathedral (CP1) in Pozzuoli (Naples) (Pergoli Campanelli 2010)
- The temple of Antonino and Faustina (CP1) *was embodied by* the church of St. Lorenzo in Miranda (CP1) in Rome (Spera 2016)

In first-order logic:

Pc42(x,y) ⇒ CP1(x)

Pc42(x,y) ⇒ CP1(y)

Pc42(x,y) ⇒ Pc18(x,y)

Pc43 is used for (uses)

Domain:

CP1 Built Entity

Range:

E7 Activity

Quantification:

Many to many (0,n:0,n)

Scope note:

This property associates an instance of E7 Activity with an instance of CP1 Built Entity and makes it possible to describe the activity a building or a part of it is used for at the moment of the documentation. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- Palazzo Farnese (CP2, subclass of CP1) in Rome *is used for* institutional representation activity (E7)
- The ground floor of Palazzo Origo (CP1) in Rome *is used for* commercial activity (E7)

In first-order logic:

Pc43(x,y) ⇒ CP1(x)

Pc43(x,y) ⇒ E7(y)

Pc44 illustrates (is illustrated by)

Domain:

CP38 Architecture Representation Object

Range:

CP34 Architecture Depiction

Subproperty of:

E1 CRM Entity. P70 is documented in (documents): E31 Document

Quantification:

Many to many, necessary, dependent (1,n:1,n)

Scope note:

This property associates an instance of CP38 Architecture Representation Object with an instance of CP34 Architecture Depiction and allows the content of a graphic representation to be described.

Examples:

- the Fig. 9 in ACIERNO, BARATIN 2016 (CP38) *illustrates* the decay survey of the western side of the city walls (CP34)
- the Fig. 32 in CAPERNA 2014 p.44 (CP38) *illustrates* the plan survey of the church of St. Prassede (CP 34) in Rome

In first-order logic:

Pc44(x,y) ⇒ CP38(x)

Pc44(x,y) ⇒ CP34(y)

Pc44(x,y) ⇒ P70(x,y)

Pc45 has morphology type

Domain:

CP44 Construction Site

Range:

E55 Type

Subproperty of:

E1 CRM Entity. has type (is type of): E55 Type

Quantification:

One to many, necessary (1,1:0,n)

Scope note:

This property associates an instance of CP44 Construction Site with an instance of E55 Type. The property aims to describe the morphology of identifiable features, as they are described in CIDOC CRM, that “are physically attached in an integral way to particular physical objects or are portions of particular objects with partially imaginary borders, such as the core of the Earth, an area of property on the surface of the Earth, a landscape or the head of a contiguous marble statue". In architecture this property may be used to describe the morphology of the CP44 Construction Site, that is a subclass of E26 Physical Feature. It is conceived to represent the land involved in the construction, regardless of the construction consistency and nature. The morphology of the construction site may be documented either for a historic centre or for a building.

Examples:

- the site of Cortina d'Ampezzo (CP44) in Veneto (Italy) *has morphology type* mountainous (E55)
- the architectural site of San Francisco (CP44) in California *has morphology type* hilly (E55)

In first-order logic:

Pc45(x,y) ⇒ CP44(x)

Pc45(x,y) ⇒ E55(y)

Pc45(x,y) ⇒ P2(x,y)

Pc46 has geology type

Domain:

CP44 Construction Site

Range:

E55 Type

Subproperty of:

E1 CRM Entity. has type (is type of): E55 Type

Quantification:

One to many, necessary (1,1:0,n)

Scope note:

This property associates an instance of CP44 Construction Site with an instance of E55 Type. The property aims to describe the specific geological nature of an area of property on the surface of the Earth or a landscape involved in the built area. As for the morphology documentation, this may concern either historic centres or buildings.

Examples:

- The site of the Mascherone fountain (CP44) in Monte Romano (Viterbo, Italy) *has geology type* marly (E55)
- The Domus Aurea site (CP44) in Rome *has geology type* clay (E55)

In first-order logic:

Pc46(x,y) ⇒ CP44(x)

Pc46(x,y) ⇒ E55(y)

Pc46(x,y) ⇒ P2(x,y)

Pc47 has modified (was modified by)

Domain:

CP49 Urban Plan

Range:

CP49 Urban Plan

Subproperty of:

E29 Design or Procedure. P69 has association with (is associated with): E29 Design or Procedure

Quantification:

Many to many (0,n:0,n)

Scope note:

This property allows the modifications that may occur on an urban plan to be documented. This circumstance may be addressed either to describe modifications that may be needed during the urban designing process or as the result of later intervention. These modifications may be triggered by intrinsic or extrinsic factors that may have intervened also independently of the designer's will.

Examples:

- the urban plan of pope Paolo V (CP49) in Rome *has modified* the plan (CP49) of pope Sisto IV (FAGIOLO 2004)
- the urban plan of fascist regime (CP49) in Rome *has modified* the 16th century plan of the imperial forums area (CP49) (CEDERNA 2006)

In first-order logic:

Pc47(x,y) ⇒ CP49(x)

Pc47(x,y) ⇒ CP49(y)

Pc47(x,y) ⇒ P69(x,y)

Pc48 planned (was planned by)

Domain:

CP49 Urban Plan

Range:

CP16 Urban Area

Subproperty of:

E89 Propositional Object. P67i refers to (is referred to by): E1 CRM Entity

Quantification:

Many to many, necessary, dependent (1,n:1,n)

Scope note:

This property associates an instance of CP49 Urban Plan with an instance of CP16 Urban Area and it makes it possible to refer an urban area to an urban plan.

Examples:

- Borgo Sant'Angelo, the former Via Sistina (CP16) in Rome *was planned by* the plan of Sisto IV (CP49) (Tomei 1942, pp. 2,3)
- the Bernardo Rossellino's urban plan *planned* the central area (CP49) of Pienza (Siena, Italy) (Del Sole 2020)

In first-order logic:

Pc48(x,y) ⇒ CP49(x)

Pc48(x,y) ⇒ CP16(y)

Pc48(x,y) ⇒ P67i(x,y)

Pc49 was fostered by (fostered)

Domain:

CP43 Structural Damage

Range:

E3 Condition State

Quantification:

Many to many, necessary (1,n:0,n)

Scope note:

This property makes it possible to relate an instance of CP43 Structural Damage with an instance of E3 Condition State. It allows the conditions of a building or part of it that have fostered a structural damage to be described. The structural damage in fact may be caused by specific events or by special building conditions that may influence the decay phenomena. Those conditions may be referred either to an inadequate maintenance or to inappropriate interventions. For example, a defect in a roof, if not quickly repaired, could allow the presence of water that the structure might be unable to withstand. As a consequence, the building or part of it at first shows cracks and then collapses. Also, a superelevation of a building, if not adequately designed may provoke an excessive load on the masonry, generating cracks. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the cracks on the beams (CP43) *were fostered by* the state of the roof (E3). (fictitious)
- the cracks of the eastern façade (CP43) *were fostered by* the state of the building which was superelevated of a floor (E3) (fictitious)

In first-order logic:

Pc49(x,y) ⇒ CP43(x)

Pc49(x,y) ⇒ E3(y)

Pc50 incorporates (is incorporated in)

Domain:

CP33 Architecture Conservation Project

Range:

CP34 Architecture Depiction

Subproperty of:

E89 Propositional Object. P148 has component (is component of): E89 Propositional Object

Quantification:

One to many, necessary, dependent (1,n:1,1)

Scope note:

This property associates an instance of CP33 Architecture Conservation Project with an instance of CP34 Architecture Depiction. The property aims to describe the specificity of the conservation project that is conceived as a result of the gathering of several analyses that are normally represented through different architectural depictions.

Examples:

- the architecture conservation project of the Mascherone fountain (CP33) in Monte Romano (Viterbo, Italy) *incorporates* the drawings of the historic surveys (CP34) made in 18th century
- the architecture conservation project of the church of St. Sebastiano e Rocco (CP33) in San Vito Romano (Rome) *incorporates* the depiction of the typological study (CP34) (FIORANI 2003)

In first-order logic:

Pc50(x,y) ⇒ CP33(x)

Pc50(x,y) ⇒ CP34(y)

Pc50(x,y) ⇒ P148(x,y)

Pc51 is affected by (is generated on)

Domain:

CP9 Building Material

Range:

CP42 Material Decay

Quantification:

Many to many (0,n:0,n)

Scope note:

This property associates an instance of CP9 Building Material with an instance of CP42 Material Decay. The property aims to describe which is the material decay that affects the material constituing a particular physical object or part of it. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the globigerina of the city walls of La Valletta (CP9) in Malta *is affected by* weathering (CP42) (Acierno, Baratin 2016)
- the plaster of the Mascherone fountain (CP9) in Monte Romano (Viterbo, Italy) *is affected by* blistering (CP42)

In first-order logic:

Pc51(x,y) ⇒ CP9(x)

Pc51(x,y) ⇒ CP42(y)

Pc52 was assessed by (assessed)

Domain:

CP1 Built Entity

Range:

CP31 Mechanical Damage Assessment

Subproperty of:

E1 CRM Entity. P141i was assigned by (assigned): E13 Attribute Assignment

Quantification:

One to many, dependent (0,n:1,1)

Scope note:

This property associates an instance of CP1 Built Entity with an instance of CP31 Mechanical Damage Assessment. The property aims to describe which structural evaluation process refers to a particular building or part of it.

Examples:

- The Pisa tower (CP2) *was assessed by* Michele Jamiolkowski mechanical damage assessment (CP31), which established that the overturning could be maintained through the consolidation project (JAMIOLKOWKY, VIGGIANI 2007)
- The façade of the church of St. Antonio Abate at Introdacqua (CP2) (L'Aquila, Italy) *was assessed by* experts' evaluation (CP31) after the earthquake in 2009 (DONATELLI 2010)

In first-order logic:

Pc52(x,y) ⇒ CP1(x)

Pc52(x,y) ⇒ CP31(y)

Pc52(x,y) ⇒ P141i(x,y)

Pc53 has modified (was modified by)

Domain:

CP45 Architecture Project

Range:

CP45 Architecture Project

Subproperty of:

E29 Design or Procedure. P69 has association with (is associated with): E29 Design or Procedure

Quantification:

One to one (1,1:1,1)

Scope note:

This property makes it possible to relate two different instances of CP45 Architecture Project, allowing all the modifications that may occur during the constructive phases of an architecture project to be described. Often, an additional project is needed to modify the former as new circumstances may occur during the realisation.

Examples:

- the new Renzo Piano's architecture project of the Auditorium (CP45) in Rome, following discovery of a roman villa, *has modified* the original one (CP45)
- the new architecture project for the Villa near the river (CP45), triggered by the discovery of a groundwater, *has modified* the original one (CP45) (fictitious)

In first-order logic:

Pc53(x,y) ⇒ CP45(x)

Pc53(x,y) ⇒ CP45(y)

Pc53(x,y) ⇒ P69(x,y)

Pc54 planned (was planned by)

Domain:
CP45 Architecture Project

Range:

CP1 Built Entity

Subproperty of:

E89 Propositional Object. P67i refers to (is referred to by): E1 CRM Entity

Quantification:

One to one (1,1:1,1)

Scope note:

This property makes it possible to relate a project to a building or a part of it. Such a description is generally needed within the documentation of an architecture when it is necessary to distinguish the phases of the transformation that occurred, and more specifically the origin of the particular parts.

Examples:

- the Acropolis Museum (CP1) in Athens *was planned by* Bernard Tschumi's architecture project (CP45) (Bernard Tschumi Architets 2009)
- the Norman Foster's architecture project (CP45) *planned* the Reichstag glass dome (CP1) in Berlin (Foster 1999)

In first-order logic:

Pc54(x,y) ⇒ CP45(x)

Pc54(x,y) ⇒ CP1(y)

Pc54(x,y) ⇒ P67i(x,y)

Pc55 directed (was directed by)

Domain:
CP45 Architecture Project

Range:

CP46 Building Activity

Subproperty of:

E89 Propositional Object. P67i refers to (is referred to by): E1 CRM Entity

Quantification:

One to one (1,1:1,1)

Scope note:

This property associates an instance of CP45 Architecture Project to an instance of CP46 Building Activity to allow the description of the document the building activity is referring to. The architecture project in fact involves many different activities, not only describing the design but also giving practical instructions to make the realisation of the building possible, such as the executive drawings or the planning of the yard.

Examples:

- The building activity of the construction of St. Maria della Pace (CP46) in Rome *was directed by* the architecture project (CP45) of Pietro da Cortona (BENEDETTI et al. 2022)
- The Berlin Reichstag glass dome activity construction (CP46) *was directed by* the Norman Foster's architecture project (CP45) (FOSTER 1999)

In first-order logic:

Pc55(x,y) ⇒ CP45(x)

Pc55(x,y) ⇒ CP46(y)

Pc55(x,y) ⇒ P67i(x,y)

Pc56 was realised on (was subject to)

Domain:

CP46 Building Activity

Range:

CP1 Built Entity

Subproperty of:

E7 Activity. P15 was influenced by (influenced): E1 CRM Entity

Quantification:

Many to one, necessary (1,1:0,n)

Scope note:

This property makes it possible to relate a CP1 Built Entity to the CP46 Building Activity that has generated it. It is particularly useful when the documentation of a building or a part of it requires referring to the specific intervention that was at the origin of it.

Examples:

- the superelevation by Mario Ridolfi (CP46) *was realised on* Villino Alatri (CP1) designed by Manlio Morpurgo in via Paisiello in Rome (ALATRI 2022)

- the elevation of a concrete wall (CP46) *was realised on* the inner façade of the church of St. Balbina (CP2) in Rome (Caradonna 2024)

In first-order logic:

Pc56(x,y) ⇒ CP46(x)

Pc56(x,y) ⇒ CP1(y)

Pc56(x,y) ⇒ P15(x,y)

Pc57 shows decoration type (is decoration type of)

Domain:

CP7 Architecture Decoration

Range:

CP47 Decoration Type

Subproperty of:

E1 CRM Entity. P2 has type (is type of): E55 Type

Quantification:

Many to one, necessary, dependent (1, 1:1, n)

Scope note:

This property makes it possible to relate an instance of CP7 Architecture Decoration to an instance of CP47 Decoration Type and refers to the several thesauri that may be considered within an architectural description. The description of the decoration may refer to its material, formal or typological nature.

Examples:

- the Parthenos frieze (CP7) *shows decoration type* doric style (CP47)
- the frescoes of the Domus Aurea (CP7) in Rome *show decoration type* grotesque type (CP47)

In first-order logic:

Pc57(x,y) ⇒ CP7(x)

Pc57(x,y) ⇒ CP47(y)

Pc57(x,y) ⇒ P2(x,y)

Pc58 represents (is representation of)

Domain:

CP7Architecture Decoration

Range:

E1 CRM Entity

Subproperty of:

E24 Physical Human-Made Thing. P62 depicts (is depicted by): E1 CRM Entity

Quantification:

Many to many, necessary (1,n:0,n)

Scope note:

This property makes it possible to relate an instance of CP7 Architecture Decoration to an instance of E1 CRM Entity and aims to describe the contents its representation.

Examples:

- the Parthenos east frieze (CP7) *represents* the priestesses carrying the sacrificial instruments (E1)
- the frescoes in the inner façade of the church of St. Angelo in Formis (CP7) near Capua (Caserta, Italy) *represents* the Christ Pantocrator (E1)

In first-order logic:

Pc58(x,y) ⇒ CP7(x)

Pc58(x,y) ⇒ E1(y)

Pc58(x,y) ⇒ P62(x,y)

Pc59 shows equipment type (is equipment type of)

Domain:

CP8 Equipment

Range:

CP48 Equipment Type

Subproperty of:

E1 CRM Entity. P2 has type (is type of): E55 Type

Quantification:

Many to one, necessary (1,1:0,n)

Scope note:

This property makes it possible to relate an instance CP8 Equipment to an instance of CP48 Equipment Type and aims to specify the nature of the equipment referring to existing thesauri. Equipment a conservation project refers to may be of any kind hydraulic, electric, air conditioning, heating, etc.

Examples:

- the equipment realised in the Orti Farnesiani loggia (CP8) in Rome *shows equipment type* electric (CP48)

- the equipment realised in the Villa Adriana Baths (CP8) near Tivoli (Roma, Italy) *shows equipment type* heating (CP48)
- the equipment foreseen by Francesco Scoppola in palazzo Altemps (CP8) in Rome *shows equipment type* lighting (CP48) (Scoppola 1997)

In first-order logic:

Pc59(x,y) ⇒ CP8(x)

Pc59(x,y) ⇒ CP48(y)

Pc59(x,y) ⇒ P2(x,y)

Pc60 realised (was realised by)

Domain:

CP46 Building Activity

Range:

CP1 Built Entity

Subproperty of:

E7 Activity. P15 was influenced by (influenced): E1 CRM Entity

Quantification:

Many to one, necessary, dependent (1,1:1,n)

Scope note:

This property makes it possible to relate an instance CP46 Building Activity to an instance of CP1 Built Entity. It aims to identify the activity that produced the building or part of it, allowing all the activities connected to the yard, the providing of materials, the workers, etc. to be described.

Examples:

- the building activity directed by Michelangelo (CP46) *realised* the Biblioteca Laurenziana (CP1) in Florence between 1519 and 1534 (Ackerman 1986)
- the Basilica of Madonna dell'Umiltà (CP1) in Pistoia (Italy) *was realised by* the building activity (CP46) directed by Bartolomeo Ammannati between 1575-1585 (Fossi 1973)

In first-order logic:

Pc60(x,y) ⇒ CP46(x)

Pc60(x,y) ⇒ CP1(y)

Pc60(x,y) ⇒ P15(x,y)

Pc61 was affected by (was generated on)

Domain:

CP1 Built Entity

Range:

CP43 Structural Damage

Subproperty of:

E77 Persistent Item. P12i was present at (occurred in the presence of): E5 Event

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to relate an instance of CP1 Built Entity to an instance of CP43 Structural Damage. It aims to identify the structural damage that was produced in a building and specify which part of it was involved. It allows the structural condition within a decay analysis to be described.

Examples:

- the St. Balbina façade (CP1) in Rome *was affected by* out of plumb (CP43) (CARADONNA 2024)
- the eastern wall of the Mascherone fountain in Monte Romano (CP1) (Viterbo, Italy) *was affected by* cracks (CP43)

In first-order logic:

Pc61(x,y) ⇒ CP1(x)

Pc61(x,y) ⇒ CP43(y)

Pc61(x,y) ⇒ P12i(x,y)

Pc62 was caused by (caused)

Domain:

CP43 Structural Damage

Range:

E5 Event

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to relate an instance of CP 43 Structural Damage with an instance of E5 Event. It identifies which event was at the origin of a specific structural damage. This property is out of the

CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the diagonal crack in the façade of the church of St. Nicola (CP43) in Alba Vecchia (Aquila, Italy) *was caused by* the earthquake of 1915 (E5) (Donatelli 2009)
- the out of plumb of the façade of the church of St. Balbina (CP43) in Rome *was caused* by seabed subsidence (E5) (Caradonna 2024)

In first-order logic:

Pc62(x,y) ⇒ CP43(x)

Pc62(x,y) ⇒ E5(y)

Pc63 is crossed by (crosses)

Domain:

CP1 Built Entity

Range:

CP20 Construction Work

Subproperty of:

CP1 Built Entity. Pc18 has physical relation with: CP1 Built Entity

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to relate an instance of CP20 Construction Work to an instance of CP1 Built Entity. It aims to describe the relationship between a construction element and an architecture work or part of it when they are in a condition of mutual interference. In particular, this property makes it possible to describe the condition of a construction element intersecting a building or part of, as for example a lintel intersecting the apse of a church or a trace to realise electric system intersecting a wall.

Examples:

- the reinforced concrete frame (CP1) *crosses* the nave of the church of St. Angelo in Audoaldis (CP20) in Capua (Caserta, Italy)
- the reinforced concrete curb (CP1) *crosses* the wall of the church (CP20)

In first-order logic:

Pc63(x,y) ⇒ CP20(x)

Pc63(x,y) ⇒ CP1(y)

Pc63(x,y) ⇒ Pc18(x,y)

Pc64 is cladded by (clads)

Domain:

CP1 Built Entity

Range:

CP5 Construction Element Plural

Subproperty of:

CP1 Built Entity. Pc18 has physical relation with: CP1 Built Entity

Quantification:

One to many, dependent (0,n:1,1)

Scope note:

This property makes it possible to relate an instance of CP5 Construction Element Plural to an instance of CP1 Built Entity. It aims to describe the relationship between a construction element plural and a built entity, whether it is an architecture work or a part of it, describing the cladding function of the first towards the second.

Examples:

- the brick curtain (CP5) *clads* the Vitra Design Museum (CP1) in Weil am Rhein, Germany
- the plaster (CP5) *clads* the walls of the building (CP1) (fictitious)

In first-order logic:

Pc64(x,y) ⇒ CP51(x)

Pc64(x,y) ⇒ CP20(y)

Pc64(x,y) ⇒ Pc18(x,y)

Pc65 is delimited by (delimits)

Domain:

CP40 Historic Centre

Range:

E18 Physical Thing

Subproperty of:

E18 Physical Thing. P46 is composed of (forms part of): E18 Physical Thing

Quantification:

One to many (0,n:0,1)

Scope note:

This property makes it possible to relate an instance of CP40 Historic Centre to an instance of E18 Physical Thing and describe their topographical relationship. The property connects the CP40 Historic Centre class with E18 Physical Thing, which can represent a very broad condition so as to describe any kind of boundary a historic centre may have.

Examples:

- the historic centre of Rome (CP40) *is delimited by* the roman walls (CP1)
- a green belt (E18) *delimits* the Golden Horseshoe (CP1), in southern Ontario (Deaton, Vyn 2010)

In first-order logic:

Pc65(x,y) ⇒ CP40(x)

Pc65(x,y) ⇒ E18(y)

Pc65(x,y) ⇒P46(x,y)

Pc66 is defined by (defines)

Domain:

CP51 Building Component

Range:

CP20 Construction Work

Subproperty of:

E18 Physical Thing. P46 is composed of (forms part of): E18 Physical Thing

Quantification:

Many to many, necessary (1,n:0,n)

Scope note:

This property makes it possible to relate an instance of CP51 Building Component with an instance of CP20 Construction Work so as to describe their topographical relationship and the boundaries that a building component, such as a nave of a church, may have. The property refers to boundaries that are constituted by built elements or part of them.

Examples:

- the naos of the temple (CP51) *is defined by* walls (CP20) (fictitious)
- the central nave of St. Prassede (CP51) in Rome *is defined by* columns (CP20) (Caperna 2013).

In first-order logic:

Pc66(x,y) ⇒ CP1(x)

Pc66(x,y) ⇒ CP1(y)

Pc66(x,y) ⇒P46(x,y)

Pc67 shows as construction component (is construction component of)

Domain:

CP3 Construction Unit

Range:

CP4 Construction Component

Subproperty of:

E18 Physical Thing. P46 is composed of (forms part of): E18 Physical Thing

Quantification:

One to many, necessary (1,n:0,1)

Scope note:

This property makes it possible to relate an instance of CP3 Construction Unit with an instance of the class CP4 Construction Component to describe their specific mereological relation. The property aims to make explicit the components that are constituting the construction unit – for example, the façade of a church shows as construction component the wall.

Examples:

- the first floor of the central wing of the St. Balbina complex (CP3) in Rome *shows as construction component* some cross vaults (CP4) (BIANCHI, COPPOLA, MUTARELLI 2014)
- the roof of the church of St. Giovanni dei Falegnami (CP3) in Rome *shows as construction component* a wooden ceiling (CP4)

In first-order logic:

Pc67(x,y) ⇒ CP3(x)

Pc67(x,y) ⇒ CP4(y)

Pc67(x,y) ⇒P46(x,y)

Pc68 shows as construction element plural (is construction element plural of)

Domain:

CP4 Construction Component

Range:

CP5 Construction Element Plural

Subproperty of:

E18 Physical Thing. P46 is composed of (forms part of): E18 Physical Thing

Quantification:

One to many (0,n:0,1)

Scope note:

This property makes it possible to relate an instance of CP4 Construction Component with an instance of the class CP5 Construction Element Plural to describe their specific mereological relation. The property aims to make explicit the components that are constituting the construction component – for example, a wall, instance of CP4 Construction Component, *shows as construction element plural* the masonry and the plaster cladding it, both instances of CP5 Construction Element Plural.

Examples:

- the floor of the church of St. Menna in Sant'Agata de' Goti (CP4) (Caserta, Italy) *shows as construction element plural* a Cosmatesque flooring (CP5)
- the wall of the eastern wing of the St. Balbina complex (CP4) in Rome *shows as construction element plural* the opus reticulatum (CP5) as outer layer (Bianchi, Coppola, Mutarelli 2014)

In first-order logic:

Pc68(x,y) ⇒ CP4(x)

Pc68(x,y) ⇒ CP5(y)

Pc68(x,y) ⇒P46(x,y)

Pc69 shows as construction element singular (is construction element singular of)

Domain:

CP5 Construction Element Plural

Range:

CP6 Construction Element Singular

Subproperty of:

E18 Physical Thing. P46 is composed of (forms part of): E18 Physical Thing

Quantification:

Many to many, necessary, dependent (1,n:1,n)

Scope note:

This property makes it possible to relate an instance of CP5 Construction Element Plural with an instance of the class CP6 Construction Element Singular to describe their specific mereological relation. The property aims to make explicit the instances of CP6 Construction Element Singular that are constituting instances of CP5 Construction Element Plural – for example, the plaster shows as construction element singular the different layers of mortar, or a masonry shows as single construction elements the stone ashlars.

Examples:

- the plaster covering the walls of the church of St. Francesca Romana (CP5) in Rome *shows as construction element singular* porphyry marble powder outer plaster (CP6)
- the masonry of the apse of the church of St. Balbina (CP5) in Rome *shows as construction element singular* reused bricks (CP6) (KRAUTHEIMER 1937-77)

In first-order logic:

Pc69(x,y) ⇒ CP5(x)

Pc69(x,y) ⇒ CP6(y)

Pc69(x,y) ⇒P46(x,y)

Pc70 passes through (is crossed by)

Domain:

CP8 Equipment

Range:

CP20 Construction Work

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to relate an instance of CP8 Equipment with an instance of the class CP20 Construction Work to describe the condition of an equipment crossing any part of the building. Within conservation process in particular, this is a very sensitive condition that requires a major care, as ancient buildings may not bear their presence if they are not adequately designed. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the electric equipment (CP8) *passes through* the southern wall of the Horti Farnesiani building on the Palatine (CP20), Rome
- the rainfall catchment equipment (CP8) *passes through* the southern façade of the St. Balbina complex (CP20)

In first-order logic:

Pc70(x,y) ⇒ CP8(x)

Pc70(x,y) ⇒ CP20(y)

Pc71 is intrinsically connected to

Domain:

CP12 Building Floor

Range:

CP12 Building Floor

Subproperty of:

CP1 Built Entity. Pc18 has physical relation with: CP1 Built Entity

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to relate two instances of CP12 Building Floor to describe the condition of the connection between two floors. This property is not transitive, it is symmetric, reflexive.

Examples:

- the ground floor of palazzo Farnese (CP12) in Rome *is intrinsically connected to* first floor (CP12) through a stone ladder
- the floor of the roman aula (CP12*) is intrinsically connected to* the floor (CP12*)* of the medieval church of St. Saba in Rome

In first-order logic:

Pc71(x,y) ⇒ CP12(x)

Pc71(x,y) ⇒ CP12(y)

Pc71(x,y) ⇒ Pc18(x,y)

Pc72 shows geometry plan type (is geometry plan type of)

Domain:

CP13 Urban Unit

Range:

E55 Type

Subproperty of:

E1 CRM Entity. P2 has type (is type of): E55 Type

Quantification:

Many to one, necessary (1,1:0,n)

Scope note:

This property makes it possible to relate an instance of CP13 Urban Unit to an instance of E55Type in order to identify the geometry plan type of the building. The property is conceived to allow referring to thesauri describing the different geometries that are relevant not only for the formal reasons but mainly because they influence the structural vulnerability of the buildings.

Examples:

- the Royal Crescent (CP13) in Bath *shows geometry plan type* circular (E55)
- the Louvre Museum (CP13) in Paris *shows geometry plan type* rectangular (E55)

In first-order logic:

Pc72(x,y) ⇒ CP13(x)

Pc72(x,y) ⇒ E55(y)

Pc72(x,y) ⇒ P2(x,y)

Pc73 is facing onto (is the overlook of)

Domain:

CP2 Architecture work

Range:

CP15 Open Air Area

Superproperty of:

CP 16 Urban Area. Pc11 is bounded by (bounds): CP20 Construction Work CP2 Architecture Work. Pc40 is facing onto (is the overlook of): CP15 Open Air Area

Quantification:

Many to many (0,n:0,n)

Scope note:

This property associates an instance of CP2 Architecture work with an instance of CP15 Open Air Area and makes it possible to describe that a building is facing onto an area that is not an urban area. This property is necessary to express the physical relationship that is established between a building and the space onto which it is facing. It describes a twofold relationship that refers either to the connection that an observer may have with the external space through a window looking outside or to the role that the building façade plays as a backdrop for the open-air area. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the Aviary designed by Carlo Rainaldi (CP2) in 1688 *is facing onto* Villa Borghese (CP15) in Rome
- the Victor Hugo's row house (CP2) *is facing onto* Place des Voges (CP15) in Paris

In first-order logic:

Pc73(x,y) ⇒ CP2(x)

Pc73(x,y) ⇒ CP15(y)

Pc74 was caused by (caused)

Domain:

CP42 Material Decay

Range:

E5 Event

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to relate an instance of CP42 Material Decay to an instance of E5 Event in order to describe the event that may have caused the material decay. Although material decay is mostly triggered by environmental conditions, some events may occur that foster decay or trigger some specific deterioration. The property is mainly conceived to describe extraordinary events, such as earthquakes or flood events. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the flood event (E5) *caused* painted plaster blistering (CP42) on the building (fictitious)
- the water leakage (E5) derived by a damage in the gutter *caused* plaster blistering (CP42) on the building (fictitious)
- the crack on the marble of the façade of the church of St. Maria del Suffragio (CP42) in L'Aquila *was caused by* the earthquake of 2009 (E5) (Simone 2018)

In first-order logic:

Pc74(x,y) ⇒ CP42(x)

Pc74(x,y) ⇒ E5(y)

Pc75 can be referred to landscape element type (landscape element type can be referred to)

Domain:

CP17 Landscape Element

Range:

E55 Type

Subproperty of:

E1 CRM Entity. P2 has type (is type of): E55 Type

Quantification:

Many to many (1,n:0,n)

Scope note:

This property makes it possible to relate an instance of CP17 Landscape Element to an instance of E55 Type in order to describe the element. The Institutional Cultural Heritage Protection Lists and the Italian Cultural Heritage code provide thesauri specifying different types of landscape element such as parks, panoramic views, etc.

Examples:

- the area surrounding San Felice Circeo (CP17) (Latina, Italy) *can be referred to landscape element type* park (E55) (TOURING CLUB ITALIANO 1982)
- the Gianicolo park in Rome (CP17) *can be referred to landscape element type* panoramic view (E55) (PARATORE 2019)

In first-order logic:

Pc75(x,y) ⇒ CP17(x)

Pc75(x,y) ⇒ E55(y)

Pc75(x,y) ⇒ P2(x,y)

Pc76 is marked by (marks)

Domain:

CP40 Historic Centre

Range:

CP17 Landscape Element

Subproperty of:

E18 Physical Thing. P46 is composed of (forms part of): E18 Physical Thing

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to relate an instance of CP40 Historic Centre to an instance of CP17 Landscape Element in order to describe the features characterizing the urban landscape of a historic centre. Different types of landscape element could be parks, gardens, special viewpoints, panoramic views, etc.

Examples:

- the historic centre of Civita di Bagnoregio (CP40) (Viterbo, Italy) *is marked by* panoramic views (CP17) (Palazzetti 1998)
- the historic centre of Trento (CP40) (Italy) *is marked by* parks (CP17) (Bagnasco 2023)

In first-order logic:

Pc76(x,y) ⇒ CP40(x)

Pc76(x,y) ⇒ CP17(y)

Pc76(x,y) ⇒P46(x,y)

Pc77 has as space component (is space component of)

Domain:

CP21 Space Unit

Range:

CP22 Space Component

Subproperty of:

E92 Spacetime Volume. P10i Contains (falls within): E92 Spacetime Volume

Quantification:

One to many (0,n:1,1)

Scope note:

This property makes it possible to relate an instance of CP21 Space Unit to an instance of CP22 Space Component in order to describe the mereological relations between the elements that produce the spatial composition of an architecture work considering both dimensions of space and time. A space unit may be a unitary area or the result of the juxtaposition of several space components. For example, a church that shows *Hallenkirche* typology is conceived as a CP 21 Space Unit that cannot be further divided into spatial components. Besides, a three-nave church with an apse, is considered as an instance of CP21 Space Unit, which may be divided into several space components such as the central nave, the two aisles and the apse.

Examples:

- the church of St. Prassede (CP21) in Rome *has as space component* the central nave (CP22), the two aisles (CP22), the transept (CP22), the apse (CP22) (Caperna 2014)
- the Roman aula of the church of St. Saba (CP21) in Rome *has as space component* the apse (CP22) and the aula (CP22) from its creation to the beginning of 12th century (Cutarelli 2022)

In first-order logic:

Pc77(x,y) ⇒ CP21(x)

Pc77(x,y) ⇒ CP22(y)

Pc77(x,y) ⇒ Pc10i(x,y)

Pc78 is visually related to

Domain:

CP18 Space Entity

Range:

CP18 Space Entity

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to describe the relationship between two instances of CP18 Space Entity to specify whether there or not a visual continuity. For example, a chapel may be visually related to the aisle of a church or may be separated from it through a wall and placed into connection by means of a door. The property is conceived to express the relationship at the higher level of the hierarchy of the architecture spaces so as to describe all the possible spatial solutions occurring in a specific time. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the church of St. Maria del Popolo (CP18) in Rome *is visually related to* the Chigi chapel (CP18) currently (ZUCCARI, BARBIERI 2023)
- the apse of church of St. Andrea in Flumine (CP18) in Ponzano Romano (Rome, Italy) *is visually related to* the nave (CP18) from 11th century to 14th century (CANCELLIERI 2007)

In first-order logic:

Pc78(x,y) ⇒ CP18(x)

Pc78(x,y) ⇒ CP18(y)

Pc79 transformed (was transformed by)

Domain:

CP26 Typological Variation

Range:

CP2 Architecture Work

Subproperty of:

CP1 Built Entity. Pc31 was transformed by (transformed):E81 Transformation

Quantification:

One to one (1,1:1,1)

Scope note:

This property makes it possible to relate an instance of CP26 Typological Variation with an instance of CP2 Architecture Work to describe the kind of transformation that occurred in an architecture work. The typological variation implies the transformation of architecture identity, as it may take on the figurative, functional and structural issues that qualify a building.

Examples:

- The typological variation in Borgo (CP26) in Rome *transformed* two terraced houses in via di Campo Santo (CP2), became a residential unit for different families (Corsini 1998)
- The 18th century Della Riccia prince's Villa (CP2) in Airola (Benevento, Italy) *was transformed by* the typological variation (CP26) that turned it into a prison in 19th century (Ruggiero 2015)

In first-order logic:

Pc79(x,y) ⇒ CP26(x)

Pc79(x,y) ⇒ CP2(y)

Pc79(x,y) ⇒ Pc31

Pc80 is referred to (is referred to by)

Domain:

CP29 Building Phase

Range:

CP1 Built Entity

Subproperty of:

E14 Condition Assessment. P34 concerned (was assessed by): E18 Physical Thing

Quantification:

Many to many (1,n:0,n)

Scope note:

This property makes it possible to relate an instance of CP29 Building Phase with an instance of CP1 Built Entity to refer a building or part of it to the reconstruction of the transformation phases formulated through a study to assess its historic and architectural value. More in detail, the property makes it possible to specify which is the building phase the architecture may be referred to.

Examples:

- the porch of the church of St. Balbina (CP1) in Rome *is referred to by* the 15th century building phase (CP29) (BIANCHI COPPOLA MUTARELLI 2014)
- the 9th century building phase (CP29) *is referred* to the oratory found under the St. Saba church (CP1) in Rome (CUTARELLI 2019)

In first-order logic:

Pc80(x,y) ⇒ CP29(x)

Pc80(x,y) ⇒ CP1(y)

Pc80(x,y) ⇒ P34(x,y)

Pc81 planned the conservation of (was planned by)

Domain:

CP50 Urban Conservation Plan

Range:

CP16 Urban Area

Subproperty of:

E89 Propositional Object. P67i refers to (is referred to by): E1 CRM Entity

Quantification:

Many to many (1,n:0,n)

Scope note:

This property makes it possible to relate an instance of CP50 Urban Conservation Plan with an instance of CP16 Urban Area. It specifies the object of the urban conservation plan.

Examples:

- the conservation plan of Corinaldo (CP 50) (Ancona, Italy) *planned the conservation of* the municipal street called Le cento scale (CP16) (SERGI 2014)
- the conservation plan of San Salvo (CP 50) (Chieti, Italy) *planned the conservation of* Corso Garibaldi (CP16), focussing on the façades of the buildings facing onto it (<https://www.comunesansalvo.it/wp-content/uploads/2020/12/pianorecupero_centro_storico.pdf>)

In first-order logic:

Pc81(x,y) ⇒ CP50(x)

Pc81(x,y) ⇒ CP16(y)

Pc81(x,y) ⇒ P67i(x,y)

Pc82 assessed the structural condition of (was assessed in its structural condition by)

Domain:

CP30 Architecture Condition Assessment

Range:

CP2 Architecture Work

Subproperty of:

E14 Condition Assessment. P34 concerned (was assessed by): E18 Physical Thing

Quantification:

One to one, necessary (1,1:0,1)

Scope note:

This property makes it possible to relate an instance of CP30 Architecture Condition Assessment with an instance of CP2 Architecture Work, specifying the nature of the assessment the building or part of it is going through. In particular, the property refers to the structural assessment that may detect a structural damage.

Examples:

- the Fendi Foundation building in Rome (CP2) *was assessed in its structural condition by* the architecture condition assessment (CP30) developed by studio Croci (Acierno 2020)
- the Michele Jamiolkowski's architecture condition assessment (CP30) *assessed the structural condition of* the Pisa tower (CP2) in 1990 (Jamiolkowski, Viggiani 2007)

In first-order logic:

Pc82(x,y) ⇒ CP30(x)

Pc82(x,y) ⇒ CP2(y)

Pc82(x,y) ⇒ P34(x,y)

Pc83 assessed the decay condition of (was assessed in its decay condition by)

Domain:

CP30 Architecture Condition Assessment

Range:

CP9 Building Material

Subproperty of:

E14 Condition Assessment. P34 concerned (was assessed by): E18 Physical Thing

Quantification:

One to many (1,n:0,1)

Scope note:

This property makes it possible to relate an instance of CP30 Architecture Condition Assessment with an instance of CP9 Building Material, specifying the nature of the assessment the building is going through. In particular, the property refers to the decay condition of the building materials the architecture is made of.

Examples:

- the architecture condition assessment produced by the AStRe LabMat, Laboratory of Sapienza University of Rome (CP30) *assessed the decay condition of* the marble modelled for the Mascherone Fountain (CP9) in Monte Romano (Viterbo, Italy)
- the architecture condition assessment derived from the study of La Valletta city walls in 2016 (CP30) (Malta) *assessed the decay condition* of globigerina (CP9) (ACIERNO, BARATIN 2016)

In first-order logic:

Pc83(x,y) ⇒ CP30(x)

Pc83(x,y) ⇒ CP9(y)

Pc83(x,y) ⇒ P34(x,y)

Pc84 gathers (is gathered by)

Domain:

CP34 Architecture Depiction

Range:

CP27 Architecture Analysis Output

Subproperty of:

E1 CRM Entity. P70 is documented in (documents): E31 Document

Quantification:

One to many (1,n:0,1)

Scope note:

This property makes it possible to relate an instance of CP34 Architecture Depiction with an instance of CP27 Architecture Analysis Output. This property makes it possible to describe the nature of the class architectural depiction. It specifies its role within conservation process as a document that, gathering the results of the analysis that have been developed on the building, represents the knowledge required to orient a conservation project.

Examples:

- the project report (CP34) *gathers* the results of the masonry analysis and the building material analysis (CP27) (fictitious)
- the historic report developed for the conservation project of the church of St. Sebastiano e Rocco (CP34) in San Vito Romano (Rome) (CP33) *gathers* the results of the archival research (CP27) and the thematic studies (CP27) made in 2000-03 (Fiorani 2003)

In first-order logic:

Pc84(x,y) ⇒ CP34(x)

Pc84(x,y) ⇒ CP27(y)

Pc84(x,y) ⇒ P70(x,y)

Pc85 was subject to (was realised on)

Domain:

CP1 Built Entity

Range:

CP23 Maintenance

Subproperty of:

E70 Thing. P16i was used for (used specific object): E7 Activity

Quantification:

One to many (0,n:0,1)

Scope note:

This property makes it possible to relate an instance of CP1 Built Entity with an instance of CP23 Maintenance. This property makes it possible to describe that a building or part of it was the object of a maintenance activity. Differently from the conservation intervention, maintenance may be realised without a proper project, but just referring to a sequence of activities to be repeated in time.

Examples:

- the water stairway fountain from Ferdinando Fuga of Orto Botanico (CP1) in Rome *was subdued to* maintenance (CP23) (Michle 2011)
- the St. Anne chapel of the church of St. Maria della Passione (CP1) in Rome *was subdued to* maintenance (CP23) in 2021 (<https://09_Piano-di-manutenzione.pdf (beniculturali.it>)

In first-order logic:

Pc85(x,y) ⇒ CP1(x)

Pc85(x,y) ⇒ CP23(y)

Pc85(x,y) ⇒ P16i(x,y)

Pc86 addressed (was addressed by)

Domain:

CP50 Urban Conservation Plan

Range:

CP33 Architecture Conservation Project

Subproperty of:

E29 Design or Procedure. P69 has association with (is associated with): E29 Design or Procedure

Quantification:

One to many (0,n:0,1)

Scope note:

This property makes it possible to relate an instance of CP50 Urban Conservation Plan with an instance of CP33 Architecture Conservation Project addressing the hierarchical relationship existing between the urban and the architectural scale. The conservation activity developed at the urban level necessarily orients the conservation of the buildings.

Examples:

- The colour plan of Anagni (CP50) (Frosinone, Italy) *addressed* the architecture conservation project (CP33) of the façades facing onto corso Vittorio Emanuele (ERCOLANI 1986)
- The conservation plan of San Salvo (CP50) (Chieti, Italy) *addressed* the architecture conservation project (CP33) of the façades in Corso Garibaldi (ttps://www.comunesansalvo.it/wp-content/uploads/2020/12/pianorecupero_centro_storico.pdf)

In first-order logic:

Pc86(x,y) ⇒ CP50(x)

Pc86(x,y) ⇒ CP33(y)

Pc86(x,y) ⇒ P69(x,y)

Pc87 specified (was specified by)

Domain:

CP50 Urban Conservation Plan

Range:

CP49 Urban Plan

Subproperty of:

E29 Design or Procedure. P69 has association with (is associated with): E29 Design or Procedure

Quantification:

Many to one (0,1:0,n)

Scope note:

This property makes it possible to relate an instance of CP50 Urban Conservation Plan with an instance of CP49 Urban Plan addressing the hierarchical relationship existing between the urban planning and urban conservation planning. The former needs to be specified by the latter, and necessarily leaves some open issues that are addressed to by conservation.

Examples:

- the urban conservation plan of Maiori (CP50) (Salerno, Italy) developed in 2013 *specified* the Piano Regolatore Generale (CP49), focussing on the conservation interventions to be done in the historic centre of the town (<https://maiori.servizigis.it/Resources/Documenti/Modelli/MODULISTICA%20E%20NORME/NORME%20TECNICHE/Relazione%20Generale%20Piano%20di%20Recupero.pdfRIF>)
- the urban conservation plan of Corinaldo (CP50) (Ancona, Itay) *specified* the Piano Regolatore Generale (CP49) realised in 2006, identifying the historic building to be subject to a conservation intervention (Sergi 2014)

In first-order logic:

Pc87(x,y) ⇒ CP50(x)

Pc87(x,y) ⇒ CP49(y)

Pc87(x,y) ⇒ P69(x,y)

Pc88 is regulated by (regulates)

Domain:

CP16 Urban Area

Range:

E32 Authority Document

Subproperty of:

E1 CRM Entity. P70 is documented in (documents): E31 Document

Quantification:

Many to many, necessary (1,n:0,n)

Scope note:

This property documents that an instance of CP16 Urban area is regulated, from the legislative point of view, by an instance of E32 Authority Document, in the sense that every intervention performed on the area must follow the prescriptions expressed in the document.

The authority document may be a monumental constraint, an urban planning tool, etc. There is no case of an urban area not being under the control of a legislative authority.

Examples:

- Piazza Farnese in Rome (CP16) *is regulated by* Piano Regolatore Generale (E32)
- the via Castello Alessandro (CP16) in Monte Romano (Viterbo, Italy) *is regulated by* the building rules document (E32) approved by the Municipality in 2018

In first-order logic:

Pc88(x,y) ⇒ CP16(x)

Pc88(x,y) ⇒ E32(y)

Pc88(x,y) ⇒ P70(x,y)

Pc89 covers (is covered by)

Domain:

CP1 Built Entity

Range:

CP1 Built Entity

Subproperty of:

CP1 Built Entity. Pc18 has physical relation with: CP1 Built Entity

Quantification:

Many to many (0,n:0,n)

Scope note:

This property associates an instance of CP1 Built Entity with another instance of CP1 Built Entity documenting the physical relation of roofing existing between them. This property allows to describe the relation between the roof and the building it is covering and has not to be confused with the cladding role that is played by tiles, or plaster. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.
This property is transitive, not symmetric, irreflexive.

Examples:

- a light protective shelter (CP1) covers the archeological site (CP1) of Pianosa in Desenzano del Garda (fictitious)
- a dome (CP1) covers the Pantheon(CP1) (BELARDI 2006)

In first-order logic:

Pc89(x,y) ⇒ CP1(x)

Pc89(x,y) ⇒ CP1(y)

Pc89(x,y) ⇒ Pc18(x,y)

PART II

Using the Conservation Process Model
for historic centres and architectures

2. Modelling the Italian Risk Map with CPM and a task ontology

2.1. Introduction to CdRont

The Risk Map is one of the digital systems created and used by the Italian Ministry of Culture[1]. The GIS platform was designed with the objective of producing an objective and comparable assessment of the risk of loss of artistic, archaeological and architectural cultural heritage assets[2].

Risk assessment is related to the evaluation of the vulnerability of the cultural element and the hazard of the area where this element is located. This assessment is expressed by a value that relates to the result offered by the calculation of an algorithm. In turn, vulnerability and hazard are expressed by values related to numbers still produced by algorithms; these algorithms are designed following different criteria depending on the type of artifact and danger we are considering.

Vulnerability assessment, in particular, is the product of qualitative and quantitative observations regarding existing heritage. Such observations are particularly numerous in reference to architectural heritage, whose complexity requires more detailed observation of formal, constructional, structural and material features.

The use of an ontological model for the Risk Map system makes it possible to transfer data to other digital systems, amplifying the overall information power of IT applied to cultural heritage. Such use requires, however, that the data collected within the GIS have to be linked together to be effective. Most of the documentation required by the Risk Map survey can be modelled through CPM and CIDOC CRM classes and properties, although part of it entails excessively specific information that has required the building of a task ontology named CdRont[3]. The in-depth study of the domain that has preceded the building of the ontology was included in the Risk Map guidelines that were used as a main reference[4].

Data modelled by CdRont are mostly related to numerical specifications required by the Risk Map survey to elicit both architectural description and vulnerability as-

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1 <http://www.cartadelrischio.beniculturali.it>.

2 For more on the Risk Map, see Baldi 1998; Carta del Rischio 1996; Accardo, Giani, Giovagnoli 2003; Cacace 2019; Fiorani et al. 2019; Fiorani et al. 2020.

3 We refer to task ontology in the sense clarified in Guarino 1998, ps 8-9.

4 Historic centre Risk Map guidelines were published in Fiorani et al. 2022, 2023.

sessments. These data, although rarely reusable in other contexts, gather into the algorithm processing that generates assessment indexes. Moreover, a large part of the Risk Map modelling relies on vocabularies, most of which have been specifically customized for it. Therefore, to manage this hybrid condition that requires, on the one hand being grounded to the architecture heritage conservation domain and on the other hand dealing with specific data, a task ontology was built describing the specific activity of Risk Map and integrating CPM. Although this should not lead to thinking that Risk Map processing can be reduced to a simple procedure, this solution proved to be suitable as it has allowed to model specific data, to anchor them in a wider domain and to refer to a standard ontology as CIDOC CRM[5]. For example, some numeric data, as the percentage of buttressed walls existing in a building (Pr23 *has percentage of buttressed walls*), the use of which may appear very restricted, could be shared with other contexts, like a structural survey. In the meantime, vocabularies necessarily refer to CIDOC CRM E 55 Type classes. To enable this integration condition, a particular attention was given to the mapping between CdRont, CPM and CIDOC CRM.

CdRont collects 11 classes and 49 properties, most of them dedicated to calculating the values used and produced by the algorithms. The 11 classes are all subclasses of CIDOC CRM classes. To account for the mapping, three of them, CR8 CdR Built Entity, CR11 CdR Historic Centre and CR10 Space Entity, are mirror classes of CPM classes CP1 Built Entity, CP40 Historic Centre and CP18 Space Entity, respectively. Each pair of classes belonging to the two different ontologies is related by the "is a" relationship. This allows multiple subclasses to be included in the domain and range connected by CdRont properties.

This possibility is particularly important for the CR8 CdR Built Entity class, which is related to the CIDOC CRM class E60 Number through 29 different properties. These properties may concern the number of storeys or construction/functional aspects considered important to calculate the level of vulnerability and transformation of an urban or building unit or spatial area (see, among the others, Pr15 *has number of building voids* or Pr17 *has number of architectural fronts on urban area*). They can also consider the presence or the characteristics of specific components, which condition the state of the urban or building unit (e.g. Pr1 *has total number of storeys* or Pr24 *has number of inner windows/doors*). Lastly, they may express some significant percentage, such as Pr19 *has percentage of thrusting extension*, Pr22 *has percentage of thin walls* or P23 *has percentage of buttressed walls*.

As is to be expected, CR8 CdR Entity is the class with the largest number of properties. In addition to those already mentioned, two of them allow dimensions to be specified, also related to a CIDOC CRM class E54 Dimension. These properties are Pr28 *shows resistant areas towards X direction* and Pr29 *shows resistant areas towards Y direction*. Four other properties connect CR8 CdR Entity with the CIDOC CRM class E7 Activity: Pr34 *has generic function (is generic function of)*; Pr35 *has specific function (is specific function of)*; Pr36 *has specific function at ground level (is specific function at ground level of)*; Pr37 *has specific function at upper level (is specific function at upper level of)*. Lastly, CR8 CdR Entity is linked to the CIDOC CRM class E31 Document through the properties Pr42 *is totally documented in (totally documents)* and Pr43 *is partly documented in (partly documents)*.

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[5] To better understand the relations between the ontologies employed the reader may refer to the schema proposed by Nicola Guarino considering CIDOC CRM as a 'Top level ontology' and CPM and CdRont as a 'domain' and 'task' ontology (GUARINO 1997, 1998).

In three cases, CdRont properties relate the CR8 CdR Built Entity with other CdRont classes. The class CR11 CdR Historic Centre is related with the CIDOC CRM class E18 Physical Thing via two properties Pr38 *is totally characterized by (totally characterises)* and Pr39 *is partly characterized by (partly characterises)*.

CP18 Space Entity is specified through three properties, two of which with range the CIDOC CRM class E31 Document – Pr40 *is totally documented in (totally documents)* and Pr41 *is partly documented in (partly documents)* –, while the other linked to the CIDOC CRM class E60 Number – Pr45 *are in number of.*

The relationships of these three CdRont classes with five CIDOC CRM classes define 42 out of 49 total CdRont properties, making it possible to formalize quantitative data or data inherent in the comprehensiveness of documentation, general or specific functional uses, and the relationship of the built environment to physical objects of various kinds. These are very specific relationships that refer to data collected from the Risk Map system, which are difficult to extend outside of this digital context.

In order to account for the main output of the Risk Map survey, namely the information that allows the vulnerability and risk calculation algorithm, three subclasses of the CIDOC CRM E73 Information Object class have been formalized in CdRont: CR1 CdR Index, CR2 CdR Ratio and CR3 CdR Check Factor. These three classes collect data expressing vulnerability values, accessibility of information, "incidences" – proportionality between different parts of the building with dissimilar characteristics – and the presence/absence or adequacy/inadequacy of data per se. The CdRont CdR8 Built Entity class is linked to the last two classes with specific properties: Pr30 *shows CdR ratio (is referred to)* and Pr31 *shows CdR check factor (is referred to)* respectively.

Four CdRont classes refer to assessment activity, again considering a very specialized mode of appraisal. The formalization of two new subclasses of E13 Attribute Assignment, CR7 CdR Assessment and CR6 Index Calculation Event, recalls two different types of evaluation. In the first case (CR7 CdR Assessment), again dealing with a very specialized form of assessment, one assesses the effectiveness or the building phase of a construction component – respectively instantiated in the subclasses of CR7 CdR Assessment subclasses named CR4 Effectiveness Assessment and CR5 Building Phase. In the second case (CR6 Index Calculation Event), the evaluation is expressed as a calculation event of the Risk Map indices[6]. CR7 CdR Assessment is specified through two properties, inherited by its two subclasses, Pr49 *has type of reliability*, relating with the CIDOC CRM E55 Type, so to allow the level of data reliability to be specified, and Pr32i *assessed (was assessed by)*, linking with CR8 Built Entity[7].

Both subclasses CR4 Effectiveness Assessment and CR5 Building Phase have an additional single property relating to the class CR8 Built Entity: they are respectively Pr47i *assessed effectiveness of (has effectiveness assessed by)* and Pr48i *assessed coherence to building phase to (has coherence to building phase assessed by)*. CR6 Index

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[6] A specific in-depth study on the modelling of the risk of loss of cultural property was conducted by the authors with Anais Guillem and Athanasis Velios, taking into consideration, in addition to the model proposed by the Italian Risk Map system, further proposals put forward especially in the European context. This formalization, which made use of the CIDOC CRM ontology and its extensions, in particular CRMinf, was presented at the 58th CIDOC CRM & 51st FRBR/LRMoo CRM Sig held in Paris in March 2024. Pending publication of this work, it was preferred here to model the specific classes using the CdRont purpose ontology.

[7] The importance of documenting 'reliabiliy' of evidence interpretation in archaeology and in heritage science was discussed in Niccolucci 2016.

Calculation Event has its propriety Pr33 *provides as output (is an output of)* relating with CR1 CdRont Index.

The last class of CdRont is very specific: the CR9 Inhabitants, subclass of the CIDOC CRM class E74 Group, allows the instantiation of inhabitants of a built environment and is related to the class E60 Number through the property Pr27 *are in number of*.

Risk Map modelling pursued a dual aim. On the one hand enhancing of Risk Map interoperability, and on the other hand accounting for a bottom-up modelling within a structured domain while further exploring the interlinking between operational scopes and scientific research. Such an attempt is elicited by the urgent demand, to strengthen full sharing of information between different operational levels, but also to foster a major awareness within the building of knowledge-based models avoiding overproduction. Although research on risk modelling for cultural heritage is currently widely addressed[8] what we are hopefully pursuing is the possibility to connect scientific research to operational and institutional contexts.

2.2. CdRont Class and Property hierarchy

CdRont Class Hierarchy

E1	CRM Entity
E2	- Temporal Entity
E3	- - Condition State
E4	- - Period
E5	- - - Event
E7	- - - - Activity
E13	- - - - - Attribute Assignment
CR7	- - - - - - CdR Assessment
CR4	- - - - - - - Effectiveness Assessment
CR5	- - - - - - - Building Phase
I5	- - - - - - Inference Making
CR6	- - - - - - - Index Calculation Event
E92	- Spacetime Volume
CR10	- - CdR Space Entity
E77	- Persistent Item
E39	- - Actor
E74	- - - Group
CR9	- - - - Inhabitants
E70	- - Thing
E72	- - - *Legal Object*
E18	- - - - Physical Thing
E24	- - - - - Physical Human-Made Thing
CR8	- - - - - - CdR Built Entity
CR11	- - - - - - CdR Historic Centre
E72	- - - Legal Object
E90	- - - - Symbolic Object
E73	- - - - - Information Object
CR1	- - - - - - CdR Index
CR2	- - - - - - CdR Ratio
CR3	- - - - - - CdR Check Factor

8 The scientific literature broadly addresses risk modelling within cultural heritage, but not especially through ontologies applied to architecture cultural heritage; nonetheless, a recent contribution is provided by SALAZAR, FIGUEIREDO, ROMAO 2024.

CdRont Property Hierarchy

Property ID	Property Name	Entity – Domain	Entity – Range
Pr1	has total number of storeys	CR8 CdR Built Entity	E60 Number
Pr2	has current use percentage	CR8 CdR Built Entity	E60 Number
Pr3	has number of ground level entrances	CR8 CdR Built Entity	E60 Number
Pr4	has number of underground storeys	CR8 CdR Built Entity	E60 Number
Pr5	has number of surveyable Building Units	CR8 CdR Built Entity	E60 Number
Pr6	has residential use percentage	CR8 CdR Built Entity	E60 Number
Pr7	has number of connected urban units	CR8 CdR Built Entity	E60 Number
Pr8	has number of assumed floors	CR8 CdR Built Entity	E60 Number
Pr9	has number of cladded floors	CR8 CdR Built Entity	E60 Number
Pr10	has number of residential real estate units	CR8 CdR Built Entity	E60 Number
Pr11	has number of not residential real estate units	CR8 CdR Built Entity	E60 Number
Pr12	has maximum number of storeys over ground level	CR8 CdR Built Entity	E60 Number
Pr13	has minimum number of storeys over ground level	CR8 CdR Built Entity	E60 Number
Pr14	has number of modern replacement building units	CR8 CdR Built Entity	E60 Number
Pr15	has number of building voids	CR8 CdR Built Entity	E60 Number
Pr16	has number of storeys over ground level	CR8 CdR Built Entity	E60 Number
Pr17	has number of building fronts on urban area	CR8 CdR Built Entity	E60 Number
Pr18	has number of inner building fronts	CR8 CdR Built Entity	E60 Number
Pr19	has percentage of thrusting extensions	CR8 CdR Built Entity	E60 Number
Pr20	has percentage of partly thrusting extensions	CR8 CdR Built Entity	E60 Number
Pr21	has percentage of deformable extensions	CR8 CdR Built Entity	E60 Number
Pr22	has percentage of thin walls	CR8 CdR Built Entity	E60 Number
Pr23	has percentage of buttressed walls	CR8 CdR Built Entity	E60 Number
Pr24	has number of inner windows/ doors	CR8 CdR Built Entity	E60 Number
Pr25	has number of outer windows/ doors	CR8 CdR Built Entity	E60 Number
Pr26	has number of semi-basements and mezzanines	CR8 CdR Built Entity	E60 Number
Pr27	are in number of	CR9 Inhabitants	E60 Number
P43	has dimension (is dimension of)	E70 Thing	E54 Dimension
Pr28	- shows resistant areas towards X direction	CR8 CdR Built Entity	E54 Dimension
Pr29	- shows resistant areas towards Y direction	CR8 CdR Built Entity	E54 Dimension
P67i	is referred to by (refers to)	E1 CRM Entity	E89 Propositional Object
Pr30	- shows CdR ratio (is referred to)	CR8 CdR Built Entity	CR2 CdR Ratio
Pr31	- shows CdR check factor (is referred to)	CR8 CdR Built Entity	CR3 CdR Check Factor

PROPERTY ID	PROPERTY NAME	ENTITY – DOMAIN	ENTITY – RANGE
Pr32	- was assessed by (assessed)	CR8 CdR Built Entity	CR7 CdR Assessment
Pr33	- provides as output (is an output of)	CR6 Index Calculation Event	CR1 CdR Index
Pr34	has generic function (is generic function of)	CR8 CdR Built Entity	E7 Activity
Pr35	has specific function (is specific function of)	CR8 CdR Built Entity	E7 Activity
Pr36	has specific function at ground level (is specific function at ground level of)	CR8 CdR Built Entity	E7 Activity
Pr37	has specific function at upper level (is specific function at upper level of)	CR8 CdR Built Entity	E7 Activity
P46	is composed of (forms part of)	E18 Physical Thing	E18 Physical Thing
Pr38	- is totally characterized by (totally characterises)	CR11 CdR Historic Centre	E18 Physical Thing
Pr39	- is partly characterized by (partly characterises)	CR11 CdR Historic Centre	E18 Physical Thing
P70i	is documented in (documents)	E1 CRM Entity	E31 Document
Pr40	- is totally documented in (totally documents)	CR10 CdR Space Entity	E31 Document
Pr41	- is partly documented in (partly documents)	CR10 CdR Space Entity	E31 Document
Pr42	- is totally documented in (totally documents)	CR8 CdR Built Entity	E31 Document
Pr43	- is partly documented in (partly documents)	CR8 CdR Built Entity	E31 Document
Pr44	are in number of	CR8 CdR Built Entity	E60 Number
Pr45	are in number of	CR10 CdR Space Entity	E60 Number
Pr46	shows number of artworks	CR8 CdR Built Entity	E60 Number
P141i	was assigned by (assigned)	E1 CRM Entity	E13 Attribute Assignment
Pr47	- has effectiveness assessed by (assessed effectiveness of)	CR8 CdR Built Entity	CR4 Effectiveness Assessment
Pr48	- has coherence to building phase assessed by (assessed coherence to building phase to)	CR8 CdR Built Entity	CR5 Building Phase
P2	has type	E1 CRM Entity	E55 Type
Pr49	has type of reliability	CR7 CdR Assessment	E55 Type

2.3 CdRont Class declarations

CR1 CdR Index

Subclass of: E73 Information Object

Scope note:

This class includes instantiations that define various indices calculated by the Risk Map algorithms. These indices express the different levels of transformation, vulnerability, hazard and risk related to classes and subclasses of CR11 Historic Centre and CR8 Built Entity.

Examples:

- the CdR index derived by the index calculation event on the façade of Palazzo Chigi in Rome (fictitious)
- the CdR index derived by the index calculation event on St. Maria della Luce in Rome

In first-order logic:

CR1(x) ⇒ E73(x)

Properties:

Pr33i is an output of (provides as output): CR6 Index Calculation Event

CR2 CdR Ratio

Subclass of: E73 Information Object

Scope note:

This class includes instantiations of incidences and 'confidence factors' calculated for the Risk Map algorithms.

The confidence factors define the accessibility of information for the Risk Map concerning subclasses of CR8 Built Entity. It is determined by the proportionality between the number of observable storeys and the total number of storeys considered. This accessibility may be influenced by the actual possibility of carrying out thorough inspections or by the presence of elements – such as plaster or greenery – that prevent full visibility of the built environment. In other terms, the confidence factors allow the indices of the Risk Map to be appropriately calibrated in consideration of the different conditions in which buildings or building components are surveyed.

The incidences express the proportionality between the number of parts of the built environment affected by specific construction or degradation characteristics and the total number of parts (generally storeys or construction components) that make up the built environment considered, represented by subclasses of CR8 Built Entity. In a few cases, the class includes the instantiation of incidences whose value is predefined by the Risk Map guidelines.

The Risk Map examines the following incidences referring to urban unit-aggregates: empty volumes; distribution of empty volumes; open hallways; replaced modern building units; empty volumes; voids over full volumes. Other incidences referring to urban unit-aggregates and urban unit-punctual residential or specialistic building are: modern building elements of transformation; replaced modern building units; unsupervised storey elevations and additions; modern replacements; modern repairs; modern replacement of plaster or cladding; modern replacement of external doors and windows; vertical juxtapositions between traditional and modern building elements; horizontal overlaps between traditional and modern building elements; masonry construction discontinuities; structural damage; deterioration of surfaces; degradation of roofs.

The Risk Map examines the following incidences referring to urban spaces: modern floors, elements of urban design; green area; historic green area; compatible lighting systems; surface degradation over the fronts; structural damages over the fronts; damage on horizontal planes: damage on floors; decay of lighting systems; decay of stairs or ramps.

The incidences indicated by the Risk Map at the scale of the building units are: modern distribution changes; modern transformation in space and volumes; transformation of staircases; modern structural modifications; modern structural transformations; replacements of historic floors. Other incidences both for building units and building fronts are: modern unsupervised storey elevations and additions; replacements of historic plasters and claddings; replacements of historic doors and windows.

Lastly, the incidences indicated by the Risk Map for the building fronts are: structural modifications; modern non-structural modifications; replacement of historic decorations; modern equipment.

Examples:

- the information availability of the urban unit aggregate no. 2 in Ciciliano (Rome, Italy)
- the incidence of modern building element of transformation in the building unit no. 2a in Ciciliano (Rome, Italy)
- the incidence of modern reparations in the building unit no. 2a in Ciciliano (Rome, Italy)

In first-order logic:

$CR2(x) \Rightarrow E73(x)$

Properties:

Pr30i is referred to (shows CdR ratio): CR8 CdR Built Entity

CR3 CdR Check Factor

Subclass of: E73 Information Object

Scope note:

This class defines the presence/absence or the adequacy/inadequacy of instantiations concerning subclasses of CR8 Built Entity in a building unit.

Examples:

- the check factor related to the presence of plaster over the Royal Crescents in Bath
- the check factor expressing the adequacy of the equipment in Palazzo Barberini in Rome

In first-order logic:

CR3(x) ⇒ E73(x)

Properties:

Pr31i is referred to (shows CdR check factor): CR8 CdR Built Entity

CR4 Effectiveness Assessment

Subclass of: CR7 CdR Assessment

Scope note:

This class includes instantiations that define the effectiveness of built elements (instantiated in class CR8 Built Entity and its subclasses). This definition of effectiveness is stated in a conventional manner, as illustrated in the Risk Map Guidelines.

Examples:

- the effectiveness assessment referred to the water disposal system in palazzo Venezia in Rome
- the effectiveness assessment referred to the covering of St. Marco in Venice

In first-order logic:

CR4(x) ⇒ CdR7(x)

Properties:

Pr47i is referred to (has effectiveness assessed by): CR8 CdR Built Entity

CR5 Building Phase

Subclass of: CR7 CdR Assessment

Scope note:

This class includes instantiations that define the construction phase of building components with reference to the different building phases of the historic façade they are part of.

Examples:

- the baroque building phase of the window frames in the façade of Palazzo Falconieri in Rome
- the last 20^{th} building phase of the white painting of the plaster in the façade of Palazzo Falconieri in Rome

In first-order logic:

CR5(x) ⇒ CdR7(x)

Properties:

Pr48i assessed coherence to building phase to (has coherence to building phase assessed by)

CR6 Index Calculation Event

Subclass of: I5 Inference Making

Scope note:

This class includes instantiations related to the calculation of instantiations of CR1 CdR Index in the Risk Map.

Examples:

- the index calculation event for the CdR index related to the façade of Palazzo Chigi in Rome (fictitious)
- the index calculation event for the CdR index related to St. Maria della Luce in Rome

In first-order logic:

CR6(x) ⇒ I5(x)

Properties:

Pr33 provides as output (is an output of): CR1 CdR Index

CR7 CdR Assessment

Subclass of: E13 Attribute Assignment

Superclass of:

CR4 Effectiveness Assessment; CR5 Building Face

Scope note:

This class comprises instantiations expressing evaluations of a different nature on built elements (instantiated in the CR8 Built Entity class and its subclasses).

Examples:

- the effectiveness assessment related to the water disposal system in palazzo Venezia in Rome (fictitious)
- the coherence assessment to the baroque building phase of the window frames in the façade of Palazzo Falconieri in Rome (fictitious)

In first-order logic:

CR7(x) ⇒ E13(x)

Properties:

Pr32i assessed (was assessed by): CR8 CdR Built Entity
Pr49 has type of reliability: E55 Type

CR8 CdR Built Entity

Subclass of: E24 Physical Human-Made Thing

Scope note:

This class comprises instances of human-made things such as free-standing buildings, construction units, construction components, construction elements, and complexes of buildings. It refers to human-made environments serving a practical purpose, being relatively permanent and stable.
The CdR ont class CP8 CdR Built Entity is equivalent to the CPM class CP1 Built Entity. As such, it also relates to the subclasses of CP1 Built Entity: CP2 Architecture Work; CP20 Construction Work as well as subclasses thereof (respectively CP10 Building Unit; CP11 Building Front; CP12 Building Floor; CP13 Urban Unit; CP14 Urban Unit Front and CP51 Building Component; CP3 Construction Unit; CP4 Construction Component; CP5 Construction Element Plural; CP6 Construction Element Singular).

Examples:

- the Pisa tower (Pierotti 2003)
- the underground basilica of Porta Maggiore in Rome (Aurigemma 1961)
- the façade of the monastic church of St. Salvatore Maggiore in Concerviano (Rieti) (Fiorani 1995)
- the painted wooden beams of the Carli Benedetti palace in L'Aquila (Bartolomucci 2011)

In first-order logic:

CR8(x) ⇒ E24(x)

Properties:

Pr1 has total number of storeys: E60 Number
Pr2 has current use percentage: E60 Number
Pr3 has number of ground level entrances: E60 Number
Pr4 has number of underground storeys: E60 Number
Pr5 has number of surveyable Building Units: E60 Number
Pr6 has residential use percentage: E60 Number
Pr7 has number of connected urban units: E60 Number
Pr8 has number of assumed floors: E60 Number
Pr9 has number of cladded floors: E60 Number
Pr10 has number of residential real estate units: E60 Number

Pr11 has number of not residential real estate units: E60 Number
Pr12 has maximum number of storeys over ground level: E60 Number
Pr13 has minimum number of storeys over ground level: E60 Number
Pr14 has number of modern replacement building units: E60 Number
Pr15 has number of building voids: E60 Number
Pr16 has number of storeys over ground level: E60 Number
Pr17 has number of architectural fronts on urban area: E60 Number
Pr18 has number of inner architectural fronts: E60 Number
Pr19 has percentage of thrusting extensions: E60 Number
Pr20 has percentage of partly thrusting extensions: E60 Number
Pr21 has percentage of deformable extensions: E60 Number
Pr22 has percentage of thin walls: E60 Number
Pr23 has percentage of buttressed walls: E60 Number
Pr24 has number of inner windows/doors: E60 Number
Pr25 has number of outer windows/doors: E60 Number
Pr26 has number of semi-basements and mezzanines: E60 Number
Pr28 shows resistant areas towards X direction: E54 Dimension
Pr29 shows resistant areas towards Y direction: E54 Dimension
Pr30 shows CdR ratio (is related to): CR2 CdR Ratio
Pr31 shows CdR check factor (is related to): CR3 CdR Check Factor
Pr32 was assessed by (assessed): CR7 CdR Assessment
Pr34 has generic function (is realised in): E7 Activity
Pr35 has specific function (is realised in): E7 Activity
Pr36 has specific function at ground level (is realised in): E7 Activity
Pr37 has specific function at upper level (is realised in): E7 Activity
Pr42 is totally documented in (totally documents): E31 Document
Pr43 is partly documented in (partly documents): E18 Document
Pr44 are in number of: E60 Number
Pr46 shows number of artworks: E60 Number
Pr47 has effectiveness assessed by (assessed effectiveness of): CR4 Effectiveness Assessment
Pr48 has coherence to building phase assessed by (assessed coherence to building phase to): CR5 Building Phase

CR9 Inhabitants

Subclass of: E74 Group

Scope note:

This class comprises organisations of human individuals residing in the same city. The residency status must be recorded in special official registers and is therefore referred to in specific years.

Examples:

- the inhabitants of Rome in 2012

In first-order logic:

CR9(x) ⇒ E74(x)

Properties:

Pr27 are in number of: E60 Number

CR10 CdR Space Entity

Subclass of: E92 Spacetime Volume

Scope note:

This class includes instances representing 4D ensembles and can refer to the set that collects the constructed buildings and the empty spaces between them or to just the footprint of the empty spaces bounded by an urban physical perimeter or an architectural envelope. In either case, these instances are changeable over time, meaning that the shape and extent of the CR10 CdR Space Entity can be changed over time and become precisely defined with the intersection of E53 Place and E52 Time-Span instances.
The CdRont class CP10 CdR Space Entity is equivalent to the CPM class CP18 Space Entity. As such, it also relates to the subclasses of CP18 Built Entity: CP19 Historic Centre; CP21 Space Unit; CP22 Space Component.

Examples:

- the extension in space and time defined by the area approximating the historic centre of L'Aquila from its beginning into existence to 1919 (Clementi, Piroddi 1986)
- the extension in space and time of the set of interior and confined spaces of Palazzo Venezia in Rome from 15th to 19th century (Bova 2017-18)
- the extension in space and time defined by Piazza del Campo in Siena from 12th to 21st century (Galli 2011)
- the extension in space and time defined by the central nave of St. Prassede in Rome from the 9th to the 20th century (Caperna 2014)

In first-order logic:

CR10(x) ⇒ E92(x)

Properties:

Pr40 is totally documented in (totally documents): E31 Document
Pr41 is partly documented in (partly documents): E31 Document

CR11 CdR Historic Centre

Subclass of: E24 Physical Human-Made Thing

Scope note:

This class includes instances of urban agglomeration composed by the historic buildings and the open spaces which formerly constituted the town. The historic centre is delimited by a perimeter that can sometimes coincide with the boundary of the city walls when they still exist or when they can be identified on the basis of historic records, material evidence, or on natural limits (streams, strong slopes, etc.).
The CdRont class CP11 CdR Historic Centre is equivalent to the CPM class CP40 Historic Centre.

Examples:

- the historic centre of L'Aquila in the 20th cent. (CLEMENTI, PIRODDI 1986)
- the historic centre of Marseille at the beginning of the 21st cent. (BAJARD, PLANCHENAULT 2022)

In first-order logic:

CR11(x) ⇒ E24(x)

Properties:

Pr38 is totally characterized by (totally characterises): E18 Physical Thing
Pr39 is partly characterized by (totally characterises): E18 Physical Thing

2.4. CdRont Property declarations

Pr1 has total number of storeys

Domain:

CR8 CdR Built Entity

Range:

E60 Number

Quantification:

Many to many, necessary (1,n:0,n)

Scope note:

This property makes it possible to document the total number of storeys of a building, comprising both underground and out of ground floors. It relates an instance of the class CR8 CdR Built Entity to an instance of the class E60 Number. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- Palazzo Farnese in Rome (CR8) in Rome *has total number of* storeys 4

(E60).

- the church of St. Saba (CR8) in Rome *has total number of storeys* 2 (E60).

In first-order logic:

Pr1(x,y) ⇒ CR8(x)

Pr1(x,y) ⇒ E60(y)

Pr2 has current use percentage

Domain:

CR8 CdR Built Entity

Range:

E60 Number

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document the current percentage of the building that is currently used in terms of activities developed inside it. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the St. Balbina complex (CR8) in Rome *has current use percentage* 90% (E60).
- the Fendi Foundation building (CR8) in Rome *has current use percentage* 100% (E60).

In first-order logic:

Pr2(x,y) ⇒ CR8(x)

Pr2(x,y) ⇒ E60(y)

Pr3 has number of ground level entrances

Domain:

CR8 CdR Built Entity

Range:

E60 Number

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document the number of ground level entrances of a building. It relates an instance of the class CR8 CdR Built Entity with an instance of the class E60 Number. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- Palazzo Farnese (CR8) in Rome *has number of ground level entrances* 3 (E60).
- Palazzo Odescalchi (CR8) in Santa Marinella (Rome, Italie) *has number of ground level entrances* 4 (E60).

In first-order logic:

Pr3(x,y) ⇒ CR8(x)

Pr3(x,y) ⇒ E60(y)

Pr4 has number of underground storeys

Domain:

CR8 CdR Built Entity

Range:

E60 Number

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document the number of underground storeys of a building, It relates an instance of the class CR8 CdR Built Entity to an instance of the class E60 Number. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the church of St. Saba (CR8) in Rome *has number of underground storeys* 1 (E60).
- the Fondazione Fendi building (CR8) in Rome *has number of underground storeys* 0 (E60).

In first-order logic:

Pr4(x,y) ⇒ CR8(x)

Pr4(x,y) ⇒ E60(y)

Pr5 has number of surveyable Building Units

Domain:

CR8 CdR Built Entity

Range:

E60 Number

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document the number of surveyable building units that compose the building. The property is useful for providing an idea of the building dimensional knowledge that it has been possible to achieve within the Risk Map survey. It makes clear where it was possible to enter and measure the building units. It relates an instance of the class CR8 CdR Built Entity to an instance of the class E60 Number. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the Fondazione Fendi building (CR8) in Rome *has number of surveyable Building Units* 6 (E60). (fictitious)
- the Federici building (CR8) in Rome *has number of surveyable Building Units* 35 (E60). (fictitious)

In first-order logic:

Pr5(x,y) ⇒ CR8(x)

Pr5(x,y) ⇒ E60(y)

Pr6 has residential use percentage

Domain:

CR8 CdR Built Entity

Range:

E60 Number

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document the percentage of the building that is used for dwellings at the time of the Risk Map survey. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the Unité d'abitation (CR8) in Marseille *has residential use percentage* 96% (E60).

- the Federici building (CR8) in Rome *has residential use percentage* 70% (E60).

In first-order logic:

Pr6(x,y) ⇒ CR8(x)

Pr6(x,y) ⇒ E60(y)

Pr7 has number of connected urban units

Domain:

CR8 CdR Built Entity

Range:

E60 Number

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document the number of urban units to which the building is connected. Connection to other buildings is a feature that influences the behaviour's behaviour in seismic conditions, and therefore its vulnerability. The property relates an instance of the class CR8 CdR Built Entity to an instance of the class E60 Number. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- Palazzo Ducale (CR8) in Venice *has number of connected urban units* 2 (E60)
- Palazzo Farnese (CR8) in Rome *has number of connected urban units* 0 (E60)

In first-order logic:

Pr7(x,y) ⇒ CR8(x)

Pr7(x,y) ⇒ E60(y)

Pr8 has number of assumed floors

Domain:

CR8 CdR Built Entity

Range:

E60 Number

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document the number of assumed floors that have been assigned to the building within the Risk Map survey. This property is useful for introducing a measurement unit which can be used within a visual measurement to document decay or transformations that may have involved the whole building or a part of it that can be approximated to a number of floors. The property relates an instance of the class CR8 CdR Built Entity to an instance of the class E60 Number. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- Palazzo Ducale (CR8) in Venice *has number of assumed floors* 3 (E60)
- Palazzo Farnese (CR8) in Rome *has number of assumed floors* 3 (E60)

In first-order logic:

Pr8(x,y) ⇒ CR8(x)

Pr8(x,y) ⇒ E60(y)

Pr9 has number of cladded floors

Domain:

CR8 CdR Built Entity

Range:

E60 Number

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document the number of floors that show historic claddings that can be observed in the building during the Risk Map survey. This property is useful for describing whether the building is cladded or not. The property relates an instance of the class CR8 CdR Built Entity to an instance of the class E60 Number. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- Palazzo Ducale (CR8) in Venice *has number of cladded floors* 3 (E60)
- Palazzo Farnese (CR8) in Rome *has number of cladded* floors 3 (E60)

In first-order logic:

Pr9(x,y) ⇒ CR8(x)

Pr9(x,y) ⇒ E60(y)

Pr10 has number of residential real estate units

Domain:

CR8 CdR Built Entity

Range:

E60 Number

Quantification:

Many to many (0,n:0,n)

Scope note:

This property allows to document the number of residential real estate units that have been identified in the building within the Risk Map survey. This property is useful to describe the kind of activity that is developed inside the building. The property relates an instance of the class CR8 CdR Built Entity to an instance of the class E60 Number. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the Unité d'habitation (CR8) in Marseilles *has number of residential real estate units* 337 (E60)
- the Federici building (CR8) in Rome *has number of residential real estate units* 442 (E60)

In first-order logic:

Pr10(x,y) ⇒y60(y)

Pr11 has number of not residential real estate units

Domain:

CR8 CdR Built Entity

Range:

E60 Number

Quantification:

Many to many (0,n:0,n)

Scope note:

This property allows to document the number of not residential real estate units that have been identified in the building within the Risk Map survey. This property is useful to describe the kind of activity that is developed inside the building. The property relates an instance of the class CR8 CdR Built Entity to an instance of the class E60 Number.

This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the Unité d'habitation (CR8) in Marseilles *has number of not residential real estate units* 13 (E60).
- the Federici building (CR8) in Rome *has number of not residential real estate units* 208 (E60).

In first-order logic:

Pr11(x,y) ⇒ CR8(x)

Pr11(x,y) ⇒ E60(y)

Pr12 has maximum number of storeys over ground level

Domain:

CR8 CdR Built Entity

Range:

E60 Number

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document the maximum number of storeys that have been identified in the building within the Risk Map survey. This property is useful for providing an idea of the physical extension of the building, particularly when it is composed of parts that show different heights. The property relates an instance of the class CR8 CdR Built Entity to an instance of the class E60 Number. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the Zwinger (CR8) in Dresda *has maximum number of storeys over ground level* 2 (E60)
- the Federici building (CR8) in Rome *has maximum number of storeys over ground level* 12 (E60)

In first-order logic:

Pr12(x,y) ⇒ CR8(x)

Pr12(x,y) ⇒ E60(y)

Pr13 has minimum number of storeys over ground level

Domain:

CR8 CdR Built Entity

Range:

E60 Number

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document the minimum number of storeys that have been identified in the building within the Risk Map survey. This property is useful for providing an idea of the physical extension of the building, particularly when it is composed of parts that show different heights. The property relates an instance of the class CR8 CdR Built Entity to an instance of the class E60 Number. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the Zwinger (CR8) in Dresda *has minimum number of storeys over ground level* 2 (E60)
- the Federici building (CR8) in Rome *has minimum number of storeys over ground level* 10 (E60)

In first-order logic:

Pr13(x,y) ⇒ CR8(x)

Pr13(x,y) ⇒ E60(y)

Pr14 has number of modern replacement building units

Domain:

CR8 CdR Built Entity

Range:

E60 Number

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document the number of building units that have been identified as modern substitutions within the Risk Map survey. This property is useful for providing an idea in terms of new materials and different building behaviour that may have been introduced by modern interventions in a historic building. The property relates an instance of the class CR8 CdR Built Entity to an instance of the class E60 Number. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the urban unit in 7, 9, 11 piazza Papa Innocenzo III (CR8) in Anagni (FR, Italy) *has number of modern replacement building units* 1, in 11 piazza Papa Innocenzo III (E60)
- the urban unit in 41, 42,43, via dei Riari (CR8) in Rome *has number of modern replacement building units* 1(E60), in 43, in via dei Riari

In first-order logic:

Pr14(x,y) ⇒ CR8(x)

Pr14(x,y) ⇒ E60(y)

Pr15 has number of building voids

Domain:

CR8 CdR Built Entity

Range:

E60 Number

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document the presence of voids identified in the building within the Risk Map survey. For example, a void may be an area that has not been built or has collapsed. This property is useful for providing an idea of the nature of the volume composed by voids and solids that deeply influence the behaviour of the building. The property relates an instance of the class CR8 CdR Built Entity to an instance of the class E60 Number. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- Palazzo Ducale (CR8) in Venice *has number of building voids* 0 (E60)
- Palazzo Farnese (CR8) in Rome *has number of building voids* 2 (E60)

In first-order logic:

Pr15(x,y) ⇒ CR8(x)

Pr15(x,y) ⇒ E60(y)

Pr16 has number of storeys over ground level

Domain:

CR8 CdR Built Entity

Range:

E60 Number

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document the number of storeys over ground level that have been identified in the building within the Risk Map survey. This property is useful for providing an idea of the physical extension of the building when its volume is regular. The property relates an instance of the class CR8 CdR Built Entity to an instance of the class E60 Number. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- Palazzo Ducale (CR8) in Venice *has number of storeys over ground level* 3 (E60)
- Palazzo Farnese (CR8) in Rome *has number of* storeys *over ground level* 3 (E60)

In first-order logic:

Pr16(x,y) ⇒ CR8(x)

Pr16(x,y) ⇒ E60(y)

Pr17 has number of building fronts on urban area

Domain:

CR8 CdR Built Entity

Range:

E60 Number

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document the number of *building* fronts overlooking urban spaces that have been identified in the building within the Risk Map survey. This property is useful for describing the relation of the building with the urban context. The property relates an instance of the class CR8 CdR Built Entity to an instance of the class E60 Number. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- Palazzo Ducale (CR8) in Venice *has number of building fronts on urban spaces* 3 (E60)
- Palazzo Farnese (CR8) in Rome *has number of building fronts on urban spaces* 3 (E60)

In first-order logic:

Pr17(x,y) ⇒ CR8(x)

Pr17(x,y) ⇒ E60(y)

Pr18 has number of inner building fronts

Domain:

CR8 CdR Built Entity

Range:

E60 Number

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document the number of building fronts overlooking inner areas of the building such as gardens, patios, courtyards that have been identified in the building within the Risk Map survey. This property is useful for describing the relation of the building with the inner areas. The property relates an instance of the class CR8 CdR Built Entity to an instance of the class E60 Number. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- Palazzo Ducale (CR8) in Venice *has number of inner building fronts* 4 (E60)
- Palazzo Farnese (CR8) in Rome *has number of inner building fronts* 5 (E60). Four of them overlook the courtyard, the fifth the garden.

In first-order logic:

Pr18(x,y) ⇒ CR8(x)

Pr18(x,y) ⇒ E60(y)

Pr19 has percentage of thrusting extensions

Domain:

CR8 CdR Built Entity

Range:

E60 Number

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document the percentage of the thrusting roofs, referring to the roofs' total surface, identified in the building within the Risk Map survey. By the term 'thrusting elements' we mean those constructive units, whose horizontal thrust push is not adequately constrained by walls. This property is useful for describing the structural behaviour of the building. The property relates an instance of the class CR8 CdR Built Entity to an instance of the class E60 Number. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the Federici building (CR8) in Rome *has percentage of thrusting extensions* 0% (E60)
- Palazzo Farnese (CR8) in Rome *has percentage of thrusting extensions* 100% (E60)

In first-order logic:

$Pr19(x,y) \Rightarrow CR8(x)$

$Pr19(x,y) \Rightarrow E60(y)$

Pr20 has percentage of partly thrusting extensions

Domain:

CR8 CdR Built Entity

Range:

E60 Number

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible allows to document the percentage of the thrusting roofs, referring to the roofs' total surface, identified in the building within the Risk Map survey. By the term 'thrusting elements' we mean those constructive units, whose horizontal thrust is not adequately constrained by walls. This property is useful for describing the structural behaviour of the building. The property relates an instance of the class CR8 CdR Built Entity to an instance of the class E60 Number.

This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the Federici building (CR8) in Rome *has percentage of thrusting extensions* 0% (E60)
- the building in via Filippo d'Aragona (CR8) in Borgo Casamale (Somma Vesuviana, Naples, Italy) *has percentage of thrusting extensions* 0% (E60)

In first-order logic:

Pr20(x,y) ⇒ CR8(x)

Pr20(x,y) ⇒ E60(y)

Pr21 has percentage of deformable extensions

Domain:

CR8 CdR Built Entity

Range:

E60 Number

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document the percentage of deformable roofs, referring to the roofs' total surface, identified in the building within the Risk Map survey. This property is useful for describing the structural behaviour of the building. The property relates an instance of the class CR8 CdR Built Entity to an instance of the class E60 Number. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the building in via dei Cerignoni (CR8) in Ciciliano in Rome *has percentage of deformable extensions* 70% (E60)
- the Casa Grande Barberini in via dei Giubbonari (CR8) in Rome *has percentage of thrusting extensions* 100% (E60)

In first-order logic:

Pr21(x,y) ⇒ CR8(x)

Pr21(x,y) ⇒ E60(y)

Pr22 has percentage of thin walls

Domain:

CR8 CdR Built Entity

Range:

E60 Number

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document the percentage of thin walls, referring to the walls' total surface, identified in the building within the Risk Map survey. By the term 'thin walls' we mean those constructive units that are subject to buckling. This property is useful for describing the structural behaviour of the building. The property relates an instance of the class CR8 CdR Built Entity to an instance of the class E60 Number. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the bell tower (CR8) *has percentage of thin walls* 100% (E60) (fictitious)
- the church whose façade has been built without adequate constraints (CR8) *has percentage of thin walls* 20% (E60) (fictitious)

In first-order logic:

Pr22(x,y) ⇒ CR8(x)

Pr22(x,y) ⇒ E60(y)

Pr23 has percentage of buttressed walls

Domain:

CR8 CdR Built Entity

Range:

E60 Number

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document the percentage of buttressed walls, referring to the walls' total surface, identified in the building within the Risk Map survey. By the term 'buttressed walls' we mean those constructive units that have been consolidated through the use of buttresses. This property is useful for describing the structural behaviour of the building. The property relates an instance of the class CR8 CdR Built Entity to an instance of the class E60 Number. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the Sarriod de la Tour castle (CR8) in St. Pierre (Aosta, Italy) *has percentage of buttressed walls* 25% (E60)
- the St. Balbina complex (CR8) in Rome *has percentage of buttressed* walls 20% (E60)

In first-order logic:

Pr23(x,y) ⇒ CR8(x)

Pr23(x,y) ⇒ E60(y)

Pr24 has number of inner windows/doors

Domain:

CR8 CdR Built Entity

Range:

E60 Number

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document the number of inner windows/doors identified in a building within the Risk Map survey. It relates an instance of the class CR8 CdR Built Entity with an instance of the class E60 Number. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the upper church of St. Maria del Pozzo (CR8) in Somma Vesuviana (Naples) *has number of inner doors* 4 (E60)
- the upper church of St. Maria del Pozzo (CR8) in Somma Vesuviana (Naples) *has number of inner windows* 8 (E60)

In first-order logic:

Pr24(x,y) ⇒ CR8(x)

Pr24(x,y) ⇒ E60(y)

Pr25 has number of outer windows/doors

Domain:

CR8 CdR Built Entity

Range:

E60 Number

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document the number of outer windows/doors identified in a building within the Risk Map survey. It relates an instance of the class CR8 CdR Built Entity with an instance of the class E60 Number. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the upper church of St. Maria del Pozzo (CR8) in Somma Vesuviana (Naples) *has number of outer doors* 1(E60)
- the tower bell of St. Maria del Pozzo (CR8) in Somma Vesuviana (Naples) *has number of outer windows* 17 (E60)

In first-order logic:

Pr25(x,y) ⇒ CR8(x)

Pr25(x,y) ⇒ E60(y)

Pr26 has number of semi-basements and mezzanines

Domain:

CR8 CdR Built Entity

Range:

E60 Number

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document the number of semi-basements and mezzanines that have been identified in the building within the Risk Map survey. This property is useful for providing an idea of the physical extension of the building when its volume is regular. The property relates an instance of the class CR8 CdR Built Entity to an instance of the class E60 Number. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the St. Balbina complex (CR8) in Rome *has number of semi-basements and mezzanines* 0 (E60)
- Palazzo Farnese (CR8) in Rome has number of *semi-basements and*

mezzanines 1 (E60)

In first-order logic:

Pr26(x,y) ⇒ CR8(x)

Pr26(x,y) ⇒ E60(y)

Pr27 are in number of

Domain:

CR9 Inhabitants

Range:

E60 Number

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document the number of inhabitants identified in a historic centre within the Risk Map survey The property relates an instance of the class CR9 Inhabitants to an instance of the class E60 Number. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the inhabitants of Paris (CR9) *are in number of* 2 229 095 (E60)
- the inhabitants of Stockholm (CR9) *are in number of* 984748 (E60)

In first-order logic:

Pr27(x,y) ⇒ CR9(x)

Pr27(x,y) ⇒ E60(y)

Pr28 shows resistant areas towards X direction

Domain:

CR8 CdR Built Entity

Range:

E54 Dimension

Subproperty of:

E70 Thing. P43 has dimension (is dimension of): E54 Dimension

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document the dimension of the surfaces resisting towards X direction identified in the building within the Risk Map survey. This property is useful for describing the structural behaviour of the building. The property relates an instance of the class CR8 CdR Built Entity to an instance of the class E54 Dimension.

Examples:

- the building in via Filippo d'Aragona (CR8) in Borgo Casamale, Somma Vesuviana (Naples) *shows resistant areas towards X direction* 21 m^2 (E60)
- the building in via dei Cerignoni (CR8) in Ciciliano (Rome) *shows resistant areas towards X direction* 13 m^2 (E60)

In first-order logic:

Pr28(x,y) ⇒ CR8(x)

Pr28(x,y) ⇒ E54(y)

Pr28(x,y) ⇒ P43(x,y)

Pr29 shows resistant areas towards Y direction

Domain:

CR8 CdR Built Entity

Range:

E54 Dimension

Subproperty of:

E70 Thing. P43 has dimension (is dimension of): E54 Dimension

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document the dimension of the surfaces resisting towards Y direction identified in the building within the Risk Map survey. This property is useful for describing the structural behaviour of the building. The property relates an instance of the class CR8 CdR Built Entity to an instance of the class E54 Dimension.

Examples:

- the building in via Filippo d'Aragona (CR8) Somma Vesuviana (Naples) *shows resistant areas towards Y direction* 42 m^2 (E60)
- the building in via dei Cerignoni (CR8) in Ciciliano (Rome) *shows resistant areas towards Y direction* 32 m^2

In first-order logic:

Pr29(x,y) ⇒ CR8(x)

Pr29(x,y) ⇒ E54(y)

Pr29(x,y) ⇒ P43(x,y)

Pr30 shows CdR ratio (is referred to)

Domain:

CR8 CdR Built Entity

Range:

CR2 CdR Ratio

Subproperty of:

E1 CRM Entity. P67i is referred to by (refers to): E89 Propositional Object

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document the ratios considered within the Risk Map surveys. The calculated ratios refer to incidences and confidence factors as they have been described in the respective scope notes. This property is necessary to express data considered by Risk Map algorithms. The property relates an instance of the class CR8 CdR Built Entity to an instance of the class CR2 CdR Ratio. Each ratio is further specified through the CIDOC CRM property P2 *has type.*

Examples:

- the Casa Grande Barberini (CR8) in Rome *shows CdR ratio* 80% (CR2), *has type* 'significance factor'
- the building in via Filippo d'Aragona (CR8) in Borgo Casamale (Somma Vesuviana, Naples) *shows CdR ratio 0%* (CR2) that *has type* 'significance factor'

In first-order logic:

Pr30(x,y) ⇒ CR8(x)

Pr30(x,y) ⇒ CR2(y)

Pr30(x,y) ⇒ P67i(x,y)

Pr31 shows CdR check factor (is referred to)

Domain:

CR8 CdR Built Entity

Range:

CR3 CdR Check Factor

Subproperty of:

E1 CRM Entity. P67i is referred to by (refers to): E89 Propositional Object

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document instances of CR3 CdR Check Factors considered within the Risk Map surveys. The identified Check Factors makes it possible to describe both the presence/absence of specific parts of the building and the adequacy/inadequacy of equipment. The specification of the check factors is made possible through the CIDOC CRM property P2 *has type.* The property relates an instance of the class CR8 CdR Built Entity to an instance of the class CR3 CdR Check Factor.

Examples:

- the school I.C. Gesmundo (CR8) in Rome *shows CdR check factor:* presence (CR3) *has type* 'presence of vertical protection systems'
- the school Vittoria Colonna (CR8) in Rome *shows CdR check factor:* presence (CR3) *has type* 'presence of vertical protection systems'

In first-order logic:

Pr31(x,y) ⇒ CR8(x)

Pr31(x,y) ⇒ CR3(y)

Pr31(x,y) ⇒ P67i(x,y)

Pr32 was assessed by (assessed)

Domain:

CR8 Built Entity

Range:

CR7 CdR Assessment

Subproperty of:

E1 CRM Entity. P67i is referred to by (refers to): E89 Propositional Object

Quantification:

Many to one, dependant (0,n:1, n)

Scope note:

This property makes it possible to document instances of CR7 CdR Assessment attributed within the Risk Map surveys. The identified CdR Assessment makes it possible to describe any kind of evaluations developed within Risk Map surveys. The specification of the assessment is made possible through the CIDOC CRM property P2 *has type.* The property relates an instance of the class CR8 CdR Built Entity to an instance of the class CR7 CdR Assessment.

Examples:

- the St. Balbina complex (CR8) in Rome *was assessed by* shape regularity: regular (CR7).
- the abbey church of St. Galgano (CR8) near Siena (Italy) *was assessed by* completeness evaluation: ruin (CR7).

In first-order logic:

Pr32(x,y) ⇒ CR8(x)

Pr32(x,y) ⇒ CR7(y)

Pr32(x,y) ⇒ P67i(x,y)

Pr33 provides as output (is an output of)

Domain:

CR6 Index Calculation Event

Range:

CR1 CdR Index

Subproperty of:

E1 CRM Entity. P67i is referred to by (refers to): E89 Propositional Object

Quantification:

Many to one (1,1:0, n) necessary

Scope note:

This property documents that an instance of CR1 CdR Index is an output of CR6 Index Calculation Event. This property makes it possible to describe both the index itself and the event through which the index is calculated. The property is useful within Risk Map surveys as all data gather in the calculation of indexes that describe the condition of the building in terms of transformation and vulnerability. The CdR indexes are further specified through the CIDOC CRM property P2 *Has type*.

Examples:

- the St. Balbina index of global transformation (CR1) *is an output of* Transformation Index Calculation Event (CR6).
- the St. Balbina vulnerability index (CR1) *is an output of* Transformation Index Calculation Event (CR6).

In first-order logic:

Pr33(x,y) ⇒ CR6(x)

Pr33(x,y) ⇒ CR1(y)

Pr33(x,y) ⇒ P67i(x,y)

Pr34 has generic function (is generic function of)

Domain:

CR8 CdR Built Entity

Range:

E7 Activity

Quantification:

Many to may, necessary (1,n:0,n)

Scope note:

This property makes it possible to document that an instance of CR8 CdR Built Entity has a generic function that is further specified through the CIDOC CRM property P2 *Has type* and further specialized through the property Pr35 has specific function. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- Palazzo Farnese (CR8) in Rome *has generic function* institutional (E7).
- the Tate Gallery (CR8) in London *has generic function* cultural (E7)

In first-order logic:

Pr34(x,y) ⇒ CR8(x)

Pr34(x,y) ⇒ E7(y)

Pr35 has specific function (is specific function of)

Domain:

CR8 CdR Built Entity

Range:

E7 Activity

Quantification:

Many to may, necessary (1,n:0,n)

Scope note:

This property makes it possible to document that an instance of CR8 CdR Built Entity has a specific function that is further specified through the CIDOC CRM property P2 *has type*. This property aims to specialize

Pr34 *has generic function*. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- Palazzo Farnese (CR8) in Rome *has specific function* embassy (E7)
- the Tate Gallery (CR8) in London *has specific function* museum (E7)

In first-order logic:

Pr35(x,y) ⇒ CR8(x)

Pr35(x,y) ⇒ E7(y)

Pr36 has specific function at ground level (is specific function at ground level of)

Domain:

CR8 CdR Built Entity

Range:

E7 Activity

Quantification:

Many to may, necessary (1,n:0,n)

Scope note:

This property makes it possible to document that an instance of CR8 CdR Built Entity has a specific function at ground level that is further specified through the CIDOC CRM property P2 *has type*. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- Palazzo Origo (CR8) in Rome *has specific function at ground level* book shop (E7).
- the Fendi Foundation (CR8) in Rome *has specific function at ground level* art gallery (E7).

In first-order logic:

Pr36(x,y) ⇒ CR8(x)

Pr36(x,y) ⇒ E7(y)

Pr37 has specific function at upper level (is specific function at upper level of)

Domain:

CR8 CdR Built Entity

Range:

E7 Activity

Quantification:

Many to many, necessary (1,n:0,n)

Scope note:

This property makes it possible to document that an instance of CR8 CdR Built Entity has a specific function at upper level that is further specified through the CIDOC CRM property P2 *has type.* This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- Palazzo Origo (CR8) in Rome *has specific function at upper-level* dwellings (E7).
- the Fendi Foundation (CR8) in Rome *has specific function at ground level* artist dwellings (E7).

In first-order logic:

Pr37(x,y) ⇒ CR8(x)

Pr37(x,y) ⇒ E7(y)

Pr38 is totally characterized by (totally characterises)

Domain:

CR11 CdR Historic Centre

Range:

E18 Physical Thing

Subproperty of:

E18 Physical Thing. P46 is composed of (forms part of): E18 Physical Thing

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document whether a historic centre is totally characterized by specific elements either natural or human-made.

Examples:

- the historic centre of San Gimignano (CR11) (Siena, Italy) *is totally characterized by* tower buildings (E18)
- the historic centre of Alberobello (CR11) (Bari, Italy) *is totally characterized by* the ‘trulli’ (special buildings with the shape of a cone) (E18)

In first-order logic:

Pr38(x,y) ⇒ CR11(x)

Pr38(x,y) ⇒ E18(y)

Pr38(x,y) ⇒ P46(x,y)

Pr39 is partly characterized by (partly characterises)

Domain:

CR11 CdR Historicl Centre

Range:

E18 Physical Thing

Subproperty of:

E18 Physical Thing. P46 is composed of (forms part of): E18 Physical Thing

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document whether a historic centre is partly characterized by specific elements either natural or human-made.

Examples:

- Bologna (CR11) (Italy) is *partly characterized by* porches (E18)
- Cannes (CR11) (France) *is partly characterized by* palm trees (E18)

In first-order logic:

Pr39(x,y) ⇒ CR11(x)

Pr39(x,y) ⇒ E18(y)

Pr39(x,y) ⇒ P46(x,y)

Pr40 is totally documented in (totally documents)

Domain:

CR10 CdR Space Entity

Range:

E31 Document

Subproperty of:

E1 CRM Entity. P70i is documented in (documents): E31 Document

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to describe which element is entirely documenting an instance CR10 CdR Space Entity. It may refer to any document such as a scientific paper or an archival source. The property relates an instance of CR10 CdR Space Entity to an instance of E31 Document.

Examples:

- the extension in space and time defined by the area approximating the historic centre of L'Aquila from its beginning into existence to 1919 (CR10) *is totally documented in* Clementi, Piroddi 1986 (E31)
- the extension in space and time defined by the central nave of St. Prassede in Rome from the 9th to the 20th century (CR10) *is totally documented in* CAPERNA 2014 (E31)

In first-order logic:

Pr40(x,y) ⇒ CR10(x)

Pr40(x,y) ⇒ E31(y)

Pr40(x,y) ⇒ P70i(x,y)

Pr41 is partly documented in (partly documents)

Domain:

CR10 CdR Space Entity

Range:

E31 Document

Subproperty of:

E1 CRM Entity. P70i is documented in (documents): E31 Document

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to describe which element is documenting an instance CR10 CdR Space Entity albeit in a partial way. It may refer to any document such as a scientific paper or an archival source. The property relates an instance of CR10 CdR Space Entity to an instance of E31 Document.

Examples:

- the extension of the tower of the St. Balbina complex in the Middle Ages (CR10) *is partly documented in* BIANCHI, COPPOLA, MUTARELLI 2004 (E31)
- Palazzo Origo in the 18th century (CR10) *is party documented in* Giovanni Battista Nolli's plan of Rome (E31)

In first-order logic:

Pr41(x,y) ⇒ CR10(x)

Pr41(x,y) ⇒ E31(y)

Pr41(x,y) ⇒ P70i(x,y)

Pr42 is totally documented in (totally documents)

Domain:

CR8 CdR Built Entity

Range:

E31 Document

Subproperty of:

E1 CRM Entity. P70i is documented in (documents): E31 Document

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to describe which element is entirely documenting an instance CR8 CdR Built Entity. It may refer to any document such as a scientific paper or an archival source. The property relates an instance of CR8 CdR Built Entity to an instance of E31 Document.

Examples:

- the historic centre of L'Aquila (CR8) *is documented in* Clementi, Piroddi 1986 (E31)
- the central nave of the church of St. Prassede (CR8) in Rome *is totally documented in* Caperna 2014 (E31)

In first-order logic:

Pr42(x,y) ⇒ CR8(x)

Pr42(x,y) ⇒ E31(y)

Pr42(x,y) ⇒ P70i(x,y)

Pr43 is partly documented in (partly documents)

Domain:

CR8 CdR Built Entity

Range:

E31 Document

Subproperty of:

E1 CRM Entity. P70i is documented in (documents): E31 Document

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to describe which element is documenting an instance CR8 CdR Built Entity although in a partial way. It may refer to any document such as a scientific paper or an archival source. The property relates an instance of CR8 CdR Built Entity to an instance of E31 Document.

Examples:

- the historic centre of Rome (CR8) *is partly documented in* Catasto Gregoriano (Pope Gregorio 16th registry) (E31)
- the Fendi Foundation building in Rome (CR8) *is partly documented in* ACIERNO 2022 (E31)

In first-order logic:

Pr43(x,y) ⇒ CR8(x)

Pr43(x,y) ⇒ E31(y)

Pr43(x,y) ⇒ P70i(x,y)

Pr44 are in number of

Domain:

CR8 CdR Built Entity

Range:

E60 Number

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document the number of the built entities that have been identified within the Risk Map survey. This property is useful for describing the physical context of the building that is being surveyed. The property relates an instance of the class CR8 CdR Built Entity to an instance of the class E60 Number. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the buildings that compose St. Balbina complex (CR8) in Rome *are in number of* 4 (E60)
- the courtyards inside Fendi Foundation (CR8) in Rome *are in number of* 2 (E60)

In first-order logic:

Pr44(x,y) ⇒ CR8(x)

Pr44(x,y) ⇒ E60(y)

Pr45 are in number of

Domain:

CR10 CdR Space Entity

Range:

E60 Number

Scope note:

This property makes it possible to document the number of space entities that have been identified within the Risk Map survey. This property is useful for describing the physical context of the building that is being surveyed in a specific time. The property relates an instance of the class CR10 CdR Space Entity to an instance of the class E60 Number. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the buildings that compose St. Balbina complex in Rome in 16th century (CR10) *are in number of* 3 (E60)
- the courtyards inside Fedi Foundation in Rome in 19th century (CR10) *are in number of* 1 (E60)

In first-order logic:

Pr45(x,y) ⇒ CR10(x)

Pr45(x,y) ⇒ E60(y)

Pr46 shows number of artworks

Domain:

CR8 CdR Built Entity

Range:

E60 Number

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document the number of artworks that have been identified in the building within the Risk Map survey. This property is useful for providing an idea of the value which is conserved in the building. The property relates an instance of the class CR8 CdR Built Entity to an instance of the class E60 Number. This property is out of the CIDOC CRM scope as it concerns some relation that are not a concept covered in CRM.

Examples:

- the upper church of St. Maria del Pozzo (CR8) in Somma Vesuviana (Naples) *shows number of artworks* 9 (E60)
- the Villa Augustea (CR8) near Somma Vesuviana (Naples) *shows number of artworks* 2 (E60)

In first-order logic:

Pr46(x,y) ⇒ CR8(x)

Pr46(x,y) ⇒ E60(y)

Pr47 has effectiveness assessed by (assessed effectiveness of)

Domain:

CR8 CdR Built Entity

Range:

CR4 Effectiveness Assessment

Subproperty of:

E1 CRM Entity. P141 was assigned by (assigned): E13 Attribute Assignment

Quantification:

One to many, dependant (0,n:1,1)

Scope note:

This property makes it possible to document instances of CR4 Effectiveness Assessment attributed within the Risk Map surveys. The identified CR4 Effectiveness Assessment makes it possible to describe the evaluation developed within Risk Map surveys as pertains to effectiveness. The property relates an instance of the class CR8 CdR Built Entity to an instance of the class CR4 Effectiveness Assessment.

Examples:

- the drainage system of the church of Santa Balbina (CR8) in Rome *has effectiveness assessed by* Effectiveness Assessment (CR4) developed within Risk Map survey in 2013
- the electrical system of Palazzo Farnese (CR8) in Rome *has effectiveness assessed by* Effectiveness Assessment (CR4) developed within the Risk Map survey in 2013

In first-order logic:

Pr47(x,y) ⇒ CR8(x)

Pr47(x,y) ⇒ CR4(y)

Pr47(x,y) ⇒ P141(x,y)

Pr48 has coherence to building phase assessed by (assessed coherence to building phase to)

Domain:

CR8 CdR Built Entity

Range:

CR5 Building Phase

Subproperty of:

E1 CRM Entity. P141 was assigned by (assigned): E13 Attribute Assignment

Quantification:

Many to many (0,n:0,n)

Scope note:

This property makes it possible to document that an instance of CR8 CdR Built Entity shows a kind of consistency with a specific building phase that has been identified within the knowledge process.

Examples:

- the façade of Palazzo Venezia (CR8) in Rome *has coherence to building phase assessed by* 15th century building phase (CR5).
- the tower of St. Balbina complex (CR8) in Rome *has coherence to building phase assessed by* medieval building phase (CR5).

In first-order logic:

Pr48(x,y) ⇒ CR8(x)

Pr48(x,y) ⇒ CR5(y)

Pr48(x,y) ⇒ P141(x,y)

Pr49 has type of reliability

Domain:

CR7 CdR Assessment

Range:

E55 Type

Subproperty of:

E1 CRM Entity. P2 has type (is type of): E13 Attribute Assignment

Quantification:

One to many, necessary (1,1:0,n)

Scope note:

This property documents the reliability of an instance of CR7 CdR Assessment. This property relates an instance of CR7 CdR Assessment to an instance of type.

Examples:

- the assessment of the windows display in the building in 3 via dei Giubbonari (CR7) in Rome *has type of reliability* high (E55)
- the assessment of the resisting areas in the building in 2 piazza de Cupis (CR7) in Borgata Tor Sapienza (Rome) *has type of reliability* low (E55)

In first-order logic:

Pr49(x,y) ⇒ CR7(x)

Pr49(x,y) ⇒ CR5(y)

Pr49(x,y) ⇒ P2(x,y)

2.5. Modelling the Italian Risk Map

To clarify the CdRont structure, the following 48 figures reproduce the Risk Map formalization reflecting, for each scale of the survey, the sequence of the documented contents[1]. Figures numbers 2.1-2.9 refer to Historic Centre; figures 10-19 to Urban Unit; figures 2.20-2.25 to Urban Space; 2.26-2.38 to Building Unit and 2.39-2.49 to Building Front.

Each figure represents a specific section of the Risk Map that is described in the caption. All figures refer to the same graphic rules. The continuous black line of the arrows represents properties while the dashed line represents subclasses. The properties text is written differently, according to the model it refers to. CPM properties are written in Italics, CIDOC CRM in black and CdRont in grey. 'Is A' relationships are represented with a double arrow. In each figure, the legend clarifies the nature of the classes. Vocabularies are outlined within the boxes of the E55 Type classes and have been kept in Italian as they relate to the platform contents.

[1] The sequence can be easily followed in the Guidelines (FIORANI et al. 2022 and FIORANI et al. 2023).

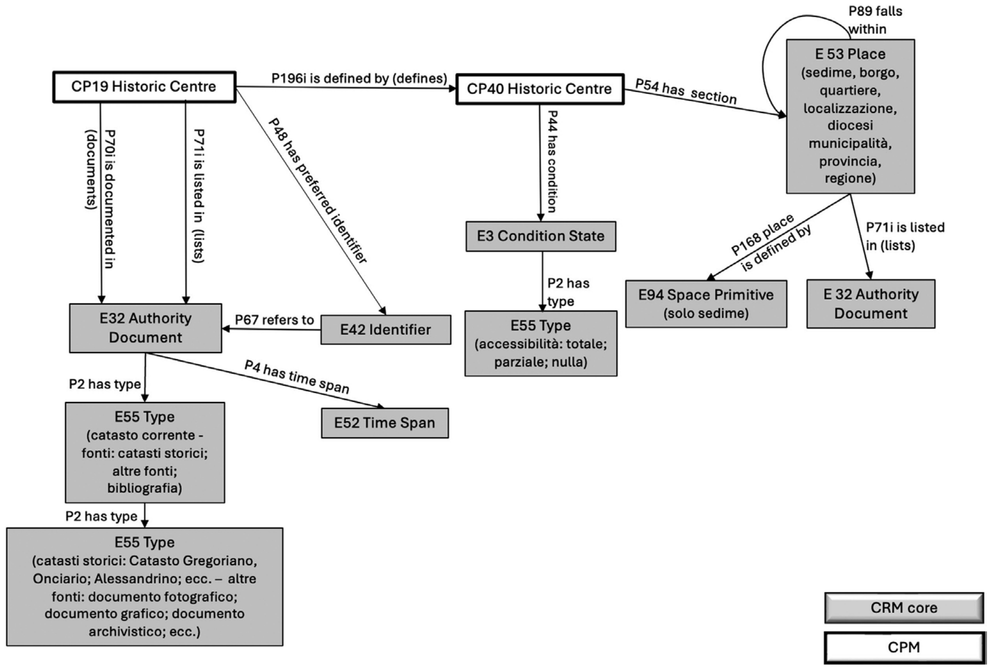

Fig. 2.1. Historic Centre. Location (*Centro Storico. Localizzazione*).

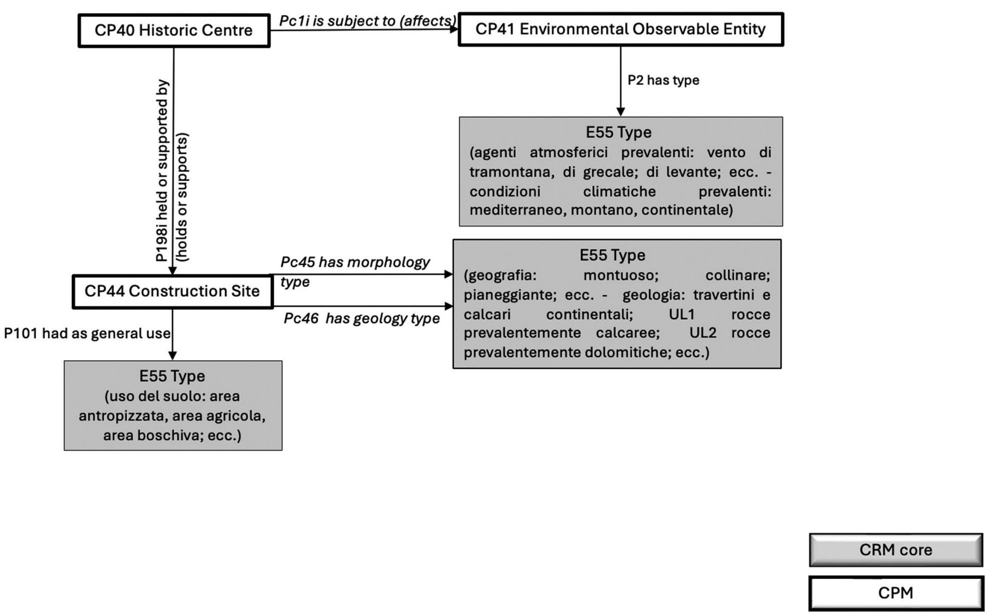

Fig. 2.2. Historic Centre. Identification (*Centro storico. Anagrafica*).

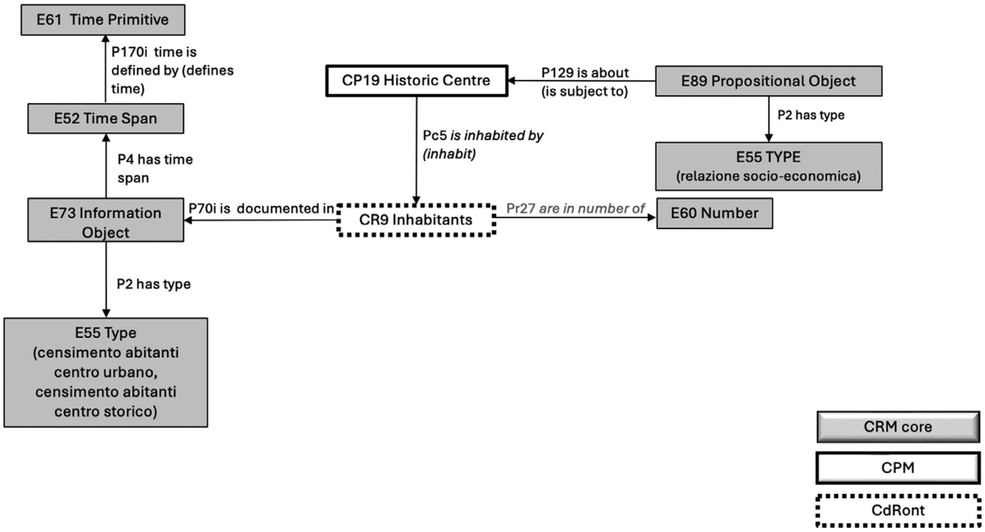

Fig. 2.3. Historic Centre. Identification and demography (*Centro Storico. Anagrafica e demografia*).

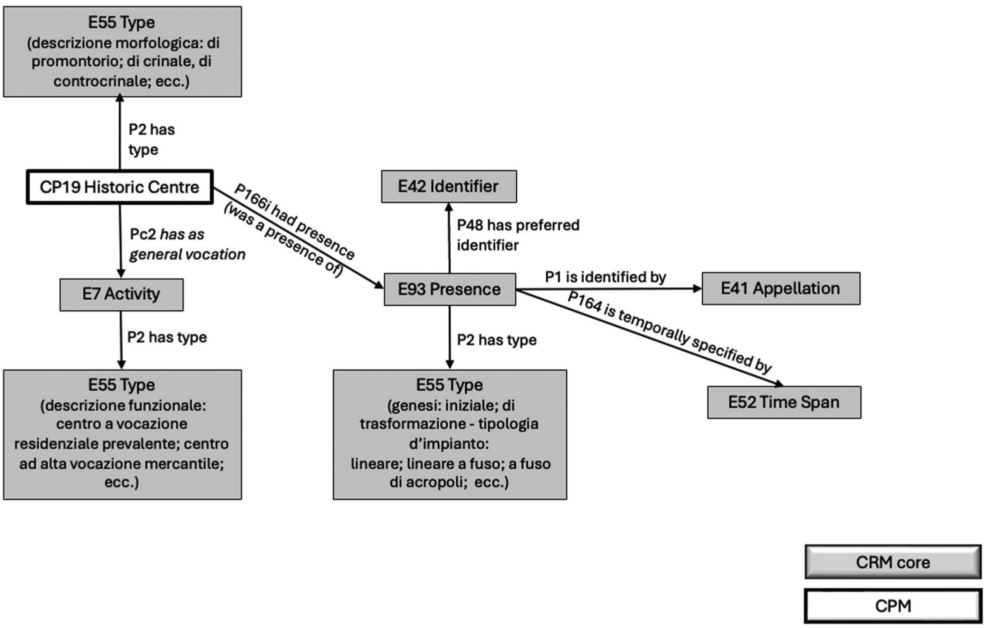

Fig. 2.4. Historic Centre. Urban configuration: description (*Centro storico. Configurazione urbana: descrizione*).

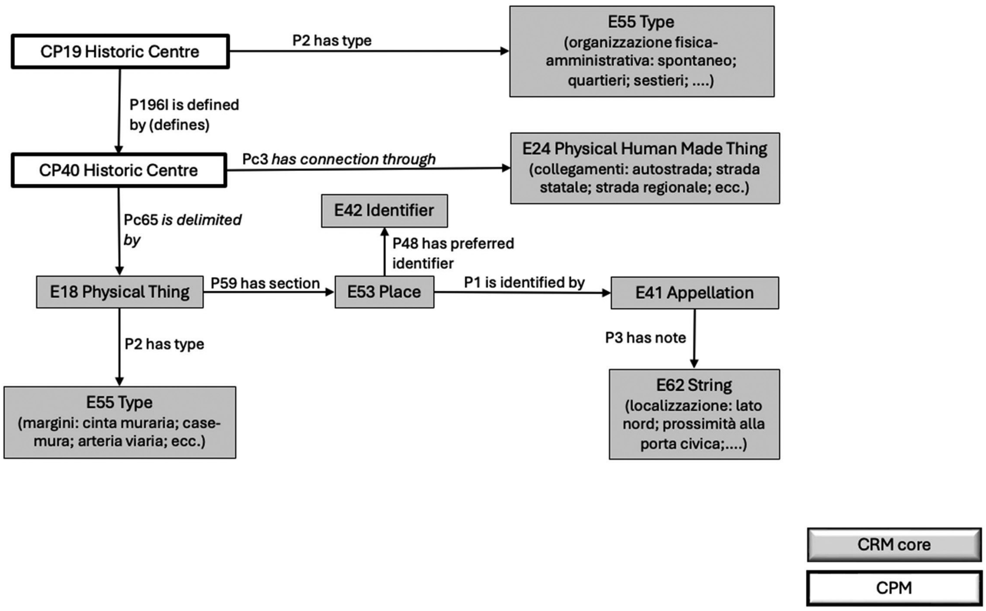

Fig. 2.5. Historic Centre. Urban configuration: description (*Centro Storico. Configurazione urbana: descrizione*).

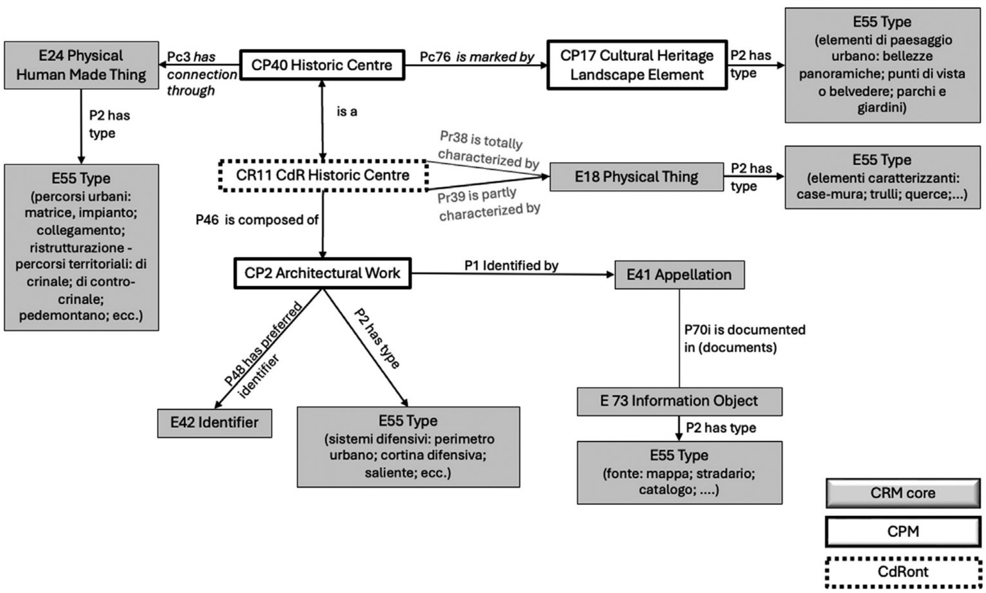

Fig. 2.6. Historic Centre. Urban configuration: description (*Centro Storico. Configurazione urbana: descrizione*).

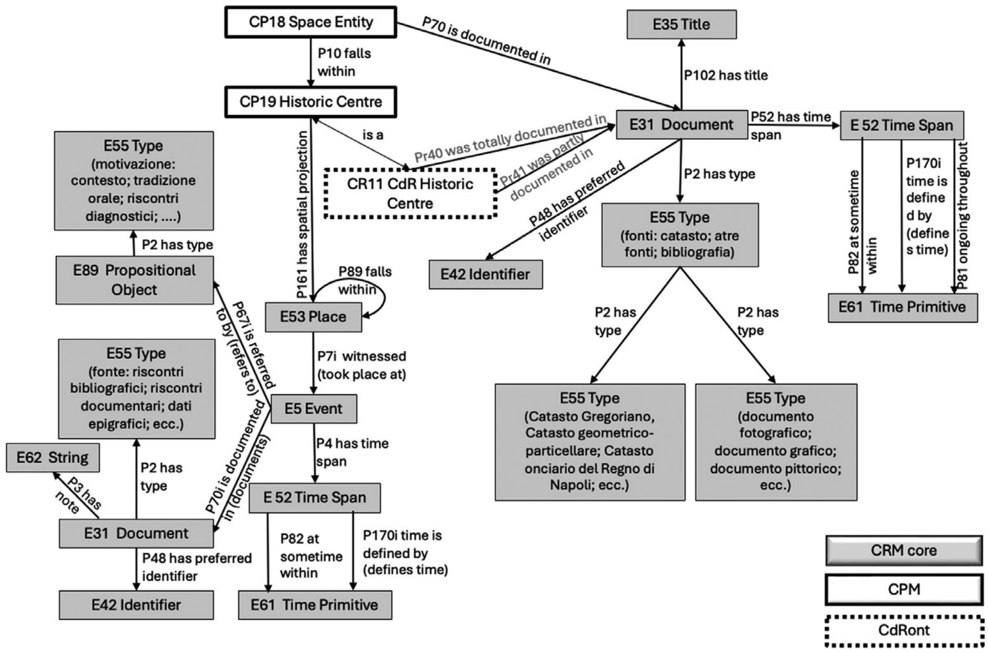

Fig. 2.7. Historic Centre. Chronology, sources and bibliographic references (*Centro Storico, Cronologia, fonti e bibliografia*).

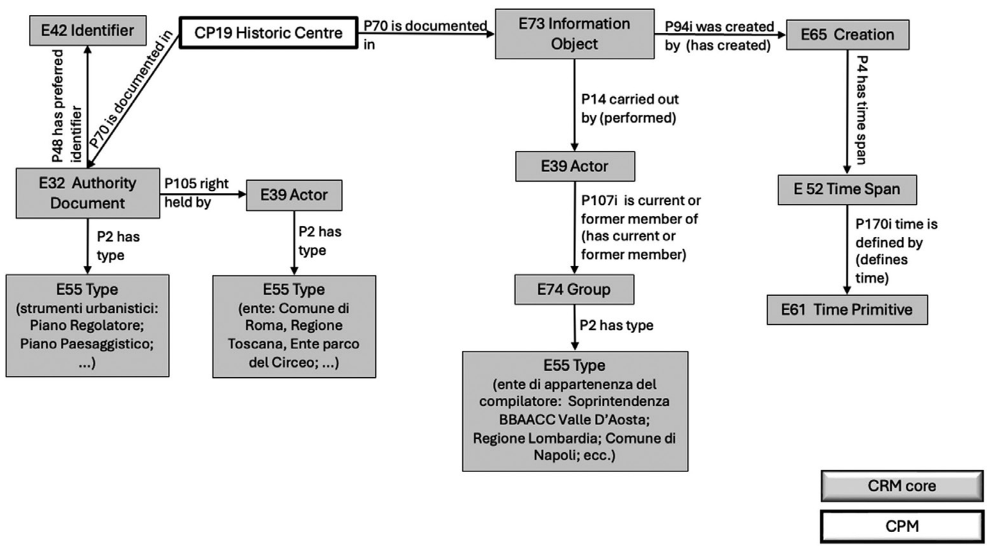

Fig. 2.8. Historic Centre. Chronology, Urban planning and compilation (*Centro Storico. Strumenti urbanistici e compilazione scheda*).

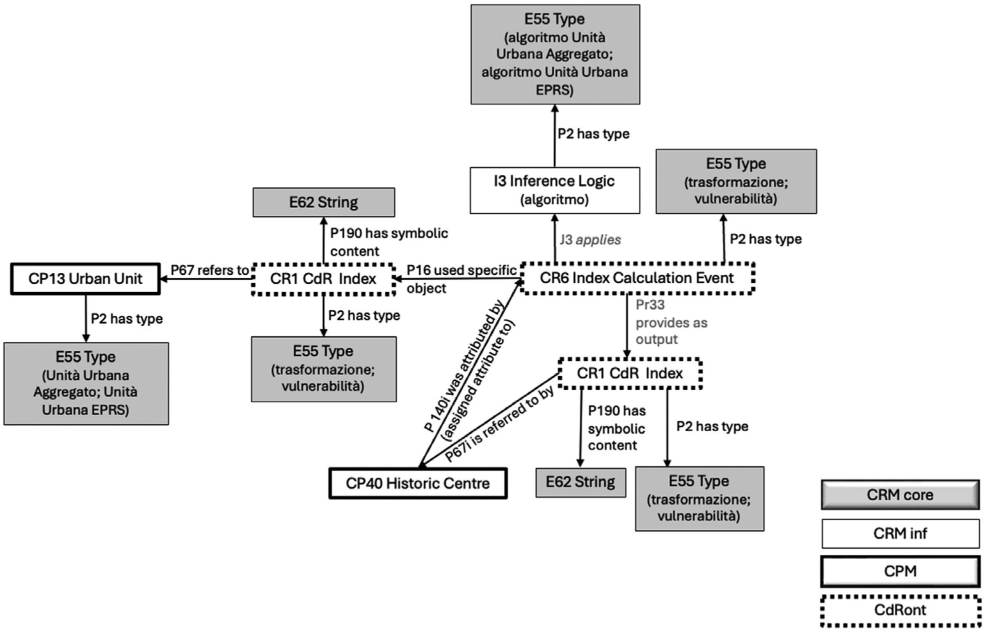

Fig. 2.9. Historic Centre. Vulnerability and transformation (*Centro Storico. Vulnerabilità e trasformazioni*).

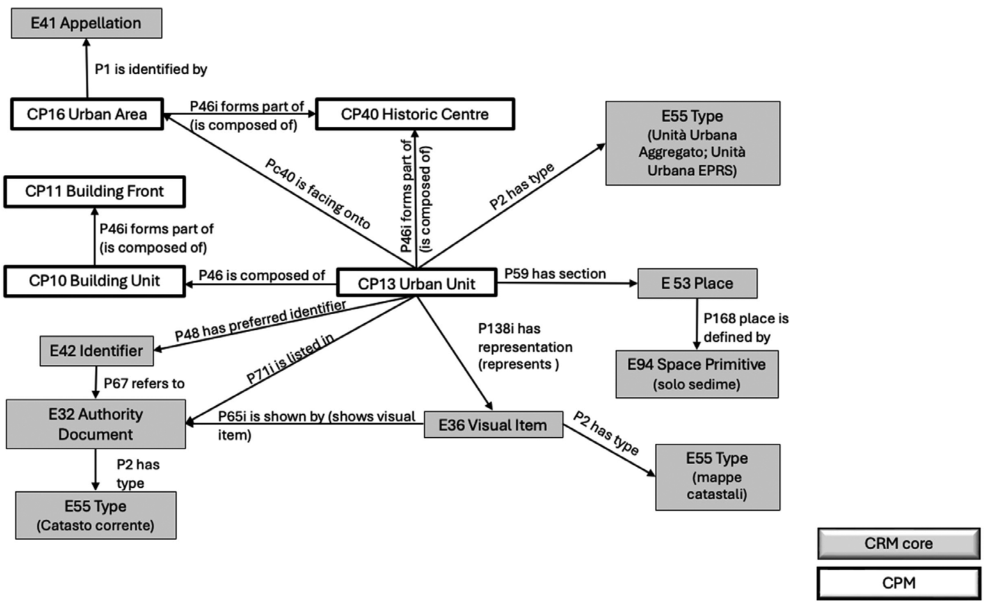

Fig. 2.10. Urban Aggregate Unit - Urban Punctual Residential and Specialised Building Unit. Location (*Unità Urbana Aggregato - Unità Urbana Edilizia Residenziale Puntuale e Specialistica. Localizzazione*).

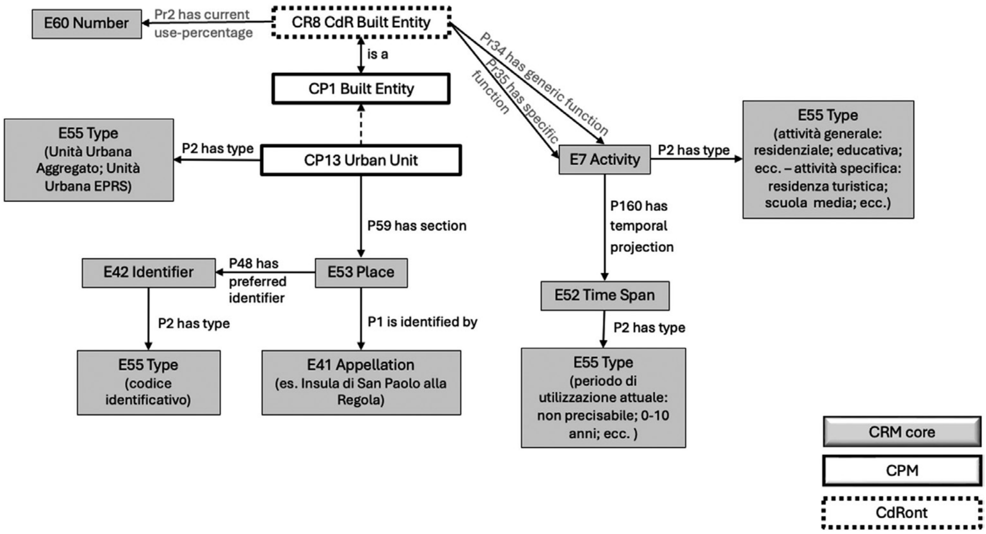

Fig. 2.11. Urban Aggregate Unit - Urban Punctual Residential and Specialised Building Unit. Identification (*Unità Urbana Aggregato - Unità Urbana Edilizia Residenziale Puntuale e Specialistica. Anagrafica*).

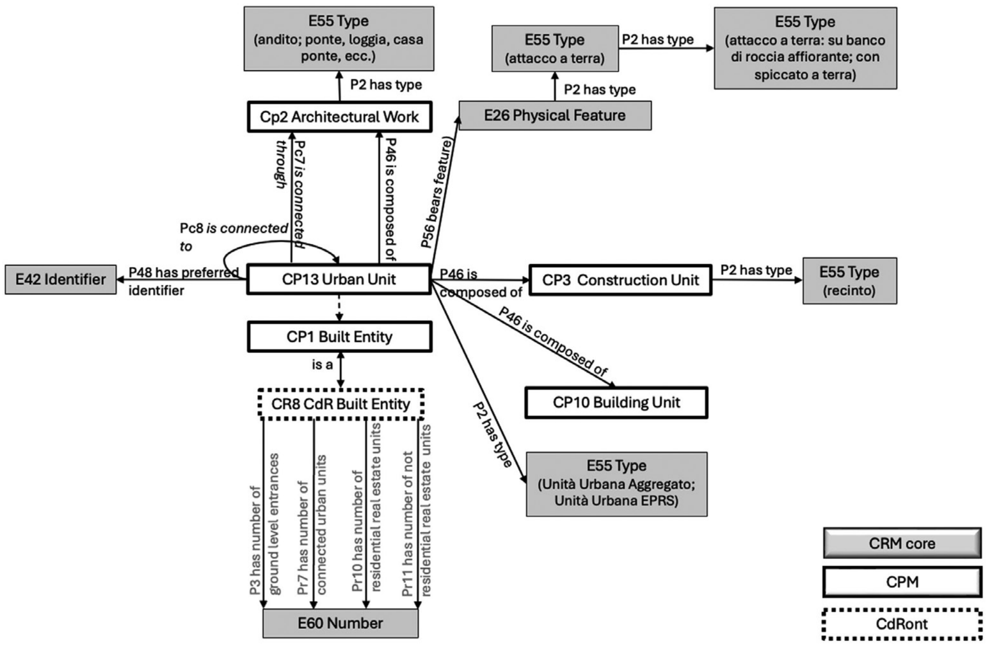

Fig. 2.12. Urban Aggregate Unit - Urban Punctual Residential and Specialised Building Unit. Building system (*Unità Urbana Aggregato - Unità Urbana Edilizia Residenziale Puntuale e Specialistica. Sistema edilizio*).

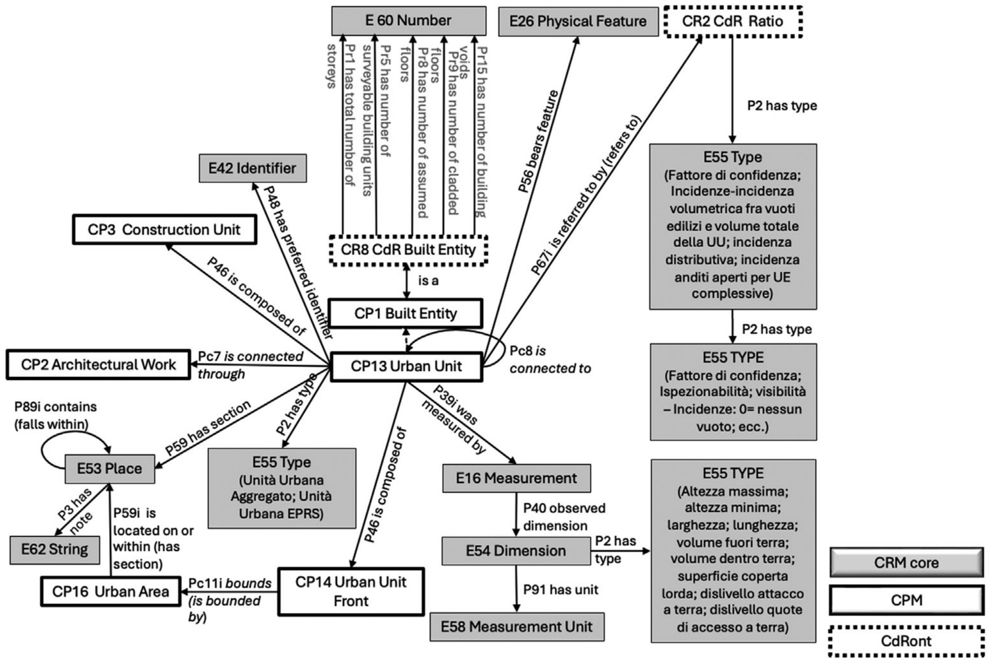

Fig. 2.13. Urban Aggregate Unit - Urban Punctual Residential and Specialised Building Unit. Building system (*Unità Urbana Aggregato - Unità Urbana Edilizia Residenziale Puntuale e Specialistica. Sistema edilizio*).

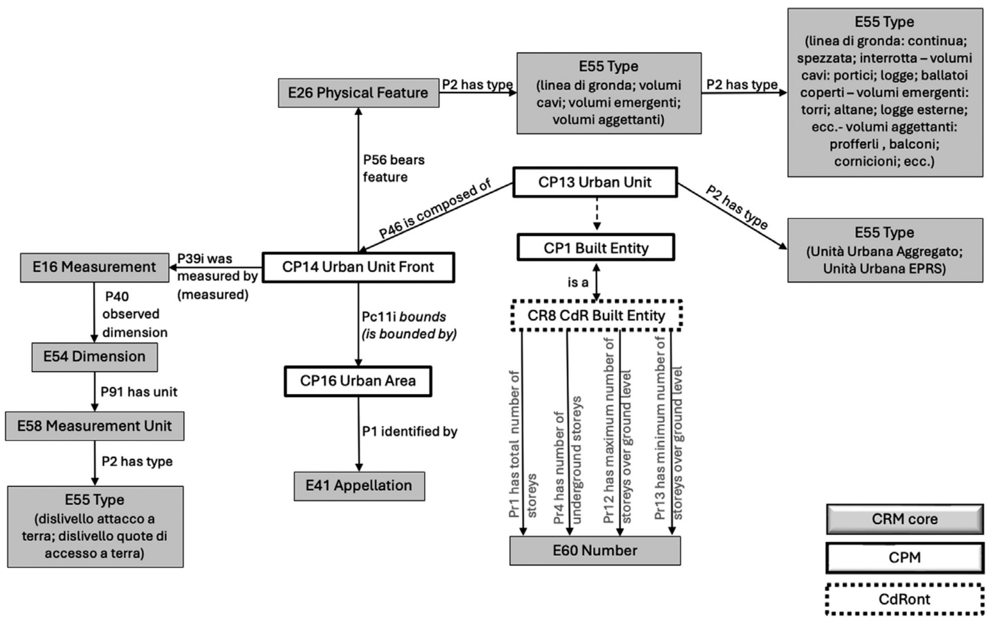

Fig. 2.14. Urban Aggregate Unit - Urban Punctual Residential and Specialised Building Unit. Building system urban unit fronts (*Unità Urbana Aggregato - Unità Urbana Edilizia Residenziale Puntuale e Specialistica. Sistema edilizio fronti unità urbana*).

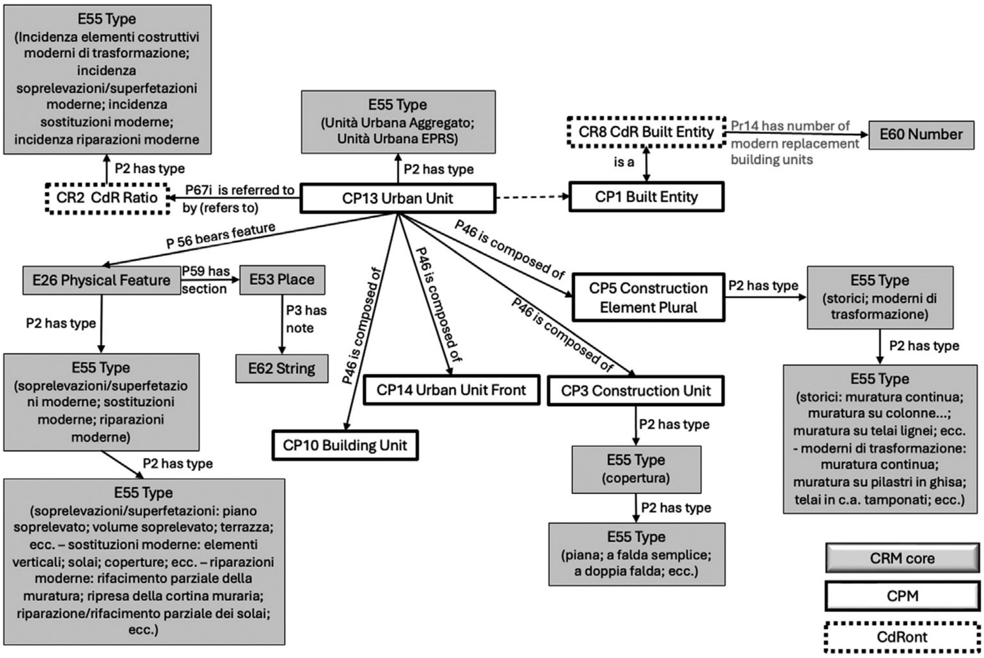

Fig. 2.15. Urban Aggregate Unit - Urban Punctual Residential and Specialised Building Unit. Construction and trasformation system – finishes and fixtures – accessibility of information (*Unità Urbana Aggregato - Unità Urbana Edilizia Residenziale Puntuale e Specialistica. Sistema costruttivo e di trasformazione, componenti edilizie ed elementi costruttivi*).

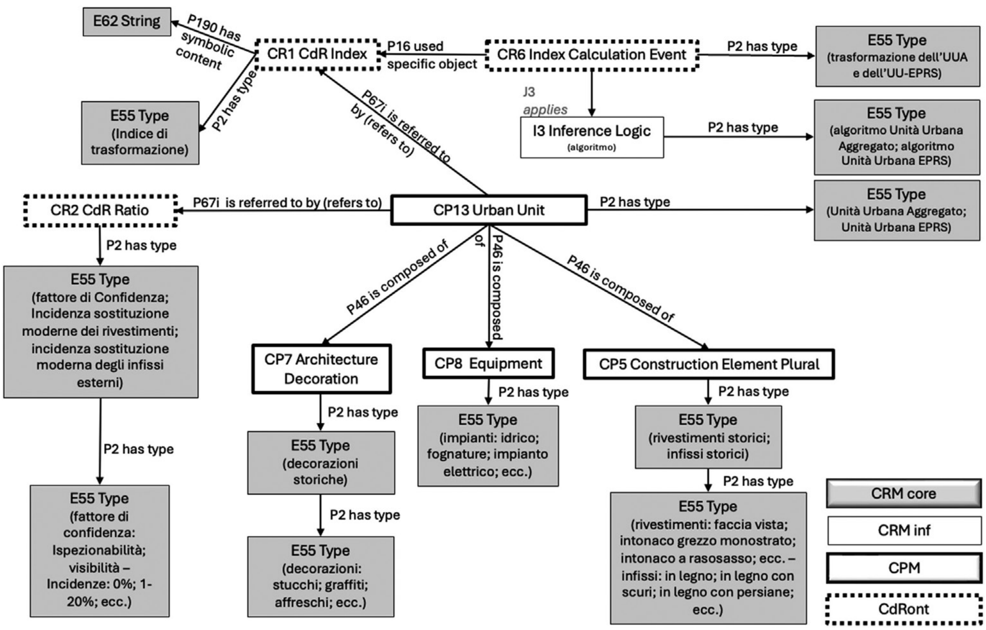

Fig. 2.16. Urban Aggregate Unit - Urban Punctual Residential and Specialised Building Unit. Construction and transformation system - building components and building elements (*Unità Urbana Aggregato - Unità Urbana Edilizia Residenziale Puntuale e Specialistica. Sistema costruttivo e di trasformazione, finiture e infissi, accessibilità alle informazioni*).

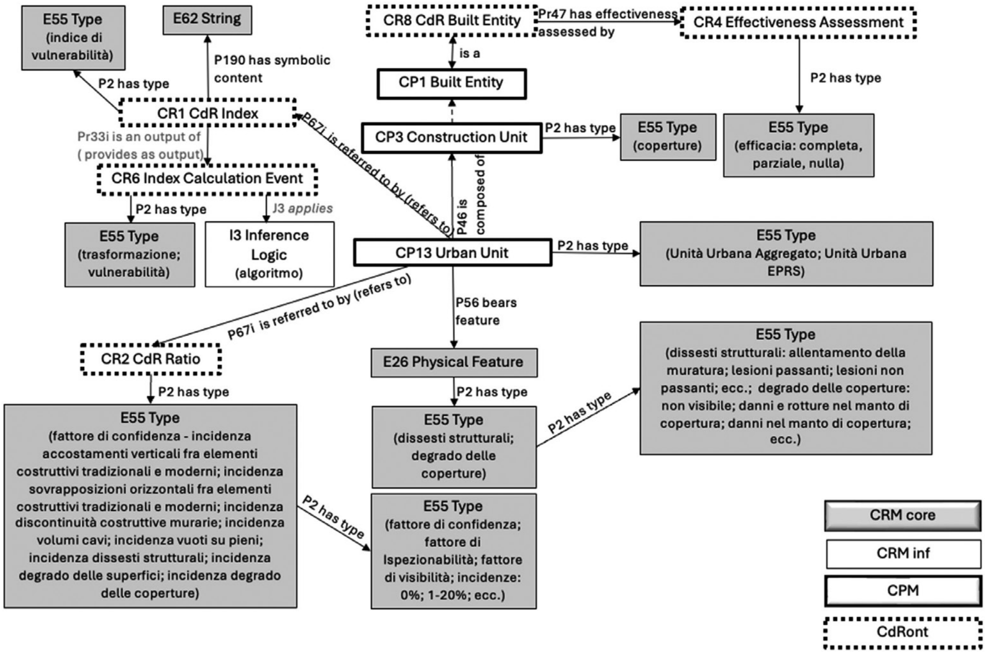

Fig. 2.17. Urban Aggregate Unit - Urban Punctual Residential and Specialised Building Unit. Conservation state (*Unità Urbana Aggregato - Unità Urbana Edilizia Residenziale Puntuale e Specialistica. Stato di conservazione*).

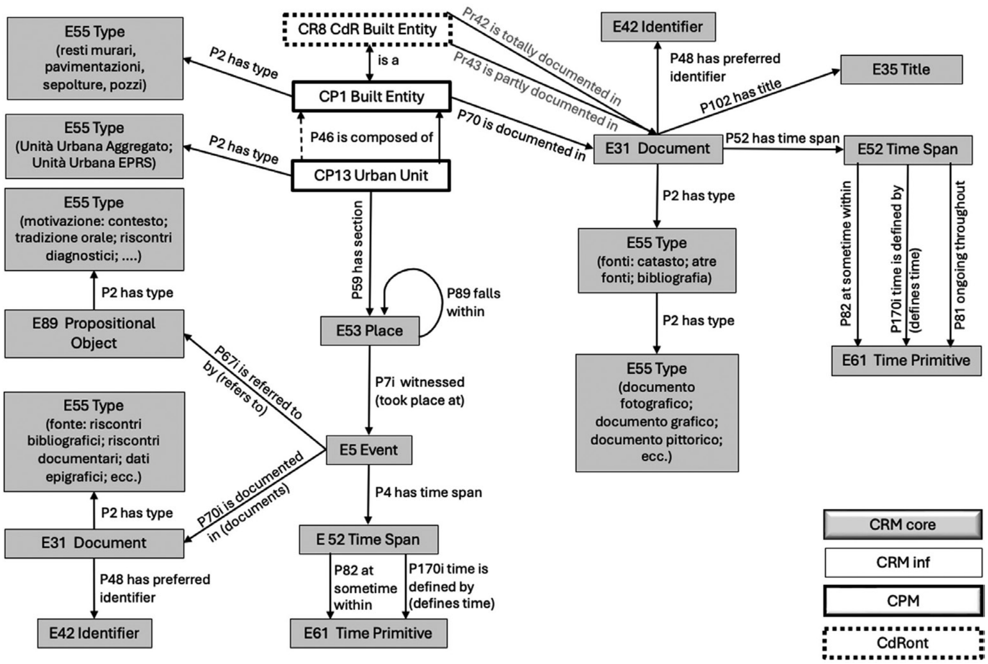

Fig. 2.18. Urban Aggregate Unit - Urban Punctual Residential and Specialised Building Unit. Historic Data (*Unità Urbana Aggregato - Unità Urbana Edilizia Residenziale Puntuale e Specialistica. Dati storici*).

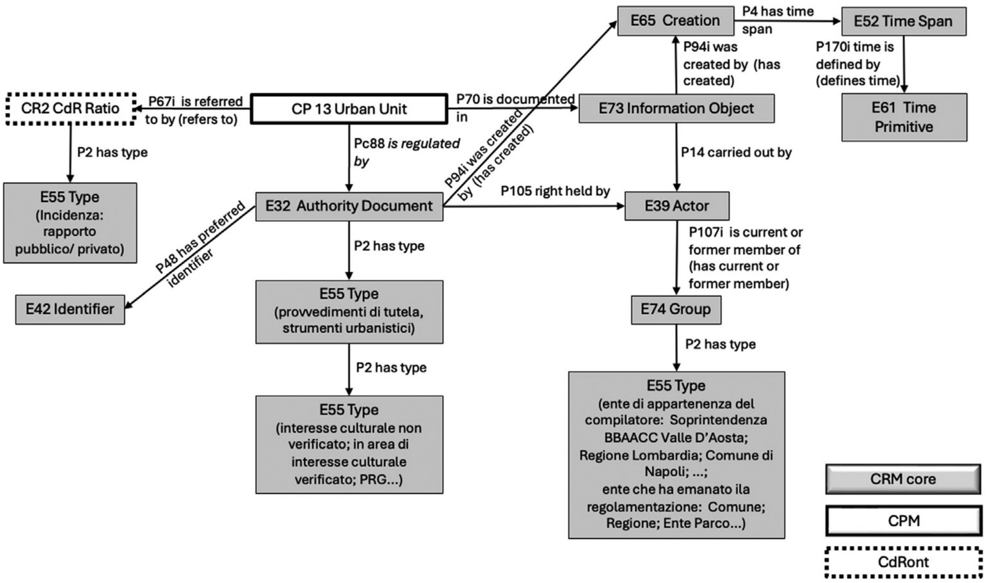

Fig. 2.19. Urban Aggregate Unit - Urban Punctual Residential and Specialised Building Unit. Rules (*Unità Urbana Aggregato - Unità Urbana Edilizia Residenziale Puntuale e Specialistica. Normative*).

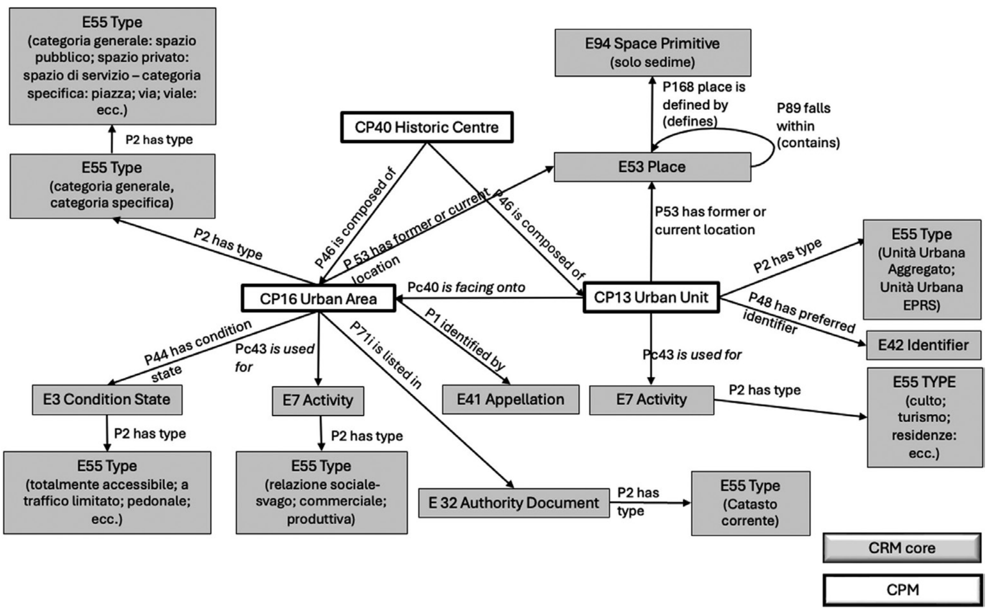

Fig. 2.20. Urban Space. Location and Identification (*Spazio Urbano. Localizzazione e anagrafica*).

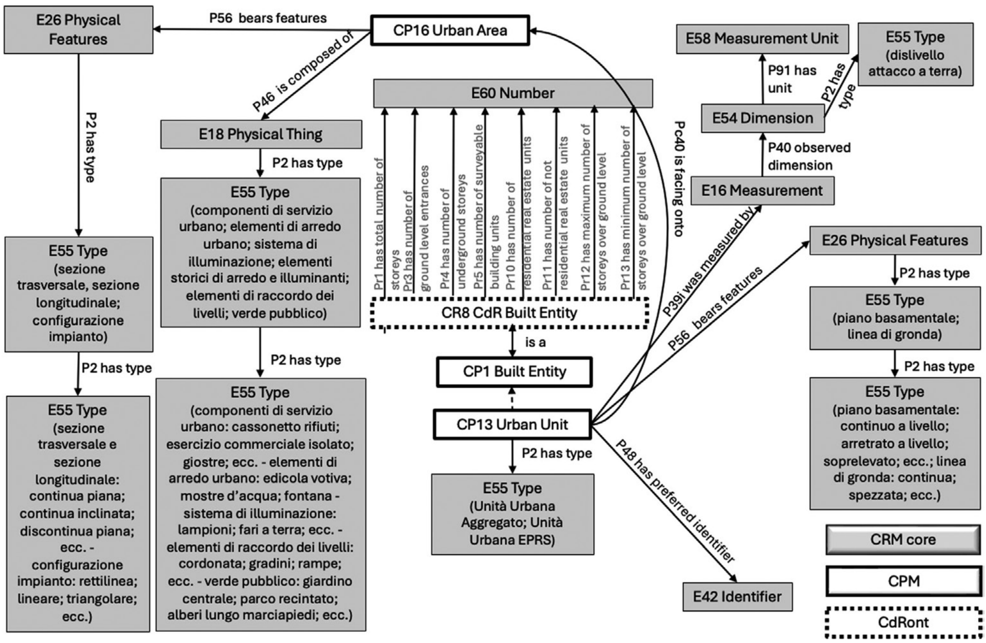

Fig. 2.21. Urban Space. Urban System (*Spazio Urbano. Sistema urbano*).

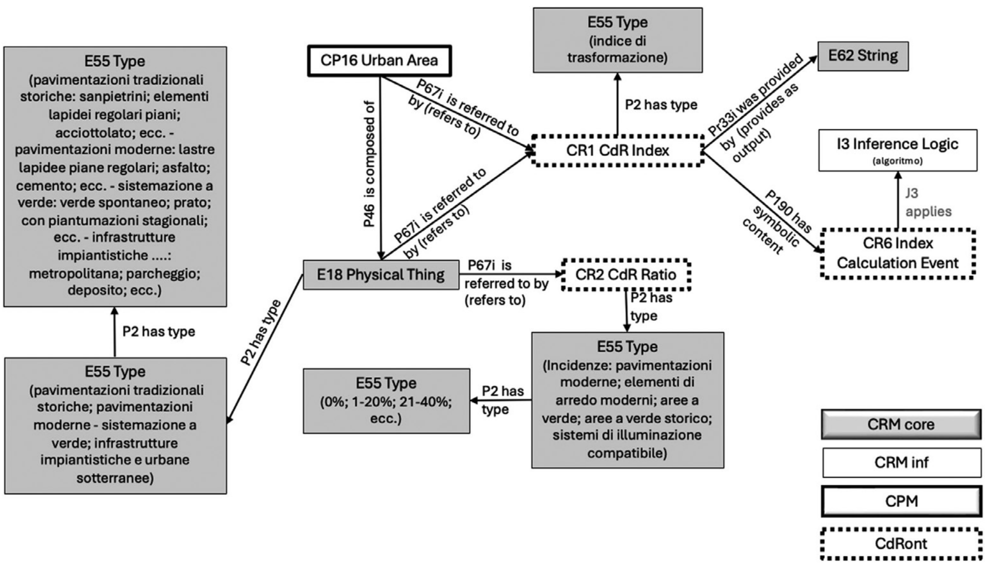

Fig. 2.22. Urban Space. Artificial/natural system and transformation system (*Spazio Urbano. Sistema artificiale/naturale e di trasformazione*).

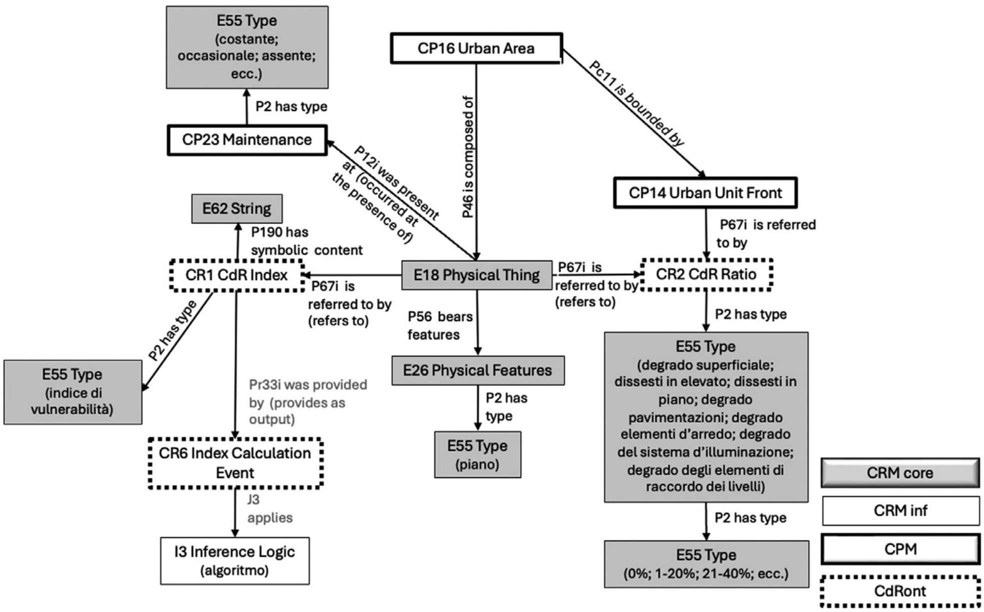

Fig. 2.23. Urban Space. Decay and damages (*Spazio Urbano. Degrado e dissesti*).

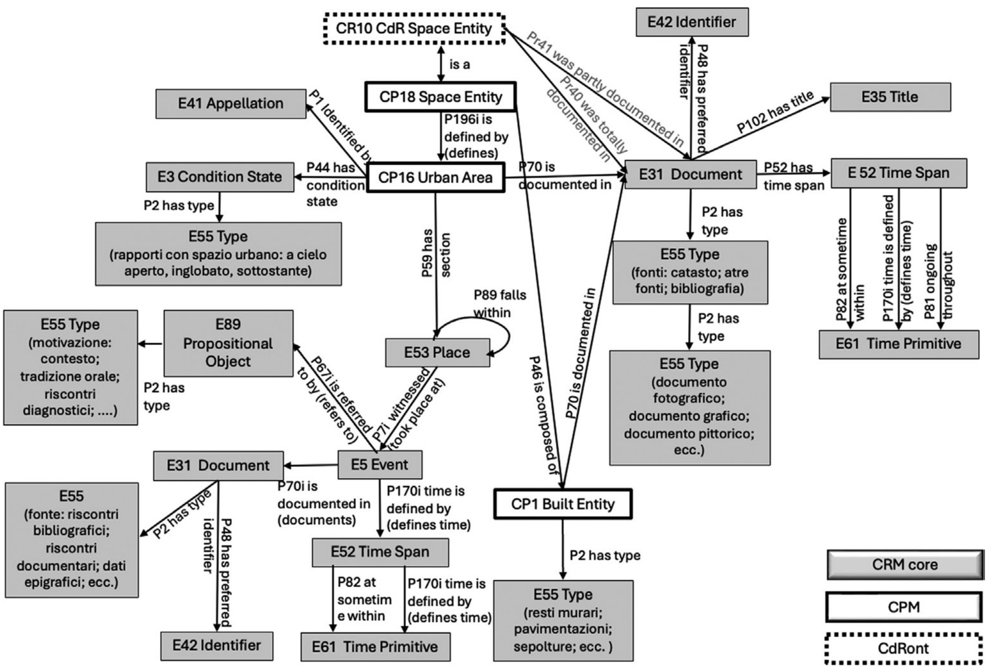

Fig. 2.24. Urban Space. Historica datas (*Spazio Urbano. Dati storici*).

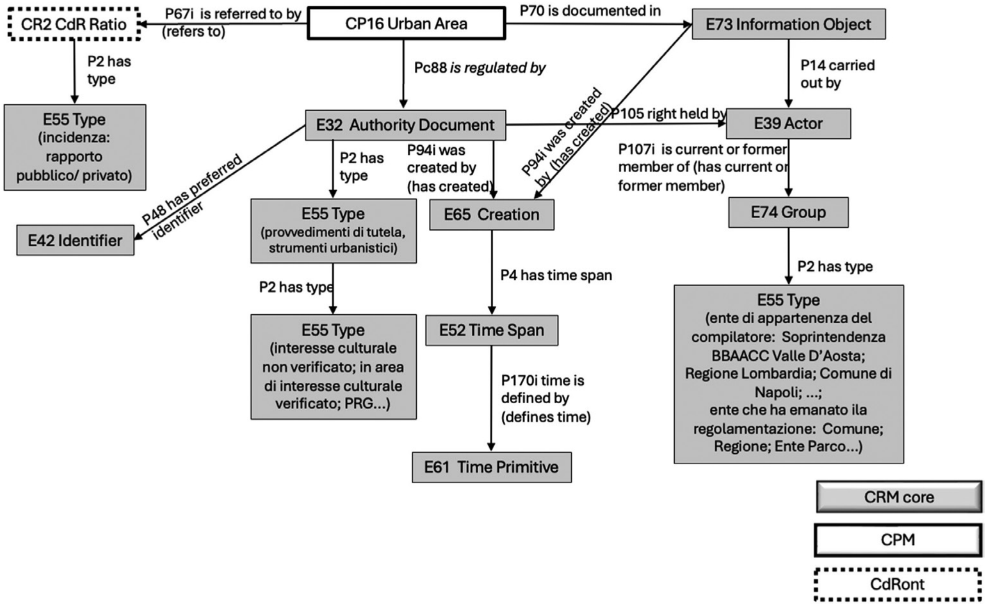

Fig. 2.25. Urban Space. Rules (*Spazio Urbano. Normative*).

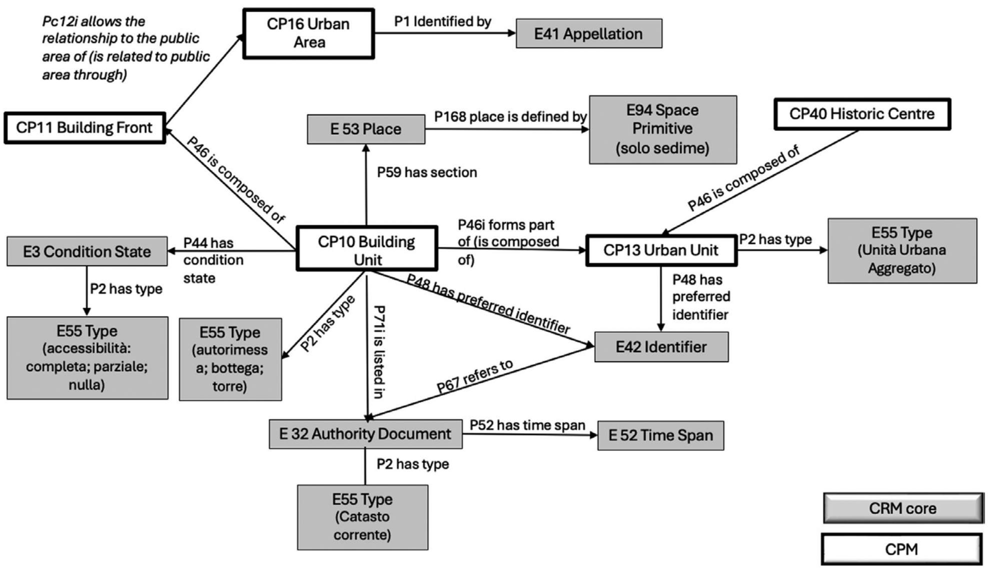

Fig. 2.26. Building Unit. Location (*Unità Edilizia. Localizzazione*).

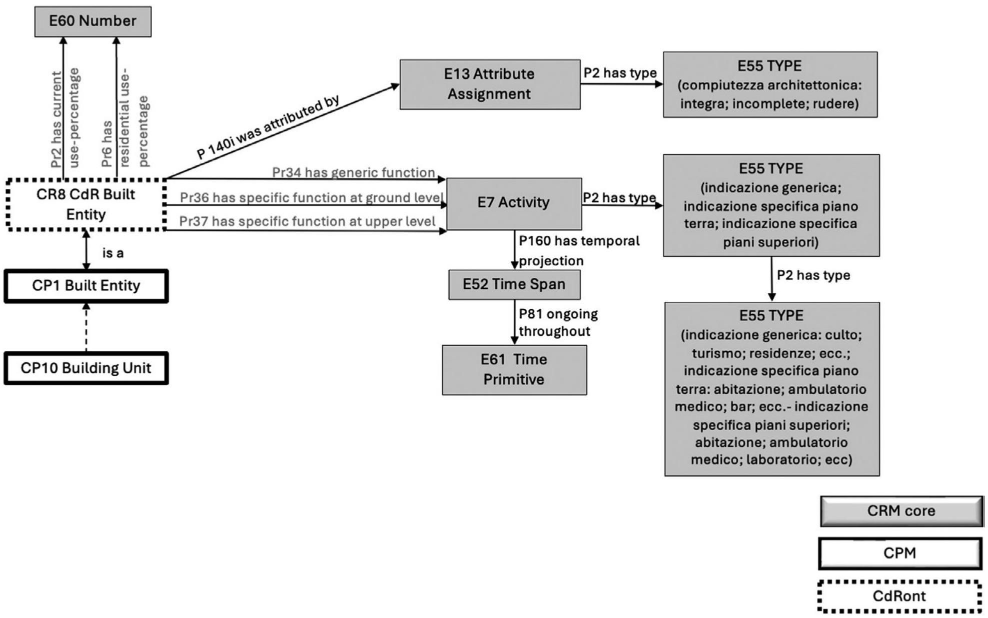

Fig. 2.27. Building Unit. Identification (*Unità Edilizia. Anagrafica*).

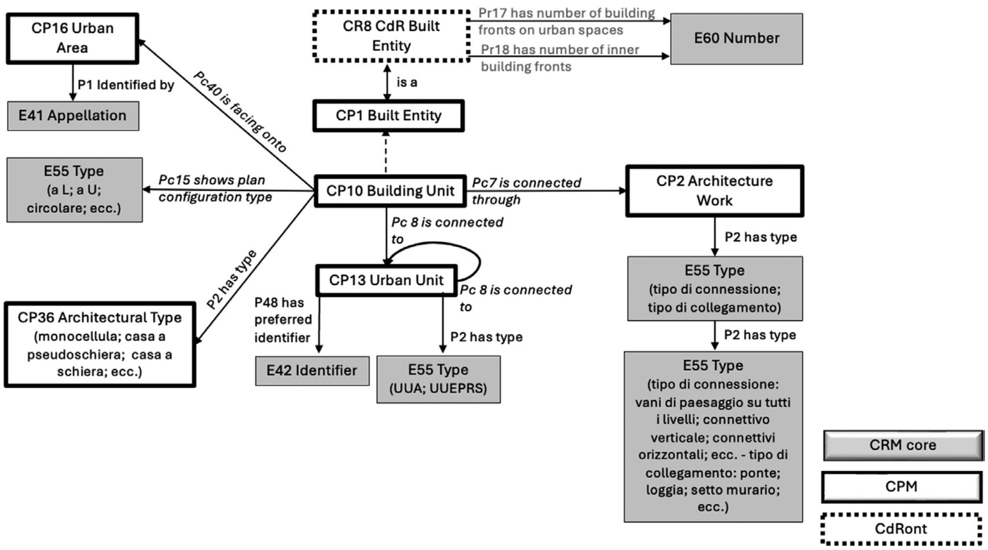

Fig. 2.28. Building Unit. Building system (*Unità Edilizia. Sistema edilizio*).

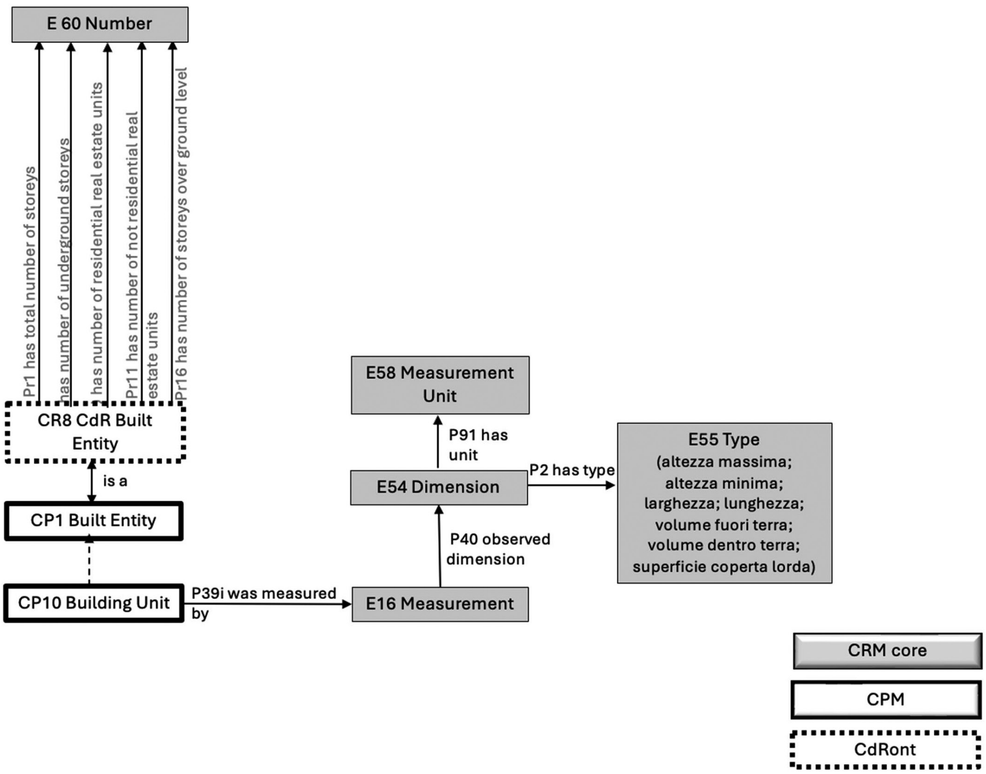

Fig. 2.29. Building Unit. Building system (*Unità Edilizia. Sistema edilizio*).

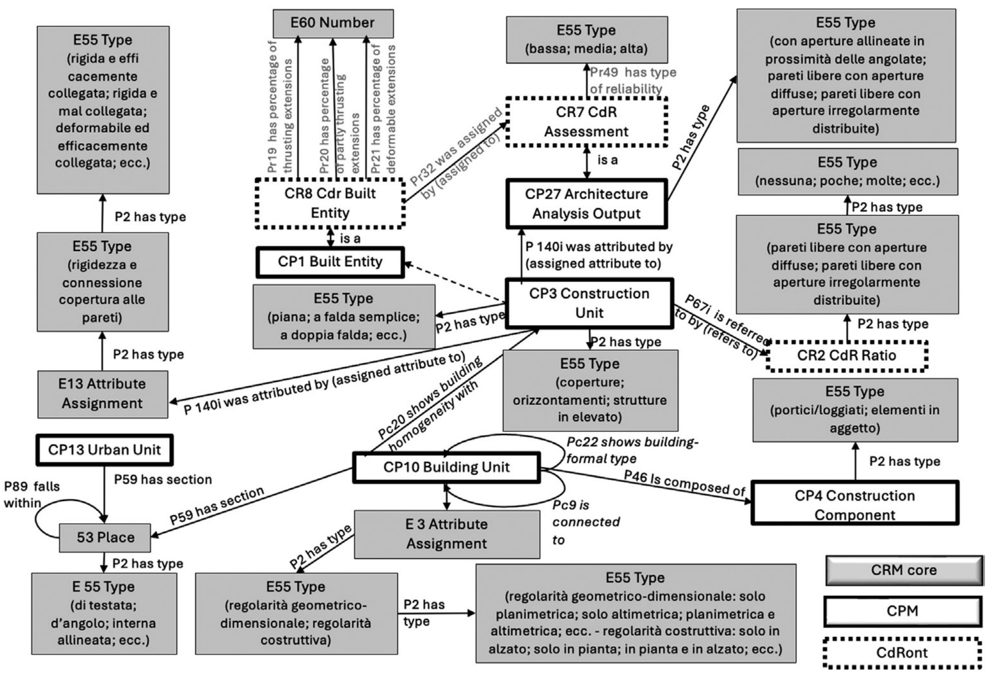

Fig. 2.30. Building Unit. Structural system (*Unità edilizia. Sistema strutturale*).

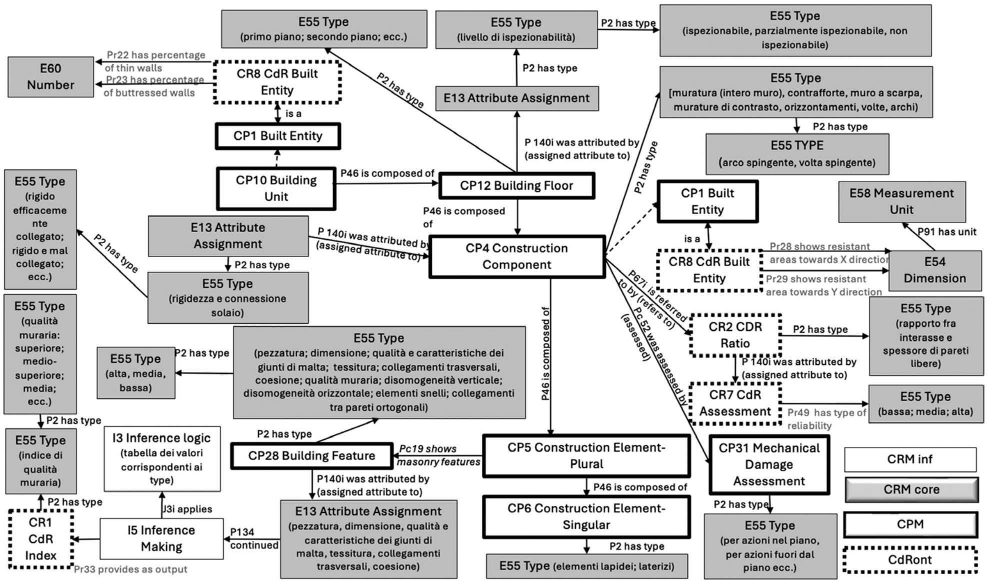

Fig. 2.31. Building Unit. Structural system according to floors (*Unità edilizia. Sistema strutturale per piani*).

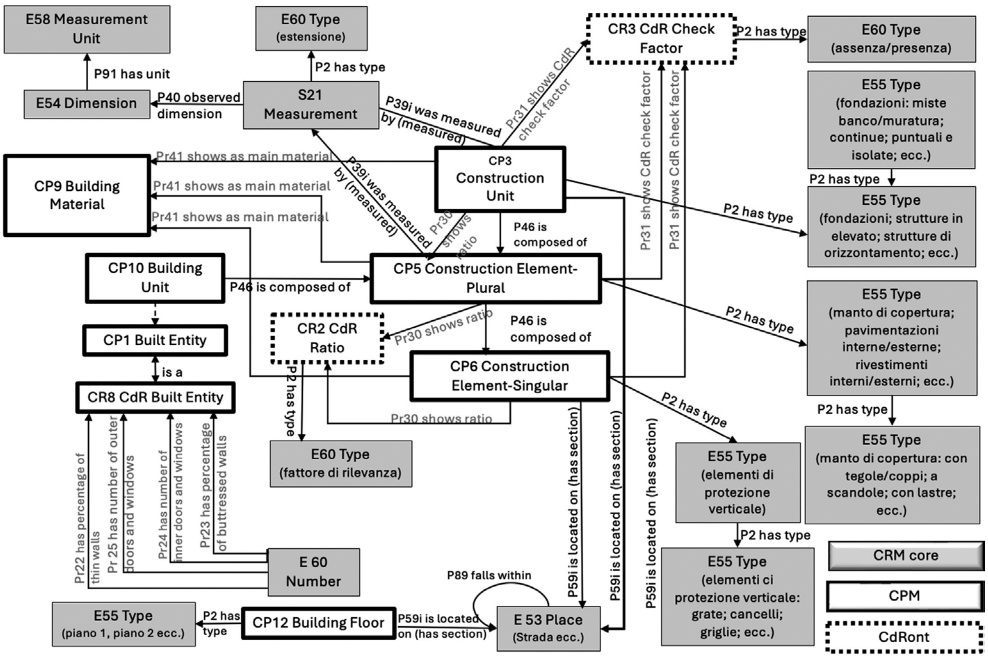

Fig. 2.32. Building Unit. Construction system and conservation state (*Unità edilizia. Sistema costruttivo e stato di conservazione*).

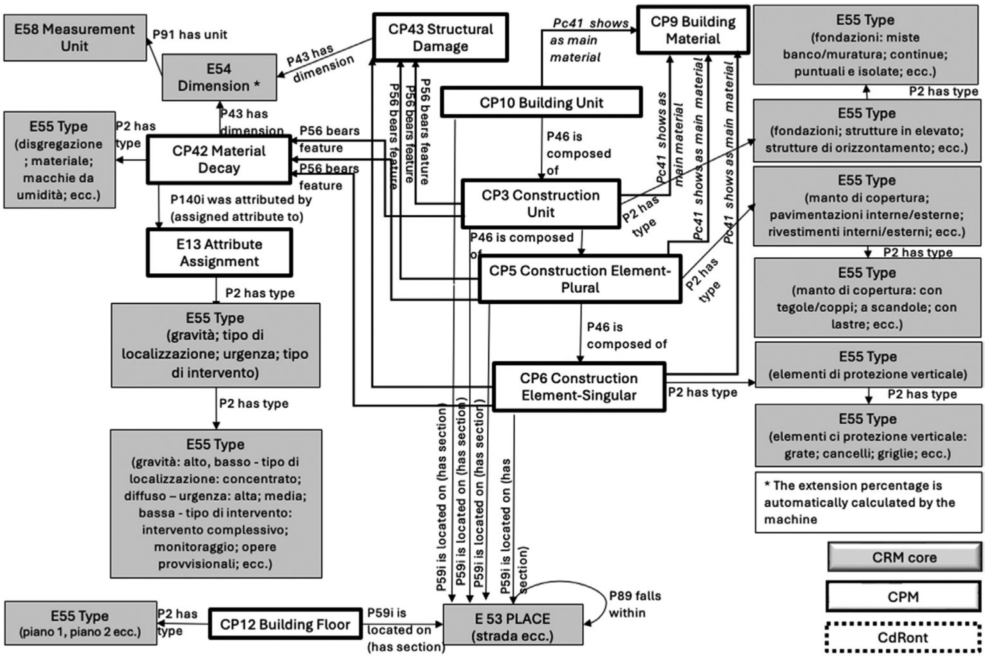

Fig. 2.33. Building Unit. Construction system and conservation state (*Unità Edilizia. Sistema costruttivo e stato di conservazione*).

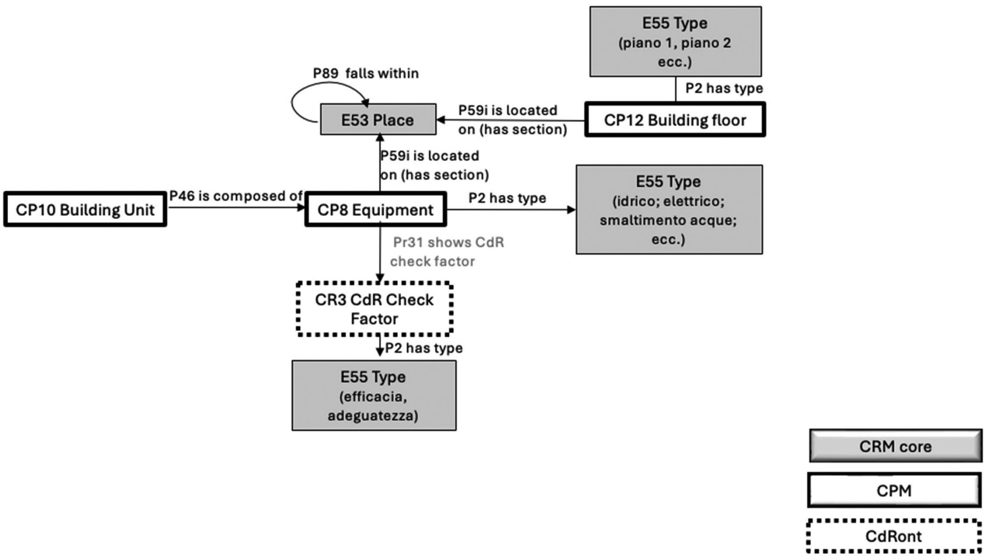

Fig. 2.34. Building Unit. Utility system (*Unità edilizia. Impianti*).

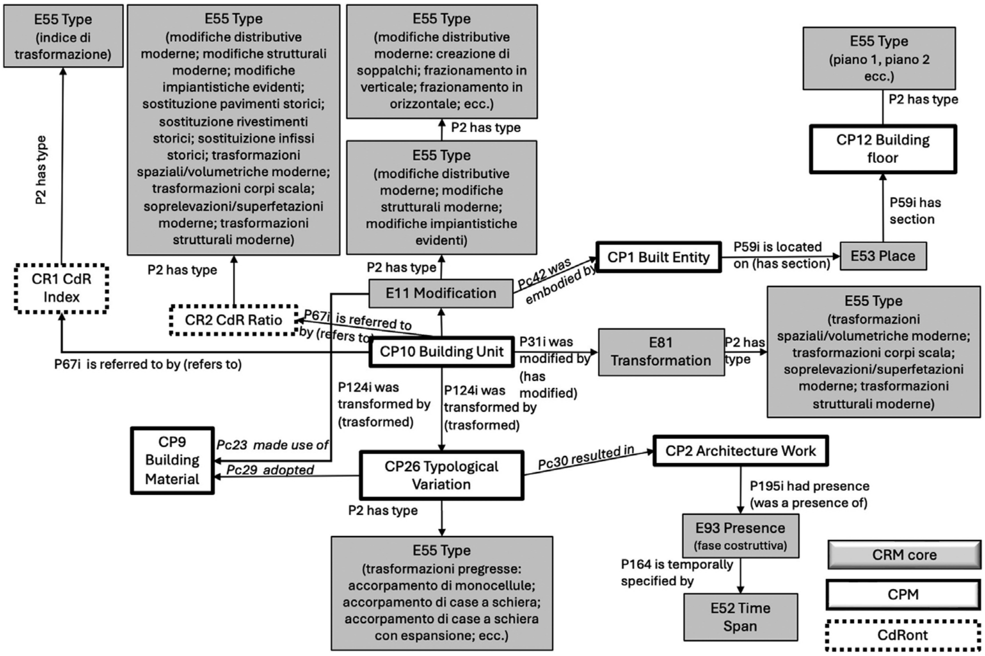

Fig. 2.35. Building Unit. Modifications and transformations (*Unità Edilizia. Modifiche e trasformazioni*).

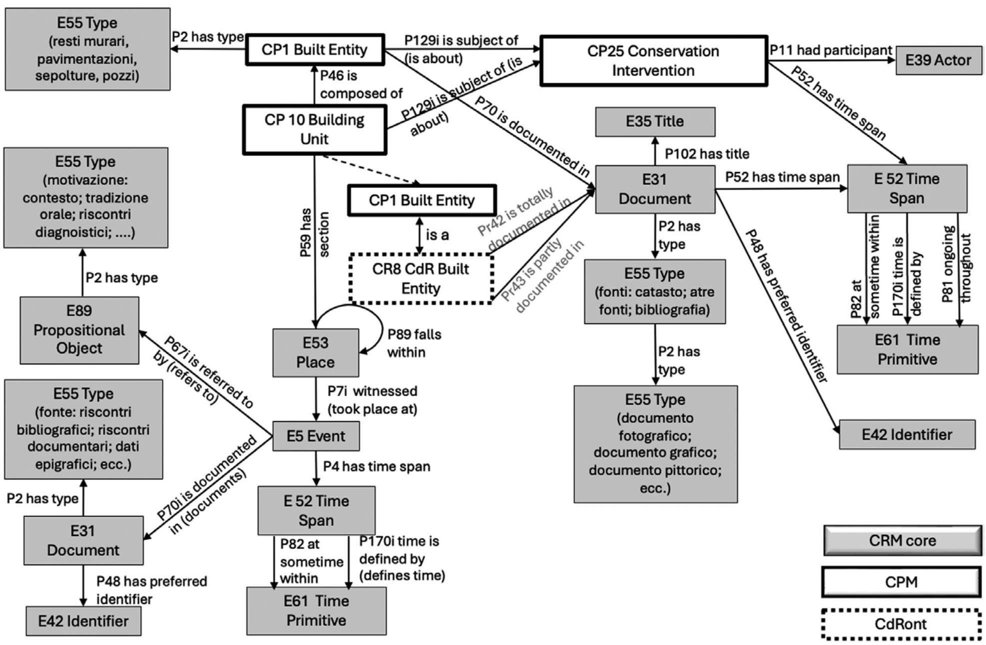

Fig. 2.36. Building Unit. Chronology, conservation interventions, sources and bibliographic references (*Unità Edilizia. Cronologia, interventi di restauro, fonti e bibliografia*).

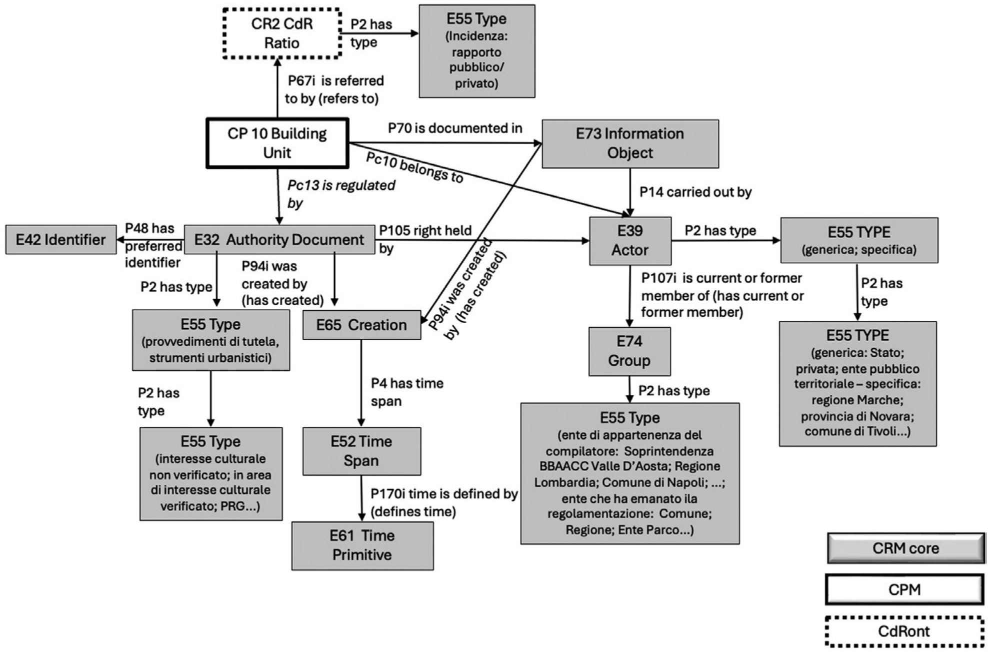

Fig. 2.37. Building Unit. Rules (*Unità edilizia, normative*).

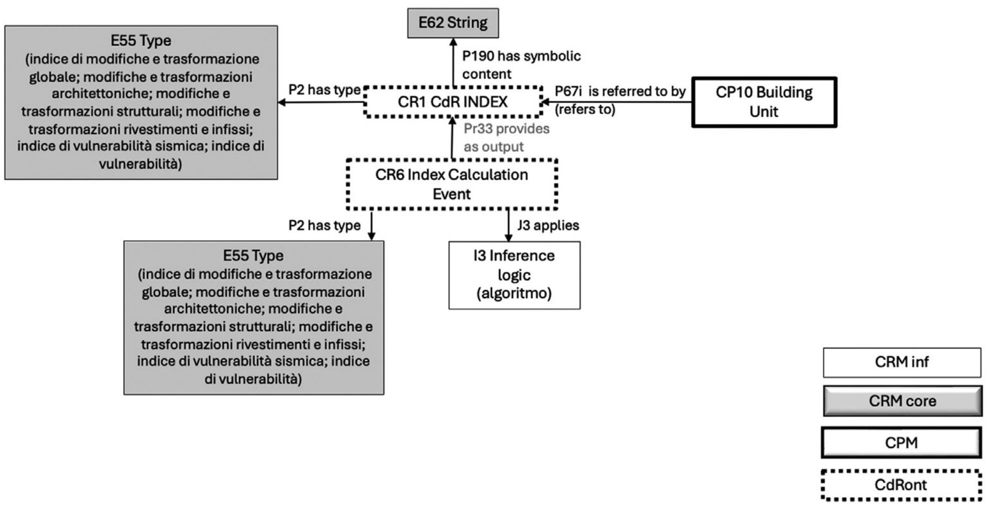

Fig. 2.38. Building Unit. Conservation state (*Unità Edilizia. Stato di conservazione*).

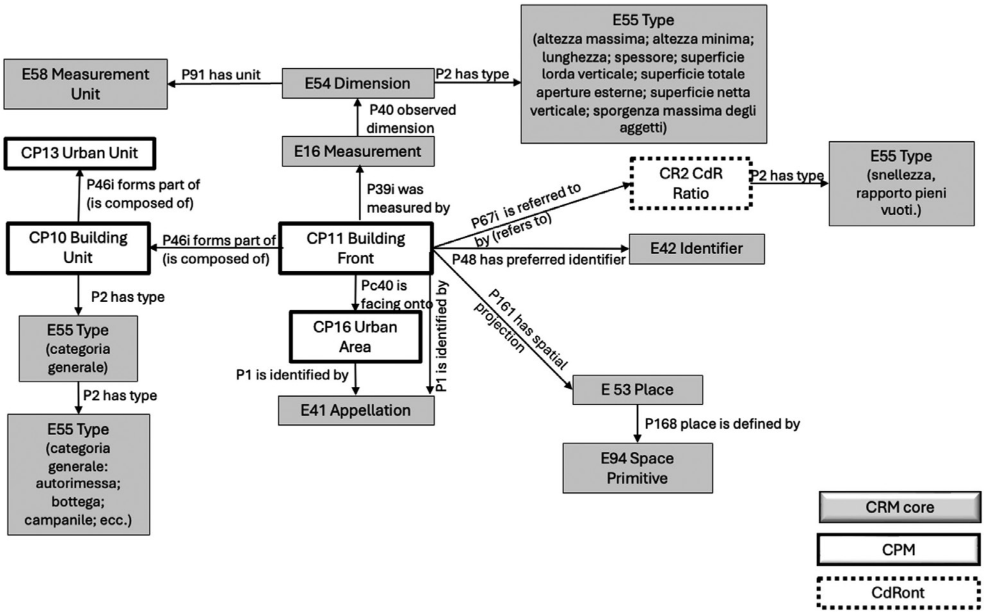

Fig. 2.39. Building Front, location and dimensional data (*Fronte Edilizio. Localizzazione e dati dimensionali*).

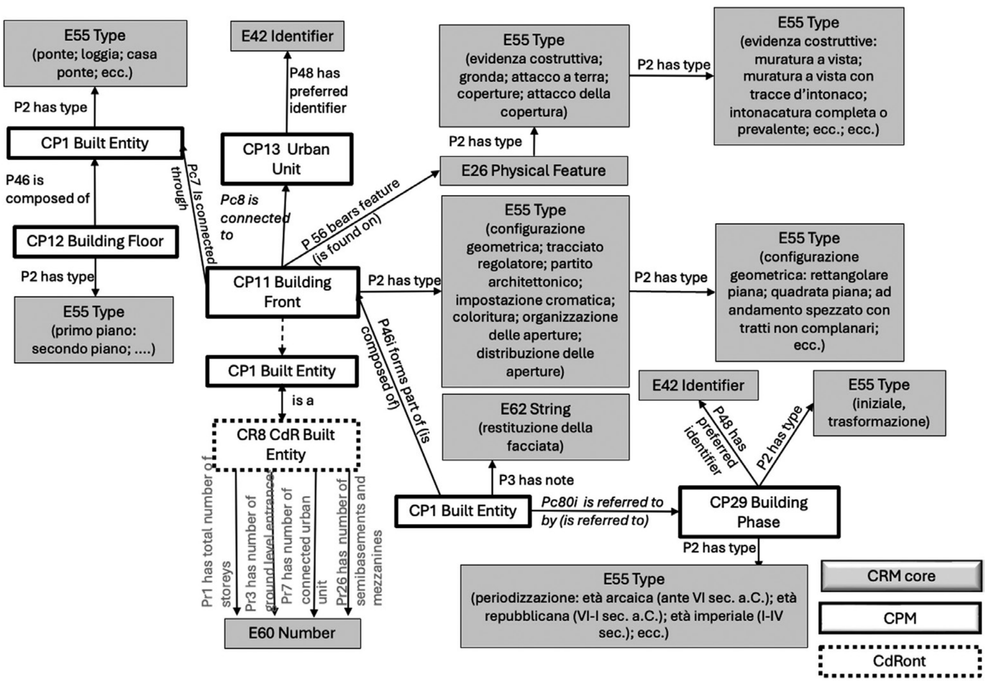

Fig. 2.40. Building Front. Architecture/construction system-building connections, general quantities data, architecture and construction features, building phases (*Fronte Edilizio, sistema architettonico costruttivo, collegamenti edilizi, dati quantitativi generali, caratteristiche architettoniche e costruttive, fasi costruttive*).

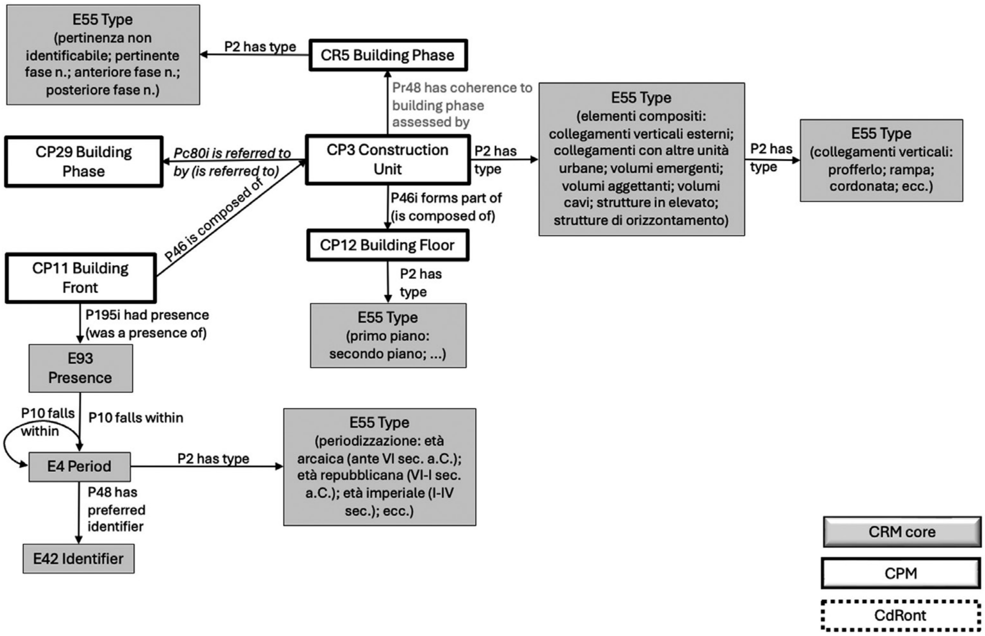

Fig. 2.41. Building Front. Construction elements-utility system: complex elements (*Fronte Edilizio. Elementi costruttivi-impianti: elementi compositi*.

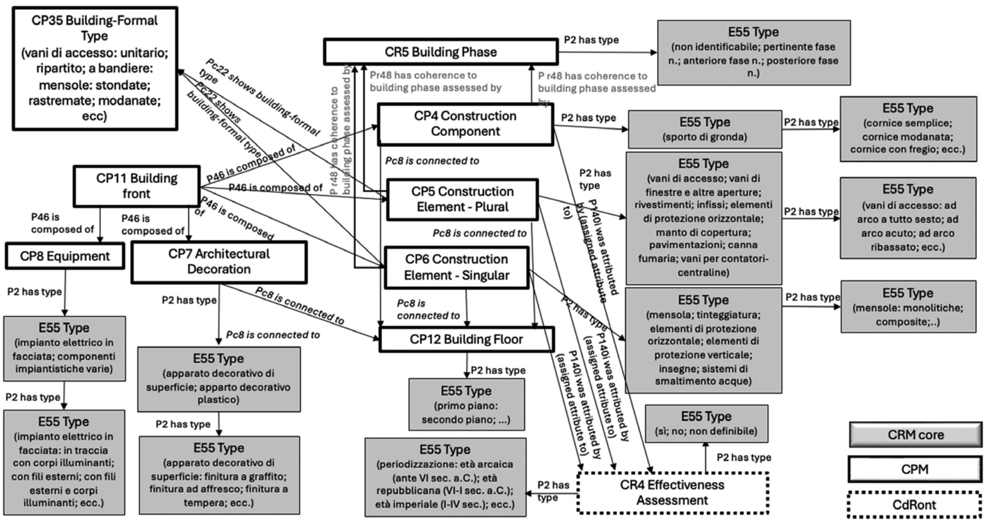

Fig. 2.42. Building Front. Construction elements and utility system: singular component elements *(Fronte Edilizio. Elementi costruttivi e impianti: elementi componenti individui*).

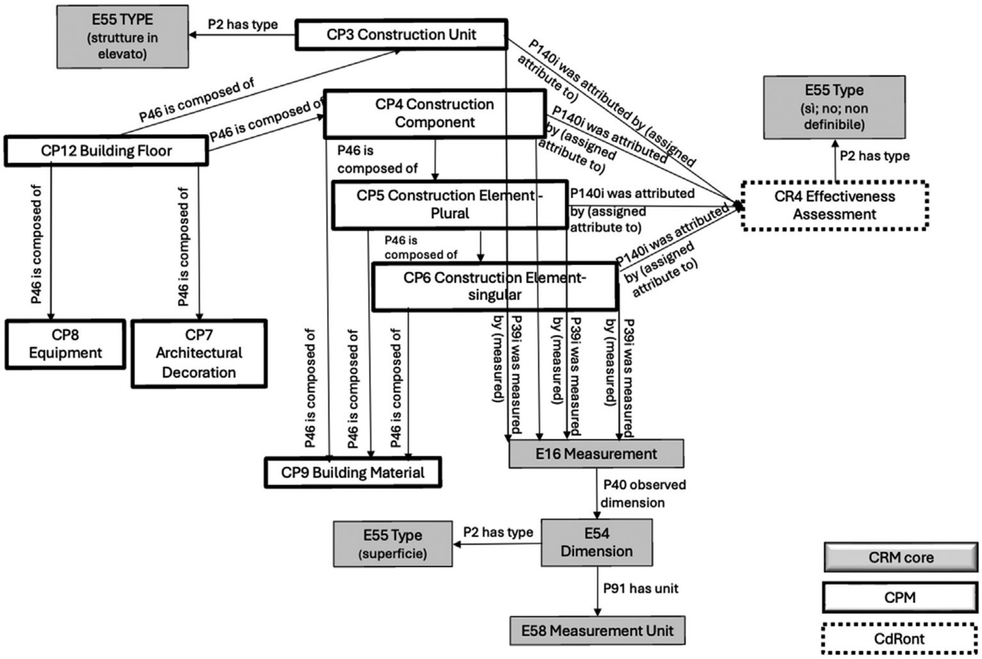

Fig. 2.43. Building Front. Construction elements and utility system: singular component elements (*Fronte Edilizio. Elementi costruttivi e impianti: elementi componenti individui)*.

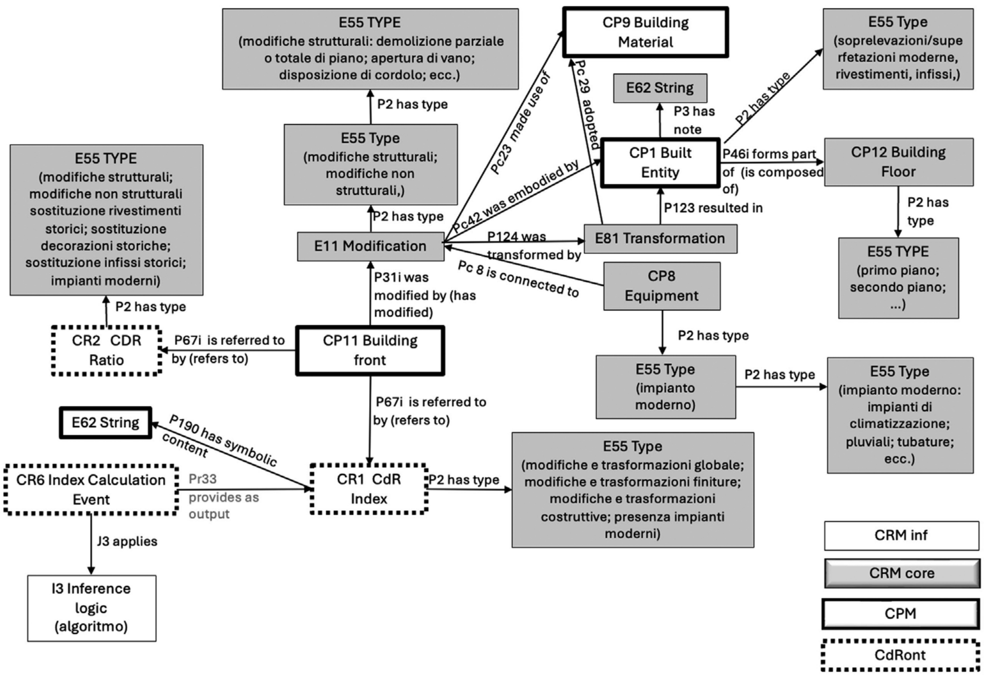

Fig. 2.44. Building Front. Modifications and transformations *(Fronte Edilizio. Modifiche e trasformazioni*).

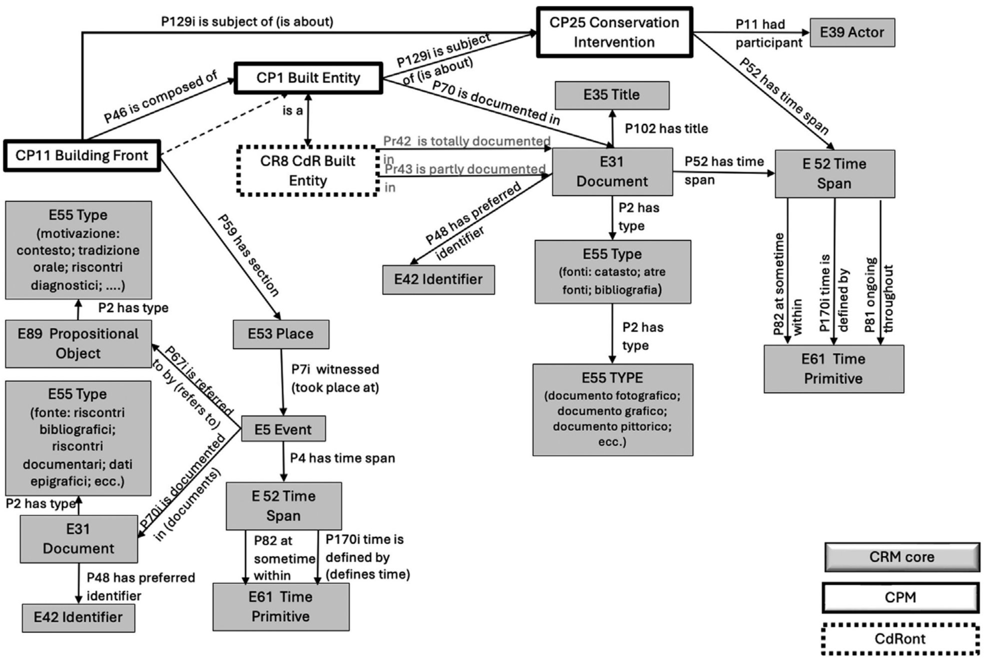

Fig. 2.45. Building Front. Chronology, conservation interventions, sources and bibliographic references (*Fronte Edilizio. Cronologia, interventi di restauro, fonti e bibliografia*).

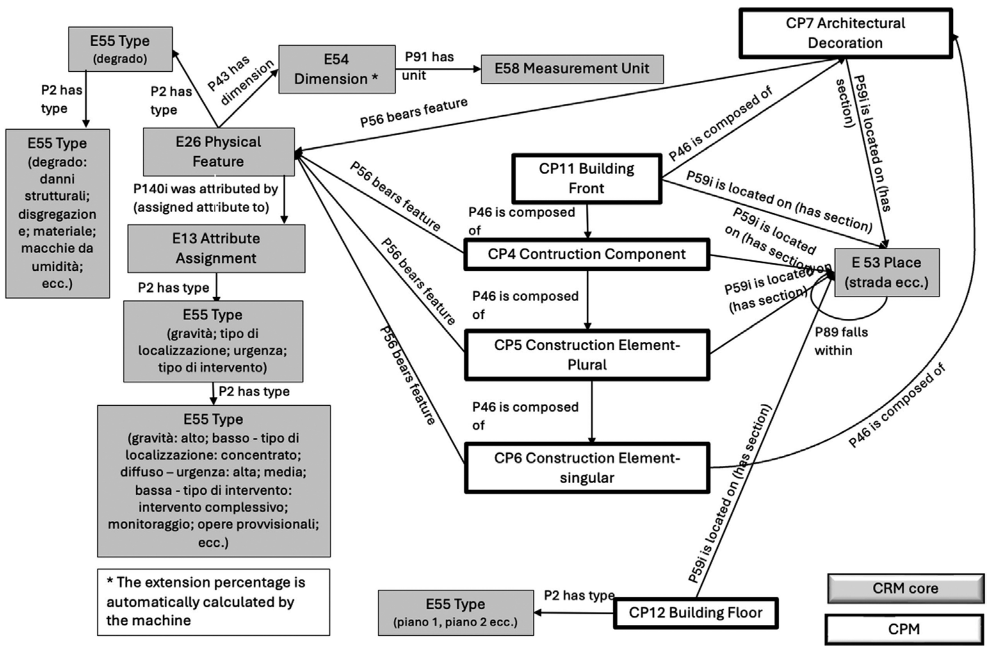

Fig. 2.46. Building Front. Construction system and conservation state (*Fronte Edilizio, sistema costruttivo e stato di conservazione*).

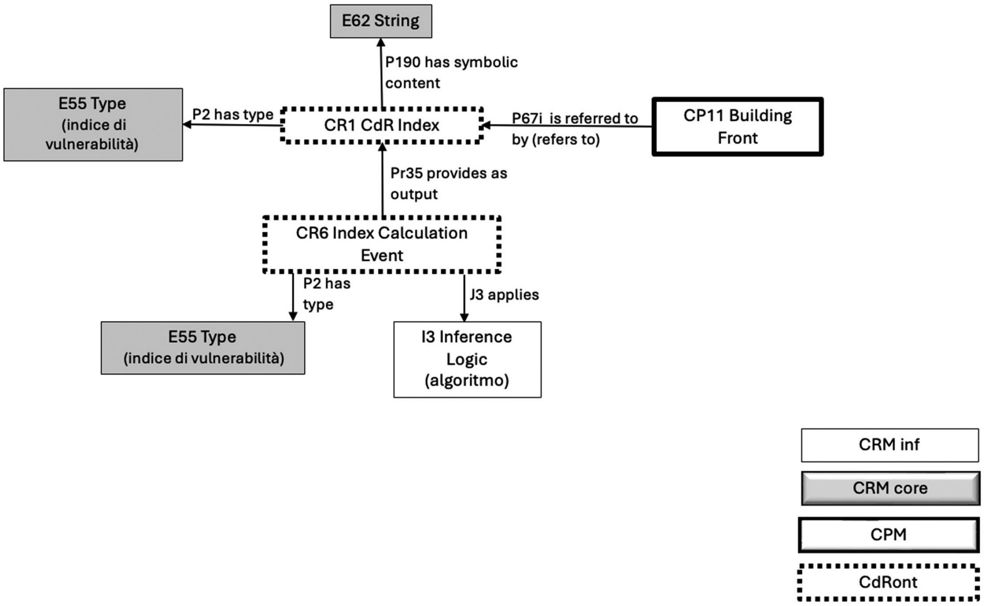

Fig. 2.47. Building Front. Vulnerability and trasformation (*Fronte Edilizio. Vulnerabilità e trasformazioni*).

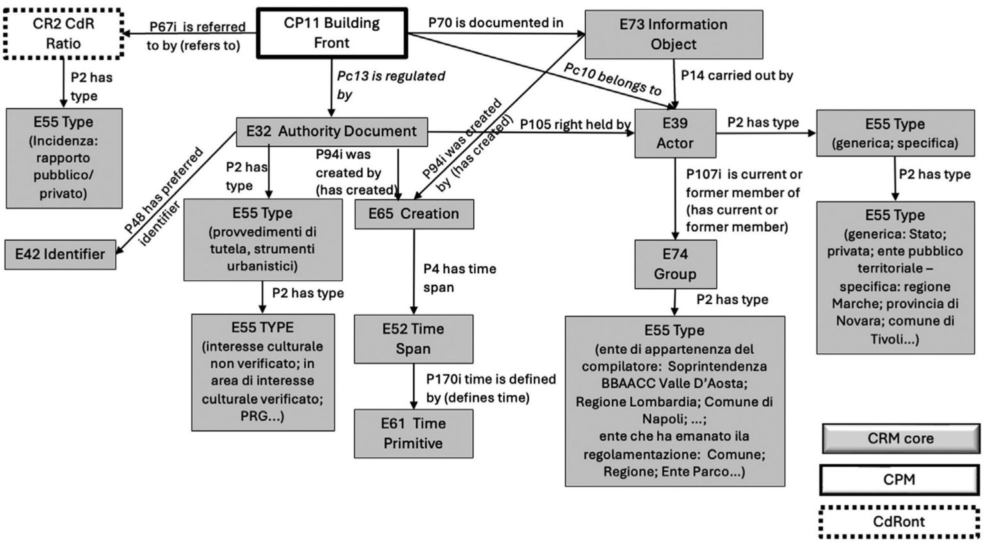

Fig. 2.48. Building Front. Rules (*Fronte Edilizio. Normative*).

3. Instantiating the historic architectures

Alessia Vaccariello

3.1. Applying CPM: the use of protégé and ontome

The creation and management of ontologies at a conceptual level can be assisted by using software programs in the field of *knowledge-based* applications, among which the most commonly used and web-available are *Protégé* and *Ontome*. The development and verification of the CPM ontology is aimed at comparing these two management systems to better understand their specific advantages and disadvantages. Consequently, three case studies were instantiated using different sets of data to test the conceptual model at various scales and elucidate the various relational aspects between parts and these parts with whole they belong to. Specifically, three different architectures were instantiated, each subjected to three types of information selection and aggregation and linked to distinct operational purposes. Firstly, the description of the building façade belonging to a historic palace in Genazzano (Rome) was considered, following the model of the Risk Map for Historic Centres, which focuses on a rapid analysis dedicated to defining the vulnerability of the structure[1]. Secondly, the illustration of the data related was addressed to the study and design for the restoration of the Mascherone Fountain in Monte Romano (Viterbo)[2]. Lastly, the characterization of the Tempietto of San Pietro in Montorio in Rome was chosen, paying particular attention to its complex historic and construction events, including Bramante's design, the construction site, and subsequent restoration interventions[3].

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1 Studies related to events at urban scale, building fabrics, architecture and construction characteristics of buildings are illustrated in Fiorani et al. 2020, pp. 75-78.

2 Preliminary study for the architecture restoration project of the Mascherone Fountain in Monte Romano (Viterbo), conducted as part of a research agreement between the Municipality of Monte Romano and the Department of History, Design, and Restoration of Architecture at Sapienza University of Rome, carried out in 2021 by the working group composed of: architects. Marta Acierno, Maurizio Caperna, Donatella Fiorani, Elisabetta Giorgi, Annarita Martello.

3 See Cantatorea 2017; Cantatoreb 2017: Pallottino 2017.

Protégé

Protégé[4] is an open-source platform that provides a growing community of users with the tools to build domain models and knowledge-based applications through ontologies. It was the result of a project created at Stanford University in the 1980s and is still widely used today to construct reusable ontologies and design computer systems across various fields of knowledge[5]. The software, initially considered merely a tool for building knowledge-based systems, quickly became well-known for ontology definition and construction. Among other things, it was the first system to support the OWL (Ontology Web Language), which is a standard of the World Wide Web Consortium (W3C)[6].

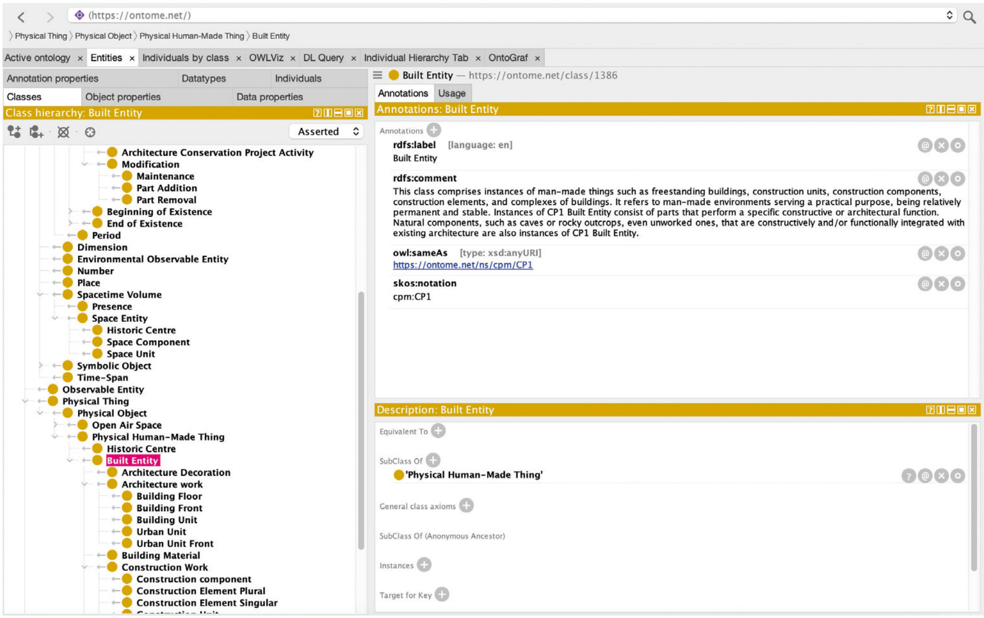

Fig. 3.1. Protégé 5 Desktop v.5.2.6. The hierarchy of the CPM ontology related to the reference hierarchy CIDOC CRM.

At the moment, there are several versions of Protégé[7]. A desktop system, predominantly used in the modeling of the present project with local installation (Protégé 5), which makes it possible to have access to numerous advanced features in order to build and manage OWL ontologies (Fig. 3.1), and a Web-based version (WebProtégé)[8] (Fig. 3.2), developed by the Protégé team of the Biomedical Informatics Research Group (BMIR) at Stanford University, California (USA). The web version allows easy sharing among a distributed group of users, who can use it for collaborative creation projects activities (collaborative authoring), accessible simultaneously from anywhere

4 Demo online version at: <http://webprotege.stanford.edu>.

5 See GENNARI et al. 2003; MUSEN 2015.

6 The *World Wide Web Consortium* (W3C) develops technologies that ensure interoperability between different information systems by providing specifications, guidelines, software, and applications. For more information see <https://www.w3.org/TR/w3c-vision/> and KNUBLAUCH et al. 2004.

7 See NOY et al. 2001; NOY, MCGUINNESS 2001.

8 TUDORACHE et al. 2013.

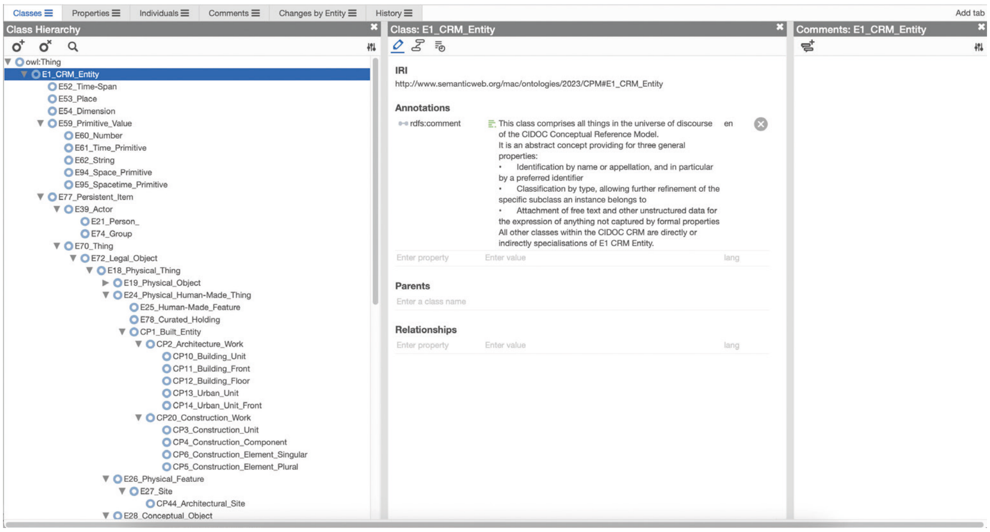

Fig. 3.2. WebProtégé. The web version of Protégé offers users the opportunity to share and edit ontologies. The image shows the CPM ontology. In the left panel, the user has selected the class from the reference ontology CIDOC CRM; in the center, the panel displays the characteristics of the selected class.

in the world. Once Protégé has been acquired in its desktop version, users can take advantage of the manual that guides every step of project modeling and software usage. The system allows both the new definition of classes, with their corresponding hierarchy, and the implementation of already existing ontologies.

These ontologies, when expressed in OWL, XML, or RDF format, can be managed by the platform and imported into the system through the use of local files or the web via URL. Thanks to the tree structure diagram with which each ontology is visualized by the software (Fig. 3.1), the hierarchy can be easily managed by modifying the relative position of the classes and implementing their definitions through the provided annotation and description menus. Similarly, the properties related to each class (*Object Properties*) can be created and managed hierarchically, specifying their domain, range, and characteristics of each relationship. The ability to use 'reasoners'[9] has most likely contributed to nearly forty-year success of Protégé in ontology development.

Protégé works with seven different reasoners[10] and makes it possibile to ensure, at any time, the absence of logical inconsistencies in the modeling. Using the dedicated 'tab' allows the most appropriate reasoner to be selected and the inferential verification process to be started. However, the outcome of the logical reasoning process might often be challenging to understand. If the user is not a technician but a domain expert, the machine language used to display the process and the errors detected by

[9] A 'reasoner' is a piece of software capable of deducing logical consequences from a set of facts or axioms. The notion of a semantic 'reasoner' generalizes that of an 'inference engine' while providing a richer set of mechanisms to work with.

[10] The seven reasoners offered by the system consist of five different software programs and two alternative versions of some of them. Specifically, the available systems are: ELK, HermiT, Ontop, Pellet, and Jcel. Each of these uses the OWL language necessary for manipulating the project on Protégé and different inferential processes. For further information and details: <http://liveontologies.github.io/elk-reasoner/>; <http://www.hermit-reasoner.com>; <https://ontop-vkg.org/tutorial/mapping/existential.html>; <http://tinman.cs.gsu.edu/~raj/8711/sp11/presentations/pelletReport.pdf>; <http://julianmendez.github.io/jcel/>; see Horridge 2011.

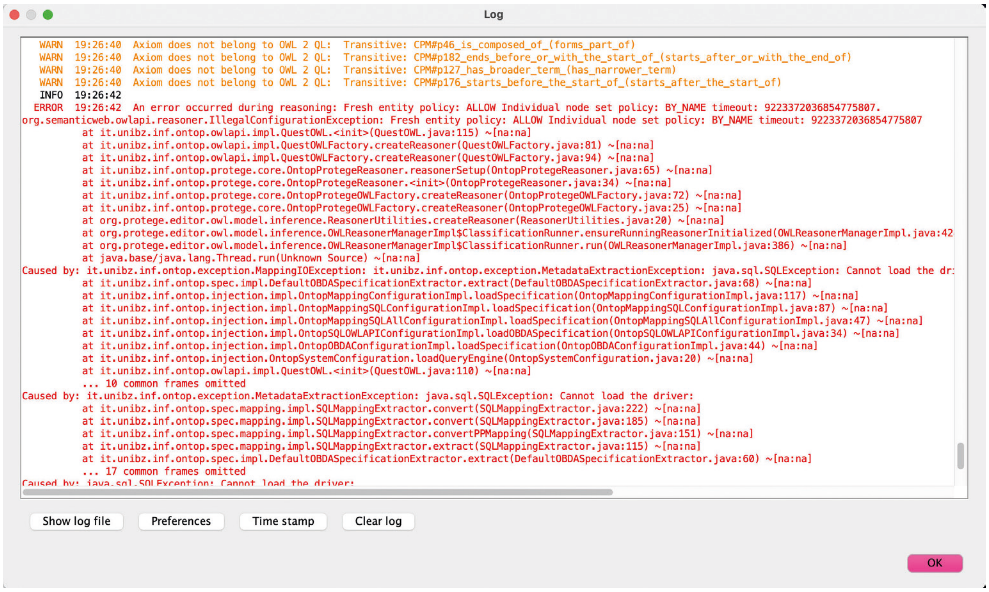

Fig. 3.3. Reasoner Output. The screenshot shows the results of the responses obtained following an error detected by the reasoner. The use of technical language makes it particularly difficult for non-experts to understand and resolve any issues encountered, but it allows technicians to work with more specialized tools.

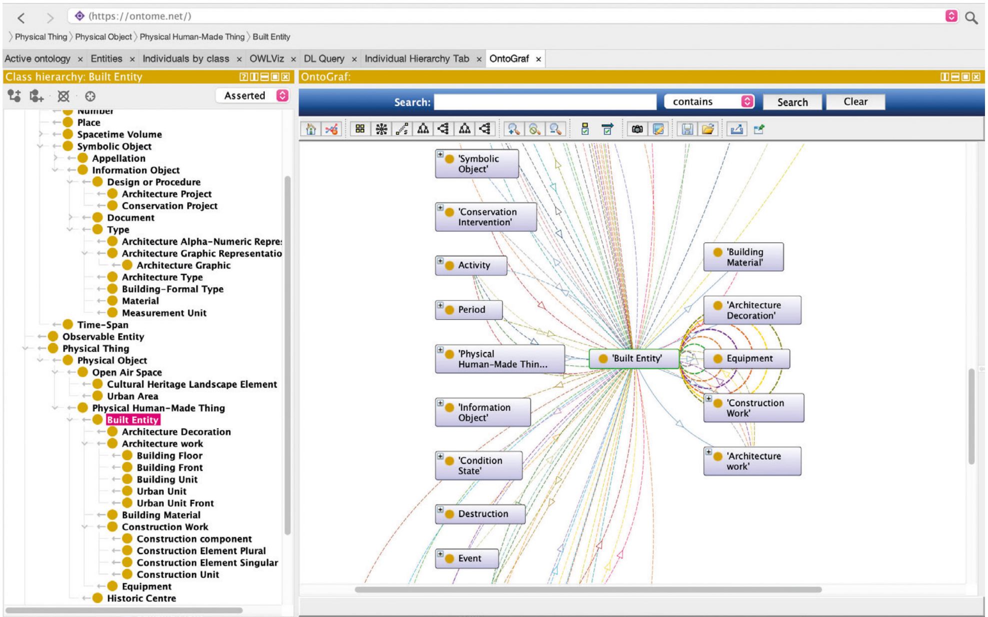

Fig. 3.4. OntoGraf. Diagram of Classes Related to the CPM Ontology.

the system (Fig. 3.3) could represent an obstacle to the solution of modeling issues. Without natural language references, in fact, such an expert might not be able to correctly interpret the outcomes of the software and consequently fail to address the previously identified problems. Another particularly interesting aspect is the possibility of using the numerous additional modules (plug-ins) that are constantly being developed to expand the software potentialities. Besides specifying the entities constituting the ontology, Protégé makes it possible to use two visualizers (OntoGraf, OWLViz) that represent classes and their hierarchical relationships through diagrams (Fig. 3.4).

Ontome

Ontome[11] (*ONTOlogy Management Environment*) is an application that allows the construction, management, and alignment of online ontologies. The platform enables the use of stable and structured ontologies, such as CIDOC CRM and its extensions, or any other model that has been encoded and made available online, as a support or starting point. Ontome was developed by the LARHARA *Digital Research Team* with the aim of enabling researchers from various domains[12] to work collectively on existing instances, thereby avoiding the creation of new applications for each specific modeling. The philosophy of Ontome is based on collaborative conceptual modeling and the integration of systems compatible with object-oriented models[13] that can be encoded in Unified Modeling Language (UML) – through class diagrams – in RDF, and in OWL2 DL. UML class diagrams are a graphical notation used to construct and visualize systems, based on a static structure; they allow the description of the model by representing its classes, attributes, operations and relationships with existing systems. The graphical interface of Ontome, which is quite intuitive, conceals the more technical aspects and allows domain specialists, interested in modeling and semantic interoperability, who are generally not IT experts, to focus on the conceptual design alone[14]. Ontome is primarily based on the concept of 'namespace', which refers to a set of classes and properties[15] designed to host entities within the same domain. The namespace allows the assignment of unique identifiers to each entity of the ontology, facilitating their identification even by those who, internal or external to the project, want to use it as a reference for their own work. Ontome is organized into menus and tables that allow a quick overview of all the tools needed to create and manage classes and properties, as well as easy access, at any stage of the modeling, to a summary of the entire project or the entity being modeled (Fig. 3.5). Once an account and a namespace have been created, it is possible to proceed with the identification of the reference namespaces to support the characterization of the project. These reference projects cannot be modified except by the managers and/or creators of the specific namespace. It is therefore recommended that only stable versions of the projects be used because, in the presence of subsequent changes, inconsistencies could potentially invalidate the modeling or parts of it. In any case, at any time, the reference projects can be reloaded and, unless there are specific situations of class deprecation that could cause misalignments, the changes that are made are automatically imported. Each ontology is based on the relationships – the properties – existing between categories of objects that share one or more identifying traits – the classes – and for each of these two entities, the following must be specified:

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11 See <https://ontome.net>.

12 At present, there are two prototypes with which the ontologies on Ontome can be linked to vocabularies for simultaneous management. Specifically, these are the projects: 'Themas', developed by ICS-FORTH, and 'Opentheso', developed by Miled Rousset.

13 In object-oriented data models, the data and the relationships between them are contained within a single structure that references the data model used as an abstraction of a real-world object. In object-oriented models, real-world problems are represented as objects characterized by multiple attributes.

14 For further information see Beretta 2021.

15 See <http://forum.dataforhistory.org/node/86>.

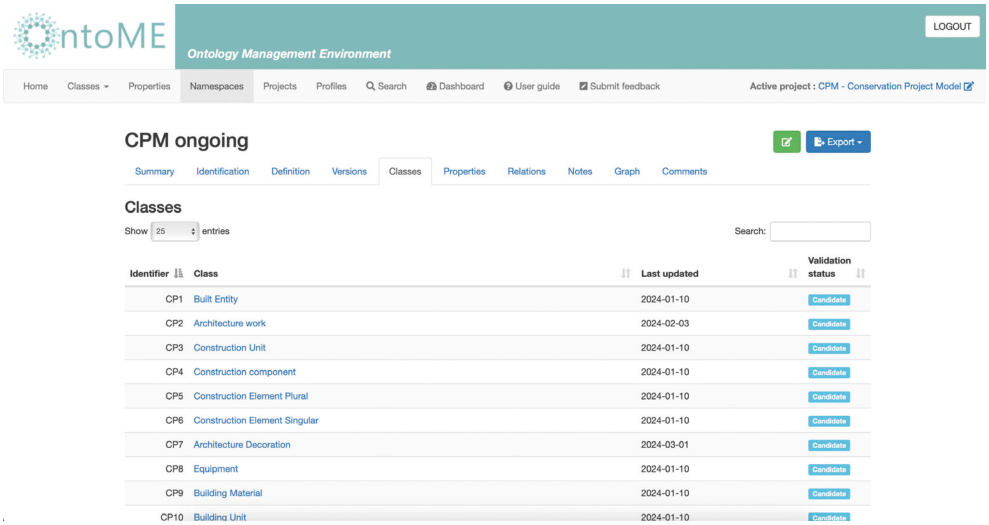


Fig. 3.5. OntoME. The image shows the Classes tab, from which it is possible to view and edit all the classes of the created ontology.

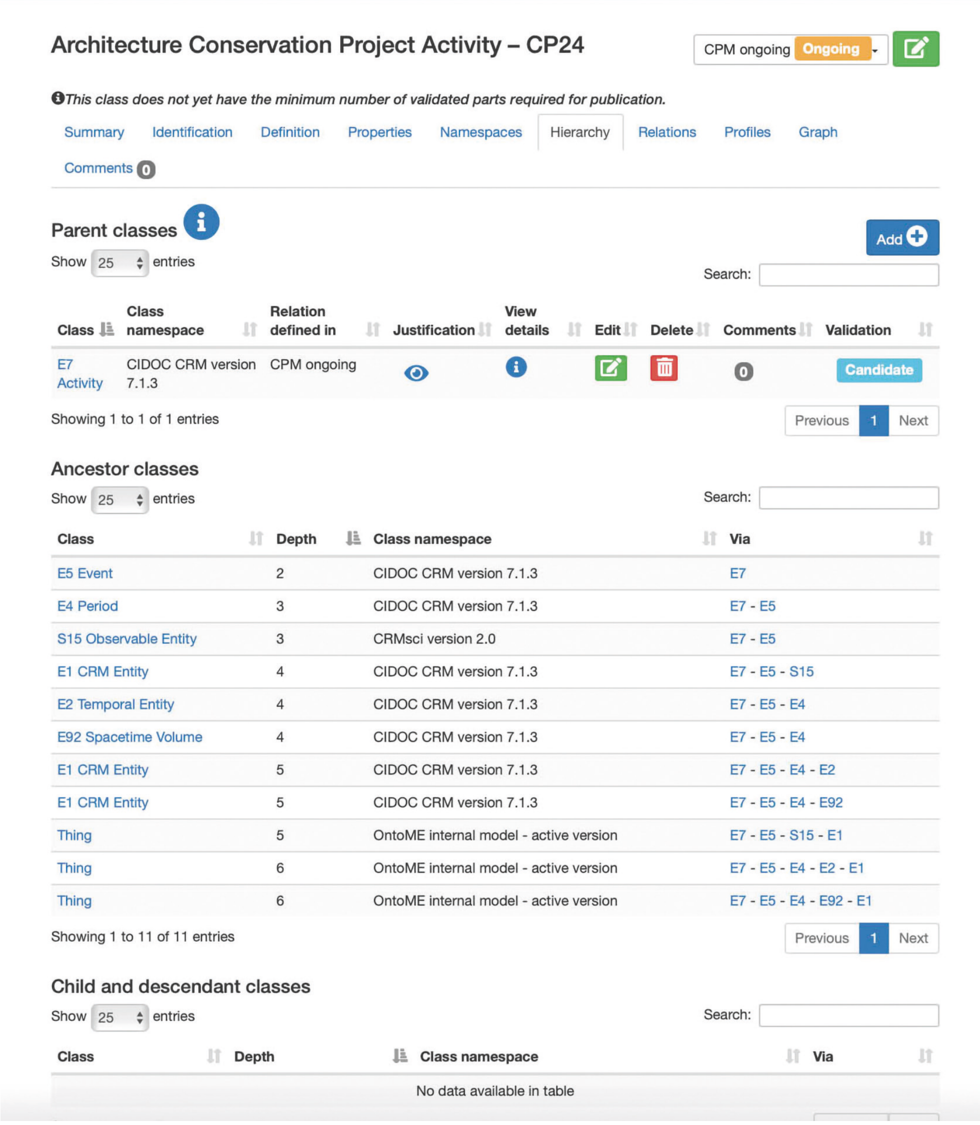
- an identifier, automatically or manually;
- a label that concisely explains the characteristics of what is being modeled;
- definition, scopenote, and appropriate examples that can be helpful for the correct and unequivocal use of classes and properties.

Ontome allows each class to be uniquely linked to its properties and explicitly shows the hierarchical relationships between the classes of the reference ontology and the initially chosen reference classes. Once the hierarchical relationship (Fig. 3.6) between the classes and the direct properties is associated, the system automatically imports the domain and range properties 'inherited' from the superclasses (Fig. 3.7), facilitating the control and management of the entire project. The project itself, just like each entity it is composed of, is not only linked to an identifier but also distinguished by a URI code[16], which allows it to be used and imported into other applications (e.g., Protégé, Opentheso, Geovistory, etc.). Additionally, the system enables the export of the project in RDFS, OWL-DL, and DOCX formats.

The system is continuously updated, and the use of the online platform is supported by an active community[17] that quickly provides answers to any doubts about using the program or the modeling of some aspects according to the users' direct

[16] A Uniform Resource Identifier (URI) is a sequence of characters that identifies a logical, abstract, or physical resource, usually, but not always, connected to the Internet. A URI distinguishes one resource from another and enables Internet protocols to facilitate interactions between these resources. The character strings embedded in a URI serve as identifiers, as well as a schema name and a file path. A URI provides a simple and extensible way to identify Internet resources, and due to the uniformity that URIs provide, different types of resource identifiers can be used within the same context, regardless of the mechanisms used to access those resources. Unlike a URL, a URI identifies a resource but does not imply or guarantee direct access to it. See <https://www.techtarget.com/whatis/definition/URI-Uniform-Resource-Identifier>.

[17] Access to the community requires only registration and allows users to follow, participate in, and consult various sections. These sections include opportunities for both direct and active participation by members, as well as the ability to ask questions to which any community member can respond, propose solutions, or share their experiences. See <https://discord.com/channels/714732839266025532/1093169306973503548>.



Class	Class namespace	Relation defined in	Justification	View details	Edit	Delete	Comments	Validation
E7 Activity	CIDOC CRM version 7.1.3	CPM ongoing					0	Candidate

Class	Depth	Class namespace	Via
E5 Event	2	CIDOC CRM version 7.1.3	E7
E4 Period	3	CIDOC CRM version 7.1.3	E7 - E5
S15 Observable Entity	3	CRMsci version 2.0	E7 - E5
E1 CRM Entity	4	CIDOC CRM version 7.1.3	E7 - E5 - S15
E2 Temporal Entity	4	CIDOC CRM version 7.1.3	E7 - E5 - E4
E92 Spacetime Volume	4	CIDOC CRM version 7.1.3	E7 - E5 - E4
E1 CRM Entity	5	CIDOC CRM version 7.1.3	E7 - E5 - E4 - E2
E1 CRM Entity	5	CIDOC CRM version 7.1.3	E7 - E5 - E4 - E92
Thing	5	OntoME internal model - active version	E7 - E5 - S15 - E1
Thing	6	OntoME internal model - active version	E7 - E5 - E4 - E2 - E1
Thing	6	OntoME internal model - active version	E7 - E5 - E4 - E92 - E1

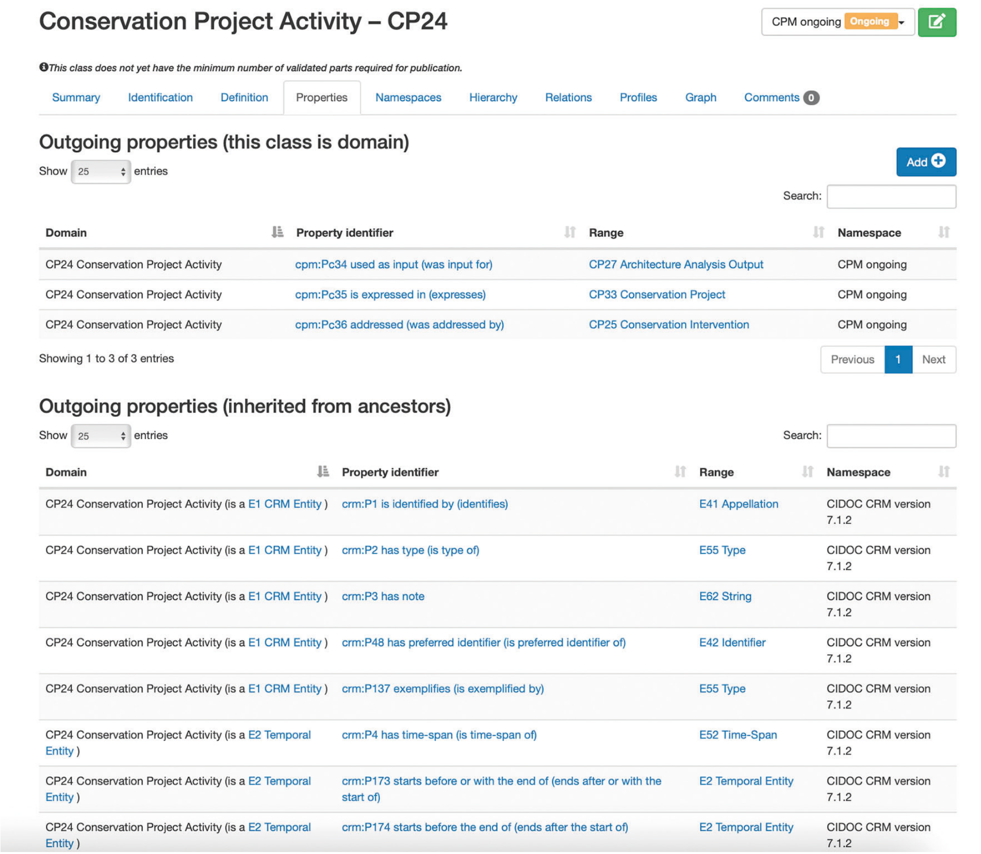
Class	Depth	Class namespace	Via
No data available in table			

Fig. 3.6. Visualization of the hierarchy related to the class CP24 Architecture Conservation Project Activity in the OntoME platform. The selected class is linked to the parent class, and the system CRM base properties related to the class CP3 Construction Unit were retained, but not those automatically imported from the CRMsci extension.

needs[18]. This advantage, linked to the constant verification and implementation work, conducted by the LAHARA team, can occasionally and for very short periods result in operational issues of the system.

In addition to the tabular visualization system, Ontome features a schematic viewer enabled by the integrated tool called 'GRAPH'. This tool makes it possible both to indicate the relationships established between the entities of the created ontology

[18] For example, this is the case when there is a need to deprecate classes and/or properties that are no longer necessary within a project by domain researchers. Such a request, accepted by the system developers working on its resolution, would allow a clearer and more understandable method of reading, using, and managing the ontology, keeping only the useful classes within the project and avoiding the retention of all classes created during modeling. Currently, classes cannot be deleted but can only be marked with specific tags indicating the status of the entity: candidate, validated, validation request, denied.



Conservation Project Activity – CP24

CPM ongoing Ongoing

This class does not yet have the minimum number of validated parts required for publication.

Summary | Identification | Definition | Properties | Namespaces | Hierarchy | Relations | Profiles | Graph | Comments 0

Outgoing properties (this class is domain)

Show 25 entries Add

Search:

Domain	Property identifier	Range	Namespace
CP24 Conservation Project Activity	cpm:Pc34 used as input (was input for)	CP27 Architecture Analysis Output	CPM ongoing
CP24 Conservation Project Activity	cpm:Pc35 is expressed in (expresses)	CP33 Conservation Project	CPM ongoing
CP24 Conservation Project Activity	cpm:Pc36 addressed (was addressed by)	CP25 Conservation Intervention	CPM ongoing

Showing 1 to 3 of 3 entries Previous 1 Next

Outgoing properties (inherited from ancestors)

Show 25 entries

Search:

Domain	Property identifier	Range	Namespace
CP24 Conservation Project Activity (is a E1 CRM Entity)	crm:P1 is identified by (identifies)	E41 Appellation	CIDOC CRM version 7.1.2
CP24 Conservation Project Activity (is a E1 CRM Entity)	crm:P2 has type (is type of)	E55 Type	CIDOC CRM version 7.1.2
CP24 Conservation Project Activity (is a E1 CRM Entity)	crm:P3 has note	E62 String	CIDOC CRM version 7.1.2
CP24 Conservation Project Activity (is a E1 CRM Entity)	crm:P48 has preferred identifier (is preferred identifier of)	E42 Identifier	CIDOC CRM version 7.1.2
CP24 Conservation Project Activity (is a E1 CRM Entity)	crm:P137 exemplifies (is exemplified by)	E55 Type	CIDOC CRM version 7.1.2
CP24 Conservation Project Activity (is a E2 Temporal Entity)	crm:P4 has time-span (is time-span of)	E52 Time-Span	CIDOC CRM version 7.1.2
CP24 Conservation Project Activity (is a E2 Temporal Entity)	crm:P173 starts before or with the end of (ends after or with the start of)	E2 Temporal Entity	CIDOC CRM version 7.1.2
CP24 Conservation Project Activity (is a E2 Temporal Entity)	crm:P174 starts before the end of (ends after the start of)	E2 Temporal Entity	CIDOC CRM version 7.1.2

Fig. 3.7. Ontome Screenshot highlighting classes inherited from their superclasses.

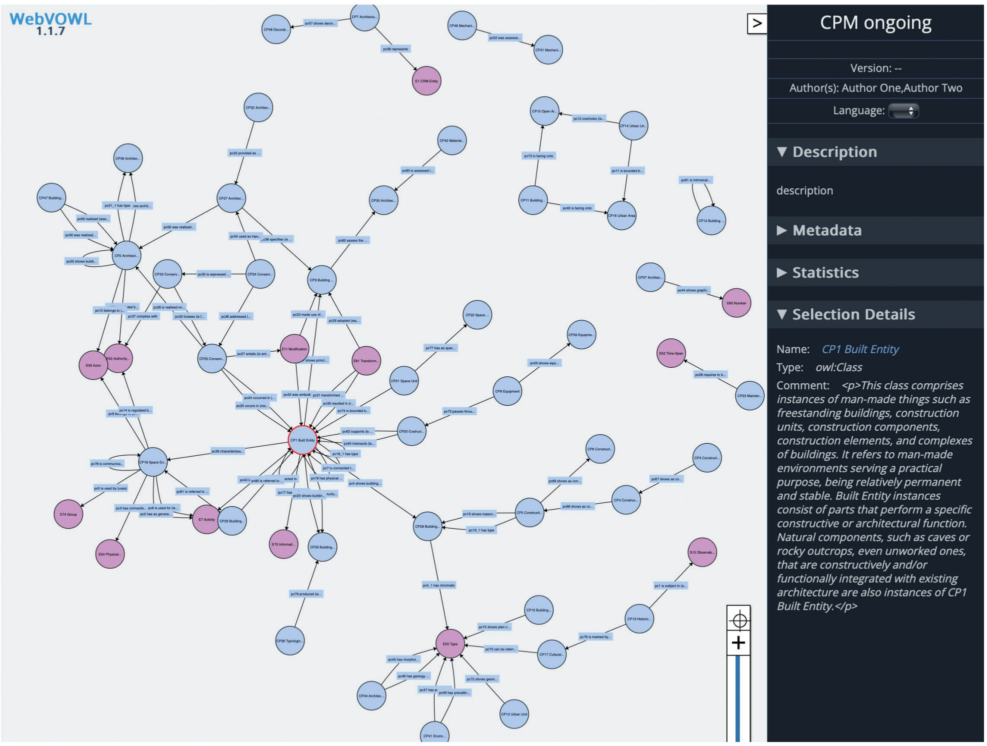


Fig. 3.8. Graph. The integrated Graph tool allows the visualization of classes and the properties that connect them to each other.

and to modify the project, adding new instances, or modifying existing ones directly from the graphical interface, except for the properties 'inherited' from the reference ontologies. In this manner, it is possible to understand the relationships established among entities and also any potential problems or gaps in the modeling (Fig. 3.8).

According to the vision that inspired the development of Ontome system, all case studies and work processes involved were designed to be conducted in dynamic and research contexts[19]. Members of the scientific community who want to develop their project, alongside IT experts, can evaluate and discuss new classes and properties at any time during their work, allowing the process to be modified or guided in order to enable the constant expansion and progressive improvement of the system towards increasingly specific scientific fields. This methodology ensures interoperability and allows the integration of standards adopted by heritage institutions. Moreover, Ontome, combined with semantic control tools, particularly with thesauri like the French Opentheso[20] or the Getty Institute's AAT, and other platforms that allow project instantiation, could constitute the prototype of an IT infrastructure for the construction, management, and expansion of databases. This becomes particularly useful when what is desired is to apply logical description and other formalisms to verify the consistency of the ontology being worked on and integrate this project into a system that allows real-time verification during all phases of modeling.

Comparing systems

When applying Protégé, numerous attempts were made to understand how it could be best utilized. Initially, a new project was created from scratch, without using any support model; it soon became apparent that to fully define the hierarchical and typological characteristics of the new entities, it was still necessary to include the superclasses derived from the CIDOC CRM ontology. Then, a second modeling attempt used files directly imported from the system, including the latest version of the base CIDOC CRM[21] and CRMsci[22]; starting from the CIDOC superclasses, CPM classes and properties were added manually. A final attempt was then initiated to understand how Protégé and Ontome could be used together, and in this perspective, the OWL file previously obtained from Ontome was imported into the Protégé workspace. For all three case-studies, both the local and web-based versions were experimented with.

With Ontome, the work consisted of the modeling of CPM classes and properties by setting as referenced namespaces, the projects related to the CIDOC CRM base and CRMsci of which some CPM classes are subclasses. These have been imported from URLs.

During the first modeling attempt in Protégé, multiple errors were detected through the use of reasoners. In the second and third attempts, the situation improved, demonstrating the greater cost-effectiveness of directly importing external projects when there

19 See Alamercery, Beretta 2019.

20 See <https://opentheso.hypotheses.org>.

21 See <http://www.cidoc-crm.org/cidoc-crm/> extracted from <https://cidoc-crm.org/versions-of-the-cidoc-crm>.

22 See <http://www.cidoc-crm.org/extensions/crmsci/> extracted from <https://cidoc-crm.org/crmsci/fm_releases>.

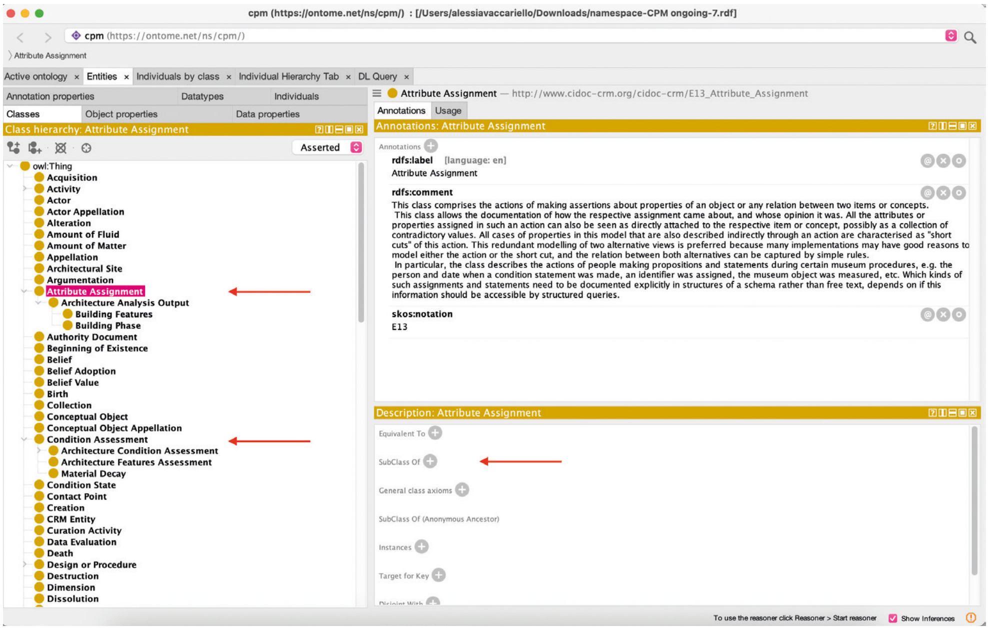


Fig. 3.9. Protégé Screenshot highlighting hierarchical issues of classes belonging to different namespaces.

entities and those already existing in other contexts. Importing the work already developed on the Ontome platform revealed that the hierarchical relationships of the ontologies imported from reference namespaces, which are crucial from an architectural and practical formalization perspective, were lost.

Fig. 3.9, corresponding to a screenshot of the system, highlights the preservation of the hierarchy of new classes and their respective superclasses (i.e. CP27 Architecture Analysis Output is a subclass of E13 Attribute Assignment, and CP30 Architecture Condition Assessment is a subclass of E14 Condition Assessment) and the simultaneous loss of the hierarchical relationship between superclasses (e.g., E13 Attribute Assignment) and subclasses (E14 Condition Assessment) which refer to different namespaces. This issue, observable in all 'inherited' classes, is also evident from the table describing the individual classes where the 'subclass of [23].' definition field appears empty. In order to use the ontological modeling encoding for the following instantiations, it was necessary to manually align the class hierarchy in Protégé. Such problems did not arise, obviously, when starting with the preliminary import of individual reference ontologies and adding the new project as a modification/reworking of the files imported via URL. In this case, it was sometimes necessary only to align the classes that appeared in multiple imports and thus were listed as parallel duplicates in the hierarchy.

Fig. 3.9 also highlights a second critical issue. The code exported from Ontome includes all the classes of the reference namespace and not just those directly con-

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[23] The detected anomaly has been reported to the Ontome platform's referents and creators, who have shown interest in understanding and resolving the issue. The process of verifying and resolving the anomaly is still ongoing and has required direct and systematic collaboration between the domain expert and IT technicians. To follow the progress and resolution of the issue, refer to the ongoing discussion on the GitHub community at the following link: <https://github.com/orgs/geovistory/discussions/22>. Special thanks go to Vincent Alamercery, who provided his constant support throughout the development of this work.

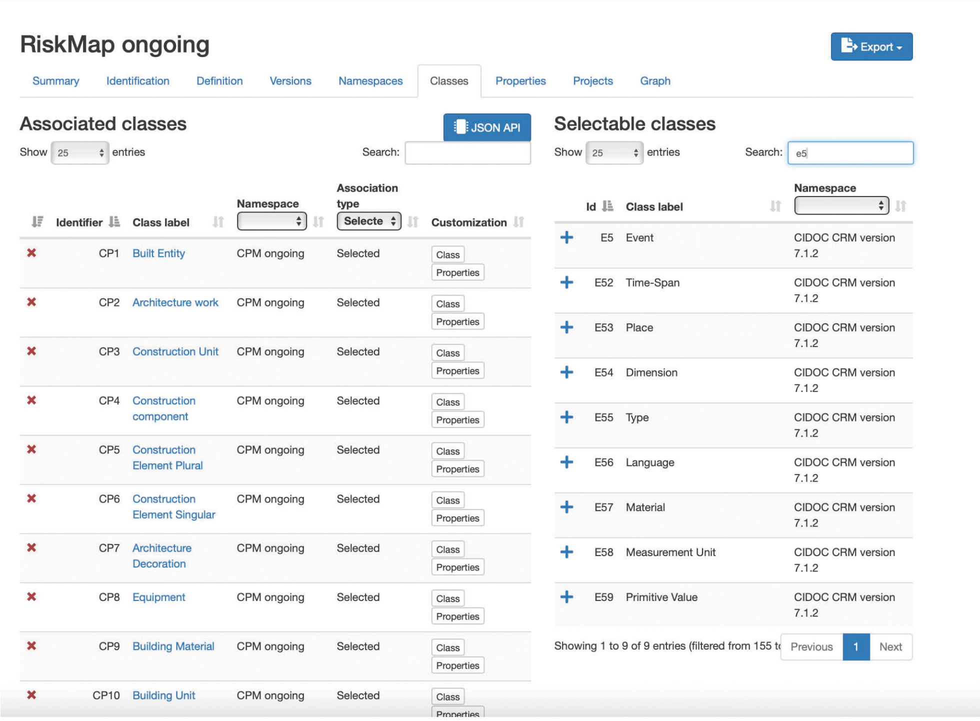

Fig. 3.10. Ontome Screenshot of the Profile creation section. Through the Classes tab, it is possible to manually select individual classes from the chosen namespaces to be added to the project. Additionally, by adopting the customization buttons, users can manage the characteristics of both classes and properties (Fig. 3.11).

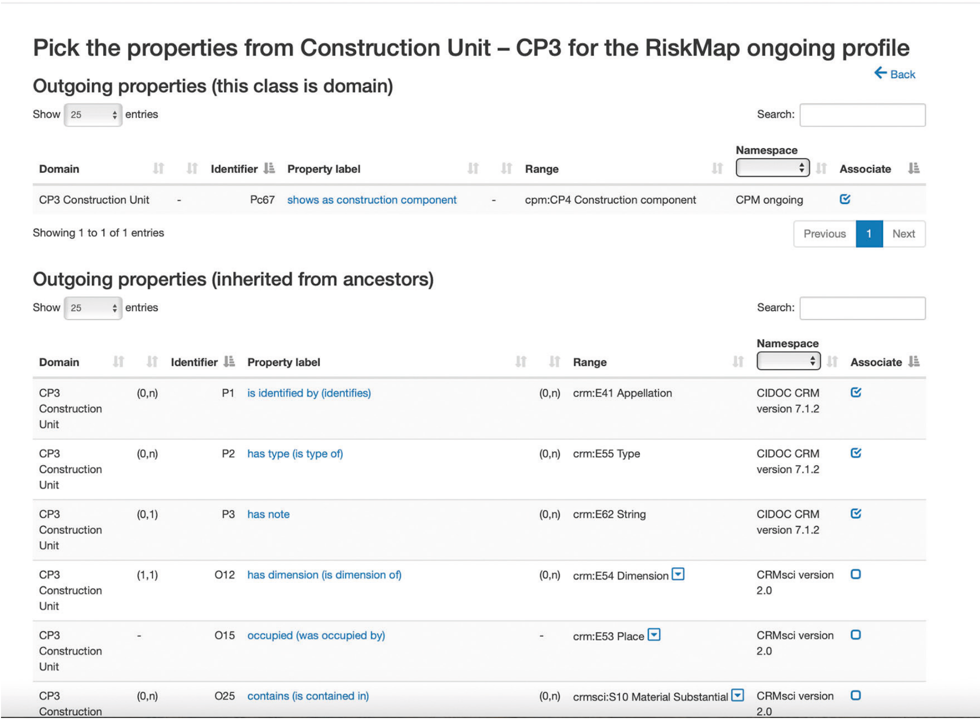

Fig. 3.11. Ontome Screenshot highlighting how the properties of an imported class can be managed individually. In this specific case, given the needs of the Risk Map application, for example, the CPM and CIDOC CRM base properties related to the class CP3 Construction Unit were retained, but not those automatically imported from the CRMsci extension.

Confronting Protégé and OntoME Systems	PROTÉGÉ		ONTOME	
	POSSIBILITIES	LIMITS	POSSIBILITIES	LIMITS
Works at top-general conceptual level	X		X	
Allows to quickly visualize hierarchical relations among classes	X			
Allows to quickly visualize relations and properties among classes			X	It does not represent relations with reference ontology properties, hence classes may appear isolated
Can be used for creating a new ontology for a given domain in OWL	X		X	
Can be used for building an extension of an existing ontology	X		X	
Allows to edit and add entities to the ontology from the graphic visualization			X	
Allows to add class related instances	X			
Allows reasoning and reasoning solving	X	Results of the reasoners are completely manageable only by technicians	X	The reasoners shows mismatches related to possible incompatibilities among the namespaces of the project. At the moment, there are unsolved issues with the reasoner
Allows to import top-reference models	X		X	
Allows to public the ontology and make it usable from other users			X	
If a reference namespace gets modified, it can be demi-automatically uploaded			X	Mismatches may happen and should then be manually solved

Fig. 3.12. Comparison between Protégé and Ontome Systems.

nected to the CPM entities. This condition, combined with the lack of hierarchical links between classes, can make project management particularly complex. A possible solution comes from creating a 'Profile' defined as a set of classes and properties from multiple namespaces that can be selected and grouped within a single project for application purposes.

As shown in Figs. 3.10 and 3.11, this possibility has the advantage of allowing the customization of every aspect of the model and achieving a more manageable result in terms of the number and conformity of the acquired entities. On the other hand, classes and their properties must be entered manually, and in this case, unlike what was previously described, any hierarchical links are lost as all reference models are equally considered as imports.

As previously mentioned, the modeling in Protégé was conducted both with a local installation and using the open WebProtégé platform. The latter, although featuring more attractive graphics, is more complex to use. Indeed, the minimal interface makes to locate the functions and tools necessary for proper software use less intuitive to find.

In conclusion, the two systems are not strictly alternative to each other, and, for CPM modeling, they have been used rather as auxiliary tools. The Ontome system, more intuitive and suitable for domain experts, allows collaborative project development and the definition of a true semantic level thanks to the ability to import and view, through the dedicated tab, thesauri developed with other systems[24] as well

[24] In particular, reference is made to Themas, Opentheso, and AAT. THEMAS was developed as part of the DARIAH project (Development of Greek Research Infrastructure for the Humanities ΔΥΑΣ). It is an open-source web-based system for the creation, management, and administration of multilingual thesauri according to the principles of ISO 25964-1 and ISO 25964-2. For more information, see <https://www.ics.forth.gr/isl/themas-thesaurus-management-system?lang=en>, for entering the system using a demo account <https://demos.isl.ics.forth.gr/themas-en/>. Opentheso is a multilingual, multi-

to visualize the relations between classes and properties of the project of interest. However, the use of this system has shown issues with the hierarchies of export files, which required the auxiliary use of Protégé. The latter program offers considerable opportunities for ontology development and implementation, but the visualization and language used sometimes require more specific technical skills than those generally possessed by a domain expert (Fig. 3.12).

3.2. Instantiating historic architectures

Instantiating historic architectures in various forms and degrees of complexity was necessary in order to understand and evaluate the validity and objective completeness of the CPM ontology. Understanding cultural heritage relies on contextual knowledge and the concatenation of events and circumstances; these are details related to people, places, historic periods, and technological-constructive aspects that can be crucial in characterizing historic architectures and their complexity. In order to focus data structuring on these details, project resources can be organized into Knowledge Organization Systems (KOS) [25].

This operation was carried out using already available information – derived from previous research, projects, and database – modeled through 'knowledge graphs'[26], which facilitate the interpretation, management, capture, and abstraction of knowledge from multiple application scenarios and various sources[27]. Graphs provide a concise and intuitive abstraction for a wide variety of domains, where vertices and connections capture the potential complex and differentiated relations between entities in their domains[28].

The modeling was enabled by multi-relational datagraphs[29] developed using Draw.io[30], a free online system for creating schematics and diagrams. The produced graphs are meant to document a specific aspect of the abstraction achieved through the application of the conceptual model defined by the CPM ontology. Reference

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hierarchical thesaurus manager. It complies with ISO 25964-1:2011 and ISO 25964-2:2012 standards (Information and Documentation. Thesauri and interoperability with other vocabularies). It was developed under the direction of Miled Rousset, head of the Semantic Web and Thesauri (WST) technology platform at the Maison de l'Orient et de la Méditerranée (MOM), and by the IT director of GDS Frantiq. For more information, visit < https://opentheso.hypotheses.org>. The Getty Art and Architecture Thesaurus (AAT) is one of the most well-known and widely used international vocabularies. It is structured and includes both generic terms and data related to relationships and information about concepts in art, architecture, and visual cultural heritage. For more information, visit <https://www.getty.edu/research/tools/vocabularies/aat/index.html>.

25 The current structure of various Knowledge Organization Systems (KOS) is supported by Simple Knowledge Organization Systems (SKOS). SKOS is the most widely used standard in the context of Linked Conservation Data, a consortium established to promote interoperability among computer systems in the field of cultural heritage. SKOS is designed to represent thesauri, classification schemes, and taxonomies, and it also enables the unique encoding of vocabularies, facilitating the sharing and web-based linking of knowledge organization systems.

26 For a general overview see Hogan et al. 2021.

27 Noy et al. 2019.

28 Angles, Gutiérrez 2008.

29 Hogan et al. 2021.

30 See <https://app.diagrams.net/#G1aLtcnqlF4x9kM2zSXTgeXW_WbpKVKQ8Y#%7B%22pageId%22%3A%22ZYJh2ubxcYmSQlm-T2KL%22%7D>.

classes from the four ontological models used[31] were associated with coloured labels – the actual conceptual model – while individual specific declinations appear in white. For all schemata, the colour code used has been established by diagrams.net libraries, curated by the Canadian Heritage Information Network (CHIN)[32] in collaboration with CIDOC CRM Sig[33].

3.2.1. Instantiating a Building Front

The instantiation began at the urban scale, in continuity with the modeling work of the Risk Map; therefore, the decision was made to operate with reference to the façade of a three-level residential building in Piazza D'Amico, in the historic centre of Genazzano, not far from Rome. This building had already been catalogued to validate the data model related to the Building Front in the Risk Map[34].

The façade presents a broken frontline with protruding bodies and non-coplanar sections, a homogeneous layout, generally symmetrical, with uniform distribution of vertically aligned openings on levels which are divided by horizontal bands. The base level, covered with a faux ashlar plaster, is marked by large round-arched openings; the main portal, highlighted by a travertine frame with doric capitals, is surmounted by a balcony supported by moulded corbels. On the upper floors, plastered and treated with faux brickwork, rectangular windows are crowned by semicircular tympanum or frame tops.

The data extracted from the Building Front datamodel of the CdR (Fig. 3.13) were reprocessed in two phases, starting with a schematic in an Excel table where the information, discretized during the compilation of the schedule in natural language, was entered, along with the corresponding translation into triples linked to the reference ontologies. In Fig. 3.14, the results of the two operations have been compared in order to have an initial check of the consistency of the adopted languages. The correspondence to the second row of the digital schedule (Fig. 3.13) in natural language can be read as "the historic centre (Genazzano) is located in the municipality of Genazzano" which can then be divided into two propositions: the first "the historic centre is named Genazzano", and the second "the historic centre is located in the municipality of Genazzano". Both can be seen as ontological triples[35] following the

[31] The four ontology models are: CIDOC CRM-base <http://www.cidoc-crm.org/cidoc-crm/>; CIDOC CRMsci <http://www.cidoc-crm.org/extensions/crmsci/>; CPM <https://ontome.net/ns/cpm/>; CdRont (task ontology) <https://ontome.net/ns/cdront/>.

[32] A collection of library files in custom formats (.xml) of ontologies used to represent semantic models is in *diagrams.net libraries*. It is managed by the CHIN and used to generate diagrams in the context of Linked Open Data projects. Currently, CHIN provides seven libraries for CIDOC CRM ontologies and officially released extensions in RDFS format. For more details, see <https://github.com/chin-rcip/diagrams.net_libraries>.

[33] The representation of CPM and CdRont classes through CHIN has been enhanced with colored borders to maintain the coding that associates each color with a specific type of superclass, while still distinguishing them from CIDOC CRM classes.

[34] See CUTARELLI 2022 and, for more details, FIORANI et al. 2022; FIORANI et al. 2023, pages 156-160.

[35] A semantic triple, or RDF triple, or simply triple, is the basic unit on which Resource Description Framework (RDF) data models are structured. A triple is a sequence of three entities that encodes a statement about semantic data in the form of subject-predicate-object expressions (for example, "Felice is 30 years old" or "Felice knows Francesco"). This format allows knowledge to be represented in a machine-readable way. See <https://en.wikipedia.org/wiki/Semantic_triple>.

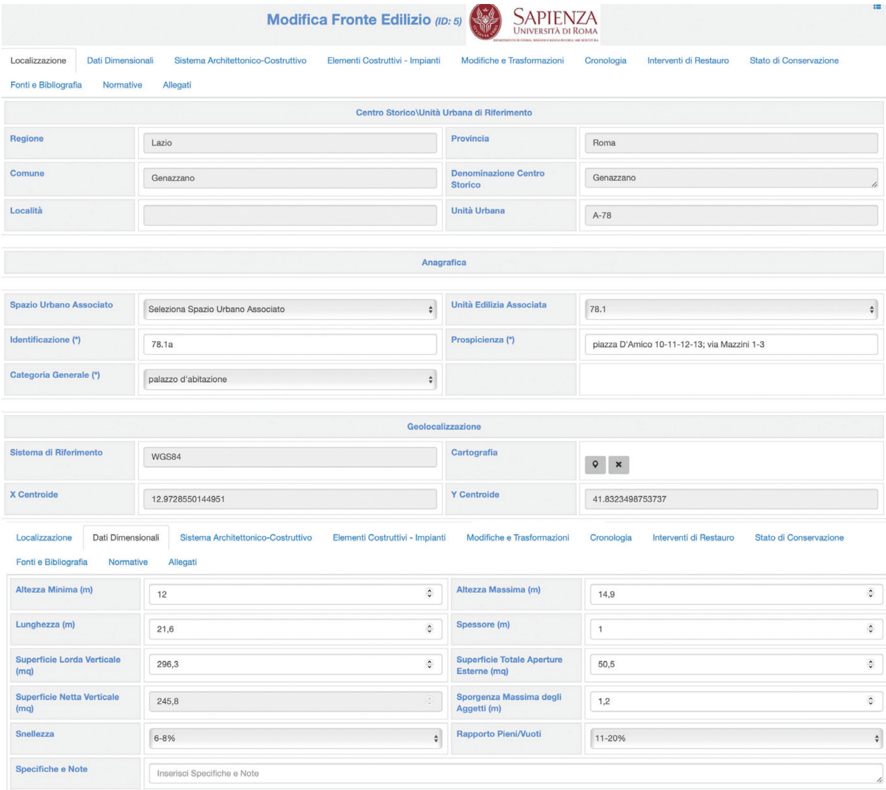

Fig. 3.13. Excerpt of the first two tabs, Localization and Dimensional Data, related to the filing of the Building Front of the palace in Piazza d'Amico in Genazzano (Rome), completed on 23/05/2021 by the cataloger Silvia Cutarelli.

URI	subject	istance	property	predicate	object	istance		
	CP19 Historic Centre	The Historic Centre	P48 has preferred identifier	has name	E42_identifier	Genazzano		
	CP19 Historic Centre	The Historic Centre	P161 has spatial projection	is in	E53_Place	Municipality of Genazzano		
	E53 Place	Municipality of Genazzano	P89 falls within	falls within	E53_Place	Lazio Region		
	CP13 Urban Unit	Urban Unit	P46i forms part of	is part of	CP40_Historic Centre	Historic Centre		
	CP13 Urban Unit	Urban Unit	P48 has preferred identifier	is identified as	E42_identifier	A-78		
	CP10 Building unit	Building Unit	P46i forms part of	is part of	CP13_Urban Unit	Urban Unit		
			P48 has preferred identifier	is identified as	identifier	78.1a		
			P2 has type	has as general vocation	E55_type	Residential Palace		
	CP13 Urban Unit	Urban Unit	P168 place is defined by	has coordinates	E94_Space Primitive	12.9728550144951, 41.8323498753737		
	CP11 Building Front	Building Front	P46i forms part of	is part of	CP10_Building unit	Building Unit		
			P39i was measured by	is measured by	E16_measurement	Measurements		
	E16 Measurement	Measurements	observed dimension	have dimensions	E54_dimension	12	p2_has type	min. height
						14.9		max height
						21.6		length
						1		thickness
						206.3		gross area
						50.5		total area
						245.8		net area
						1.2		max. projection
								full/empty
	CP11 Building Front	Building Front	P67i is referred to	is caracterized by	CR2_CdR Ratio	ratio		
	CR2 CdR Ratio	ratio	P2 has type	of type	E55_type	slenderness		

Fig. 3.14. Excerpt of the instantiation schema related to the Building Front.

'subject-predicate-object' structure and that, for each portion, find direct correspondence within the instances of the CIDOC CRM and CPM ontologies, where subject and object correspond to specific classes and the predicate corresponds to a property.

In the grey columns, the information can be read from the schedule in natural language, and in the white columns, the same information is linked to the reference classes. Therefore, the proposition "the historic centre – is named – Genazzano" corresponds to "CP19 Historic Centre" (CPM class) – "P48 has preferred identifier" (CIDOC CRM property inherited by class CP19 being a subclass of E92 Spacetime Volume) – "E42 Identifier" (CIDOC CRM base class).

This method was used for all data entered during the Risk Map scheduling, and at the end of this initial phase of translation and verification, the graphic representation of classes, properties, and instances was represented in Draw.io (Fig. 3.15).

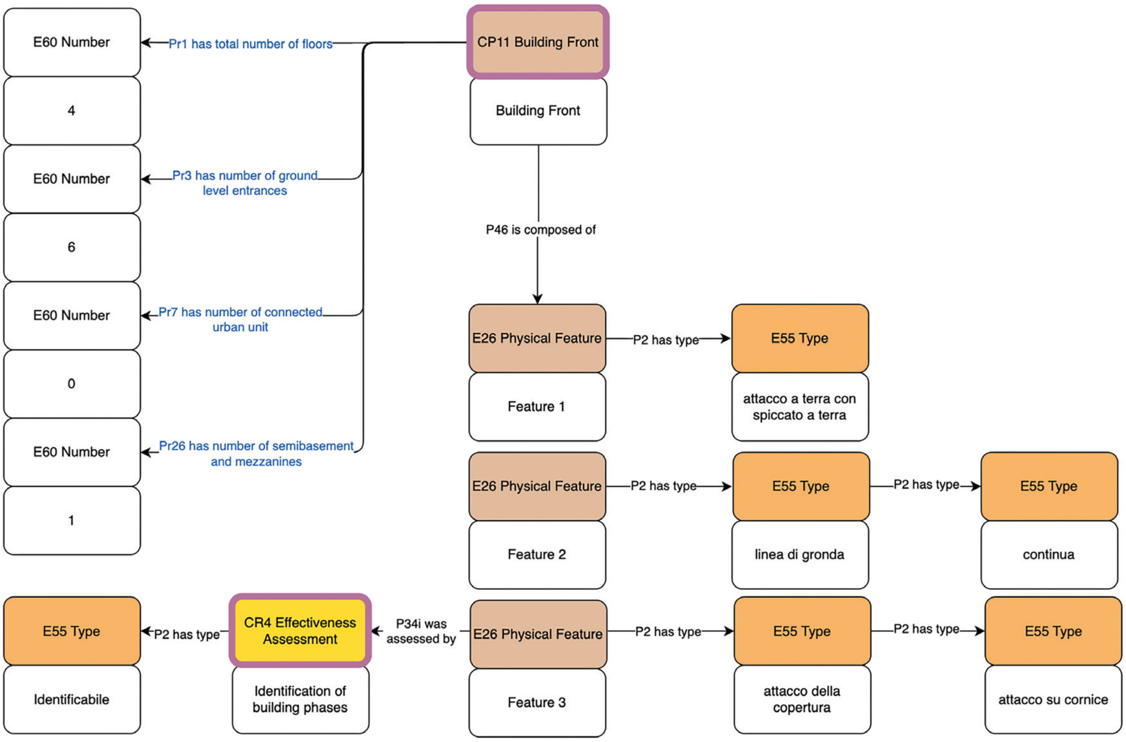

Fig. 3.15. Datagraph Representation of the Architectural Construction System from the CdR sheet related to the Building Front of the Palazzo in Piazza d'Amico in Genazzano (Rome).

Using the datagraph helped to clarify the relations established between instances, considering the substantial amount of data to be entered and managed. Compiling the Excel table requires constant repetition of the subject-predicate-object structure, which, in case of multi-connections, causes a loss of the richness of the available information. The duality of language present in the table[36] was maintained in the data-

[36] This concept is the basis of the *X3ML* mapping definition language designed by Martin Doerr in 2006 and codified through the X3ML mapping framework by the CCS laboratory team at ICS-FORTH. This framework serves as an interface between mapping activities conducted by domain experts and the translation and implementation solutions carried out by computer engineers. The use of such a language is among the potential future scenarios. For further details see MARKETAKIS et al. 2017; DOERR, KONDYLAKIS, PLEXOUSAKIS 2006.

graph. In this way, the instantiation was released from redundancies induced by the tabular schema construction, making it easier to recognize potential inconsistencies in the modeling. The instantiation exercise highlighted one of the fundamental features of the Risk Map which emblematically describes the purpose of the system: the need to foresee, in addition to fieldwork, the possibility of progressively implementing the acquired knowledge; this aspiration is encapsulated in the inclusion of the term "altro" (other) present in all closed vocabularies[37] available in digital schedules. In general, the vocabularies are conceptually definable as the CIDOC E55 Type class[38] as they specify a type related to a semantic deepening. The "altro" term in the Risk Map[39] was created as a tool to empirically collect new terms and expand the starting vocabularies borrowed from the Central Institute for Catalog and Documentation (ICCD) and other schedule models already existing in the platform; it is ontologically modeled as an instance of E62 String (Fig. 3.16).

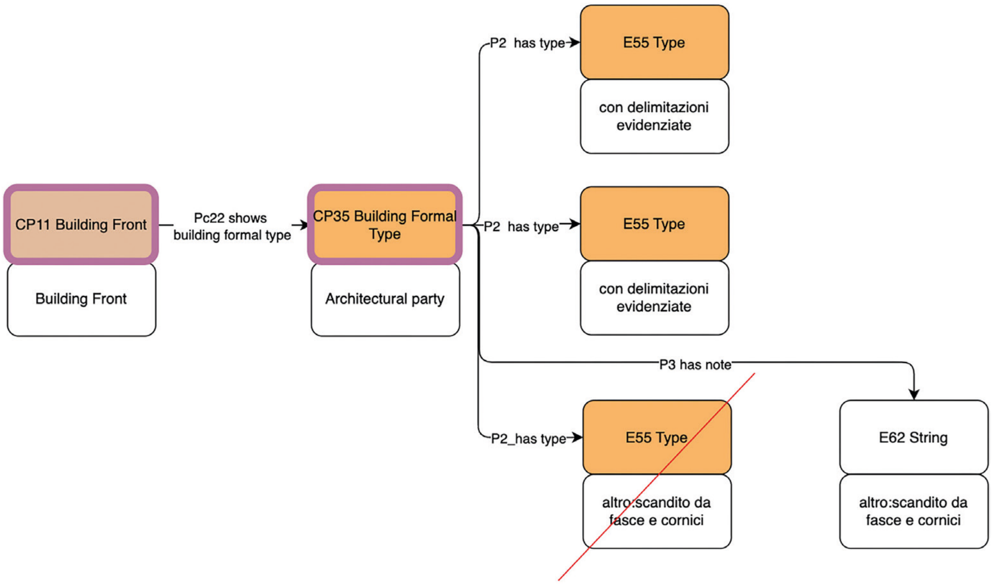

Fig. 3.16. The definition of the open field 'altro' borrowed from the Risk Map vocabularies.

Starting from a semantically and conceptually functional and validated schema like that of the Risk Map, it was easy to extract data that, due to the nature of the adopted ontologies, could be modeled consistently, so the instantiation did not highlight particular critical issues.

[37] The term "altro" can be selected from the dropdown menu of the closed vocabulary field to be filled in. Selecting it unlocks an open field where a new term not included in the vocabulary can be specified. This new term may later be incorporated into the vocabulary based on the evaluation of the system administrators.

[38] "This class comprises concepts denoted by terms from thesauri and controlled vocabularies used to characterize and classify instances of CIDOC CRM classes. E55 Type is the CIDOC CRM's interface to domain specific ontologies and thesauri. These can be represented in the CIDOC CRM as subclasses of E55 Type, forming hierarchies of terms, i.e., instances of E55 Type linked via P127 has broader term (has narrower term): E55 Type. Such hierarchies may be extended with additional properties" (Bekiari et al. 2024, p. 89). For more details see <https://ontome.net/class/53/namespace/188>.

[39] For general overview see Part 2, Paragraph 2.3, of this very same volume.

3.2.2. Instantiating a conservation project for architecture

The second instantiation focused on a simple but comprehensive example of a restoration project which was indeed based on knowledge, surveys, analysis of the architecture work and its conservation status as well as the development of all specifications that enabled its realization. This instantiation concerned the so-called "Fontana del Mascherone" in Monte Romano (Viterbo, Italy) and referred only to the content of the graphic tables were the analysis of the current state and project plans are shown.

The fountain, located at the southeastern edge of the large open space in front of the church of St. Spirit, was erected in 1771, based on a project dated 1769, as a display for water from the so-called "fontanile del Torrione", located a short distance from the village. The "Fontana del Mascherone" features an aedicule design with two superimposed orders divided by a trabeation: the lower order is tripartite with pilasters and ionic capitals creating a wider central panel with a semicircular niche and two narrower side panels; the second order consists of an attic framed by a synthetic order and a triangular tympanum. The central niche hosts a basin above which a mask is placed, from whose mouth the water flows[40].

The concise description of the fountain highlights the importance of the relationships between the parts, the composition, and the morphology of the architecture work. However, this instantiation focuses on the process conducted by a domain expert from the collection of knowledge data to the drafting of the restoration project. The same approach described for the building front was followed to model the fountain, starting with the construction of an Excel table and a datagraph[41].

The CPM classes can perfectly describe the methodological process followed in an intervention on a historic architecture. Part of the information contained in the board on the material conservation status states that: "The restoration project of the so-called Fontana del Mascherone, drafted by the working group composed by Marta Acierno, Maurizio Caperna, Donatella Fiorani, Elisabetta Giorgi, and Annarita Martello, involves restoration activity-plans based on a project activity. This project used data derived from the survey (thus from observing the fountain) and various analyses, such as those of materials and their decay, each documented by graphic tables named". Thanks to the classes introduced by the CPM, it was possible to represent this statement in every detail (Fig. 3.17).

The CPM ontology also allows extensive specification of the project content. For example, each graphic table and its contents can be identified, while the materials constituting the historic structure, the decay phenomena, and the planned conservation intervention can be described.

Fig. 3.18 depicts one of the decay pathologies of the fountain's tympanum. Specifically, the graphic table shows that "the assessment of the decay of the materials constituting the fountain, which was made possible by its mapping, is detailed in the material prospectus represented in the table of the project identified by the

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40 Information derived from the historic-critical and project report, prepared in 2021 by the working group.

41 For improving readability and clarity related to the printed material, the datagraphs presented will all be excerpts from a more complex general graph, which can be consulted at: <https://app.diagrams.net/#G1aLtcnqlF4x9kM2zSXTgeXW_WbpKVKQ8Y#%7B%22pageId%22%3A%22YaLbe4zPaFXxymaDq9MV%22%7D>.

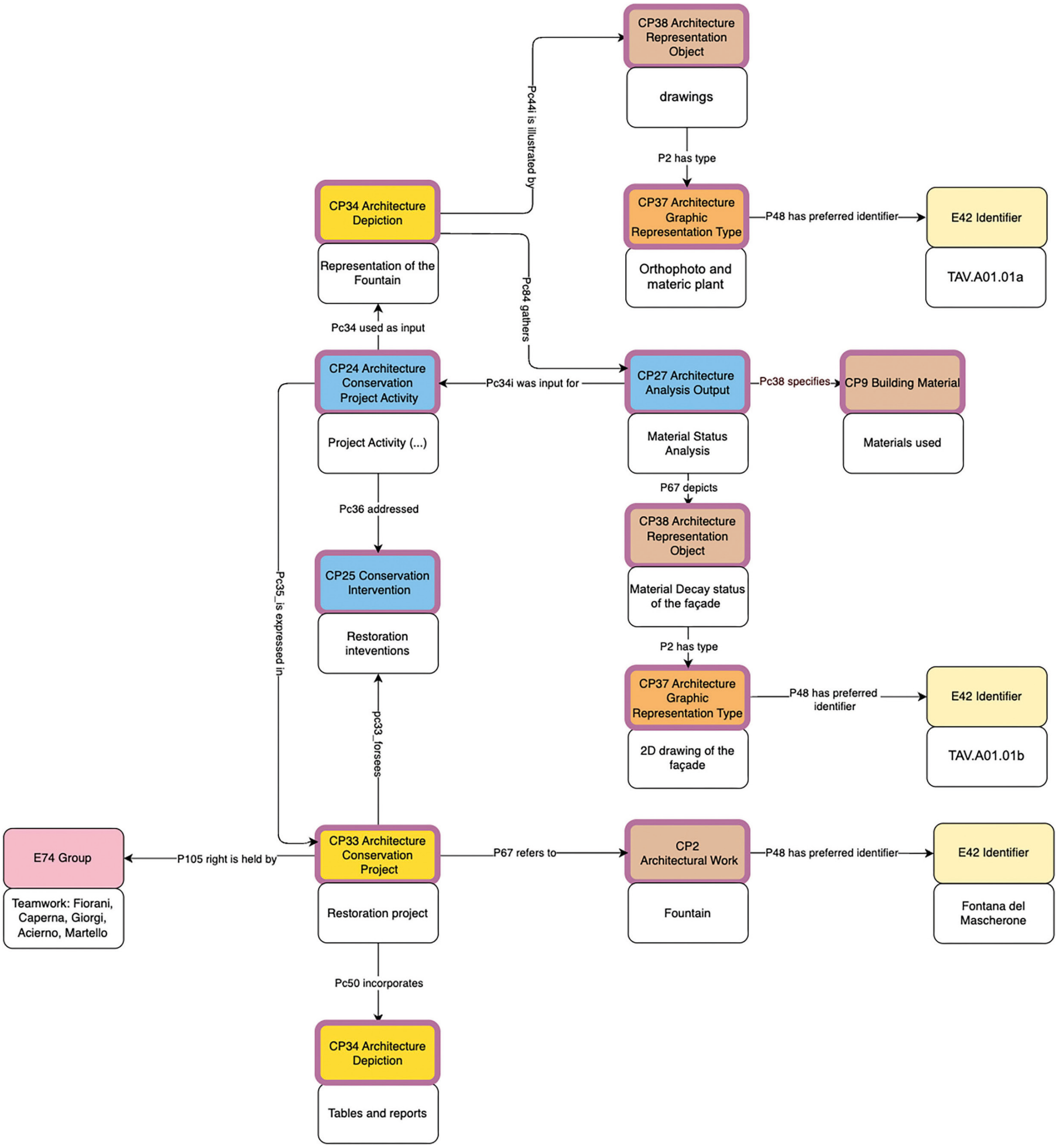

Fig. 3.17. Multi-relational datagraph illustrating the process followed by the designers for the preparation of the restoration project.

code TAV.C01.02B. It specifies here, for each of the constituent materials, the relative conservation state. On the marl limestone of the trabeation is particularly observed disintegration due to freeze-thaw cycles of water that penetrated inside the fountain components. This mapping was used as the basis of the restoration project, which involves interventions on the surfaces of the tympanum and the reintegration of missing travertine parts. Finally, the code of graphic tables documenting the planned interventions is indicated". As in the previous case, the diagram in Fig. 3.18 exemplifies the representation of the entire proposition without losing any step of the process or the data recorded through the analytical study of the artifact.

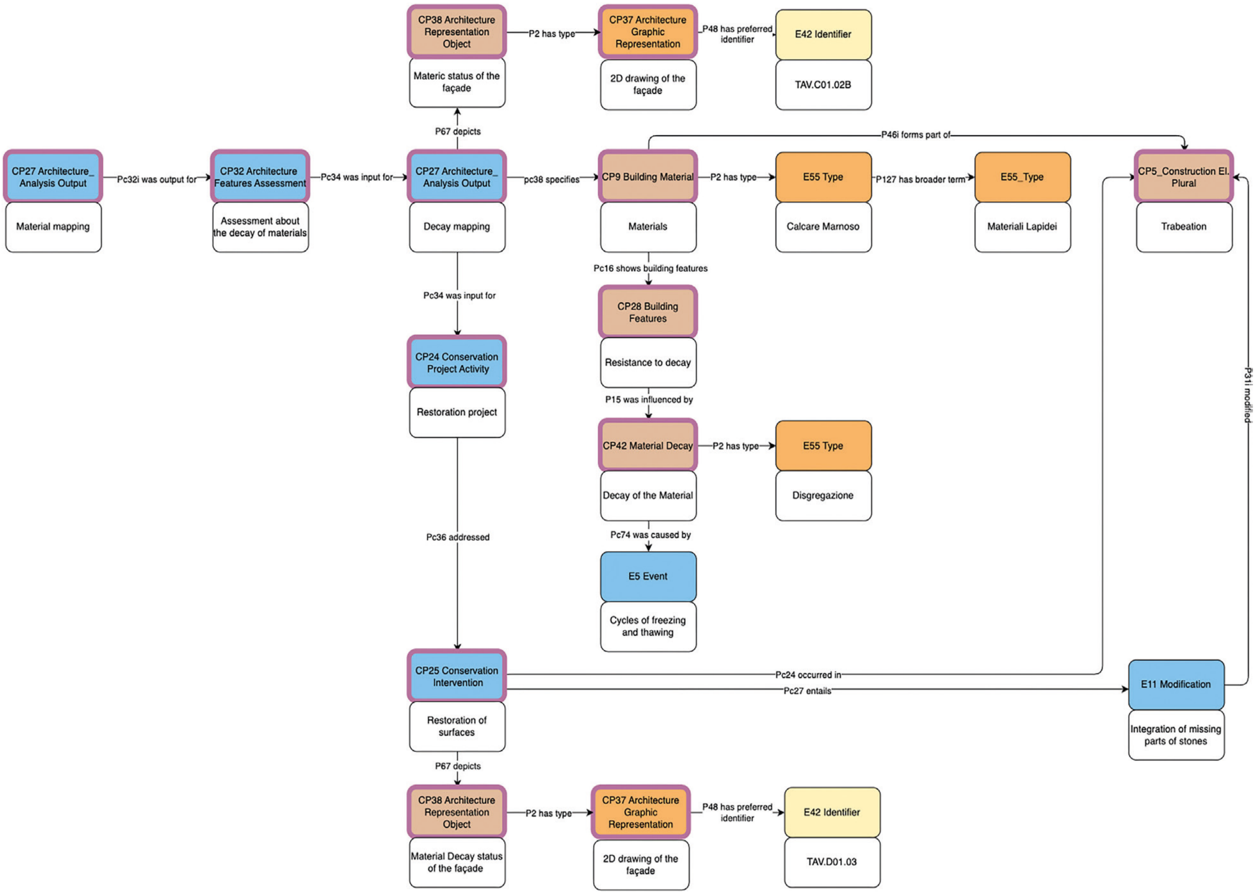

Fig. 3.18. Datagraph related to material decay.

The instantiation of the Fontana del Mascherone highlighted that, in general, the CPM can describe the restoration project process and outcomes in great detail.

The only difficulties encountered are related to the mapping of the graphic table titled "Definitive Restoration Project", in which each element constituting the fountain (plinths, coat of arms, sphere, crowning wall, etc.) is assigned with individual identification codes and the specific restoration interventions planned. This difficulty is related to a scale issue and the localization of individual constituent elements corresponding to the related conservation operations. This problem was not addressed in this case but in the subsequent example of the Tempietto of St. Pietro in Montorio.

3.2.3. Instantiating a monument

The Tempietto of St. Pietro in Montorio is one of Bramante's first works designed in Rome and stands as one of the most emblematic examples of his architecture. Regarded by contemporaries as a successful affirmation of a new expressive language, it has therefore been the subject of careful analysis, described both verbally and through graphic representations. Given the large amount of data available, the decision was made to model the Tempietto and the related knowledge data to verify whether the currently available tools can describe it in all its complexity.

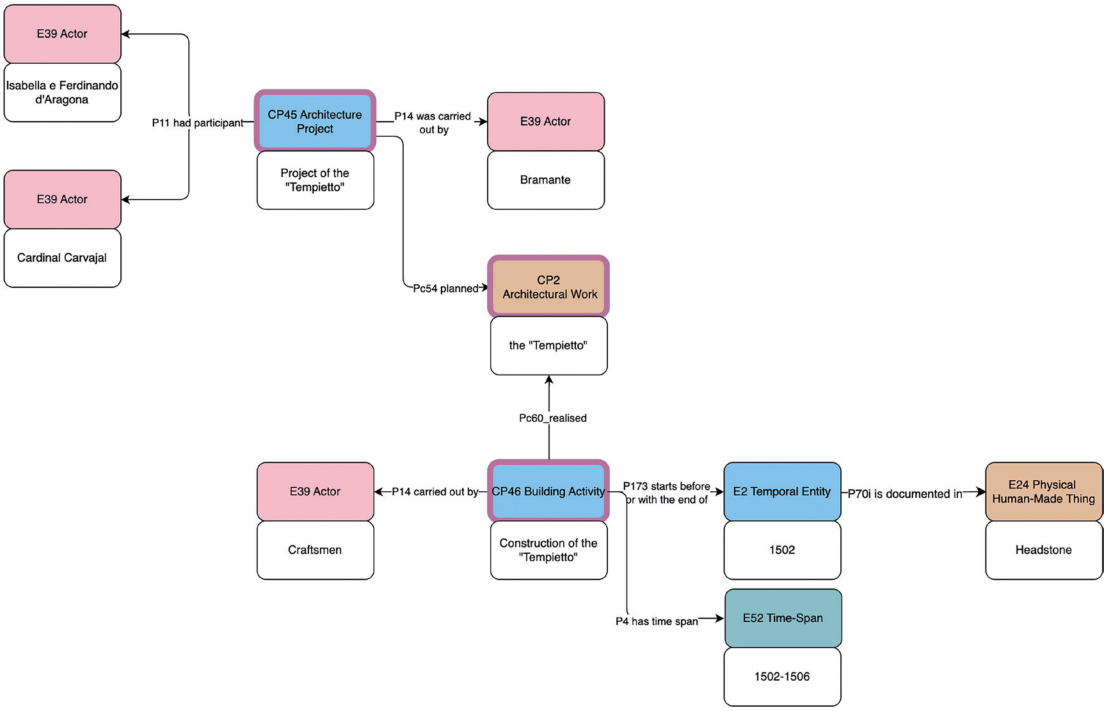

Fig. 3.19. Datagraph related to the creation and realization of the project.

Specialist literature has clarified the multitude of phases that followed both in the design and execution stages[42] as well as the difference between the architect's design intentions, the actual realization of the work, and the building that has come down to us; this constitutes a primary significant difficulty in modeling a structure of particular historic and artistic value. The last aspect, related to the current physical consistency of the work, can be managed through the CRMbase E11 Modification class, while the realization of the work can use the CP46 Building Activity class (Fig. 3.19). However, the CIDOC CRM model and its extensions alone did not allow the effective expression of the specificity of the building design. The CPM therefore modeled the CP45 Architecture Project class[43], a subclass of E29 Design or Procedure, capable of accommodating instantiations related to the same project variants. From the literature and archival documents regarding the Tempietto, it is clear that the initial project was repeatedly subjected to adjustments and variants executed by Bramante himself in response to the client's requests and the maturation of compositional solutions deemed more effective[44]. The new CPM class CP45 (Fig. 3.20) Architecture Project also makes is possible to instantiate these variants, unlike E29 Design or Procedure.

Another aspect highlighted by the instantiation concerns the localization of individual architectural components and, above all, the connections established between them in relation to the specific location of the element, as exemplified by the mouldings at the base of a column in the Tempietto peristyle.

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42 See Cantatorea 2017; Pallottino 2017.

43 For a general overview see Part 1, Paragraph 1.5, of this very same volume.

44 Cantatorea 2017, p.156.

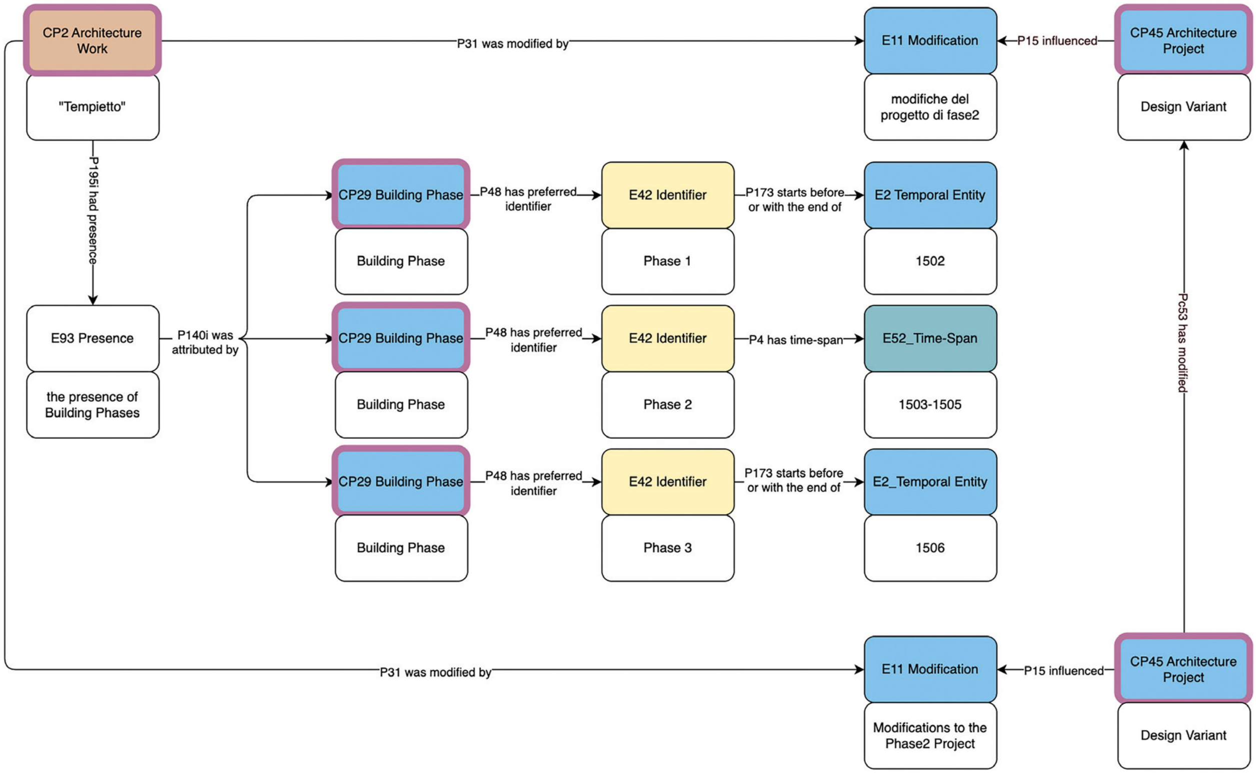

Fig. 3.20. Modeling and instantiation of the variants related to Bramante's design of the Tempietto of San Pietro in Montorio.

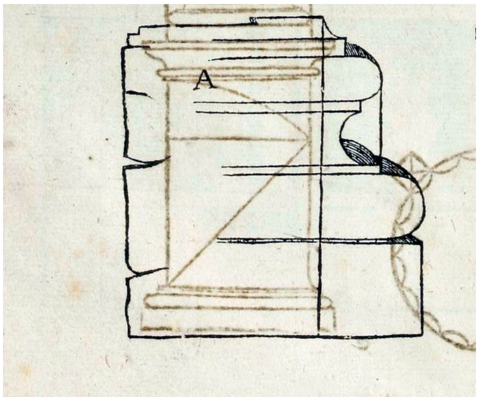

Fig. 3.21. Base of the Doric column. Sebastiano Serlio, Book IV, Venice 1551.

In historic architectures, the taxonomy and rule of order are fundamental intrinsic characteristics. The base of the doric column depicted by Serlio (Fig. 3.21) follows, from the bottom up, the sequence 'toro-listello-scozia-listello-toro', the same present at the base of Bramante's columns. At present, thanks to the properties introduced by the CPM, Pc7 *is connected through* and Pc8 *is connected to*, it is possible to explicitly state the connection relationship between parts of a constructed work (Fig. 3.19)[45]. The graph (Fig. 3.22) clearly shows that, thanks to the reflexivity of Pc8 *is connected to*, the torus is connected to the listello, the listello to the torus, the scotia to the listello, the listello to the scotia, and so on. The reciprocal placement of the parts, however, remains an open

[45] From the instantiation, the difference between the concepts of 'particular and universal', which underlie object-oriented modeling, was also emphasized. The universal, such as the base of the doric column as defined taxonomically in treatises and exemplified in all Doric columns, is modeled as E55 Type. The particular, on the other hand, the instance, the specific column of the temple being modeled, composed of man-made material parts, is a CP5 Construction Element Plural.

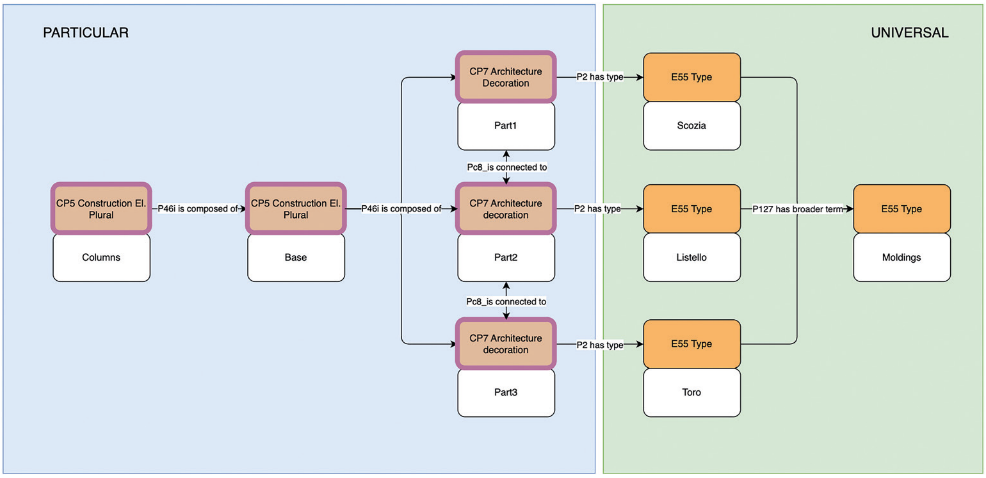

Fig. 3.22. Datagraph related to the column of the Tempietto of San Pietro in Montorio.

problem[46]. Reference was deliberately made to a particularly detailed scale of the order reading, but the same reasoning could be applied to parts of a column (capital-column-base) or the Tempietto as a whole (dome-trabeation-peristyle-podium).

The work of transposition, modeling, and instantiation presented has proven useful from multiple perspectives. Firstly, it allowed the integration of ontological formalization after the identification of the lack of tools for adequate data instantiation, such as the graphic scale of representations or the transcription of the free field attributed to the "other" vocabulary term in the Risk Map. The potential of using IT tools for cataloguing and documenting built heritage is significant, particularly for utilizing and querying collected data. Additionally, modeling in Excel and datagraph enabled the processing of data in XML and/or RDF formats, making them compatible with tools like 3M and Geovistory[47].

Furthermore, the described data structuring validated the CPM ontology could become a standard for future systems. This opens up possibilities for modeling projects or architectures at various scales in X3ML format[48] to study the full potentiality of this technology. The ultimate goal is to enhance the knowledge, conservation, and management of built heritage while ensuring maximum interoperability of available data on existing buildings. Given the complexities of integrating complementary information from various systems in the cultural heritage domain, exploring this technology potential using formal ontologies and automated information extraction (IE)[49] could be beneficial.

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46 The research is focusing on the semantics of space but not on built structures geometries. For a general overview see Part 1, Paragraph 1.4 of this very same volume; for further details, see Guillem et al. 2023.

47 <https://www.geovistory.org/about-geovistory>.

48 See Marketakis et al. 2017.

49 Information Extraction (IE) is defined as the automatic extraction of structured information, such as facts or events concerning entities or relationships between entities, from unstructured sources. See Feldman et al. 2010; Sarawagi 2008.

PART III

A debate on CIDOC and architectural heritage informatics

4. CRM Family of Models: Representing Knowledge about the Past

Martin Doerr

CIDOC Conceptual Reference Model (CRM) does not only include the basic model, that has been submitted to ISO and has become an ISO standard which is regularly updated, but also the extensions that so far have been brought to the attention of the CIDOC CRM Specialist Interest Group (SIG) and that have been reviewed and regarded as mutually compatible[1].

For the beginning, it will be useful and important to give an introduction about the sense of knowledge representation of formal ontology as applied by the CRM, and particularly about the way in which these models are being developed.

Therefore, this presentation is meant to be an overview of how this development has been approached, by describing the motivations and procedures which are behind the present work and that have the purpose to develop some effective means to represent reliable scientific and scholarly knowledge about the past in information systems. In particular, we consider important constraints for information systems about the past, so that it is possible to describe with them something that has really happened in the past and in a form that can be handled effectively in information systems in a *structured way*, rather than in free-text based information systems.

Actually, the aim of the CRM is not to represent the whole world or to discuss how to represent such things as ethics or belief systems. This is not at all a lack of interest, but, on the contrary, it is a consequence of the belief that the means provided by structured information systems are simply not adequate enough for representing properly such deep and important questions of human interest. Instead, the hope is to be able to at least provide sets of related facts, with the help of machines, so that it will be possible to *support human interpretation* about what really happened, about their impact and relevance for the material, immaterial and spiritual world we live in.

Furthermore, we support a strong belief in the superior power of human language and intellect and in the fact that the binary logic and digital data are crude but very helpful means to approximate some quite specific kinds of knowledge about reality. So, it is necessary to keep in mind that we work under these constraints and that the effort is to try making optimal use of the machines which can store a very

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1 This is a transcript of a presentation given by *Martin Doerr*, chair of the CIDOC CRM Special Interest Group, via teleconferencing with Rome, Sept. 16, 2022 and edited in Dec. 12, 2023.

large number of facts, as crude as they may be, and can relate them with and via things that human labour would not be sufficient to go through all of them and find relevant relations. But that does not imply that these means can also describe all the subtleties and the actual influence of the various causes behind human behaviour in the past and safeguard from possible misinterpretation.

Currently, in developing the models to structure this data, pure Constructivism is rejected, which would mean that such any model is just an agreement between some people that is conserved. Rather, we commit to some form of recent Scientific Realism, particularly referring to what has been discussed recently after 2000. The problem with Constructivism is that it has no concept for how to relate models objectively to the behaviour of things we make models about that exist in reality.

For example, if the topic of a discussion is the destruction of a pot or so, it is indeed a convention to say in which kind of condition a pot is regarded as being destroyed (i.e., becoming useless versus unrecognizable). But it is not a question of convention how a pot or a piece of pottery can be destroyed at all, in any of these senses, or in which way it may decay. Thus, in any case, we have to combine the models made in order to describe facts about the reality with the observation of how the intuitions by which we talk about them actually relate to a possible reality in a logical form. Therefore, it is strictly necessary to argue on an empirical base about given scientific or scholarly practices and to explore empirically how scientists and scholars do reason in various cases and different contexts. More specifically, we critically observe how they describe reality and particularly to see if, what they normally claim and how they reason is only prototypical; if there make in part exceptions in their own reasoning to these claims or if there are other cases or context in which the same people would argue differently. Even so, scientists and scholars may not primarily be aware about these deviations and their actual way of reasoning would not be their primary models to make. However, the actual reasoning is indispensable for information integration, for having robust models with long term stability in which to describe all facts[2].

This process may be regarded to be a quite difficult intellectual exercise and CRM is particularly interested in concepts which are observed to have similar or identical patterns in cross-disciplinarily contexts and therefore are theory-independent and particularly suitable for standardization. For example, we have observed in CRM-SIG for a long time that there is similarity between findings of archaeologists and biologists when they see a bird or so[3]. The difference is that the objects of the archaeologist don't fly away, whereas biologist normally do not dig in the ground to find something. But, in the end after ten years, we found that there is a common pattern to it which has the same intellectual function, i.e., to promote documented knowledge of material things encountered somewhere that were not (commonly) accessible before, a pattern which is quite interesting and helpful to simplify and understand it.

The question is, what is *knowledge representation*? In one way, it can basically be thought of as yet another form to structure data. But being based on series of statements given in predicate logics, it is closer to human thinking than a Relational Data

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[2] The fact that humans, all experts, are not completely consciously aware of the way they think has been studied and described extensively by Turner, Fauconnier 2002. This work supports the necessity of the well-known process of 'knowledge engineering' by an independent observer of the expert.

[3] In biodiversity, it is called an 'occurrence', rather than a 'find'.

Model, ooDBMS, XML, etc. The intended meaning of statements in knowledge representation is the interpretation of its expressions as statements about a 'domain' which is normally regarded as a part of reality[4]. For example, "now I am talking to you" is a simple statement; "Martin is giving a presentation" is an expression that is not just a set of words, because anyone who hears it in this audience, immediately understands that it wants to say something about the real person, others involved and the things actually done (Fig. 2).

This is more or less how it is used technically. It is exactly how Early Wittgenstein in his *Tractatus* describes this relationship, even so, of course, as a general philosophy and not a form of data encoding. Later in the *Tractatus* he said that it needs to be modified but, in practical terms, its original formulation follows precisely how we deal at present technically with knowledge representation. In contrast to Wittgenstein, we maintain that these statements should not be taken as equivalent (a direct 'image') to reality, but as approximations of reality. E.g., there may be different definitions of what a 'person' is, what a 'human being' is, when it starts to exist, what it does make it to be human. But what it aims at corresponding to in the reality, is more or less captured or approximated by such definitions, and moreover statements based on such a definition should be effective for some valid conclusions and always be compatible with observations.

The knowledge representation itself however is information, and a strict distinction between knowledge and information should be made. People may easily call something which is written down as knowledge, but we argue that knowledge is only something a person can say "I know that" or that someone else 'knows that'.

That knowledge can only exist in humans is because only they can relate a statement to the real things meant, or to the things (with intersubjective identity) they do have in their mind. But information can be read, and then can be turned into knowledge in humans by humans; and people can again document knowledge in documents as information so that other people can read it and acquire knowledge from it, as long as they are able to relate it to reality (i.e. resolving the symbols in the information to their referents[5]). This appears us to have important implications for the provenance of knowledge and the reality, also, fake news, etc. which is a hot discussion nowadays. It also seems to be more than just a philosophical idea, but it has quite practical importance to regard that knowledge exists only in humans: If knowledge is written down into documents, we need to keep track of whose knowledge that was (and can help us today in resolving the symbols in the information, but also assess authenticity).

Current popular machine implementations of knowledge representation are in RDF(S)/OWL. The CRM had other formats in the past, but since the conception of the CIDOC model a lot of different popular formats have been gone through[6]. But simply creating an RDFS/OWL schema does not make it an ontology, as often claimed by IT experts, because an ontology is *about being* and not arbitrarily subjective, whereas all forms schema encodings, including RDFS/OWL, are just a kind of software to store structured information in machines.

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4 Generally, we may talk as domain about a 'universe of discourse', which could be mathematical or even fictional. Here, we are interested only in historical sciences. Therefore, the domain must be reality regardless the ability to perceive it.

5 The 'language games' of Wittgenstein describe a process of pointing to the thing in order to impart the meaning of a name for it.

6 KL-ONE, TELOS, KIF, DAML-OIL, datalog, just to name a few.

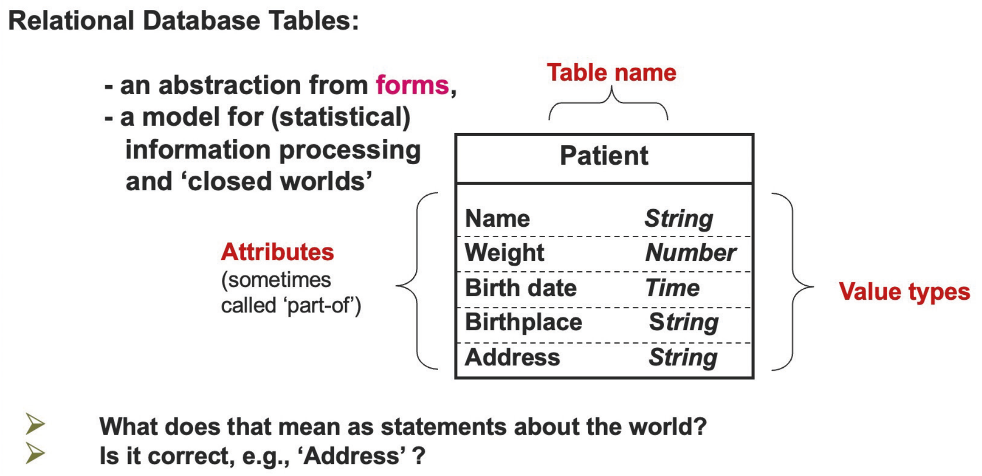

Fig. 4.1. Knowledge representation and Relational database: what makes the difference.

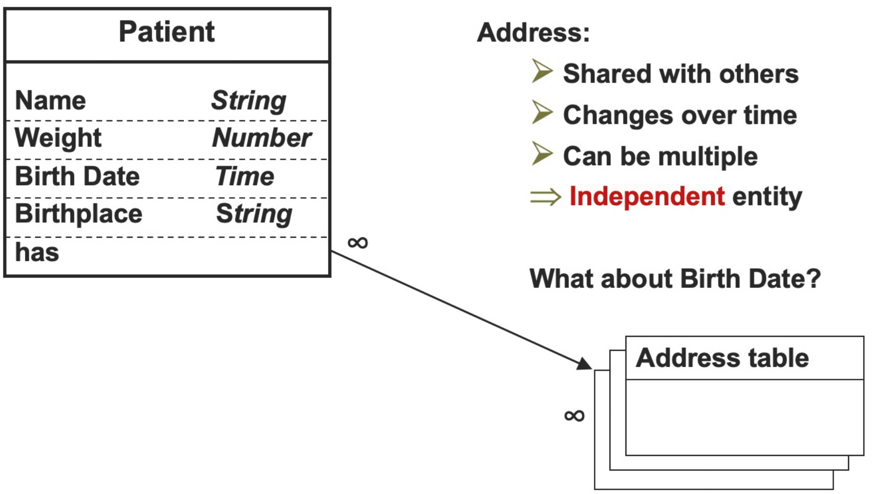

Fig. 4.2. The first reality check.

In order to discuss the difference between knowledge representation ('KR' in the following) and a Relational database, it could be said that the Relations or 'tables' of a Relational data model we talk about are an abstraction of paper forms that present a format in which 'slots' are to be filled in with characters and numbers. It is like working on paper. So, for example, if there would be a (Relational) database for patients as indicated on this slide, there would be slots for their name, weight, birthplace, birth date, address, etc. (Figs. 1-2).

And then, filled in, what would they mean for a real person described? Would they be 'properties' of the patient? If they are analysed regarding our general knowledge about the real world, I believe we agree that the address itself, the built space, is an independent entity and not 'part-of' the patient (as attributes are called sometimes), because the relation to it may change over time and be multiple. So, this attribute 'address' hides a complex relationship between a patient and independent thing (Fig. 3).

If we continue this analysis rigorously, we will find that all information in this example, even the name, has rather a complex relationship of independent things to the patient that is described, which we will all encounter in integration with other databases. There would remain forms empty of attributes, with relationships only, but this is exactly what KR takes up.

In the CIDOC CRM, we assign an identifier to each entity, so we try to make sure in a given context of use of what we talk about, the real patient, independent from

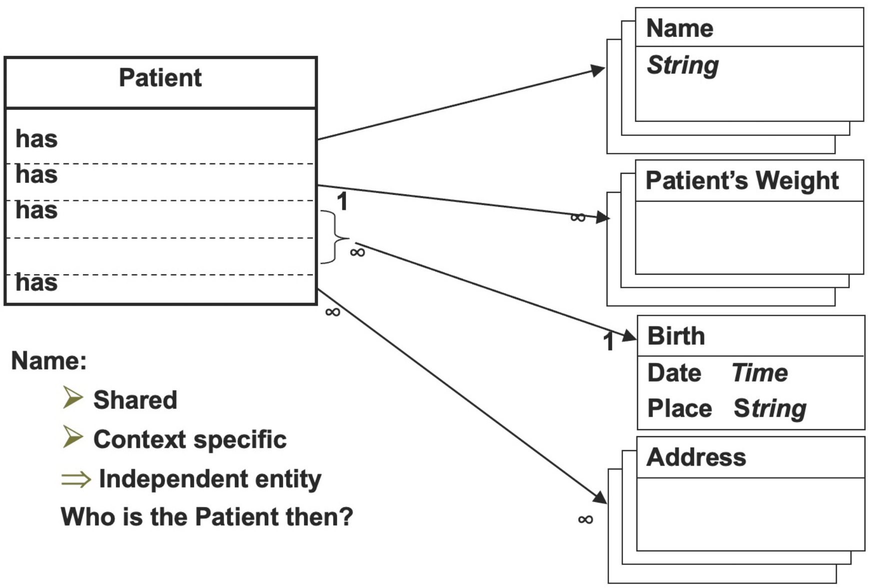

Fig. 4.3. All fields are related entities in reality.

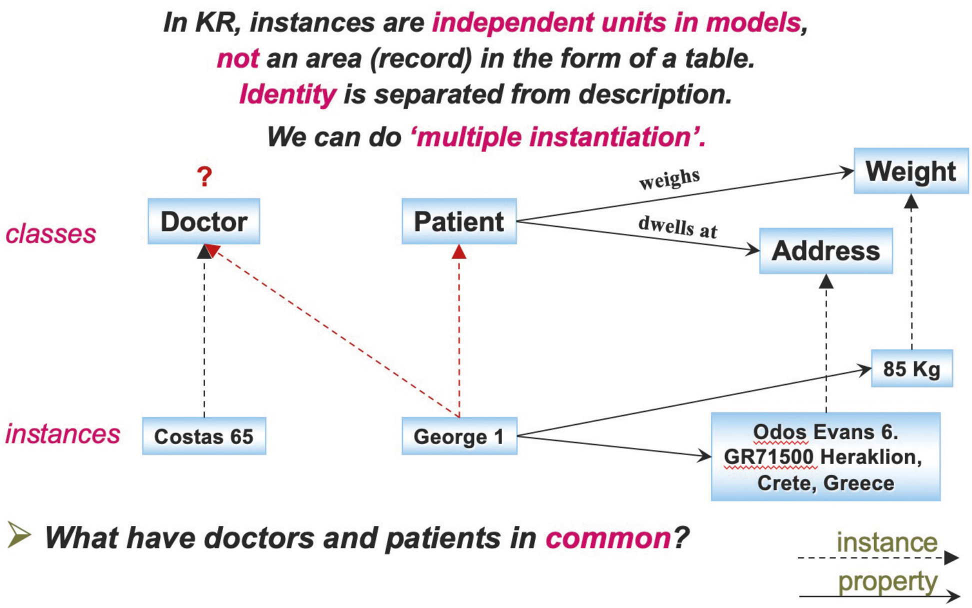

Fig. 4.4. Knowledge Representation: Classes and Instances.

any ephemeral attributes, and then we can relate it to other entities that in turn have their interrelations, without any limitations.

In KR, the individuals ('instances') are independent units and not a storage area in the form of a 'table' for all items of this kind (Fig. 4).

Identity of the individual is separated from any description and this is literally how machines would store KR data. It gives an identifier to any individual, regardless of what the classification is (e.g., doctor and patient), and link it to other data referring to it. This is the key feature why KR enables information integration.

What if I would go any further now? I could ask: what do a patient and a doctor have in common? They are both persons, so it should be possible to make a generalization (a 'superclass'). KR will then take care that if a superclass is declared, all the properties can directly be used for this kind of entity, but that these properties, being from a generalization, also apply to the instances of specializations of the more general kind, which are called its 'subclasses'. This sort of linking subclasses is literally how many machines deal with KR data internally. The above 'patient' is also an example of how we developed our model: we define a transformation 'map' from a legacy data model: we looked at its real examples and then we analyse the legacy model until we find the robust concepts fitting to the real world. Using more and more examples, we find more and more common, robust generalizations (Fig. 5).

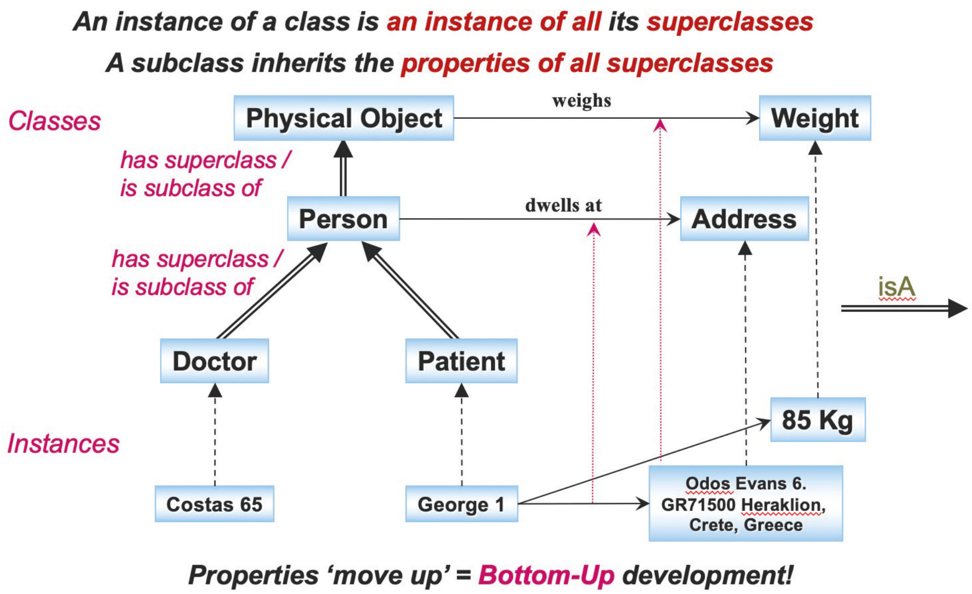

Fig. 4.5. Knowledge Representation: generalization and inheritance.

It is possible to do things with KR which are very difficult to describe in other models. For example, to define that I am a researcher, I am a farmer and so on. Each time I am declared to be an instance of another 'class', this class can bring in its own set of properties that are applicable to describe me under this additional 'aspect' (Fig. 6).

The most important feature of KR is enabling information integration. It is not only a matter of generalizing the entities we talk about in different systems and of linking instances according to any applicable class, but for integration we also need to and can generalize the properties by which things are described in different systems (Fig. 7).

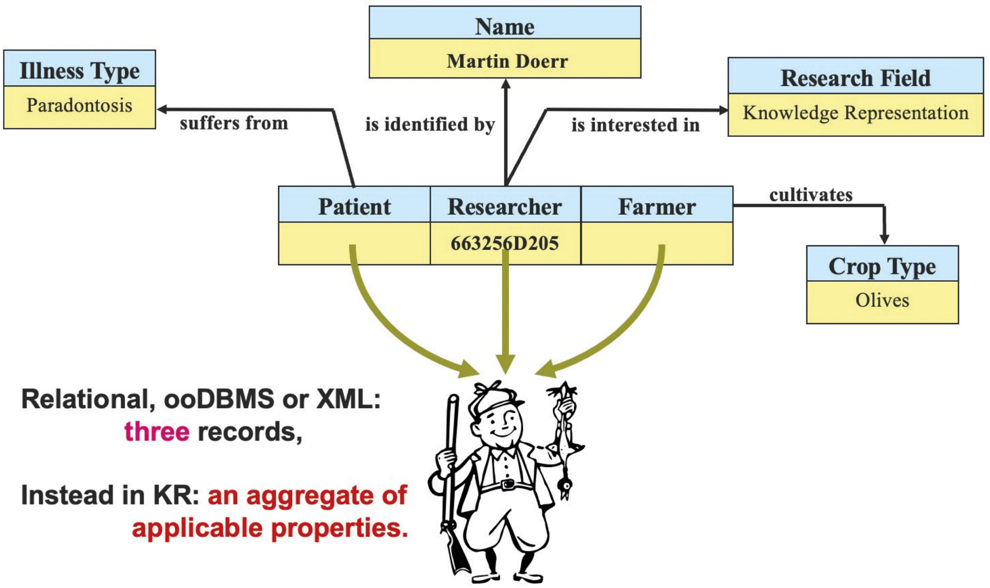

Fig. 4.6. KR: Example of multiple instantiations.

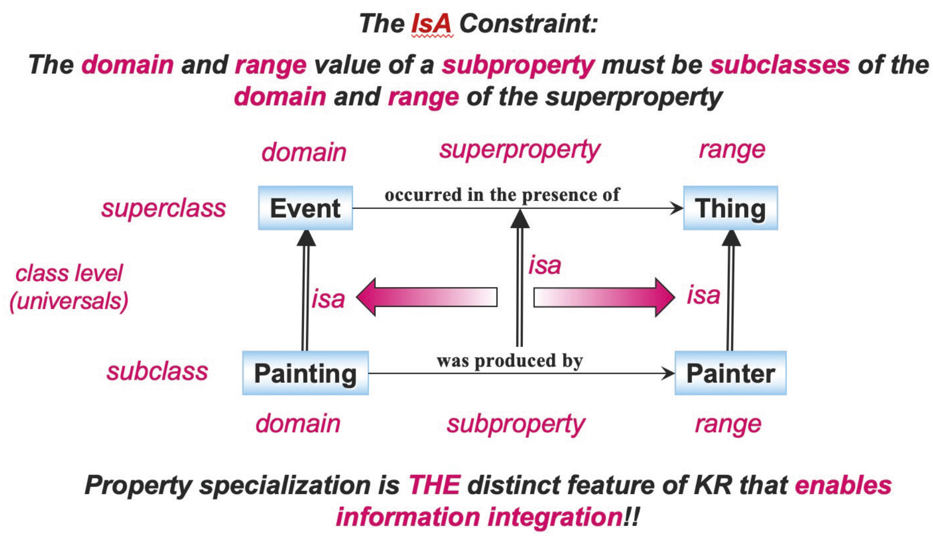

Fig. 4.7. KR: Property Specialization.

For example, if I make a model that an act of painting 'was produced by' a painter, and generalize that each painter is also a material thing, and that each act of painting is also an event, then I could generalize that *such an event*, i.e., each act of painting, actually *must* have 'occurred in the presence of" something which should have been a person but may be also a resulting painting, according to knowledge available. Indeed, we recognize now that *any event* may have 'occurred in the presence of" something. In this way, I am able to describe information at different levels of specificity and still I can query such a system and ask "give me everything that was present in this event", regardless how specific the data entered were, and the system would give me the complete answer needed, rather than enumerating each time all properties that imply this sense. This is how the CIDOC model works, and property specialization is a special feature of knowledge representation that *ultimately* enables information integration and is not provided by other paradigms.

What is the relation to ontologies? A set of knowledge representation classes and properties is called a 'model', but we must distinguish three different senses:

Firstly, a KR model can be a kind of a *database schema* and then its classes, its properties and their relations are represented by unique identifiers, names (labels) and links between them, so that, as an information structure, it can be encoded in suitable formats (e.g. RDFS/OWL) and loaded as schema on some 'knowledge base platforms', i.e., database systems typically called Triple Stores, Quad Stores, Graph Database, etc., according to their internal principles of operation. Such a schema may also include processable logical rules (nowadays typically encoded in OWL).

Another sense is that of a *knowledge base*, which means that a KR schema, is known and loaded on a platform, and *actual data* are stored in it. Then, the instances that mean things from the outside world, and therefore cannot be stored inside the machine, must be represented by unique identifiers as data, plus the links to adequate classes loaded and be connected by adequate instances of the loaded properties to other class instances (numbers and characters can be stored as they are directly in a machine). The need to represent 'outside' instances with identifiers causes the fundamental problem in information integration of whether things described in different knowledge bases by other identifiers, are in reality identical or not, and whether it is possible to create reliable links between identifiers for the same things, the so-called identifier reconciliation[7].

The sense of a KR model that deserves best this name is that of a *formal ontology*. This means that the properties and classes describe via their possible instances *possible states of affairs* in a perceived reality and that there is *common agreement on those based on shared experience*. A formal ontology is best formulated in predicate logic and not in OWL or RDFs, because the latter would introduce classes as data objects only, and in a specific but arbitrary encoding. So, for example, if you take me to be an instance of the class 'person' and not as an identifier in a knowledge base, and if you describe that a person must have one father regardless of what we know, then you talk about *possible states of affair* in the perceived reality, etc. This is what we formulate with the CIDOC model: the possible states of affairs that are to be found in the reality, as the base for information integration and regardless encoding and special forms of implementation, so that someone can refer to their definitions as a robust mechanism for relating different (equivalent or more specialized) schema declarations with a long-term validity via suitable, ever-improving IT methods.

A knowledge base derived from a formal ontology must encode the logical prototype as data objects, so that its properties or relationship or classes describe how our *states of knowing* relate to believed, *possible realities*. It will however differ slightly in some forms from the prototype ontology: in treating the unknown; the knowledge alternatives; the identifiers replacing the *beings;* and the encoding of numerical values

7 Without going into detail, in a scientific and memory institution context, we must basically rely on the maintainers of a knowledge base to be able to resolve the identifiers (e.g., to collections) or to know who knows. In the sequence, provenance research and identifier clustering as viaf.org performs, provide a viable solution. Automated matching is helpful, but only to assist manual control.

which is always limited to more specific sets and does not correspond to the mathematical spaces we would talk about ontologically.

Since the 1970's people observed that intuitive data modelling in information systems leads to mutually incompatible data structures and that these intuitive data structures are only comprehensible in local context so that, if the context had to be extended, it would be impossible to algebraically transform, combine or merge them in their encoded form. Indeed, the only successful approach since the 1990's is based on formal ontology as background theories for transformation specifications for information integration and then on using the knowledge representation mechanisms with generalization of both of classes and *of properties*, which are capable to relate different classifications, levels of specificity and granularity. Reliable transformation specifications ('mappings') still require manual work and interviews with the experts. Just note that there exist also other important forms to encode scientific knowledge, such as continuous field functions, simple and partial differential equations and neural networks[8].

For summarizing, the main differences of KR compared to the Relational model, but also to XML, is the property specialization-generalization (1) and that we do not talk about structuring storage fields on media, but about a network of unique facts, which is also more generally called a 'semantic network' (2).

In KR, we have 'context independence' of facts, i.e., things are described by 'universal resource identifiers', each existing individually and globally, and their interpretation does not depend on what other information is in the database around. In contrast, the Relational model relies on 'keys' for identification: specified combinations of values locally assigned to particular fields for each record in a table. But traditional KR has no concept of which individual facts have been said together, in a 'document', nor does the Relational. The latter is well represented in XML, or by adding to knowledge bases the 'Named Graph' mechanism, which more and more KR platforms support recently, even though a received theory of the logic of Named Graphs is still inconclusive[9].

At the moment, the CIDOC CRM is intended to support characteristic phases of scholarly/scientific processes. We use to distinguish phases of (a) collecting and organizing evidence from sources and observation, then (b) connecting collected facts via the things involved in them, then (c) interpreting facts and finally presenting and publishing the results. The particular problem is that billions of facts from various sources possibly shed light on the past in unexpected contexts across all disciplines and sciences.

In these processes, the particular value of the CIDOC CRM is in globally connecting facts, so that after evidence has been collected, organized and encoded in a common format, we are all able to connect important facts across disciplines that we expect to have a possible impact on the interpretation of some particular problem, and that we are able to retrieve a reasonable subset of what is in the connected data-

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8 Whereas knowledge representation was since its inception regarded as belonging to the discipline of 'artificial intelligence' (AI), the recent success of 'deep learning neural networks'has motivated media to call the latter exclusively 'AI'. Both methods have nothing in common besides their goals.

9 The logical problems of Named Graphs only occur when schema and instance information is used together. For the above purpose, no schema information needs to be represented by a Named Graph. Therefore, we recommend its use.

bases and that possibly has to do with my problem[10]. Further, the model aims at being theory-neutral, providing the shared concepts we need to be able even to formulate disagreements about particular interpretations.

When we started developing the CIDOC model, we had in the second meeting the problem that everyone insisted to have a special field of their application in the standard[11]. This turned out to be completely unmanageable. So, we agreed on strong constraints by which we could restrict the aspects and the things that are really important, above all for information integration across disciplines, and that will result in a manageable set of concepts which are still covering by their genericity most relevant relations, without losing basic meaning.

Sometimes in the CIDOC CRM meetings, we discuss arguing that a specific detail that was proposed is not necessary to be modelled, but rather that one can use a more general construct and queries to retrieve such facts, albeit together with a few others. Attendants sometimes might get upset by that, but we have to keep in mind that, in order to make a standard, it is necessary to have only robust statements one is sure about that they will be needed and will be highly relevant in the future and also, that there might be a problem of changing them[12] when they need adaptation but are already widely used (Fig. 8).

So, the lesson learnt from making a standard is a sort of conundrum: for using a standard, it is necessary to invest in mechanisms to transform your data to the standard; and from one standard version to next one, keeping in mind that there will never be a final version. Why not using only transformations between our data? There will be too many transformations without a standard. So, the transformation of data from

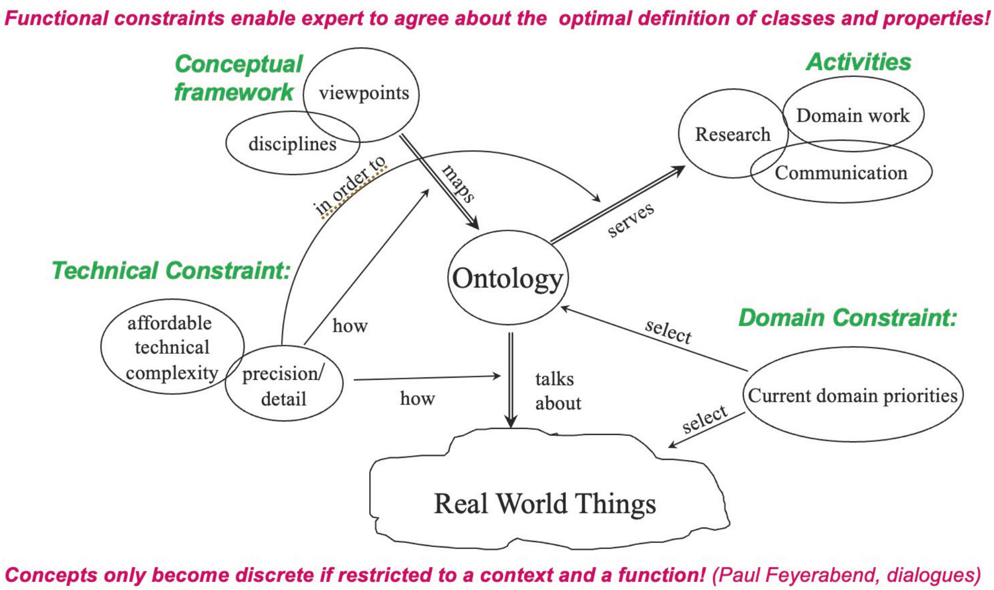

Fig. 4.8. Ontology engineering scope constraints for the CRM ontology.

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10 The hyperlink paradigm created the problem that retrieving links following links quickly results in retrieving unmanageably large data sets of mostly irrelevant facts.

11 CIDOC in 1995 gave up work on a Relational Model for all museums when more than 400 tables and 2000 attributes had been defined, and no end was in sight.

12 Only 'nonmonotonic' changes, which render legacy data invalid, cause this problem.

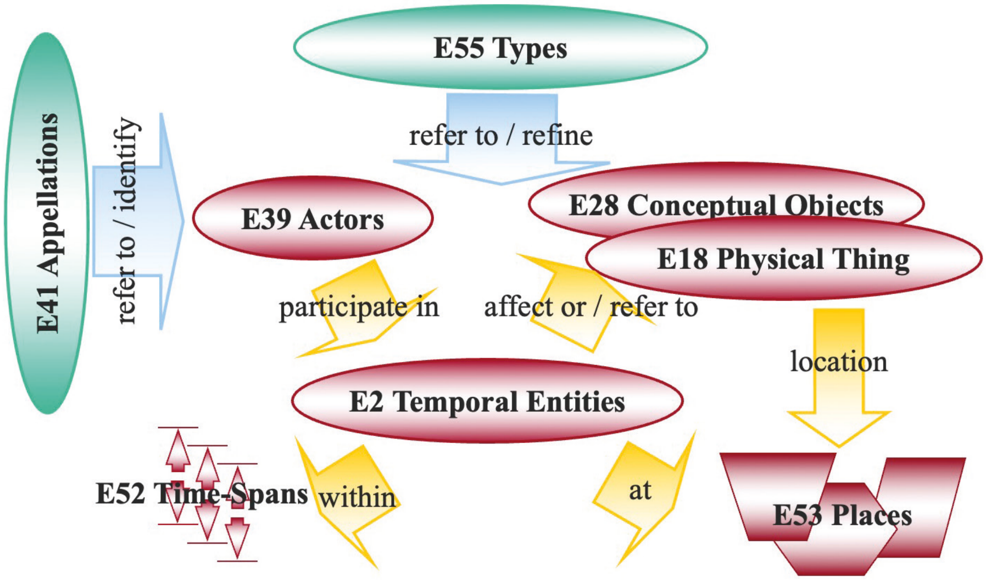

Fig. 4.9. Top-level classes useful for integration.

sources and from one standard version to the other is something we have to live with. Therefore, using the CRM should always come data transformation technology.

The central concepts of the CIDOC CRM are the Temporal Entities which are the things that can be said to be '*ongoing*' at some time, or have the substance of 'change', in contrast to things one may have 'met *again*'. Temporal Entities have many subclasses in the CRM. Any instance of it is a phenomenon of ongoing which is of a distinct, delimited and uninterrupted form in which persons and groups of people may *participate*, which has a clear identity in time and space and may *affect material* and *immaterial* things. We may have a lot of terminology, instances of E55 Type, but taken from other resources than the CRM, by which one can refine the kind of instances of any class in the CRM and finally, all items, instances of any class, may have many names assigned to at different times by different people, so that, by the names of things in their contexts, we may be able to follow items and their references through the world, in inventories, etc. (Fig. 9)

Then we describe in the CRM specialization-generalization hierarchies for each of the above base classes. As an example, to start with, we describe the Temporal Entity (Fig. 10), as something that has its existence in the world *as long* as it happened and then, we specialize it into E4 Period, as a set of coherent phenomena, in addition being within a *limited space* and having parts. Further, we have (E5) events.

When looking at their 'internals', they have everything in common with (E4) periods, but they imply change, therefore we add more specific properties. We continue with (E7) activities, bringing in *purpose* and *active* participants and so on.

I can make the example of the context of the Amphora of Tuthmosis III in the archaeological museum of Heraklion with minimal CRM properties. It was enough to convince the Europeana Development Team that events are important basic primary elements to document, in contrast to Dublin Core and others. It shows the power of using only properties in Fig. 14.

- E2 Temporal Entity
  - Properties: P4 has time-span (is time-span of): E52 Time-Span

IsA ↑

- E4 Period
  - Properties: P7 took place at (witnessed): E53 Place
    P9 consists of (forms part of): E4 Period

IsA ↑

- E5 Event
  - Properties: P12 occurred in the presence of (**was present at**): E77 Persistent Item
    P11 had participant (participated in): E39 Actor

IsA ↑

- E7 Activity
  - Properties: P14 carried out by (performed): E39 Actor
    P20 had specific purpose (was purpose of): E5 Event
    P21 had general purpose (was purpose of): E55 Type
    P16 used specific object (was used for): E70 Thing
    P125 used object of type (was type of object used in) E55 Type

Fig. 4.10. Extension by Specialization Hierarchies in CRM.

Amphora of Tuthmosis III

Identifier: *Λ2409*
Classification: *Amphora*

Event: ***Type:*** *Excavation*
Actor: *Stylianos Alexiou*
Date: *1951, October*
Place: *Katsampas, Tomb of the "blue coffin", Heraklion*

Event: ***Type:*** *Deposition*
Place: *Katsampas, Tomb of the "blue coffin", Heraklion*
Period: *LMIII A1 (14th century BC)*

Event: ***Type:*** *Production*
Place: *Egypt*
Period: *18th Dynasty, reign of Tuthmosis III (15th century BC)*
(inferred from inscription…)

Fig. 4.11. CRM: example of instantiation of the amphora of Tuthmosis III.

I only described that the amphora (1) *was present* in an excavation in Heraklion, (2) *was present*, when it was put in this tomb in the 14th century BC, and (3) *was present* when it was made in Egypt (inferred from the cartouche). It is just with this 'being present', the type of event, place and the period or date, that this relation alone allows me to infer a *terminus ante quem* that this tomb must have been made at or after the reign of Tuthmosis IV. It is actually extraordinary what you can derive just from such a simple representation, such as travels between Egypt and Crete in Bronze Age (Fig. 11).

All specializations in CIDOC CRM are illustrated in Fig. 12.

This is the idea of the CRM: to use powerful, automatically implicit generalizations of properties for accessing data and for knowledge lacking more details, without excluding much more detailed representations. Using, for example, to represent

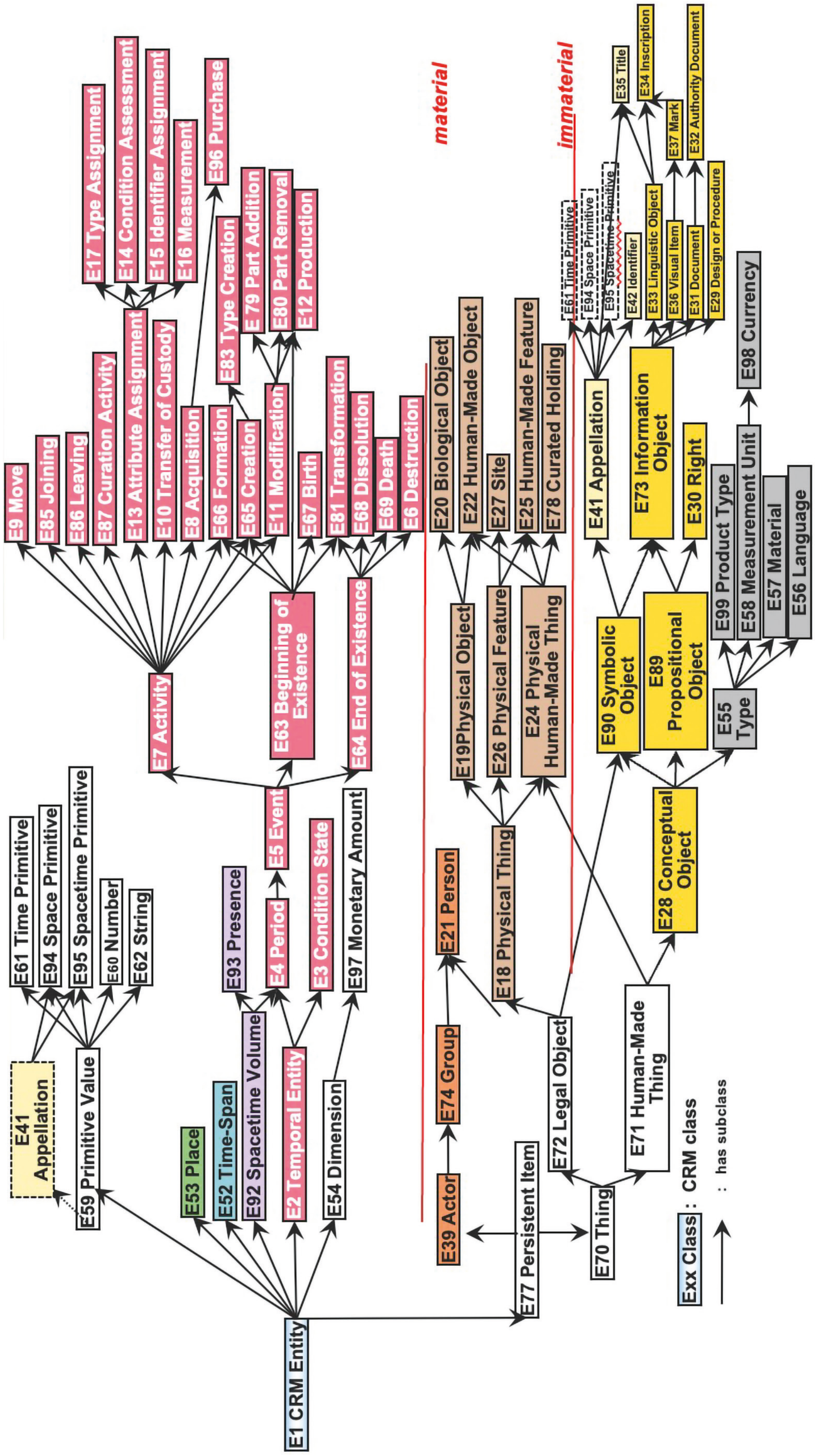

Fig. 4.12. Classes hierarchy of CRM.

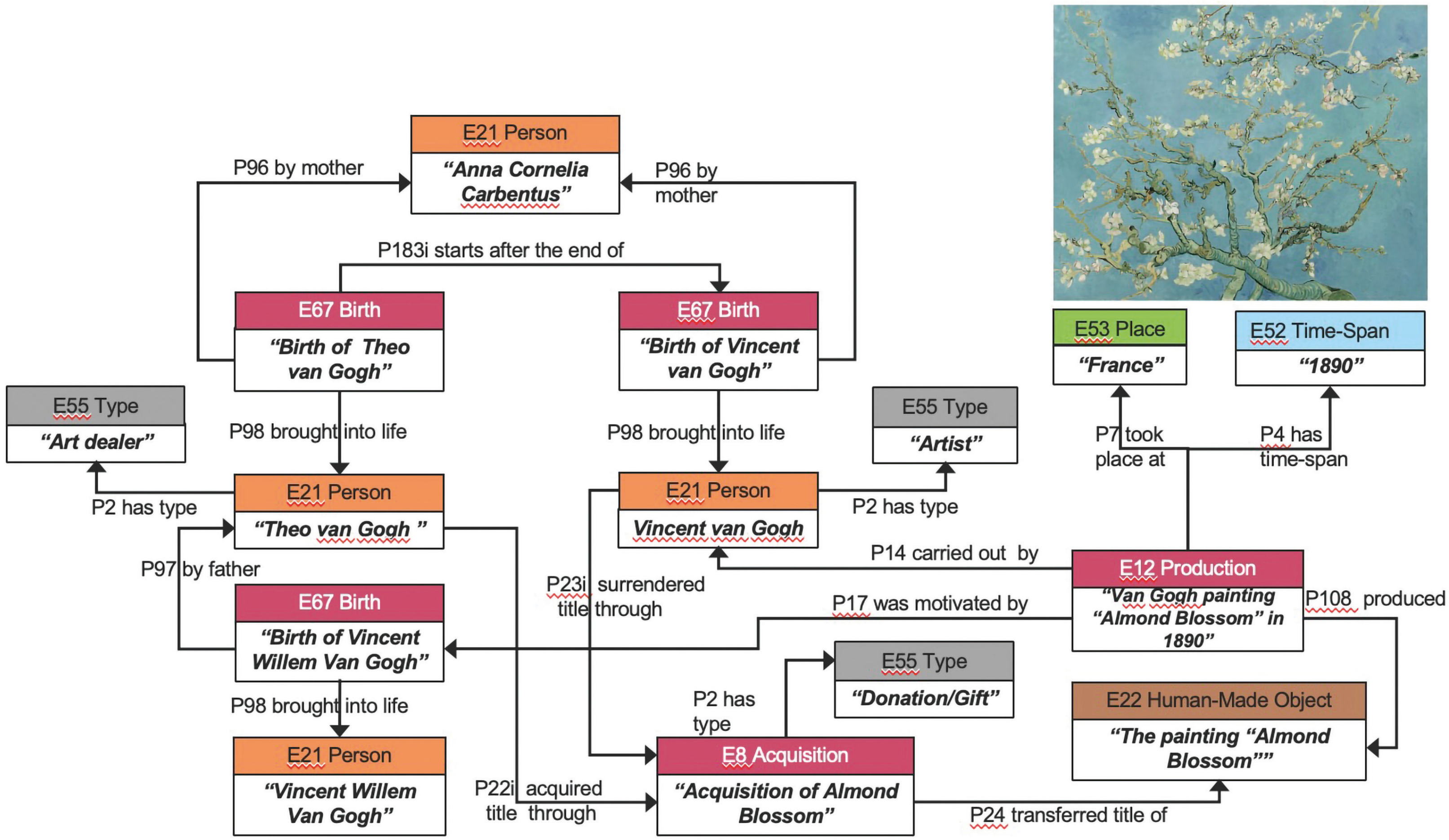

Fig. 4.13. Formalization in CIDOC CRM and instantiation of Van Gogh's Motivation for the Almond Blossoms.

such nice stories, as the motivation of Van Gogh for making the painting "Almond Blossom" for his niece' birth, shown graphically in Fig. 13. The rectangular boxes describe instances by labels and the classes they belong to, and the arrows the property instances with the property names attached. They are rendered so that you can read such graphs nearly as if they were a language. They are literally stored in the same way in a knowledge base (but without layout data).

In Fig. 14, we represent the story of Rodin, who produced the "Monument to Balzac", which caused a scandal at that time and was not cast in bronze before his death. So, we have that monument in bronze, which he never saw, even though metadata claim that he "created it". We can describe these details adequately, because the CRM allows us to differentiate the sense of "creating it" it in bronze from that in gypsum, which is completely different. It is possible to describe such complex contexts already with a small set of properties of the CRM with extraordinary precision.

Nevertheless, we often do need, of course, more specific concepts to describe complex, specialized contexts. The important feature is that the CRM is made in a way that we can specialize new concepts under the generic superproperties and superclasses so that, when we query data described with specialized extensions of the CRM by their basic superproperties, we will still get complete answers of all facts documented by the specializations and we will see them as described with *their specialized* properties. The mechanism of compatible extensions of the CRM allows us to query with the same base terms all data described by extensions, and the answer will tell us more facts than we would easily be able to formulate by explicitly enumerating specialized properties in queries. In that sense, the CRM becomes an "open family of models" (Fig. 15).

Thus, since 2003, we have the extension FRBRoo, which is related to the library world by intensive collaboration with IFLA. It was the first model transforming the Functional Requirements for Bibliographic Records into a knowledge representation model. It constitutes a *causal* model of intellectual *creation* and *derivation*, but also for integrating library concepts with other aspects, such as critical editions, or the PRESSoo model about journals and serials.

CRMgeo is a spatiotemporal model for connecting the CRM with the GIS world and the OGC standards: It allows for connecting semantic facts of what happened (CRM) with their respective topological constraints in spatiotemporal properties and reasoning (OGC).

There is the CRMInf extension, which describes how we would justify what is in a knowledge base. It serves the integration of data with reports of reasoning, i.e., what are the sources, the reasons, the evidence that would justify, question or reject facts.

There is the CRMsci, a model of scientific observation which generalizes over a set of international models and European standards to describe activities in many different fields. It introduces the concepts of units of matter and their physical genesis, concepts of *observation* and data evaluation, and it has been validated in applications in archaeology, biodiversity, geology and conservation sciences;

Further, we have CRMarcheo, which introduces concepts of stratigraphy and excavation, and is being validated by five national standards for archaeological records;

Closely related is CRMba, a model of archaeological analysis of buildings and their phases;

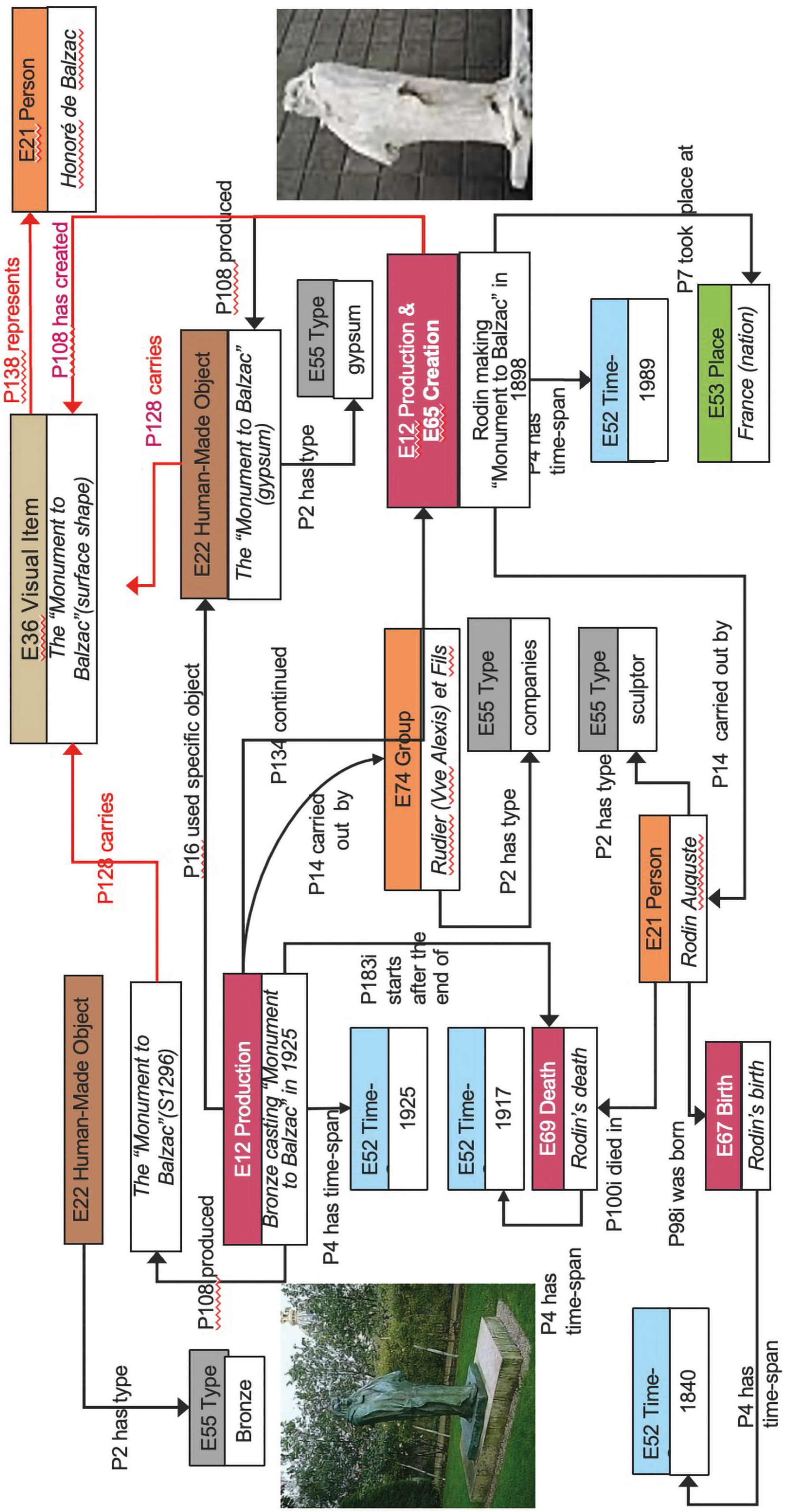

Fig. 4.14. Formalization in CIDOC CRM and instantiation of a statue by Rodin that Rodin never saw.

***LRMoo: modelling the new library practice of IFLA** (approved)*
- a causal model of intellectual creation and derivation
- how to identify intellectual content
- the thing and the word: integrating museum and library perspectives
- Revision and reduction of ***FRBRoo***, after IFLA superseded FRBR by LRM

***PRESSoo: modelling journals and serials** (approved)*

***CRMgeo: a Spatiotemporal model** (approved)*
- integrates CRM with OGC standards
- a complete model of phenomena occupying spacetime for reasoning with incomplete spatial data at different times.
- semantics-derived geometric topological relations
- core concepts are integrated into *CRM version 7*

***CRMInf: who said that? – from data to knowledge** (under review)*
- integrating data with their scholarly justification
- being validated with scholarly annotations

***CRMsci: a Scientific Observation model** (under review)*
- generalizes over **INSPIRE, OBOE, SEEK, Darwin Core**
- generalizes concepts of units of matter and their '(physical) genesis'
- introduces concept of observation and data evaluation
- validated in archeology, biodiversity and geology

***CRMarchaeo: an Excavation model** (approved)*
- introduces concepts of stratigraphy and excavation
- being validated by archaeological records

***CRM_{BA}: a Building Phases Model** (under review)*
- introduces concepts morphological and physical building units
- reconstruction of building phases from stratigraphy of walls

***CRMtex: a model of epigraphical processes** (under review)*
- from physically written texts to unambiguous symbolic representations

***CRMdig: a model of Digitization processes** (to be reviewed)*
- provenance of digital data from empirical processes

***CRMsoc: a model of social activities and institutions?** (initiated)*
- *content under discussion*

***CRMact: a model of planned activities** (initiated)*
- *content under discussion*

***CRMcom: a model of business interactions** (initiated)*
- *content under discussion*

Fig. 4.15. CRM and compatible extensions.

CRMtex is a model of epigraphical processes, which describes the processes from physically written texts to unambiguous symbolic representations accessible to all;

CRMdig, which has not yet been reviewed, is a model of digitalization processes that was used in several projects;

Then there are three models that have just been initiated:

CRMsoc a model of social activities; CRMact a model of planned activities and finally CRMcom a model of business interactions.

The relations between the extensions seen in a symbolic way is graphically symbolised in Fig. 16.

The CRMbase serves as the cover, which provides a few general concepts to deal with the below. When we query with CRMbase concepts, we get a lot of facts back, most of the related, but also many unrelated, even, if we have described facts more precisely. In order to be more precise in our questions, we need to know the more specific concepts of description, and when queried by these we will get less unrelated facts back but may also loose related facts. The extensions make use CRMbase and of some other extensions. In the meanwhile, we allow for extensions also to describe some classes and properties which are not covered by super-concepts in CRMbase, because they fall in domains arguably out of the proper scope of the CRMbase. In this case, the not-covered ones must be declared explicitly, so that people, querying CRM compatible models, can specify all high-level properties needed to be used in addition to CRMbase in order to reach all facts in the knowledge base.

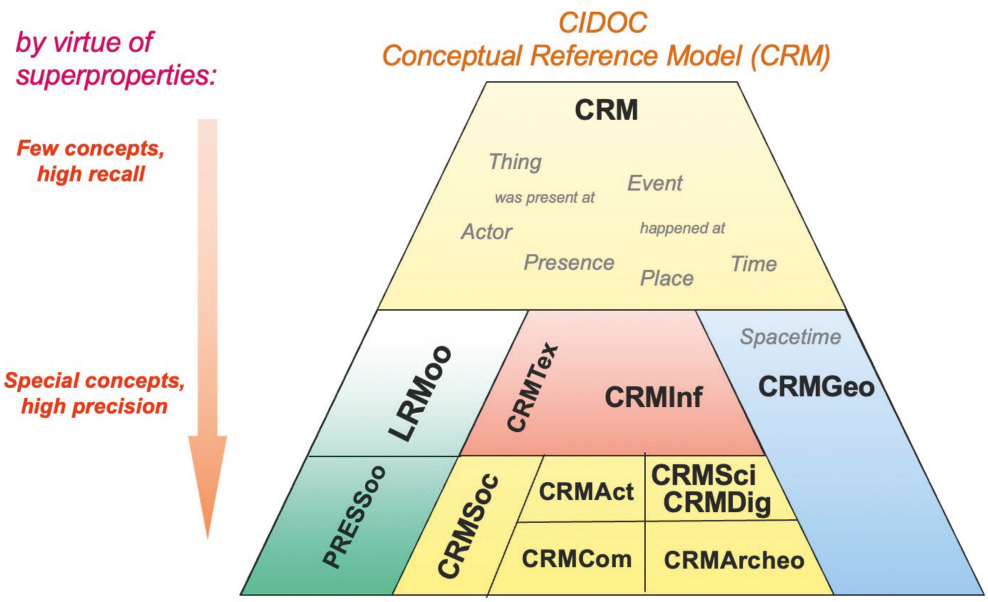

Fig. 4.16. CRM extension suite.

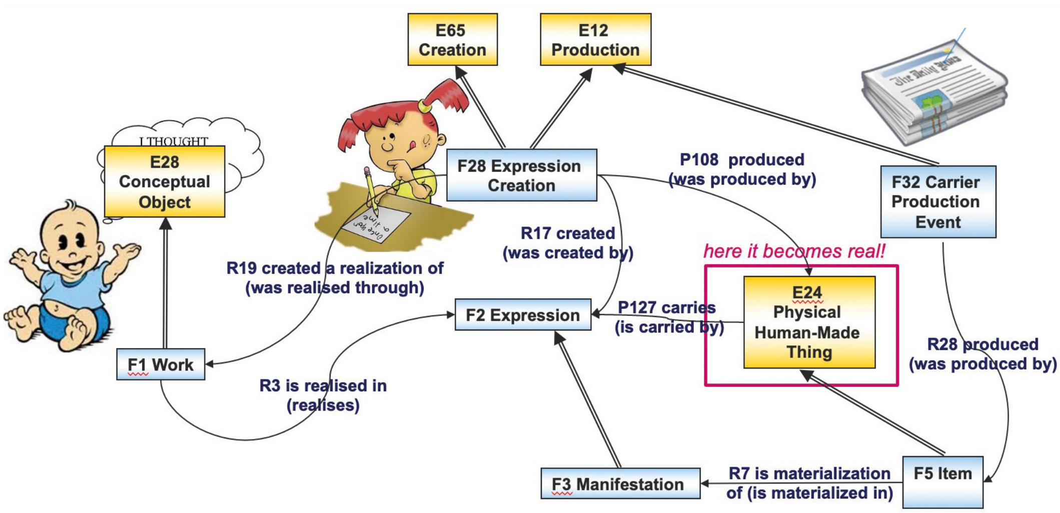

Fig. 4.17. A Causal Interpretation of LRM / FRBR.

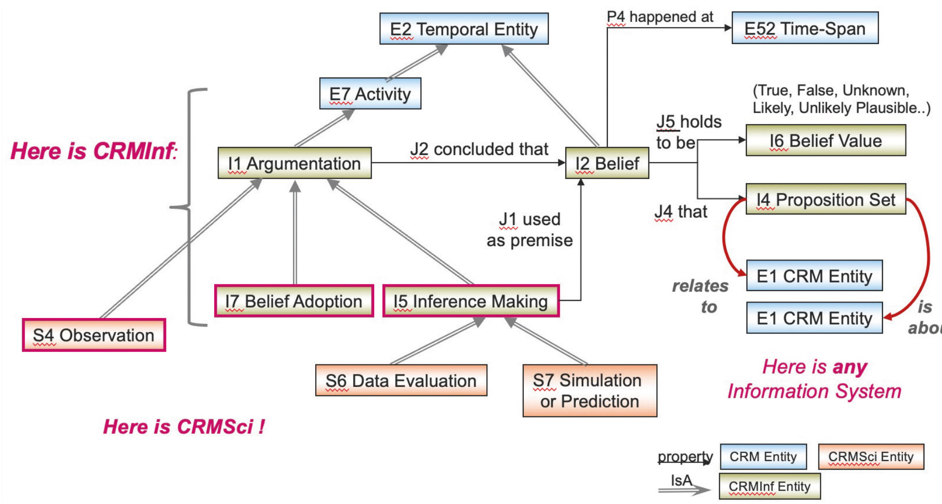

Fig. 4.18. The three sources of scientific knowledge with CRMInf (and CRM Sci).

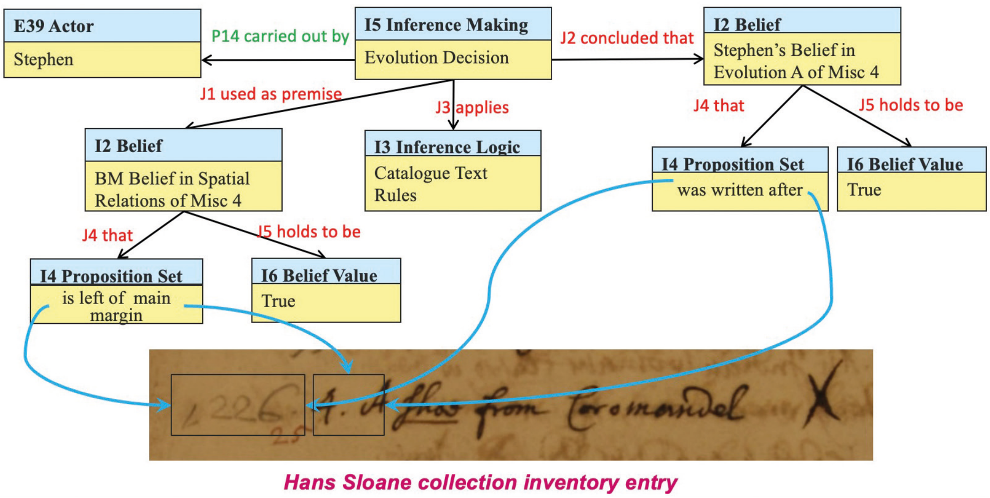

Fig. 4.19. Example of reasoning about temporal order.

We present in the following some characteristic parts of the above extensions in a graphical way, in order to give you some impression of their content. The idea of the Library Reference Model and FRBR is the conception of an intellectual content (the 'Work'), the creation of its expressions in symbolic form and the prescription of their materialized forms, called manifestations, for producing physical carriers, i.e., books, etc. The 'expression creation' process may realize a 'Work', a common umbrella of ideas and plots, pervading an evolution of its expressions sequentially or on parallel paths of evolution (Fig. 17).

CRMInf is about the sources of knowledge in historical sciences, a core analysis for documenting the argumentation used. Three distinct sources of knowledge are distinguished by the way they can be verified or falsified: (1) *Observation, i.e.,* the 'I have seen, measured'. (2) *Inference making, i.e.,* the '***if*** that is true', I maintain that 'this must be true as well', going from premises to a conclusion by applying some kind of logic or plausibility; and (3) *Believe adoption*, i.e., 'I believe this scientific paper because I have trust in the authors and not because I have reasoning of my own to support that'. This model is basically how we propose to trace provenance of knowledge in the future (Figs. 18-19).

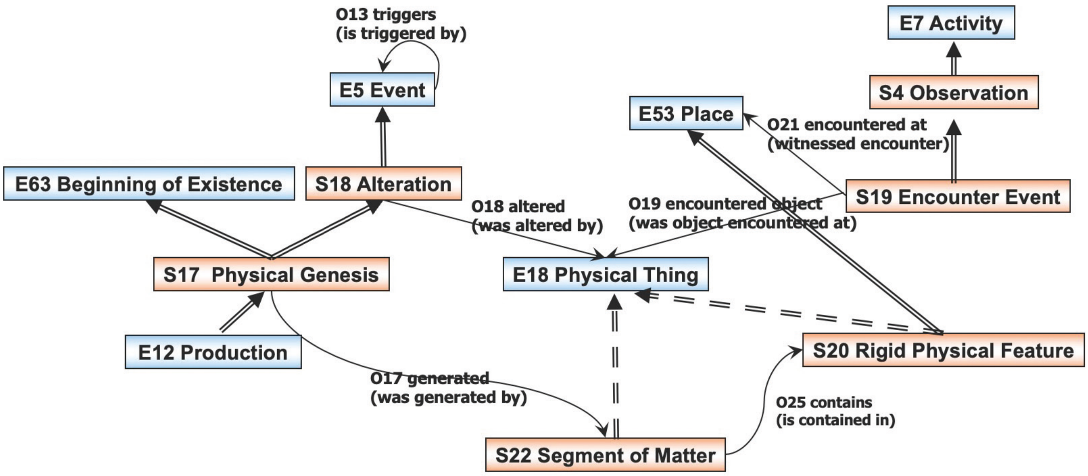

Fig. 4.20. Physical Genesis in CRMsci.

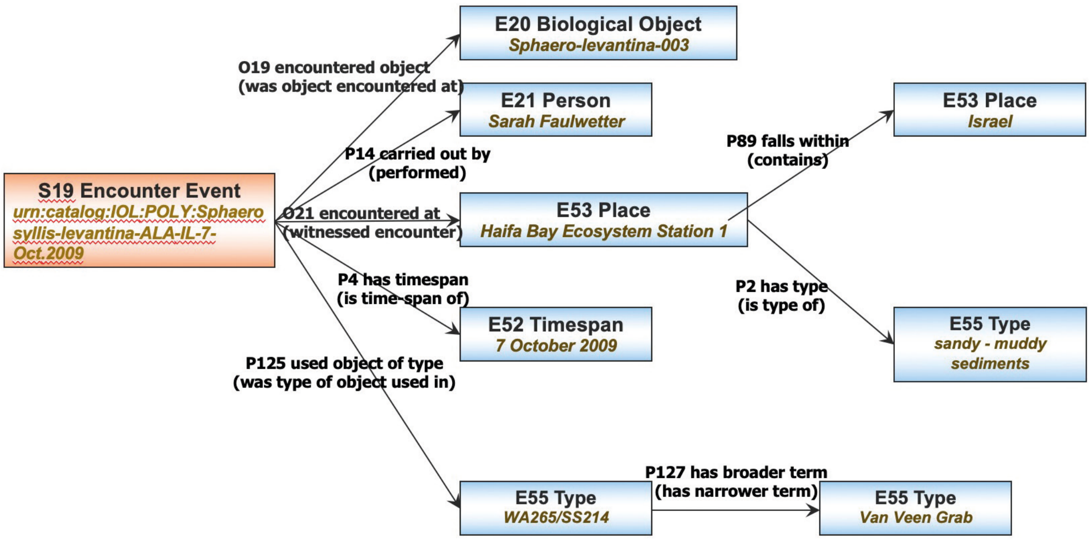

Fig. 4.21. Biodiversity App: 'Occurrence Discourse'.

CRMsci extends the notion of human activities creating or modifying things to the notions of physical genesis and physical alterations. Further, it deals with details of observation and, besides others, 'Encounter Events', which describe material things that have come to the (documented) attention of archaeologists or biologists at a specific place and time (Figs. 20-21).

CRMgeo will allow the user to distinguish between the concept of where a material thing really is by 'being there', called the 'phenomenal place', and the concept of a ('declarative') place by which one declares via coordinates how to approximate a particular 'phenomenal place', or to provide spatial boundaries for other epistemic purposes. By making these innovative distinctions we can solve in a consistent way the important problem of consolidating differing geometric data for the same physical object, between databases, but also for integrating new and old maps, etc. (Fig. 22).

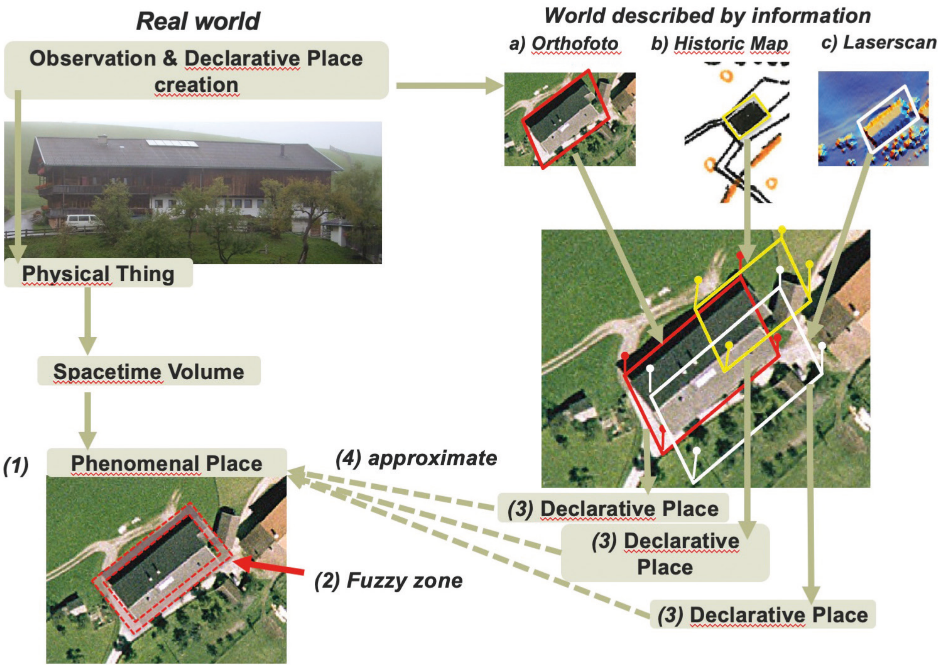

Fig. 4.22. Declarative place and Phenomenal place in CRMgeo. Source Orthofoto & Laserscan: Land Tirol 2007.

CRMarcheo is about the excavation process, how excavators cut through the ground, segment by segment, find layers and then reason about which genesis events or processes produced the observed layers and how they followed one another, and where excavators have found ("encountered") distinct objects that were embedded in the ground before (Figs. 23-24).

In conclusion, the CIDOC CRM with its extensions allows to create a global network of integrated knowledge about human history, its evidence and scientific observations, in the form of events and human activities, regardless discipline and in surprising details.

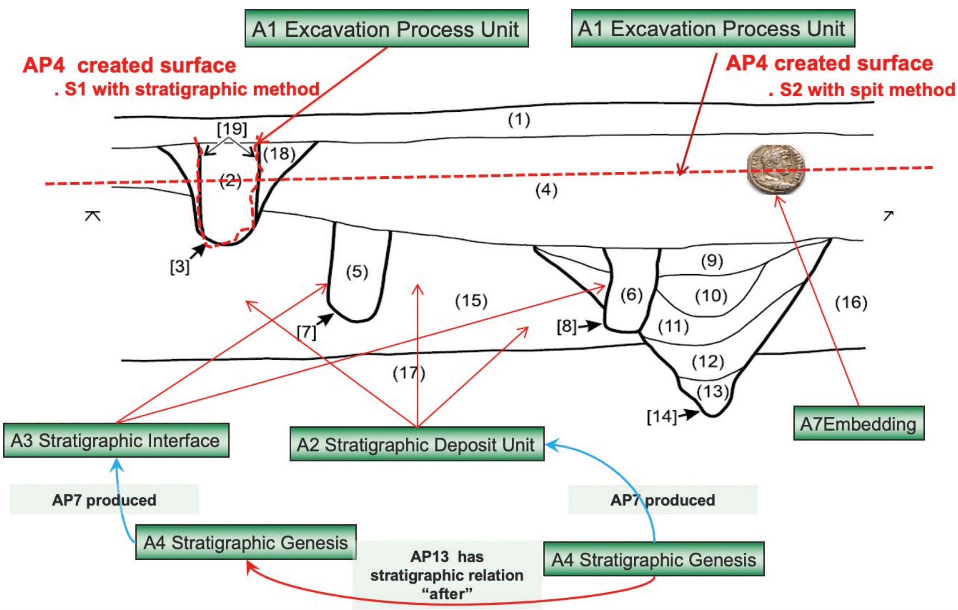

Fig. 4.23. Excavation is observation: CRMarcheo.

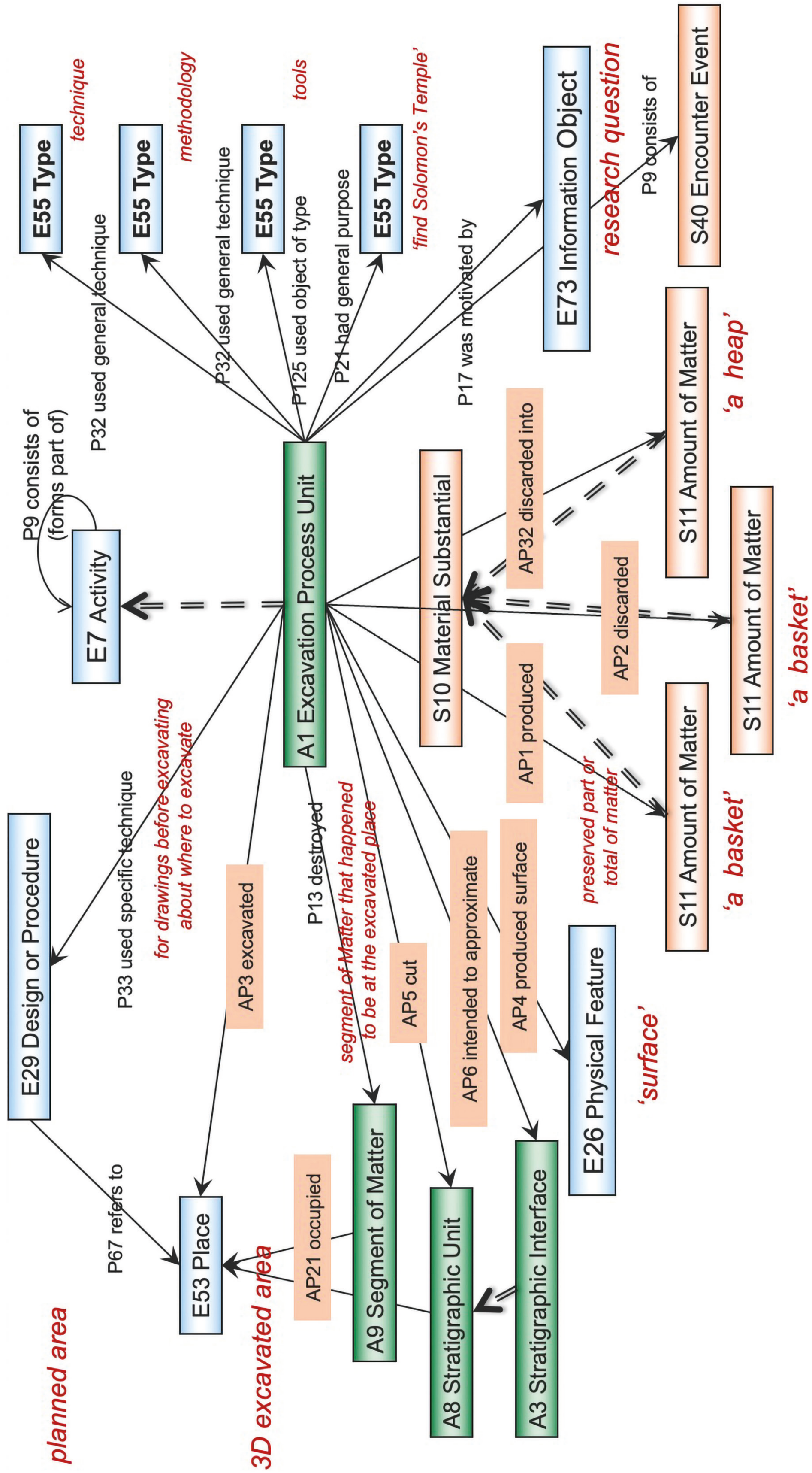

Fig. 4.24. The Ecavation Process Unit in CRMarcheo.

5. Sharing knowledge of our pasts: a practical look on the application and future potentialities of semantic data

George Bruseker

The aim of the present contribution will be to focus on how to make use of the detailed conceptual tool set given by CIDOC CRM of classes and properties – that allow the expression of complex data into a standard digital expression – towards the benefit of actual research ends in scholarship and pragmatic digital implementation.

Towards that end, we might start by framing the problem more generally by looking at what semantics and formal ontology offer to research in the first place.

We may start by offering a rather pessimistic view on the present state of data management in humanities research in general. At this juncture, much of scholarly research that is engaged in creating analytic data is, effectively, in a state of data chaos. Owing to a lack of standards for organizing, recording and managing data, anything goes. Given the typical lack of training in data management or understanding by scholars, when analytic data is created it is susceptible to poor organization, lack of documentation and a resultant lack of long or even short-term usability or interoperability. Given this typical absence of data literacy amongst scholars, they are often alienated from the key decisions in terms of forming and managing data, meaning in effect they are alienated from the results of their own research. As a result, typically, data generated today is not useful in a few years' time, being impossible to objectively interpret or understand. Knowledge is produced, at the moment, in individual databases and different spreadsheets, without employing any standards in terms of format, terminology or structure, nor even the application of much thought even to these questions as important to the scholarly endeavor itself. The result is that data produced under such models can give a partial, distorted map or vision of the world. Whereas the aim as a scholarly community might be to work together in a collaborative network of scholarship in order to be able to open up a communal view onto a wider area of knowledge, the actual state of affairs is data produced independently which is unshared, incompatible and bound for obsolescence. Towards solving this rather dire situation, semantics and formal ontology have an offer to make.

Simply put, semantics and formal ontology give us the chance to formalize our knowledge representation. What this enable is for researchers to treat the data that we generate as a first class entity which we can take control of to assure its correctness, its usability and its sustainability. When we think about adopting semantics it is because of a recognition that research data is one of the basic scholarly contributions to a knowledge community. As such it requires care and precision in creation and publication in a manner analogous to the regular scholarly process of writing and publishing. Just as a scholar does not simply write a text in an afternoon and send it to Springer in the evening, one does not just want to produce and share one's data as a randomly ordered CSV or an ad hoc and idiosyncratic database. Instead, we want to take control of data production and to be able to define with certainty exactly what it is that we are recording, when we are recording a piece of information and to tell others, with whom we are sharing this data, how to be able to interpret it. It is this possibility that semantics provides us with: to describe and organize our data using a common digital language. Insofar as this semantic approach is generally adopted, so do we build not only a better offer of our own data, but so too do we also open up the possibility for reusing and engaging in a broader scholarly network of well-formed data; we have the opportunity for wide scale knowledge integration through adopting a *lingua franca* of knowledge representation.

Formal ontologies enable this possibility because they are not prescriptive metadata standards which give you a limited set of metadata fields either small or large by which you have to describe your data. Rather, they are generative, giving you a toolset of classes and relations, which can be pieced together to make syntactically and semantically coherent sentences in any number of combinations. The generative nature of semantics means that is possible for groups to work together collaboratively to adopt these standards and come to an agreement on how to employ them to describe their information, creating, from the bottom up, a unified comparable data which defines a standard and specifies what kind of things it is possible to describe, the manner to do this, and how to retrieve the information in the end. A formal ontology thus offers a language that allows its user to create the analytically appropriate sentences to describe the knowledge they have in a formal way acting as a sort of generative grammar for enabling new sentences and new knowledge to be entered into the network over time while maintaining a formal consistency of representation.

In the field of cultural heritage, the formal ontology standard that has stood out as a central tool for creating such a knowledge network of historical facts above and beyond projects and institutions, has been the CIDOC Conceptual Reference Model (CIDOC CRM). The ontology has been developed, maintained and improved for over twenty years by the CIDOC CRM Special Interest Group (CRM SIG) under the aegis of the International Council Documentation (CIDOC) (<https://www.cidoc-crm.org/>). This commitment to the development and maintenance of the standard by a third-party body is one of the things that has made the CIDOC CRM such a powerful tool as it has benefited from scholars, researchers and professionals from various disciplines coming together in a neutral space in order to do the work of creating and sustaining this language for others. This is an important point to stress. The CRM, while having a defined scope of 'cultural heritage', does not take on a particular disciplinary or epistemological stance specific to one particular group of scholars. It aims to be a digital *lingua franca* to enable accurate expression of information regarding cultural heritage in all its objectively available facets. Thus, it can constantly be grown and improved by gaining knowledge from new contributors who highlight additional facts of interest to be able to express. CIDOC CRM is not a static standard. On the contrary, it is constantly updated and includes the things which become relevant in cultural research and researchers over time.

An example of this onward expansion and deepening of the standard has been seen in these sessions in the work of Donatella Fiorani and Marta Acierno who have engaged in expanding the range of CIDOC CRM knowledge expressivity to new domains of documentation and research. In particular they have recently worked on the modelling and representation of the idea of risk in the context of conservation[1]. This work is the beginnings of a potential expansion of CIDOC CRM which would enrich the potential knowledge network supported through it by enabling integration, sharing and common research over integrated knowledge bases of risk and cultural heritage data assets.

Thus, motivations for engaging with semantic data structuring are: making your data understandable, interoperable, sustainable and under the control of the scholar. Formal ontology and semantics give a tool to the researcher and scholar, a theoretic tool to take control of their data production.

After the idea of adopting formal semantics becomes an interesting possibility for research, the next pragmatic question becomes, how does one go about this? The practice of adopting and implementing formal ontologies for data expression and curation can be called *semantic data management*. What is necessary for such an agenda of semantic data creation and integration to be put into practice is a series of methods, tools, networks of collaborators and supportive institutions which may allow you to really take advantage of all that.

In this text, we will have a brief look over some essential steps in semantic data management which can be adopted by any project, small, medium, or large, in order to move from theory to practice in adopting and implementing formal ontologies. These steps include:

1. Creating a Semantic Data Project Registry
2. Conceptual Modelling
3. Ontology Development
4. Semantic Data Platform Setup
5. ETL Processes

It is useful to consider each of these processes independently, as each step has its own questions, procedures and tools, and potentially requires different expertise and organization. In what follows, we will outline these steps and then look at some examples of how they are implemented in various real-world projects.

5.1. Creating a Semantic Data Project Registry

The first suggested step in undertaking a semantic data project is to create a meta-map of research assets and questions one has of one's data and of the area of research one has undertaken. This first step is crucial to the semantic effort because it establishes, as explicitly as possible, the purview of one's semantic activity, as well as that which is not within one's scope. It aims to shine a light on what we are

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1 Acierno et al. 2017.

attempting to know, responding, to that infamous question posed by Meno in Platos' dialogue of the same name, "[…] and how will you enquire, Socrates, into that which you do not know? What will you put forth as the subject of inquiry? And if you find what you want, how will you ever know that this is the thing which you did not know?" (*Meno*, 80b).

While our wondering within the scope of a semantic data project may not be as profound an existential/epistemological wonder as that of Meno, this initial effort of self-recognition is nevertheless a crucial, pragmatic activity to create a firm foundation for a semantic modeling based research project. One steps back and takes stock of the things that we actually talk about, listing out the data we create and using this data as the guide of the things we want to be able to model or represent and eventually share as structured semantic data with colleagues and others.

Another critical aspect of this step phase is that, as one lists out one's data, one asks "*what do I want to learn from my data?*". Here we look to write down in both broad and very specific terms what other questions our data helps us answer because that activity will allow you to use them properly. It is possible to continuously refer back to this list as you build out your semantic data, having an important intellectual control on whether what is being devised actually answers to the goals of that research. Considerable work on the method and means for setting up such a register was expended in the Parthenos Project (<https://www.parthenos-project.eu>, WP5 Deliverables). For instance, in case I wanted to investigate questions around risk or about the artistic value of a piece of art, I would have very different competency questions which I might want to pose of the data in the first and the second case. This will affect how one models and represents one's data and where emphasis is placed.

5.2. Conceptual Modelling

Once one knows what one has to represent formally, the next step is to do just this: represent it formally. This is what we will call here *conceptual modelling*. When it comes to modelling data with good formal ontologies, there is rarely something new under the sun. Conceptual modelling is the task of analyzing existing data against chosen formal ontologies and seeing how well these data sources can be represented by the chosen ontologies without adding anything to or changing anything about that formal ontology. If you are starting a semantic modeling project, especially within the scope of cultural heritage, then there is no need to reinvent what has already been invented. Semantic projects can typically recycle what has already been developed by CIDOC CRM SIG (Special Interest Group) or by other formal ontology communities. The first stop in conceptual modelling is to look at what has already been created and which formal ontology(ies) are most appropriate to one's case. In this phase, we apply existing ontologies to conceptually represent our existing data and see how far they accurately represent our data and are capable of answering the research questions we listed in our first step.

It is worth noting here that there are on-going efforts to make it easier for non-semantic data specialists to carry out this work by creating and documenting *semantic data patterns*. The first attempt to use an ontology and represent one's data in such formal terms can seem very complex with a lot of decisions to be made. This overload of choices can be a major problem for individual's and projects thinking of starting their first semantic project. For this reason, amongst others, efforts have been undertaken by groups like Linked.Art (<https://linked.art>) and the SARI Semantic Reference Data Models (<https://docs.swissartresearch.net/>) to reduce this complexity by defining semantic data patterns for standard objects of documentation in cultural heritage and other domains. These patterns provide recipes on how to model and map typical data and data patterns using CIDOC CRM. The goal of such work is to provide ready-made solutions for how to take typical data from a field of research and represent it in CIDOC CRM. These ready-made solutions are meant not only to solve typical problems for the starting semantic modeler but also to serve as a model of good practice to solve new and novel situations. Moreover, by adopting and applying these patterns, one connects into a wider community and network of users of CIDOC CRM in specific domains. Connecting to such a network of users not only opens up horizons for relating and reusing datasets in the long run but also connects one to active communities of semantic data modelers who are able to help one answer questions and problems regarding one's conceptual modelling difficulties.

5.3. Ontology Development

The process of conceptual modelling meets its limits when the ontologies that you borrow to create semantic data are unable to accurately represent your data. This usually occurs as you deal with and encounter more specialized data recording about disciplinary topics. Good ontologies are developed to meet the general case for their field of application and left open to be specialized with further classes and properties as required by specialist topics. When the limits of an ontology are found during conceptual modelling, one discovers there are, in fact, "some new things under the sun" and then one has to engage in ontological development.

It is a whole art of science to create or extend ontologies but there is plenty of literature and some helpful tips and tricks to modeling on the CIDOC CRMsig website (<https://www.cidoc-crm.org/Resources/cm-principles-word-v.0.1.2-introduction-text>) so, there is some methodology to learn. Addressing that methodology in any detail is beyond the scope of this intervention but we can point to some basic points. Building out an ontology is like building out the language structure by which you will or will not be able to express and share your data into the future. For scientists and scholars this imposes some basic virtues for ontology construction that we could call the objectivity and intersubjectivity principles. The objective principle is imported into the enterprise of ontology development for scholarship and science as the basic limit of evidence. Ontologies that serve science must represent an objective world available, in principle, for independent analysis and verification of the same facts. The intersubjective principle of ontology development is imposed on ontology projects which aim for knowledge integration. This principle encourages the ontology developer to seek intersubjectively neutral representations within a community, abstractions above particular theoretic and positional differences, which enable a neutral representation of facts according to all parties, such that they can be used in argumentation for and against many possible theories and interpretations. There is much more to say on this topic, but we will leave it at that high level.

While the method for ontology development is obviously crucial, it is important to mention that the documentation and maintenance of the produced ontology is also fundamental to good practice. An ontology is meant to be a *lingua franca* for a group. The language only works if it is accessible, understandable and well formatted (for humans and computer). For this reason, it is important to choose a reliable tool for building and maintaining your ontology. The classic tool in this regard is called *Protégé* (<https://protege.stanford.edu/>). It allows you to create serializations of your ontology, making the classes and properties declared usable for human understanding and machine processing. An exciting recent development is a tool called OntoMe (<https://ontome.net>), developed by LARHRA (<https://larhra.fr/>), a CRM SIG member. This tool allows one to design an ontology online in a community. This means that it can be shared and seen by others as it is developed, enabling the sort of discussions and interaction that favor intersubjective agreement.

The development, publication and maintenance of specialized ontologies that are reusable by other specialists is an important outcome of a semantic data project and contribution to general scholarship and research.

5.4. Semantic Data Platform Management

Ultimately, scholars and scientists enter into the domain of semantics in order to get control over data, the content and meaning of which they have an inherent interest in and the management of which is one of their key concerns. To work with semantic data as with any other data, one needs a database and management platform for viewing, querying and interacting with the data. We call such systems *semantic data management platforms* and these things have typical feature of being able to load an ontology, to ingest and export ontological data in RDF standards, and use standard database feature to delete, edit, create, query, share, organize data. This is the technology that ultimately allows you to do the data management of your semantic data.

There are three platforms that has been developed really closely in relationship to the CIDOC CRM community. One is called WissKI (<https://wiss-ki.eu/>) which is a project out of the German National Museum; Arches (<https://www.archesproject.org>) which is a project struggled with the World Monument Foundation and the Getty Conservation Institute and it carries on; and the ResearchSpace (<https://researchspace.org/>) which is founded by the Mellon Institute and developed originally out of the British Museum all of which are different platforms that allow you to, not only build your conceptual model, but then work with your data once you have put this into the systems.

Each of these platforms is open source and enables the user to setup forms, visualizations and queries that will work with native CIDOC CRM encoded data. Their technical setup is described online though in practice external technical support would usually be required and desirable to help in the management and customization of such interfaces to meet the scholars' needs.

The next step in the practical use of semantic data is ETL (Extract, Transform, Load).

Most projects will not begin as a *tabula rasa* and will already have data created. In fact, many projects may be led to using semantic data techniques precisely because of the legacy task of managing data developed under different regimes at different times using various technologies. Such data can be highly valuable but under threat of obsolescence and incomprehensibility if it is not moved out of aging data formats and undocumented data standards. In the case where a project has to deal with legacy data and bring it into the ontology(ies) chosen and developed during conceptual modelling and ontology development processes, then the project must engage in what is called Extract, Transform and Load (ETL) processes. The aim at this point is to integrate that data and express it to the formal model created.

ETL like the other steps we have discussed in this intervention is a topic into itself. The problem at hand with semantic ETL is to make consistent and reusable workflows for getting data out of legacy systems, transforming it into the ontology and loading it into the semantic platform of choice. Many parts of that process are highly technical and can become a black box to scholars and scientists wishing to engage in semantic data in order to have a view over and understanding of their data. Since, we have highlighted the function of formal ontology giving the scholar control over their data, I wanted to highlight in this section a particular tool for ETL which empowers scholars to engage in this process at the level of the transformation in this way.

The tool in question is called 3M (<https://github.com/isl/Mapping-Memory-Manager>) and has been developed by FORTH (Foundation for research and Technology – Hellas) (<https://www.ics.forth.gr/isl/centre-cultural-informatics>). 3M is a tool which supports the scholar in developing the mapping instruction which will transform legacy data to the conceptual and ontological models that they have developed. This process of mapping from legacy data to the target semantic models is an intellectual activity in itself. It is an activity that takes time, sematic finesse and a little bit of technical skills. Typically, this is something that must be entrusted to a technician who may or may not understand one's conceptual models. The 3M tool however uses a language called X3ML which allows scholars to create a declarative map between an original data system and their semantic model with only a knowledge of their ontology and a very low level of technical knowledge of ETL.

This is truly empowering to the scholar who wants to control their data, its meaning and interpretation. As opposed to hiring a developer, an outsider to the specific domain who doesn't possess the knowledge related to the field, the notion of a declarative map lets the scholar guide the process. This way of working is extremely helpful to create a smooth interface between computer science, researchers and datasets, where what counts the most are clarity and accuracy and the ability to verify that the data has actually been expressed in the way the scholar wanted it to be.

5.5. Process Summary

All of the individual processes we have covered and the entirety of these processes considered as a whole must be considered to be cyclical, repeating processes. The linear process looks like this: creating the register allows the research to do conceptual modeling and to extend their ontology if necessary; having the semantic models and ontologies allows one to set up a semantic data platform; ETL takes up the conceptual models and uses them to guide the process to transform and load data to the platform. But the process does not usually take such a straight path. Iterative loops are going to be created where one might need to reconsider the conceptual modeling, or how the ontology was thought originally and how it was extended, how the ontologies have been supported by semantic platforms, how your ETL tools function and are limited and how this might affect your modelling. The establishment of a register makes such an iterative process sustainable and reusable over time.

Semantic data management thus becomes an ongoing process that is refining and self-reinforcing, if properly managed. What we have outlined with a semantic register down to ETL processes gives a flavor of the work involved. Following a systematic way of progressing through these knowledge cycles, in terms of setting up a register, using a tool like OntoMe to register your ontology, use and reuse a second version, etc., sets the researchers and their project up for getting better at integrating knowledge overtime.

5.6. Some Real World Examples

In conclusion the use of semantic modeling might be depicted by three examples in order to better understand what a semantic project might look like in practice and what results it may have.

The first example is the Ariadne project (<https://ariadne-infrastructure.eu/>). The Ariadne project addresses the field of archeology and it is an European project which has been funded twice by the Horizon2020 funding programme. What they set out to do was to create an European wide and, eventually, international register of archeological datasets and create semantic models that would extend CIDOC CRM in order to allow people to start opening up subfields of conversation in archeology like Archaeo DNA, survey data, etc. which hadn't been modeled before. It is a very interesting example to look at, at a very broad level, where what you do is bringing in a number of very large partners and the end result is to really build a very large initial registry of datasets and have that as a resource for building out a deeper and more expressive ontological model for covering more specific areas of knowledge, which integrating these to a wider net of information. That is one kind of scenario where semantic modeling has been applied to bring data together.

Another strategy is represented by the case of the Getty foundation which has the CIDOC CRM for its research data. They have a segment of the Getty foundation which is called Getty Digital where they have decided to use CIDOC CRM through the network called Linked.Art which makes decision about how to form data for museum information. What they are doing, as organization, is working at a way through which any research data created, could actually be born semantic so that as a new research project comes along, they use Linked.Art as starting point to start thinking about how they are doing a database for any project. They have also analyzed and re-presented the existing data that they have for the collection management systems, archives systems and library systems, etc. in order to make it available as LOD to be reused by research projects adopting Linked.Art. They create a mapping file between that in the Linked.Art standard and they use that as a pipeline to push everything out into one thing that they call Research Collections Viewer (<https://www.getty.edu/research/collections/>).

This supports the creation of a one-stop-shop where Getty can put all of their data into one format as opposed to having to support a multitude of different systems interfaces and minor databases. This example appears to be so interesting even because it is an institutional kind of way of approaching things so that, although having a minimal semantic model standard together would imply many different systems, using this way would allow having just one space in which everybody can have access for the same data.

Last is a reference project which is currently active between Takin.solutions (<https://www.takin.solutions>) and a project called the Census Project (<https://www.census.de/en/home/>), which is a Digital Humanities project which has been developed for over 40 years and a data collection project since 1950's. The aim of this project is to catalogue the reception of antiquities in the Renaissance and it has been supported and run from Rome, Berlin, Los Angeles and elsewhere over time, while being used all over the world. Basically, though it has been its isolated world for a very long time, now we are building a semantic data model for it which represent the architecture information that has within it and, what they want to do through that, is to open up to researchers who want to investigate the data in new ways which are not envisioned by the original archival decision to catalogue all documentation of antiquities in the Renaissance. To achieve this aim, we developed a register of these art historical questions and the SparQL queries before and answer them. We also created a rich documentation of the semantic models that we transformed them to, using SARI SRDM as a based. In the documentation users can find how to read, explore and query this data. Researchers can use that as spring board to start working with other scholars and trying to think about new ways of exploring and working with that data (<https://zenodo.org/communities/ikb_hu?q=&l=list&p=1&s=10&sort=newest>).

5.7. Conclusions

In this text, we looked at the semantic data offer for humanities research and how to take this up in practice. The offer is to take back control of the means of data production by adopting ontologies as a *lingua franca* for creating and sharing research data. This liberates the researcher from their alienation from the ability to define and control data production. It also builds the ground for their research data outcomes to gain value in the short run and retain value over the long term. The researcher interested in adopting this strategy must be aware of the semantic data management process. Semantic data management involves a number of unique, interrelated steps to arrive at a sustainable and successful conclusion. These include, at minimum: creating a project registry, doing conceptual modelling, doing ontological development, setting up a semantic data platform and managing ETL processes. A well thought through and documented semantic data project creates its own positive feedback loops and is a support to on-going research which has the potential to connect with other researchers and research. Semantic data offers the possibility of a community of knowledge based on a controlled and explicit digital *lingua franca*.

6. The debate

contributions by Marta Acierno, George Bruseker, Donatella Fiorani, Stefano Francesco Musso, Marco Pretelli, Stephen Stead, Athanasios Velios

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6.1. Introduction: the purpose of the roman comparison on ontologies

The event organized by prof. Donatella Fiorani and Marta Acierno named "*Conservation Process Model, an ontology for conservation in architecture*" was held at Sapienza University of Rome in September 2022.

It was an occasion where the international community of the CIDOC CRM Sig (Special Interest Group) and members of the Italian academic scientific area of architectural conservation had the opportunity to meet and share their own perspectives for the first time with the aim of defining and specifying the possible role, as well as the factual results, of using digital systems and ontologies in dealing with cultural heritage.

The meeting was also the occasion for the comparison between worlds that are traditionally dichotomously opposed in several aspects: the world of the Italian academy versus the one of international computer scientists; BIM versus linked open data and semantic web; analog versus digital; architects versus archaeologists, conservators, physicists, philosophers, computer scientists and so on. These are worlds that may have found a meeting point in the need to develop a way to use the sharing of data for knowledge and description of heritage purposes. The starting point for this meeting was the decade-long research led by Fiorani and Acierno, which began back in 2014 on occasion of a Program of Relevant National Interest (PRIN 2011), where many representatives of various Italian universities joined together in order to work on the possibilities of digital tools, in particular BIM, applied to historic architectures and to the affordability of adapting the model to architectural conservation and its limits. The above-mentioned PRIN project proved BIM – which was created to take advantage from the standardization of the processes on new building edification – not to be flexible enough to be used for historic buildings with all their intrinsic uniqueness, atypically, specificity, and non-standardized features. This might be the reason why when new types of informatic systems were encountered, the architectural conservation scientific area developed a kind of resistance and skepticism toward such systems. Nevertheless, among the Italian community, a dichotomic approach to the matter was developed: on one hand the resistance to accepting the use of information systems, on the other hand the production of an abundance of different databases related to the multitude of single projects that are completely incapable of communicating among themselves. Such a reality found its counterpoint in the international CIDOC CRM community, where the real issue is relating data from many datasets taken from different domains so that they can effectively lead somewhere: in fact, working on cultural heritage implies a multitude of areas of expertise that must interoperate. Otherwise, achieving any practical result through data sharing might be impossible. [*Alessia Vaccariello*]

6.2. Some questions about ontologies and more broadly digital humanities for architecture

Although broadly addressed by the cultural debate in the last ten years, research on digital humanities for the architecture conservation process is still suffering from a kind of distrust aroused within the scientific community of architectural conservators and historians. Nevertheless, a strong interest in the topic is growing within the cultural heritage drawing discipline. Such a gap actually jeopardises the deepening and development of research, limiting the possibility of taking advantage from a multidisciplinary vision. In the light of this premise, a round table was conceived to create a common ground to compare different scientific points of view raised about the use of ontologies and more broadly ITC to represent cultural heritage. The multifold points of view were represented by academic architecture conservation scholars, such as Stefano Musso, Marco Pretelli and Donatella Fiorani, digital humanities philosophers, such as Martin Doerr and George Bruseker, and digital humanities archeologist and book conservators, such as Steven Stead and Athanasios Velios. Aimed at exploring the boundaries and the potentiality of the debate, the idea was both to address the main issues that traditionally trigger hard contrapositions between digital humanities scholars and conservation experts, and to focus on the methodology.

Among the major controversial issues is the theme of standardization. This is in fact, it is the principle that allows data to be used and compared by different communities and contexts. Moreover, many scholars consider it as an obstacle to adequate representation of cultural heritage disregarding specificity. As a corollary to that issue another phenomenon was addressed: the growth of many different digital microcosms generated by the different scientific communities. Such a condition arises especially within communities that are locally care for cultural heritage, and that often seem to be concerned only about the need to store and retrieve data without any attention to the possibility to allow these data to be shared externally.

Moreover, since formalizing methodology may be afforded from different points of view and be developed through multiple approaches, a particular focus involving the methodological issues was proposed: on the one hand, looking at the way the data to be represented is retrieved from reality, and on the other hand addressing the way reality is represented. Referring to data deals necessarily with a twofold perspective: a top-down process that develops a broad model that is able to describe general concepts, and its opposite, that is moving in reverse from the data to the modelling. Besides, the way reality is represented copes with the way reality is looked at. Within cultural heritage a general consolidated confidence in the use of taxonomies is counterbalanced by the intent of focusing on contexts, enhancing description through relations between concepts. The first approach is working mostly with classes, the latter with properties.

Lastly, a broader subject was addressed, focusing on how a common system of representing knowledge, such as CIDOC CRM, may be used to formalize the granularity of cultural heritage scope.

In the light of the groundwork outlined by this introduction, the discussion was very interesting and although the aim was not giving a definitive answer to the critical knots proposed, a very sharp framework was defined, that will hopefully prove to be a challenging field of research. What makes this hope well-founded is that the different approaches coming from very heterogeneous contexts, although based on cultural heritage scope, were able to find a common ground on which to develop shared perspectives. [*Marta Acierno*]

6.3. What about the inadequacy of BIM systems and standards, comparing to the specificities of historic architecture and architecture conservation?

The word standardization, in general, is worrying for those who deal with historic buildings, which is in itself the result of processes far from any type of standardization. The problem is that, today, we increasingly need standards if we intend to recognize, take into account and govern the complexity of the world, extract and manage data of various kinds that mark our activities and our lives, in an interoperable and shared way with a much broader community than the narrow one to which we belong. How to represent and manage knowledge, from this point of view, is very interesting but can also represent a trap, especially in the world of architecture and its operators, because it is illusory to think of it as a way to make reality visible. When we are in front of a building, a wall or a frame, it is certainly possible to represent them by drawing them by hand or, currently, by using very sophisticated, pervasive and convincing IT tools. The available tools, however, are in turn perfectly standardized and are very effective if what you want to design, imagine, build is a completely new building. In that case, in fact, everything is predictable and standardizable in advance, and it is the same thing that happens if we use tools such as BIM. They were invented and used to try to overcome the traditional way of considering architecture and managing design processes but, unfortunately, they were created thinking about new realities that do not exist and must be built. For this reason, when BIM technology is applied to an existing reality, the result is usually contradictions, risks, deceptions, the impossibility of finding a shared meaning of the words used or of the things in question, within the same community of technicians and the designers involved. The history of architecture, moreover, is first and foremost a way of looking at the buildings, but it is also the history of the methods gradually used to describe and analyze it. Furthermore, history is full of various taxonomic systems, linked to ontologies and understood as ways to organize knowledge, to divide "things" into classes, subclasses, systems, subsystems, etc. Architects trained to deal with cultural heritage, however, are aware that there is a unique typology of buildings, or rather, that each building is its own absolute type while, every time a taxonomy is created or a typology proposed, they highlight exclusively the similarities between different buildings: what is the same, what is recurring while elusive or ignored, what is specific or unpredictable, what does not correspond to the definition of the ideal type. These and many others are the aspects that concern cultural heritage and that make the adoption of typologies and taxonomies very problematic. Taxonomies, in fact, are never neutral, each scholar has a particular and intentional way of looking at architecture, as a human product created in different times and places. These ways are the product of different schools of thought and can heavily interfere with the analysis and interpretation of each building. Secondly, there is a problem linked to the meaning assigned to the word "re-presentation" itself. In architecture, for centuries, the basic form of representation was "drawing", but then the situation changed with the introduction of software and BIM, in particular. BIM was developed to design, improve, and manage the entire process of designing, building and managing a new architectural product. On this basis, the IT tools that currently exist are designed, among which one of the most important in the sector is Autodesk's Revit. Revit has object libraries that are not strictly ontologies but are pragmatic and operational collections of pre-designed elements, such as beams, frames, pillars, etc. completely standardized. Therefore, Revit is used to represent – acquire, store, and use knowledge data about the object we are dealing with – not just to display it in a static and fixed way. For this reason, it is almost impossible to use it to analyze and describe a part of an ancient building, for example from the 17th century, considering its subsequent transformation processes, the phenomena of degradation that afflict it or its particular and unpredictable, or anomalous, structural characteristics. For example, it is difficult to describe a vault consisting of a discontinuous wooden load-bearing structure, with a reed mat and a finishing plaster on the intrados using the standard Revit libraries, because a vault is always described exclusively as geometry generally solid, regardless of its construction type and peculiar characteristics. On the contrary, the vault of a historic building could be deformed and irregular and it is necessary to take these specific features into account. To represent all these anomalies or specificities through BIM, it is necessary to force the system, and this implies that pre-established and fixed families and classes of objects cannot be used, but the specific elements of the building on which one is working must be modeled each time. This process implies, however, a considerable expenditure of time and economic and human resources, prolonging the time necessary to create an acceptable model of the building and connect it to the relevant historical information, documents and other possible data archiving databases available or in the process of acquisition and continuous updating. In conclusion, BIM used for historic architecture has proven to be not entirely, or not at all, adequate. Furthermore, when you use Revit to create a model of an existing building, especially if it is very complex and layered, it is likely that you could cause a disaster and risk transforming the existing building into a false copy of itself, destroying its values contained in its construction characteristics and also in its irregularities. To demonstrate how crucial this issue is, just think of the Italian law which, beyond a certain economic threshold, requires designing the building in a BIM environment, for which working on ontologies becomes crucial. The entire project relating to the use of ontologies for architecture and restoration projects is certainly very interesting, stimulating, and promising, but it must be kept in mind that a building is much more complex than an amphora, a sculpture, a book, or a collection of books. The scientific community involved in this project can share lexicons, thesauruses, ideas and even change them, which is unfortunately very different from what happens in the field of conservation, where researchers are a group of isolated individuals rather than a real community. They don't share much and are usually proud of their own point of view, their own classification system. It is therefore necessary to understand whether it is possible to change the state of things, keeping in mind that it is also a problem linked to the market and the European scope of the regulations in force in our field of study and work. [*Stefano Francesco Musso*]

6.4. About the general theme of knowledge system organization and the production of many databases and systems that are actually not communicating among themselves. They need to be interoperable but practically they are not. What are the solutions that have been found to overcome the problem?

Dealing with a city is complicated. Everything is complex, but the city is probably the most complicated because there, everything from the little object to the organization of systems is to be found. So, due to the fact that the city is so complicated, having an instrument to deal with it could be really useful because managing a big amount of data is nearly impossible sometimes. Using ontologies might be a big help in trying to consider more data in comparison with the data that were used before. From the beginning, everything that happens in a place has effects and consequences on the building. So, the question is: how is it possible to manage this big amount of data? It is quite impossible in traditional terms, but that system is providing something that could be useful in this sense. The final goal of the research is to find a way to protect, preserve, and maintain the historic building for future generations.

The research on historic architecture demands the need to deal with a systemic manner and so it was necessary to reason about the family of formation, belonging to each microcosmos.

Microcosmos are related to material, decay and so on, which make matters really complicated. At the moment, the issue is related to the understanding of how to use the enormous amount of data new technologies provide. Working at the urban and suburban scale, it was necessary to use Geographic Information System systems which were apparently the most appropriate ones for solving the problem. The GIS is the right way to operate on this scale, but during the research, it was found out that working with GIS was leading to a great loss of data that could be used, instead, through BIM system. So, the question became how to make these two levels interoperable. BIM was not created to be used in this kind of operation because it was thought for operating on new buildings, in fact it is helpful when used for a standardized approach to buildings and their maintenance. In architecture, one of the most dared affirmations is to state that two walls are perpendicular, but perpendicularity does not really exist and should, on the contrary, be demonstrated. BIM is something that assumes walls are perpendicular which may be totally misleading for historical buildings.

Knowing all that, working with the Risk Map has been a really good way to start because it is something that asks you to work on certain levels, to produce information that can be used in an informatic way. When dealing with preservation and decay of historic architectures there is some intrinsic and extrinsic data as well. In the municipality of Bologna it is available a great deal of data related, for instance, to where the Wi-Fi network is more occupied or how many cars pass in the street every day. The question is understanding whether this data, which is collected for different purposes, might be useful for the research carried out on historic cities. Working on the idea of the description of phenomena is not talking about standards, is trying to define something that could be useful to describe the reality. This approach could add something to what was done in the past and could open a new field of research and this could be really useful for whatever we would like to do, in terms of conservation project. [*Marco Pretelli*]

6.5. What is the bridge between the research in Italian scientific area of architectural conservation and one on conceptual modeling?

The level of sharing that standardization needs to have is related to the importance of having a shared way of organizing data and giving meaning to that data. This is the problem when dealing with new technologies related to historic buildings, because it is a kind of meta-level of work that is not normally considered.

At first, in order to think about the problem of describing the knowledge of the existing building and the process of preservation, the act of restoration and even future maintenance, at first, a top-down approach was followed. Reasoning at such an abstract level is extremely difficult and offers no guarantee of full effectiveness, and it was necessary to make a subsequent change of perspective. The decision was therefore made to work in a bottom-up manner, attempting to verify the effectiveness of the CPM ontology designed through the formalization of the Risk Map system of the Italian Ministry of Culture. This step was an excellent test-bed for this work, because the use of the Risk Map requires a standardized description of the context being studied – specifically, historic centres and their components – and thus presents in itself a hierarchy, a vocabulary and the possibility of managing the data in an inferential manner as well. These are all aspects that are crucial junctures when dealing with preservation data.

Although Italy is quite rich with words of architecture, the official, broader vocabulary lexicons by the Getty institute are English, French, German, Spanish, Chinese – and Italian is not even included. When looking for the word 'historical centre', we do not find it in the platform and there is no possible match because, in English, the word is not used, preferring the term 'downtown', that has a different meaning. Therefore, understanding what is important is fundamental in order not to have a unique way to give information in different ways and languages, but also in order to univocally define something. In architecture there are volumes, dictionaries from 17th century, in which there are drawings and everything is identified by name. To use them properly, it is necessary to understand what was thought back in the 17th to the 19th century and then, at the same time, to understand what a word means in other countries and in other languages in the present time.

Webwork is important because it is nowadays impossible to think how the future world, which is irreversibly connected with computer reality, will work differently. Therefore, being involved in the process of understanding how to properly use new technologies and how to enhance their potentiality is crucial for ensuring the knowledge and competences of domain experts, which will not disappear in the near future.

Criticizing the need for standardization that enables the advanced use of digitization even in the field of restoration in the name of the constituent complexity of the built heritage risks falling into the trap of a Luddite nostalgia of the good old days. Thus, the laborious work of defining vocabularies, rules and connections between components and concepts that describe architecture will be left in the hands of engineers and computer scientists. This will bring the result of blocking not so much the digitization of the approach to the historic built heritage – now destined for paths of innovation that are not yet fully foreshadowed – but the transmission of knowledge from the field of preservation to that of digitization.

There is an as yet unexplored world leading from the possibility of properly capturing data from the semantic web to the possibility of using the same data, appropriately filtered and validated, with the digital tools in use today in the architectural field, such as GIS and BIM, or those to be implemented in the future. This is a long path, and one not without obstacles, not only of an IT nature but also related to the commercial interests of those who work in the field producing software and to the political-social interests of the owners and users of architectural heritage. But it is also a novel perspective that can enhance and improve knowledge sharing and, with it, the cultural role of our historical-architectural heritage. [*Donatella Fiorani*]

6.6. Which obstacles are you seeing in the dissemination of ontology modeling? And are they operational or cultural obstacles?

The complexity of modelling architecture is probably the highest in cultural heritage. There are complex spatial-temporal issues of building evolution, multiple complementary aspects that are difficult to be related and to be separated, such as wall and spaces, air, water and light, design and views, contradictory perspectives, etc. All the problems mentioned before are related to a qualitative point of view, which has always been one of the encountered problems since the creation of the CIDOC CRM. What needs to be done is to start thinking differently about the solutions.

One problem, which appears to be a heritage of European philosophical history, is the illusion that taxonomy, or more and more detailed taxonomies of distinct entities, actually help understanding contexts. CIDOC CRM does not prescribe terminology, which is taken as data from the point of view of the CRM. If terms for entities do not require a relation specific to them for answering a relevant question, they are not accepted as classes in the CRM, because any proposition describing something must be based on a relation. What we found out, during the past years, is that if the focus is to find how things can be related by the same properties and still give specific answers to the relevant questions, instead of trying to classify things as detailed as possible, then the complexity of a scheme necessary for effective documentation can greatly be reduced. The specificity of architecture forces us to go back to the individual instances. It is impossible to reason with many, many types only about what is relevant for a particular building. Thinking in this way can become an obstacle to grasp the relevant, and it is unlucky that the computer science community now confuses formal ontology with terminology, which are different, at least from a practical point of view.

A second illusion in current cultural documentation is the belief that creating a sufficiently detailed "digital surrogate" of some object is efficient and useful in order to do all studies from this representation upwards. But each "surrogate" is an abstraction only geared to answer specific questions local to the object, such as idealized geometry versus actual deteriorations. What CIDOC CRM has been trying to solve since a long time is to understand which are the properties that will likely link data across detailed object studies and which information will likely not connect to some piece of information from different contexts. In the latter case, the related information would likely be delimited to an easy-to-find set of studies, and not require a global interoperability standard.

When dealing with architecture, the idea that the object can be analyzed as distinct entities and parts can become another obstacle to effective documentation, as may be exemplified by years of attempts of European committees to define unique identifier system for historical buildings. What appears to be distinct are rather aspects of sections of matter with multiple mutual roles and connections, changed over time. For example, a beam goes through and is integrated in several walls and floors, but each wall is part of forming multiple rooms, and not even separated from some other walls and even buildings, etc. This case may be seen as an example how architectural complexity can be described with an *ontology* for kinds of *overlapping* units in space and matter deeply correlated by characteristic networks of *relationships* rather than detailed individual typology. The latter networks may exhibit important cultural patterns themselves that could be queried across documentation resources.

The idea is to structure the information by an ontology giving answers to the more general questions, for which you need access to wider sets of data in between institutions, and then to specialize by concepts needed for more specific questions that can typically be answered in a more limited context, or even by very specific tools, in particular graphical ones. Organizing knowledge this way with a hierarchy of relationship as provided by CRM can make it possible to maintain all the links between the different involved and further related resources thanks to Linked open Data protocols, that can help manage all this complexity. [*Martin Doerr*]

6.7. How are European to fill this kind of gap? What is the pride of each scientist and researcher who is convinced of the absolute specificity of his or her context and the attempt to take a general model that the specific scientific context may refer to?

Architecture conservation really focuses the question on finding, for a particular building or a set of building together, a way for the preservation of this one historical fact which is a complex reality that is here and now which is not the process of our present day modality of production. Everything about it is highly unique which underlines the conflict between trying to bring a piece of technology like HBIM, BIM and its extensions as tools available for managing present objects and the material, actual manufact. BIM applied on historic building may give wrong information about the object and that could be absolutely catastrophic if what is required is the low capacity of what that object might tell experts, researchers, architects who are responsible for its conservation due to the distortion of facts that comes through with the systems of representation. In doing the ontological modeling what is done is re-presenting which is a representation in the first place so when data are extracted, that is about a real-world phenomenon and it is a form of representation which gives dimensions, materials, proportions, relations and that is where standardization comes in order to be used and compare that data. In this sense, standardizing stands for univocally defining something to capture that and all the subsets of the things that are reported by the researchers and the scientists. So, thinking about the relationship between these different tools, the very accurate BIM tools, the study of the individual monument and a system like CIDOC CRM, what has to be acknowledge in representation is that the world is always richer than its representation, that all representations – those of the stones, those of the banal dimension attributes, etc. – that we will put into the semantic network and that in all cases, there may be a deception in the model. [*George Bruseker*]

6.8. When relating to architecture, there is always the risk of thinking about classes and the difficulty of introducing properties, how would you solve this?

Archeologists tend to think in context and consequently they are more interested in the relationships between things rather than in things themselves. More than a piece of pottery, what is interesting is where that piece of pottery was found relatively to and, in this perspective, relationships actually tell the story of an artifact.

One interesting aspect of dealing with architecture, that may be as well found in some archeological findings, is the problem of the different scales of the city and buildings. One of the really powerful aspects of this matter, which has been deepened by CIDOC CRM, is that it allows to link data that has been created at different scales for different purposes. So that it is possible bring them together and simply flow to one scale to another without dichotomy in the processing.

Working with things so different allows, especially in archeology, to integrate excavation data with other kind of data, which may be related to extrinsic aspects which are not completely relatable to the manufact but that can help understanding it. That ability to work at different scales has a great advantage because it prevents fossilizing on a specific discipline which may sometimes be a limit in scientific research.

The aim of this process is not to create any new knowledge, but just to consolidate the knowledge already existing. In the eventuality of being interested in creating new knowledge what is needed would be to ask new questions and to think about new ways of interrogating the physicality of the world, recording different attributes at different times about the traits in the real world which are interesting.

One of the things that tends to break the previously described process is the scale because sometimes it is impossible to work on data from different inventory or database, in one data structure, which can be done instead by allowing the integration to work through mechanisms like CRM.

Finally, it is not unusual that people from different environments may interpret the same physicality in different ways. Such diversity can be incorporated and may allow researchers from different schools of thought to interrogate data and then bring to an integration of core processes so that a database may result useful not only for the research it was created for but also for other purposes belonging to other domains. [*Steven Steads*]

6.9. What is the point of view of a book conservator as related to information integration?

Taxonomy is not neutral and in bookbinding conservation and book history in general, there have been disagreements for years among experts. A solution to this problem might be not only through the use of the CRM, but also through the use of Linked Data and related methods. Conservation is dominated by the English language and western approaches and, because of it, sometimes those who come from outside the English-speaking world may feel excluded.

The use of taxonomy and the use of digital tools enable inclusion.

In terms of conservation, more specifically, there are a lot of unanswered potential research question that cannot be answered properly because of lack of integration. One crucial point is to understand how materials and techniques have evolved over the centuries and that question is as relevant for books as it is for buildings. Usually, the process of developing knowledge is common regardless of the objects being studied. Such a process can take time and effort, and the results obtained often cannot be shared and, as a consequence, much experience and expertise cannot be considered together. Merging all these observations into a broader scope is critical for understanding the development of bookbinding history. Due to the enormous amount of data related to historic research it becomes sometimes impossible to properly organize, manage and keep truck of the real condition state of the collection unless integrated data is used. Moreover, especially when dealing with cultural heritage conservation an object is studied by many domain experts with their own interests and aims which means that there are tons of data available which could help develop potential conservation plans as well as their management, but hardly ever all this data is correlated and properly used. Those mentioned are only few aspects of the relevance of integrating data in the profession.

The potential of the CRM, on top of integration, is related to the reasoning that can be done on the data collected. If data was structured using the CRM, then it would be possible to produce rules that would help planning and deciding on future work.

When dealing with heritage and its condition state it is sometimes necessary to proceed in a programmatic and preparatory approach in order to allow future interventions and at the moment Linked Data for information integration are a practical approach. [*Athanasios Velios*]

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