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3D MODELS CITYGML-BASED COMBINED WITH TECHNICAL DECISION SUPPORT SYSTEM FOR THE SETTING UP OF DIGITAL CONSERVATION PLANS OF HISTORIC DISTRICTS

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ABSTRACT:

The setting up of recovery plans for historic districts requires a multi-level and multi-thematic process for their analysis and diagnosis to determine classes of priorities and interventions for buildings at the district scale of relevance. Traditional tools and protocols have already highlighted operative complexity and expensive activities, affecting the organicity and effectiveness in interpreting data. On the other hand, recent scientific and practical activities based on the use of parametric Digital Models and Informative Systems have highlighted their advantages in standardizing complex issues and knowledge. Recent work by the authors has defined the structured organization of technical knowledge for the creation of a digital recovery plan using Informative Parametric Models, based on descriptors, and primary and secondary factors. These aim at converting properties and information in qualitative and quantitative data, and then structuring dependencies on descriptors and primary factors, according to thematic taxonomies, existent ontologies for the geometric and semantic representation of urban and architectural entities, thematic normative and established approaches for the recovery of cultural and landscape heritage. Thus, the present work shows a workflow for the semi-automatic setting up of intervention classes for architectures in historic districts in Italy. It is structured on CityGML-based models, coherently implemented with a Technical Decision-Support System (T-DSS). Specifically, the T-DSS is determined considering the relations among thematic normative: UNI 11182, UNI/CEN TS 17385:2019, and Italian Consolidated Law on Building. The workflow is finally tested in the historic district of Ascoli Satriano, in the Apulia Region (South of Italy).

1. INTRODUCTION

The conservation process for architectural Cultural Heritage requires interdisciplinary skills and multi-temporal phases; moreover, it follows administrative procedures that usually require extended time. When the discussion moves towards systematic architectural Heritage, such as historic districts, the landscape relevance increases the dimensionalities of the matter. Here, the historical evolution of the whole districts, the morphologies and construction techniques at the fabric scale and the unplanned transformations suffered by single fabrics spread the complexity in knowledge and understanding the inherent cultural values; on the other hand, the extension and the numerousness of fabrics increase the procedures in comprehending and evaluating proper classes of priority for intervention and types and technological relevance of solutions (Egusquiza et al., 2018). Moreover, such architectures vary in terms of ownership, mixing public and private properties, spreading the time for their improvement. These are the basis of the historical slowness in proceeding towards the creation of recovery plans for such Cultural Heritage which, particularly for Italian cases, are still affected by a critical state of conservation (Cantatore, 2022). Furthermore, the practical activities in collecting data and information are based on traditional tools and protocols in relieving (excel cataloguing, photographic survey) and map rendering (thematic maps) for the setting up of recovery plans, highlighting operative complexity and expensive activities, affecting the organicity and the effectiveness in interpreting data and the intervention setting up (Ornelas et al., 2016).
Recent scientific and practical activities with IoT tools have shown the potentialities of parametric Digital Models (CityGML, BIM) and their integration with Informative Systems (Geographical and Relational databases) in standardizing technical knowledge as well as in relating characters and properties of fabrics, their aggregations, and sub-districts furniture and sub-elements (pavements, network services, etc.) involved in analysis and management of complex issues for historic districts (Acierno et al., 2017; Ornelas et al., 2021; Prieto et al., 2017). This is a main consequence of the inherent opportunities offered by structured ontologies for Cultural Heritage (CIDOC-CRM, MONDIS), their extension in specific thematic domains (i.e., Application Domain Extensions - ADEs - for CityGML) and their openness towards the implementation of new structured categories. On the other hand, activities on automatic methods and management of information about the elements and properties involved in the recovery process of Cultural Heritage have opened the research towards the integration of external rules in order to support choices and decisions to all the technical and administrative involved (also called Decision Support Systems - DSS). Here, the main objective is the setting up of mathematical and logical relations properly integrated to the ontologies aimed at assessing and managing historic fabrics and districts and consequent interventions when exposed to natural hazards (Gandini et al., 2020), or in managing maintenance actions for urban network utilities (Chen et al., 2021).
In this framework, the present work focuses on the set up and use of CityGML-based models of historic districts for the management of data and information useful for their analysis and determination of levels of priorities and classes of intervention for their conservation. Specifically, the work takes advantage of the CityGML standard in managing:

i) the multiscale dimension of such parametric models to set up historic districts in order to manage the physical and semantic extensions of the represented elements (fabrics, streets) and their properties.

ii) the extensibility of the standard by means of structured ADEs and Generic thematic properties aiming at the complete representation and conceptualization of real cases towards the goals of the work.

iii) the integration of external rules for the representation and assessment classes of decay of fabrics and identification of classes of interventions, merging normative frameworks for their quantification and administrative outlines, here called Technical Decision-Support System (T-DSS).

The work is presented in continuity with previous activities about the issues, showing a possible workflow for the semi-automatic setting up of qualification of intervention classes and associated levels of priority, considering the state of conservation of architectures in historic districts (physical and functional obsolescence) as the basis of the T-DSS. The T-DSS relations consider the logical and mathematic functions referred to the associated thematic normative (NR): i) UNI 11182, which concerns the decay typologies for stone, ii) UNI/CEN TS 17385:2019, to evaluate the state of conservation of architectures, and iii) Italian Consolidated Law on Building (D.P.R. Decree of the President of the Republic no. 380/2001), that defines the class of interventions. Finally, the T-DSS structure is organized in order to fill the semantic data in the CityGML-based model (factors and descriptors), along with the multi-scalar standard ontologies.

Due to that, previous qualification activities of Italian historic districts within CityGML models are briefly presented in the following sections, trying to summarize the qualification of historic district within the recovery process and leaving the central core of the work to the sub-sequent automatization phases about the management of the state of conservation and identification of interventions.

2. STATE OF ART AND PREVIOUS EXPERIENCES

As introduced in the previous section, planning activities for the conservation and recovery of historic districts and Cultural Heritage are complex matters. Previous scientific studies in overcoming operative slowness in the recovery process by means of CityGML models found prevalent activities in the categorization of technical knowledge as the preliminary phase of their conservation (Colucci et al., 2018; Yaagoubi et al., 2019). This cannot be considered a limitation, but it is a consequence of the novelty of the tools, still growing coherently with the technical requests. The growing process of setting up specific domains for Cultural Heritage is the reflection of the increasing request (Noardo, 2018). On the other hand, main applications are associated to single architectures while virtuous examples focused on districts or systemic architectures are still limited or applied to the urban risk assessment and energy retrofit (Egusquiza et al., 2022; Gandini et al., 2021). Coherently with such experiences and to the scientific and Italian practical experiences for recovery planning activities, the authors have already defined the structured organization of technical knowledge for the creation of an architectural recovery plan by means of Informative Parametric Models, properly based on three levels of detail (Lasorella et al., 2022): descriptors, primary and secondary factors. These aim at converting properties and information in qualitative and quantitative data, firstly, and then at structuring dependencies on descriptors and primary factors, according to thematic taxonomies derived from the glossary of decay stones (TG), existent ontologies for the geometric and semantic representation of urban and architectural entities (O), thematic normative for the recovery of cultural and landscape heritage (NR) and established approaches in recovery activities (AR).

Section	Code	Name	Class
1.Gen. info	ID_C	Cadastral Data	B/GA
	ID_T	Toponomastics	B/GA
2. Historical-archival data	B_Cl	Building Class	B
	B_Fct	Building Function	B
	B_Use	Building Use	B
	B_CP	Construction period/year	B
	B_DP	Demolition Period/Year	B
	B_Ow	Building ownership	B/GA
	B_St	Building State	B/GA
	B_Tl	Building Title	B/GA
	B_PI	Presence of previous interventions	B/GA
	B_TPI	Type of building intervention carried out	B/GA
	B_PPL	Period/year of intervention carried out	B/GA
3. Technical knowledge data	B_nFa	Storeys above ground	B
	B_nFb	Storeys below ground	B
	B_H	Measured Building Height	B
	B_SH	Storey heights above and below ground level	B
	B_A	Floor area	B/GA
	B_Pwi	Presence of windows	B/GA
	B_nR	Number of rooms	B/GA
	B_WiA	Window area	B/GA
	B_WD	Wall dimension	B/GA
	B_WiAw	Window Area wall	B/GA
	B_WA	Wall area	B/GA
	B_Arf	Roof area	B/GA
	B_RA	Room area with window	B/GA
	B_TS	Technological system	B/GA
	B_TST	Technological system type	B/GA
	B_Typ	Building Type	B/GA
	B_Str	Structural typology	B/GA
	B_WT	Wall Type	B/GA
	B_RT	Roof Type	B
	B_VCT	Vertical Connection Type	B/GA
	B_WiT	Windows Type	B/GA
	B_FiT	Type of building finishing layers	B/GA
	B_MQ	Mortar Qualification	B/GA
	B_QJ	Quality of vertical and horizontal joints	B/GA
4. Ref. Legisl.	B_ChC	Cultural Heritage Code	B/GA
	B_LsR	Landscape restriction	B/GA
	B_MR	Municipal constraints	B/GA
5.Arch. Em.	B_EV	Elements of value	B/GA
	B_HR	Historical relevance	B/GA

Table 1. Summary of descriptors involved in the data collection for the knowledge phase of the conservation process.

These factors and descriptors already include both geometric and semantic levels of details to be acquired or determined during the

technical knowledge phase, allowing, for the data acquisition (e.g., archivist) or information (e.g., geometric data by means of ortho-images of direct surveys), traditional or innovative techniques (Sedano Espejo et al., 2021).
For the purpose of the work, the main attention is on the fabrics within the historic districts where the analysis and assessment of the state of conservation are based on building and sub-components scale. Due to that, Tab.1 sums up the descriptors involved in the preliminary phase of collection and knowledge process, as preventive re-check for subsequent activities.

3. 3D MODEL CITYGML-BASED WITH TECHNICAL DECISION SUPPORT SYSTEM

As described in the previous section, the paper aims at showing a possible workflow for the semi-automatic setting up of qualification of intervention classes and associated levels of priority, considering the state of conservation of architectures in historic districts starting from a structured T-DSS. In order to support the goal, the section is structured in order to show the translation process of normative relations in the decision support system (section 3.1) as the over-ordered phase of the practical workflow, described in section 3.2.

3.1 The conceptual normative structure of T-DSS

Coherently with the rule of a standard, all the information required for the conservation process needs to be structured according to consolidated relations. In that sense, the use of descriptors and primary and secondary factors allows the identification of relations between simple and derived data. Descriptors are determined by survey or archival activities mainly aimed at the description of basic information, while factors result from logical and mathematical relations between simple (descriptors) or complex (descriptors and primary factors) information. Specifically for the paper's aim, factors involved in the identification and characterization of the state of conservation of buildings and their sub-components in historic districts correspond to an adjunctive semantic information.

Section	Code	Name	Class	Normative Reference
6. Qualification of decays	B_Td	Type of decay	B/GA	UNI 11182
	B_S	Seriousness	B/GA	UNI CEN TS
	B_In	Intensity	B/GA	UNI CEN TS
	B_Ex	Extension	B/GA	UNI CEN TS
7. Aggregate data	D	Extension of decay	B/GA	UNI CEN TS
	Fc	Corrective factor	B/GA	UNI CEN TS
	Ad	Extension of decay	B/GA	UNI CEN TS
	Ccd	Class of condition for single decay	B/GA	UNI CEN TS

Table 2. Descriptors for the qualification of single decays, to be associated to sub-components.

Specifically, Table 2 shows descriptors identified for the qualification of type of decays for single sub-components, and the levels of seriousness and intensity and global extension. Such descriptors are determined from the assessment of:

- UNI 11182:2006 (UNI 11182) identifies, in an unambiguous way, the typologies of decay. Here, defects caused by humidity or environmental conditions (i.e., erosion, alveolation), and cracks are included (B_Td).
- UNI CEN TS 17385:2019 (UNI CEN TS) which evaluates the level of conservation of architectures and sub-components, according to the seriousness (B_S), level of intensity (B_in) and extension (B_Ex) of the identified defect/s. In detail, qualitative and quantitative indicators are identified for the descriptors (B_s, B_In, B_Ex) according to the technician's expertise and objective values (Table 3), in order to have a unique indicator (a value from 1 to 6 called Class of condition) for each type of decays.

All the descriptors are associated to single sub-components of single fabrics according to their technical classification identified in UNI 8290.

Seriousness	Intensity	Extension				
		Minimal (≤2%)	Inconsistent (>2%, ≤10%)	Consistent (>10%, ≤30%)	Significant (>30%, ≤70%)	Widespread (>70%)
Minor	Low	1	1	1	1	2
	Medium	1	1	1	2	3
	High	1	1	2	3	4
Serious	Low	1	1	1	2	3
	Medium	1	1	2	3	4
	High	1	2	3	4	5
Critical	Low	1	1	2	3	4
	Medium	1	2	3	4	5
	High	2	3	4	5	6

Table 3. Values of Classes of conditions (Ccd) (1 – 6) as the combination of Seriousness, Intensity and Extension descriptors

As far as the contents in Table 4 are concerned, the conservative states of single sub-components (wall, roof and window) are thus introduced in the semantic structure as primary factors, due to the relations and the quantification of the associated simple descriptors. When single levels of conservation are combined towards a unique factor of the global state of fabrics, the Global Conservation state of building [B_CS] is determined as a Secondary factor. While, for the identification of the unique conservative state of sub-components when multiple types of decays are present, UNI CEN TS suggests the grouping method.

Section	Code	Name	Class	Normative Reference
8. Conservation level	B_CSW	Conservative state of wall	B/GA	UNI CEN TS
	B_CSR	Conservative state of roof	B/GA	UNI CEN TS
	B_CSWi	Conservative state of windows	B/GA	UNI CEN TS
	B_CS	Global conservative state of building	B/GA	UNI CEN TS

Table 4. Factors for the qualification of the conservative state of building sub-components (walls, roof, windows) – primary factors -, and global index for buildings – secondary factor -.

For each decay class [B_Td], the defect is assessed in terms of aggregate extension [D] considering the associated class of condition [Ccd], a specific corrective factor [Fc] is linked to the real extension in order to have a weighted extension of the defect (see Table 5, Equation 1 and Equation 2).

$$D_i = F_{ci} * A_{di} \quad (i=1\ldots n) \tag{1}$$

where Di= i-th aggregate extension of decay.
Fci= i-th corrective factor assessed according to the class of condition of the i-th decay (Table 5).
Adi= extension of the i-th decay, in percentage.

Thus, the total extension of the defected area (Dtot) results as the sum of the i-th aggregated extension of decays (Di):

$$D_{tot} = \Sigma D_i \quad (i=1\ldots n) \tag{2}$$

Class of condition for single decay [Ccd]	Corrective factor [Fc]
1	1
2	1.02
3	1.10
4	1.30
5	1.70
6	2

Table 5. Corrective factors for each class of conditions

Finally, the primary factor of "conservative state" for each sub-component [B_CSx] is determined according to Equation 3, and qualitatively described according to the aggregated condition class defined in Table 7.

$$B\_CSx = D_{tot}/A_c \tag{3}$$

where Ac= extension of sub-component, in percentage

Dtot/Ac	Aggregated class of condition
x≤1.01	1
1.01<x≤1.04	2
1.04<x≤1.15	3
1.15<x≤1.40	4
1.40<x≤1.78	5
x>1.78	6

Table 6. Tange of values of Dtot/Ac and associated values for the aggregated class of conditions

As far as the assessment of the secondary factor, the Global conservation state of building [B_CS] is calculated according to the notes of UNI CEN TS 17385:2019. This is the result of the weighted average of decays and related sub-component extensions as described in Equation 4:

$$B\_CS = \Sigma\,(CSW * WA + CSR * RA + CSWi * WiA / WA + RA + WiA) \tag{4}$$

where B_CS= Global Conservation State of building
B_CSW = Conservative state of Wall
WA = Area of Wall
B_CSR= Conservative state of Roof
B_RA= Area of Roof
CSWi= Conservative state of windows
WiA= Window Area wall

As far as the relation among classes and priority of intervention with the global state of conservation is concerned, Table 8 summarized the rules. Specifically:

- The classes of intervention are determined according to the preservation strategies identified the Italian Consolidated Law on Building (D.P.R. Decree of the President of the Republic no. 380/2001). In concordance with the regulation, differences exist both for the state of conservation and direct cultural or historical restriction of single buildings. In fact, conservative restoration is the only possible class of intervention, while for historical fabrics, ordinary, extraordinary maintenance and building rehabilitation are recognized as possible classes of intervention associated to the global conservation level.
- The priority of intervention is introduced as a global index of intervention class. It is a numeric feature (1 to 3) associated to the inverse seriousness of intervention classes.

B_CS	Condition	B_IC		B_Ipr
		Listed	Not Listed	
1	Excellent	Building restoration	Ordinary maintenance	3
2	Good			
3	Fairly good		Straordinary maintenance	2
4	Low			
5	Bad		Building renovation	1
6	Very Bad			

Table 7. Relations between classes and priority of intervention to the values of Global conservation state of building

3.2 Tools and Methods

The section shows the main steps and necessary tools of the possible workflow useful for the elaboration of CityGML-based parametric models integrated with a Technical-Decision Support System (T-DSS). Specifically, the workflow is structured for the conservative analysis of historic districts, as well as to support technical users (engineers, architects) during the final phases of recovery plans: management of the conservation levels and the subsequent identification and selection of intervention classes. In detail, the proposed workflow takes advantage of four main tools:

- QGIS for the collection and geographic localization of fabric information;
- FME (Feature Manipulation Engine) is a Spatial ETL (Extract Transform Load) software used for the conversation of main data (spatial and semantic information) according to the CityGML standard;
- 3DCityDatabase is the geographic informative system CityGML-based useful for the analysis and management of data in the parametric 3D model;
- 3DCityDatabase Web Map Client is the web-based viewer of three-dimensional maps useful in supporting the digital

fruition of semantic data of architectural entities.
The methodological and operative flow consists of the following phases (Figure 1).

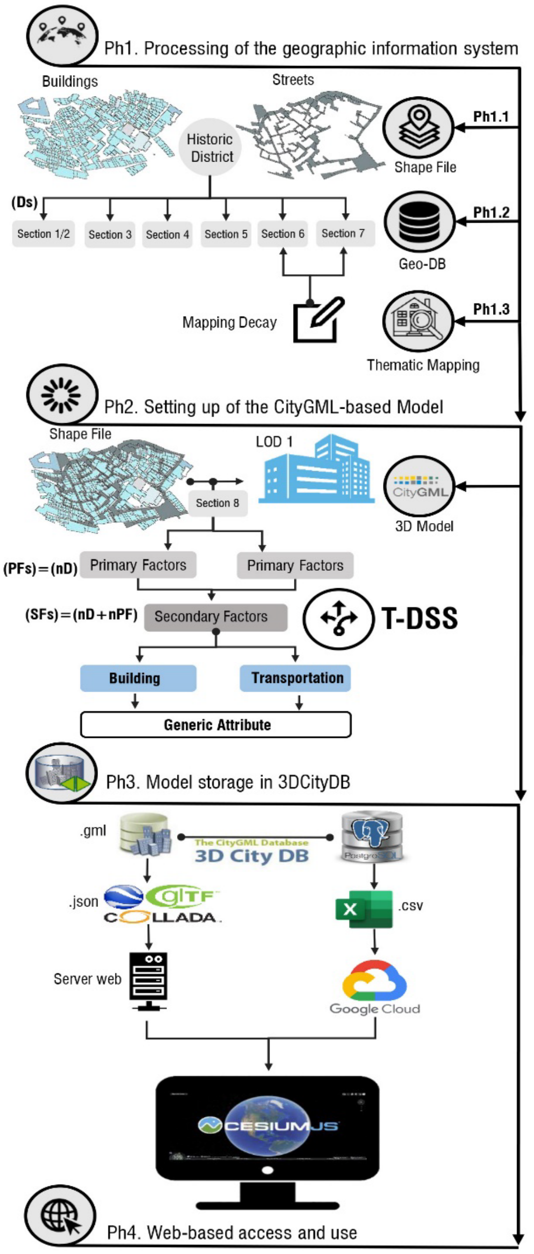

Figure 1. Phases and tools involved in the workflow

Ph1 Processing of the geographic information system. Here, three sub-phases are required:

Ph1.1 Shape file processing. Each architectural entity and the associated geometric properties are properly geolocated in the reference system. In detail, the shape file is processed starting from available territorial information systems data (e.g., regional technical map, digital surface and terrain model) for the representation of fabrics.

Ph1.2 Setting up of the Geo-database (Geo-DB). The Geo-DB is structured in order to allow the filling and systematization of semantic data required for the goal (descriptors in Table 1), resulting from the first information collection. Due to the multidisciplinary classes of data - caused by various application fields involved in the process (historical, architectural, diagnostic)- and their heterogeneity (drawings, images, documents), all the data have to be collected and properly encoded using alphanumeric values. Thus, all of them are related to the associated architectural entity (vector polygon) (Ph1.1).

Ph1.3 Thematic mapping for conservation assessment. Aiming at the qualification of the main building components (walls, roofs and windows), this sub-phase points out the identification and selection of classes of decay and the required qualitative and quantitative indicators (Table 2). Specifically, the decays (B_Td) require to be detailed according to the UNI 11182:2006, and then Seriousness, Intensity and Extension (B_S, B_In, B_Ex) can be filled for each type of decay.

Ph2. Setting up of the CityGML-based Model. This phase, prepared according to specific workbenches of the FME visual platform, concerns in the development of the parametric model starting from the geometric and geolocated data included in the shape file (Ph1.1), general semantic information organized in the Ph.1.2 and features derived from the mapping processing in Ph1.3. Here, the logical-relational structure is defined according to the T-DSS (§3.1). So, specific classes of attributes are set up according to the standard in order to introduce primary and secondary factors related to the conservation levels of sub-components and buildings (Table 3, B_CSW, B_CSR, B_CSWi, B_CS), as well as the secondary factors associated to the classes and priority of intervention of each building (Table 7, B_IC, B_Ipr).

Ph3. Model storage in 3DCityDB. The parametric model is imported into the 3DCityDatabase to archive and manage CityGML data. This allows the management of the parametric model over time and by different users in the sector, through appropriate usage coding, as well as the semantic-thematic and geometric-topological data export to be displayed in the web environment.

Ph4. Web-based access and use. This phase concerns the visualization and interaction of the three-dimensional CityGML-based model through the 3DCityDB Web-Map-Client. Here, all the final users may interact with the model, and read all the semantic information at the fabric scale, by means of an easy web browser. Specifically, the phase is conceived to allow the ease access of class and priority of interventions at the district scale by all the final users involved in the practical activities of building recovery.

4. CASE STUDY

The operative flow outlined in §3.2 has been applied and validated to an emblematic historical district of the Apulia Region (Figure 2). This is the case of the historic district of Ascoli Satriano, a small town in the province of Foggia. It has been chosen by the authors for the various historical-architectural characteristics that distinguish it.

4.1 Historical-architectural analysis of the historic district of Ascoli Satriano

The historic centre of Ascoli Satriano is in the highest part of the city promontory, also known as "Castle Hill". The prevalent features of the urban fabric in the historic centre are associated to various dimensions and distribution of street dimensions in the plan and single cell units with vertical development or terraced houses with horizontal development. 90% of buildings have residential use.

Figure 2. Location of Ascoli Satriano in the Apulia Region

Its current morphological-architectural configuration is the result of historical violent seismic events (in 1343 and 1361) and the subsequent slow process of reconstruction, caused by the absence of an urban planning regulation for the historic district. Main suffered transformations relate roofs, partially collapsed which has generated the co-presence of various constructive and material combinations. In fact, roofs, originally characterized by pitched wooden structures, have been replaced with flat slabs (iron beams and brick vaults or reinforced concrete). On the contrary, walls have preserved the original multi-layered features, showing the combined use of stone and solid brick blocks, plastered both along the external and internal sides. Finally, the transparent building sub-components (windows and doors) have different frames to the original ones (wood) and are featured by a widespread low state of conservation. Currently, they consist of aluminium frames with simple and clear double-glazed technology, commonly introduced in the last twenty years of the last century.

4.2 Validation of the operative flow to pilot cases of representative buildings

Due to the large amount of data required for the setting up of the full CityGML-based model and its implementation with the integrated T-DSS, the workflow for assessment of buildings for their state of conservation has been applied and validated for three buildings in the historic district of Ascoli Satriano (FG), representative of the main conservative level of fabrics (Figure 3). On the contrary, basic data required for the basic knowledge of buildings (Table 1) have been collected and properly structured in the parametric model. In the detail of data and activities in Ph1, geometric and geographical information of buildings are extracted from the Regional Technical Charter (SIT Apulia Region) (Ph1.1), while morpho-typological, constructive and architectural features have been collected starting from in situ surveys and previous studies and technical activities. These are thus used to set up the basic geographic information system of the historic district. Here, the architectural entities have been represented with vector polygons in the global reference system (WGS84-UTM 33N) and the GEO-DB has been structured through attribute tables (Ph1.2). In particular, a specific attribute table has been created for each section of the Geo-DB, structured to support: i) the historic-archival information; ii) the data acquired on-site; and iii) the conservation level by thematic mapping. As far as the latter is concerned (P1.3), the qualification and assessment of decays for the selected buildings have been processed in GIS environments by means of their ortho-images.

Figure 3. External facades of the Test Buildings (TBn)

Specifically, the image-based survey has been performed in situ according to the principles of digital photogrammetry, using a digital camera (Canon EOS 100D). After the acquisition campaign, the frames have been processed within a Structure-For-Motion software (Agisoft Metashape©) for the elaboration of ortho-images for each building sub-components (masonry, roof, windows), finally scaled thanks to measurements acquired in situ (Figures 4 and 5). Thus, decays are identified in GIS environment, using vector primitives, geolocated and associated to the related architectural entities in the shape file (Figure 6). Here, details on each decay (B_Td, B_S, B_In, B_Ex) and for each building sub-component are introduced in the associated attribute table in the GEO-DB, completing the implementation of data in the GIS environment. As recurrent results in the mapping process, five main classes of decays have been recognized for walls: washout in the higher part of walls due to the absence of well-design gutters; the presence of dampness in the lower part of walls caused by their direct contact with rain-flows along the impervious sidewalks; a consequent spread of detachment and degradation of surfaces, as well as local presence of vegetation. For roofs, the main decays identified are biological patina and degradation of the roof covering; while, for windows a low state of conservation of the shading elements has been identified, and the degradation of the wooden doors caused by the presence of dampness, and breakage/absence of glass for windows.

Figure 4. Orthoimage of wall of testing building n.1 (TB1)

Figure 5. Ortho-image of the roof of testing building n.3 (TB3)

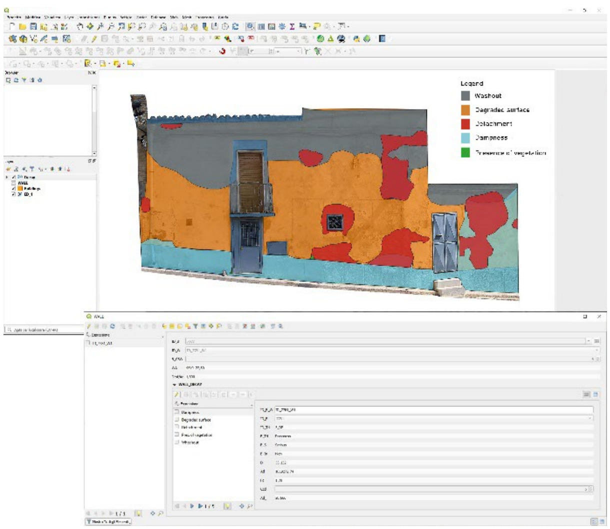

Figure 6. Thematic map of the exposed wall of a test building.

Subsequently, for every single subcomponent, the graphic-vector restitution of the state of conservation has been performed, representing the areas of decay with vector polygons. Therefore, each vector polygon mapped on the ortho-image has been related to the "Conservation level" of the section Geo-DB. The logical relationships configured, and the calculator fields have been prepared to allow: i) the identification of the type of decay, from the defined choice set; ii) the definition of the severity and level of degradation; and iii) the calculation of the decay extension, codifying it in alphanumeric attributes. So, the calculating fields prepared in the specific tables, as well as according to the equations (§3.1); it has allowed the automatic compilation of the field relating to the primary factor of the state of conservation of each component of single architecture (Figure 6).

Consequently, the CityGML-based model has been created within the Safe FME visual programming platform. Here, the specific workbenches have been used for i) the creation of the geometric model in LOD1, extruding geolocated polygons using heights collected in the shape file, ii) translation of the semantic-thematic data according to the Building class, for the attributes that complied with the standard, and the GenericAttribute class, for the attributes external to the reference ontology, and iii) the implementation of the logical-relational structure of the T-DSS, for the automatic derivation of the class and priority of intervention. The CityGML-based model created has been imported and archived within 3DCityDB, using PostgreSQL as a relational database with its PostGIS extension. The use of 3DCityDB has allowed the export of the geometric model (.json) and the semantic data (.csv) for subsequent visualization and use in a web environment, as well as the management of archived data over time. In this way, the model is set up to be used in a web environment within the Cesium virtual globe. In the 3DCityDB-Web-Map-Client platform, it is possible to query the individual architectural artefacts: at a semantic level, by creating a specific search against unique values; and at a geometric level, by selecting a single model. In both modes, the tool allows the display of semantic information relating to the queried object in a pop window (Figure 7).

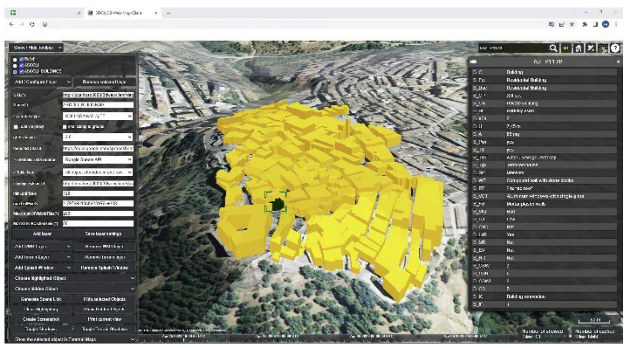

Figure 7. Visualization of the parametric model in the 3DCityDB Web Map Client and visible details of the selected building in the popup window on the right

CONCLUSIONS

As the latest scientific studies have discussed and demonstrated, parametric models for architectural and construction activities have supported the systematization of technical knowledge for simple and complex matters. Both geometric and semantic levels can be ensured, due to the wide interoperability among tools and techniques of relief and modelling, as well as the structure of solid standards based on widespread and thematic ontologies. This is even more effective when historical and cultural relevance enhances the basic knowledge of cultural heritage, regardless of their singularity or systematic presence in the urban landscape. Major effectiveness in treating single cases or systematic architectures, such as historic districts, is related to the extension of ontology in managing all the levels of details on districts or urban scales coherently with their dimension of architectural and landscape relevance.

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Systemic fabrics in historic districts are an atypical class of cultural heritage due to their landscape relevance which usually is in opposition to the simplicity of fabrics used for residential scope. These elements are at the basis of the historical necessity to preserve such places and the low interest of major administrators in solving the matter. The creation of their recovery plan usually results from the request in computing urban residential needs. Moreover, the setting up of a recovery plan is related to expensive and slow activities of technical users involved in the process aimed at collecting, reorganizing and comprehending historical, archival and technological evidence for a large number of fabrics. This is in order to identify levels of interventions and related priority in a systemic set of rules and possible solutions. In that sense, the state con conservation of fabrics has a key role in the management and choice of their preservation actions. In that complex frame, the paper introduces an operative flowchart taking advantage of innovative tools and approaches in systematizing and managing complex levels of knowledge; it also may support local administrators during the strategic choices of interventions and priorities, and subsequent transformations for their enhancement. Specifically, the flowchart is based on CityGML model useful to manage district areas and it is implemented with a well-thought-out system of relation for the assessment of the conservative state of buildings. In detail, the flowchart takes advantage of the integrability of CityGML structure with an external Informative System based on logical and mathematical rules (T-DSS); here, these are defined according to the international rules for the assessment of the state of conservation (UNI CEN TS 17385: 2019) and classes of interventions defined by Italian laws.

The identified flowchart constitutes solid support for the set-up of a complete recovery plan even if the validation is proved on a reduced number of test buildings in the historic district of Ascoli Satriano. Moreover, the operative process is conceived in order to be open towards innovative and traditional methods in computing the state of conservation. Manual techniques and automatic methods supported by artificial intelligence applied to image or orthoimages (image processing, machine learning) for the assessment of decay extensions can be ease included.

Besides, the introduction of T-DSS rules within the FME transformation tool allows the setting up of a semantic model featured by a high potential of updating over time. The continuous process of enhancement of fabrics determined by private owners can be ease included in the wide models, upgrading the priority of interventions at the district scale. Moreover, this allows administrators to modify the models even if they do not have high informatics skills or require external expertise for the aim.

As future activities about the scope, the identification of a specific ADE and the translation of the latest 3.0 version of the standard may be considered in order to have standardized knowledge based on accepted and validated rules.

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