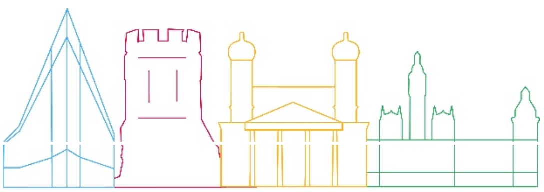
ARCH

ARCH D4.2

Historic Area Information System



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Executive Summary

This deliverable has been prepared for the European Commission-funded research project ARCH: Advancing Resilience of historic areas against Climate-related and other Hazards. It is the key output of Task 4.2 “Information Management about Historic Areas” within work package 4 “Hazard & Object Information Management System”. The aim of Task 4.2 was the development of the systems and tools to structure, query and analyse data related to the historic area and the elements it contains.

By considering historic areas as complex Social-Economic Systems, the different domains of these systems have been analysed, focusing the attention not only on the historic area itself, but also on the larger system in which it is included. The georeferenced information has been selected and structured in the Historic Area Information System with reference to the built and natural environment, the cultural heritage elements, and the social-economic context. Data and information to characterize the heritage assets and to assess their state are provided to support the subsequent vulnerability analyses (WP5), also taking into account that these indicators depend on the potential hazards.

In addition, a specific relational database has been developed to store information at building\object scale about the heritage assets and to relate information to each other.

Three specific tools have been designed and implemented - an operational guide is provided in this deliverable - to allow access to the dataset:

- GIS Dashboards enabling users to obtain info using intuitive and interactive maps;
- Building/Object electronic sheets to query structured data included into the database
- 3D Viewers to navigate 3D models produced for the constructions and objects

In addition, a methodology has been developed for automated acquisition of 3D models from automatically operated drones, followed by automated 3D model creation, leading to the Machine Learning (ML) processing of information for automated analysis and detection of structural and material degradations, employing neural-network co-processing for both more accurate and faster processing.

Table of contents

List of abbreviations

Abbreviation	Meaning
3D	Three dimensional (models)
3MF	3D Manufacturing Format
AeDES	Agibilità per edifi ci ordinari nell’emergenza post-sismica
AI	Artificial Intelligence
ANN	Artificial Neural Network
ATECO	Classification of Economic Activity (ATtività ECOnomiche)
BIM	Building Information System
BMS	Building Management System
BTH	Bottom Hat Transform
CH	Cultural Heritage
DB	DataBase
DSLR	Digital Single-Lens Reflex
DSS	Decision Support System
DWT	Discrete Wavelet Transform
ELC	Emergency Limit Condition
FBX	Filmbox (3D format from Autodesk)
GIS	Geographical Information System
GLCM	Gray-Level Co-occurrence Matrix
GPU	Graphical Processing Unit
GUI	Graphical User Interface
HA	Historical Area
HArIS	Historic Areas Information System
HUL	Historic Urban Landscape
IDE	Integrated Development Environment
ILSVRC	ImageNet Large Scale Visual Recognition Challenge

INSPIRE	Infrastructure for Spatial Information in Europe
ISCO	International Standard Classification of Occupations
ISIC	International Standard Industrial Classification
ISTAT	Instituto Nazionale di Statistica
JSON	JavaScript object notation
KPI	Key Performance Indicators
LoD	Level of Detail
DInSAR	Differential SAR Interferometry
MINOAS	Marine Inspection Robotic Assistant System
ML	Machine Learning
OBJ	OBJect (3D format from Wavefront)
RDBMS	Relational Database Management System
REST	Representational State Transfer WEB service
SDK	Software Development Kit
SES	Social-Ecological System
SGD	Stochastic Gradient Descent
SGD	Stochastic Gradient Descent
SOA	Service-Oriented Architecture
SOAP	Simple Object Access Protocol
SQL	Structured Query Language
SRI	Subsidence-Related Intensity
THIS	Threats and Hazard Information System
UAS	Unmanned Aerial System
UGV	Unmanned Ground Vehicle
UML	Unified Modelling Language
UUV	Unmanned Underwater Vehicle
WP	Work package

1. Introduction

This deliverable has been prepared for the European Commission-funded research project ARCH: Advancing Resilience of historic areas against Climate-related and other Hazards. ARCH will develop decision support tools and methodologies to improve the resilience of historic areas to climate change-related and other hazards. These tools and methodologies are developed with the pilot cities of Bratislava (Slovakia), Camerino (Italy), Hamburg (Germany), and Valencia (Spain), in a co-creative approach, including local policy makers, practitioners, and community members. The resulting solutions will be combined into a collaborative disaster risk management platform for guided resilience building, and will include:

- Information Management System for relevant geo-referenced properties of historic areas
- Information Management System for geo-referenced data regarding hazards and risks relevant for historic areas
- Decision Support System (DSS) for risk and impact analysis of historic areas
- Inventory of resilience building measures and appropriate financing sources
- Visual planning tool for resilience pathways
- Resilience assessment framework to identify resilience weak points and formulate resilience action plans

1.1. Purpose of this report and relation to other deliverables

This report (D4.2) is the accompanying document to the demonstrator for activity 4.2 "Historic Area Information System" within Work Package 4 (WP4) "Hazard and Object Information Management System". The objectives of WP4 are the development and implementation of two information systems:

- Historic Areas Information System (HArIS) for archiving the properties of the heritage and the characteristics of the historical area as a whole interacting with the surrounding urban and natural systems;
- Threats and Hazard Information System (THIS) to "combine" data from different sources to obtain measurable indicators to characterize the hazards that potentially affect the historical area and to collect historical and real-time data performed by climate services and / or through specific monitoring.

In the framework of WP4, datasets are structured and tools developed to support:

- Decision Support System (DSS) in the production of hazard models and vulnerability analyses, with the main purpose of evaluating impact scenarios and quantifying potential effects on the historic area and heritage assets, and consequently to support resilient options;
- ARCH Hub to give end-users direct access to the datasets and information relevant to their historic area.

Accordingly, the contents of this document and the developments described therein are mainly linked to:

- technological solutions provided by work package 4,
- needs arising from the co-creation process with the cities and the technical partners
- consequent analyses performed by the other work packages.

Therefore, the D4.2 is directly related to the following deliverables:

- **D3.4** Report on co-creating the information system
- **D4.1** Sensing and Repositories
- **D4.3** Threats and Hazard Information Management System (THIS)
- **D4.4** Knowledge information management system for decision support
- **D5.1** Hazard models for impact assessment
- **D5.2** Handbook on heritage asset vulnerability
- **D7.3** ARCH disaster risk management framework
- **D7.4** Requirements description
- **D7.5** Interface specification and system architecture
- **D7.6** System design, realisation, and integration

The chart in Figure 1 is a graphical representation of the interaction between D4.2 and the before mentioned deliverables with their related tasks. Please note that HArIS is a dynamic information system supported by web tools, therefore the different components can be improved even after their delivery. Likewise, any further datasets and information - as well as updates of those already included - collected within the ARCH project will feed this information system, even if they are obtained after the drafting of this document. Moreover, the same system allows authorized users to modify some information concerning the heritage assets included in the ARCH database.

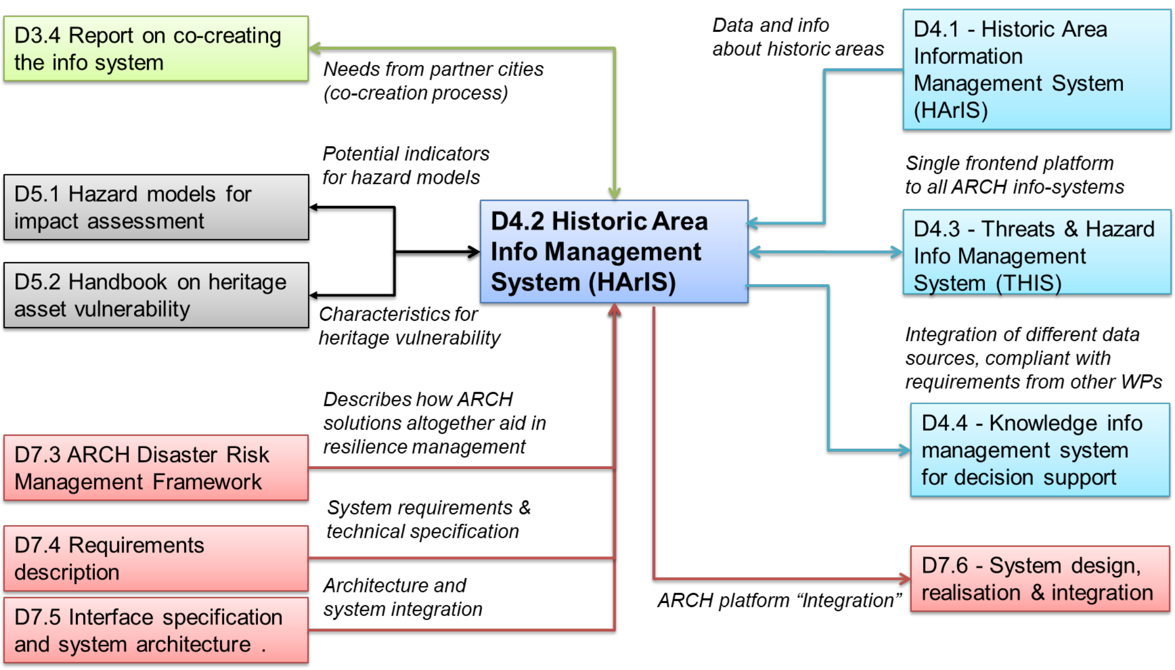

Figure 1: Representation of the main interactions between D4.2 and the other ARCH deliverables.

1.2. Gender statement

This document has been developed taking into consideration the guidance on gender in research provided in the Project Handbook (D1.2) as well as State-of-the-Art report number 5 of deliverable D7.1 on "*Gender aspects in conservation and regulation of historic areas, disaster risk management, emergency protocols, post-disaster response techniques, and techniques for building back better*".

Following these guidelines, the data collection in ARCH HArIS has taken into account gender aspects (e.g. on population, social cohesion, etc.), so that gender differences can be considered in subsequent vulnerability analyses, where relevant.

1.3. Structure of this report

The report is divided in six sections:

- Following this introduction, **Section 2** provides the background on information systems and outlines the references for data collection aimed at analysing the vulnerabilities envisaged in WP5
- **Section 3** describes the structure of the relational database for storing data and information about heritage assets, detail on the single fields is reported in Annex 8.2.2
- **Section 4** offers an overview about the functionalities of the three web-tools designed and developed to allow viewing and querying dataset in HArIS: the GIS dashboards, the electronic sheets for the heritage assets and the viewer for three-dimensional models - a quick operational guide is provided
- **Section 5** describes the methodology developed for automated acquisition of 3D models from automatically operated drones, followed by automated 3D model creation, leading to the Machine Learning processing of information for automated analysis and detection of structural and material degradations, employing neural-network co-processing
- **Section 6** reports the main findings related to the Task 4.2

Bibliographic references (**Section 7**) and annexes (**Section 8**) are reported at the end of the document.

2. References for data collection to feed HArIS

2.1. Background on the information systems

The Historical Areas Information System (HArIS) and the Threats and Hazards Information System (THIS) are the two information systems provided by the ARCH project: the first is developed to capture the characteristics of the historic areas; whereas, the second one is oriented to the collection of information and data to quantify indicators related to the hazards affecting the same areas. The two information systems have the same concept and are integrated between them. However, the databases are specifically designed to allow the storage and management of the different types of information.

The mission of HArIS was described in the *D7.4 - Requirements description*, it will enable the Decision Support System and end-users to access geo-referenced information about historic and current conditions of historic areas. The strategy chosen to implement the information systems and integrate these in ARCH platform is also described in *D7.5 Interface specification and system architecture*. The information systems are based on the service-oriented architecture (SOA), that defines a way to make software components reusable via service interfaces. The interfaces are based on common protocols and methods in such a way that they can be easily incorporated into new applications without having to perform deep integration, this turns in a reduction in software implementation.

To this end, the key elements of the service-oriented approach are:

- integration of existing services and the reusability of those developed, that are useful to meet needs, constraints, configurations and objectives;
- flexibility in adapting the configuration of the services, also to improve the existing ones in order to improve performance, functionalities, way to access it, etc.;
- composition of (distributed) services to create new value-added services, providing high-quality, and better performance capabilities.

In this framework, the integration of the HArIS components has been designed with the main objective of implementing a flexible and interoperable information system, also considering the reuse of the components and the integration of simple services to obtain more complex ones, without requiring changes in the general logic of the system. This methodology is also necessary with a view to creating information systems that make it possible to meet the different needs of the ARCH partner cities. The services use protocols that describe how it can send and parse data and messages. All HArIS components were properly tested prior to release. However, further evaluations will be carried out during the next project months as part of ARCH Task 7.7 "*Continuous system integration and validation*", taking into account the observations following validation of use cases by the technical partners, the partner cities with their stakeholders, as well as incorporating any corrective actions that might be identified.

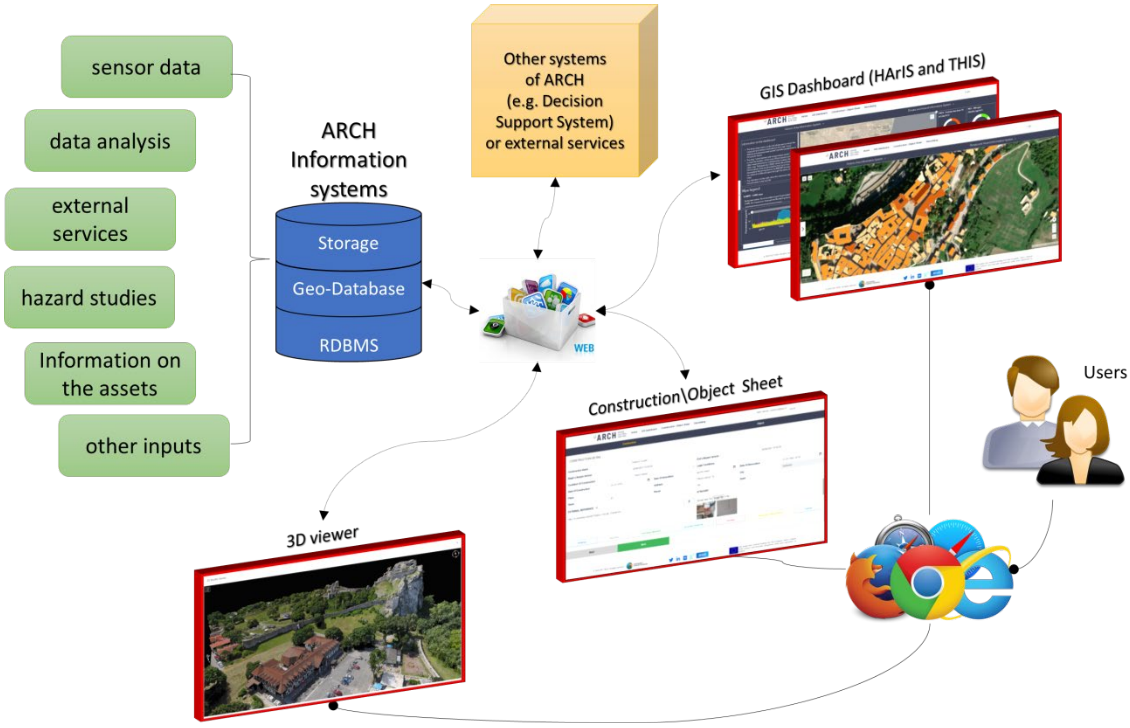

Figure 2: Functional schema of the ARCH information systems: : data sources (green boxes), relational databases, repositories and management services (blue cylinders), data consumers (yellow cube), tools to access data via WEB (red panels).

As shown in Figure 2 the HArIS systems can be fed by several different data sources:

- sensors for recording physical parameters
- collection of information from end-users in unstructured form
- data analysis by producing processed information
- external services to include data already available in other systems
- web-input to allow direct data entry by authorized persons

The symbols in Figure 2 indicate data sources in green, components of the relational database and repository in blue, data consumers in red and tools accessing data via WEB interface represented as panels.

Specific service connectors have been developed for external data-providers, taking into account different transmission protocols and update intervals (e. g. 24/7 for earthquakes, one or more times per day for environmental parameters and air pollutants, occasionally for existing hazard maps), to receive and pre-process (automatically or manually) data before storing it. With this purpose, the storage repository and relational geodatabase were designed and built to structure the data.

A Relational Database Management System (RDBMS) is responsible for storing and reading data from the databases as requested by other software components. The physical storage makes use of several proprietary components such as Microsoft SQL Server, ArcGIS for Desktop and ArcGIS Server. Simple tables and well-defined attribute types are the key elements to store the schema, rule, base, and spatial attribute data for each geographic dataset. This approach provides a formal model for storing and working with the acquired data. Following this approach, structured query language (SQL) has been used to create, modify, and query tables and their data elements. The schema includes the definitions, integrity rules, and behaviour for each geographic dataset, including properties for feature classes, topologies, networks, raster catalogues, relationships, domains. In particular, the integrity and behaviour of the geographic information are defined in a collection of meta-tables in RDBMS.

The software logic adopted for the information systems allows to access and work with a variety of geographic data in different file formats, including shapefiles, computer-aided drafting files, irregular triangulated networks, grids, images, geographic language mark-up files, and numerous other GIS data sources. Furthermore, the ArcGIS applications are used to have a transaction model for managing GIS data workflows.

The core of the system is composed of middleware, applications, and processing tools. Essentially functioning as a hidden translation layer, middleware enables communication and data management for distributed applications. The database middleware and application server middleware permit the communication among the applications using messaging frameworks such as simple object access protocol (SOAP), web services, representational state transfer (REST) and JavaScript object notation (JSON). In particular, the system can manage different information needs to be communicated, which include security authentication, transaction management, message queues, applications servers, web servers and directories.

> Web site to reach web-tools of HArIS:
>
> *http://www.cs.ingv.it/archportal*

The hardware and software components of the information systems are implemented and hosted on servers at the Laboratory of Cultural Heritage at the INGV headquarters in Rende (CS), Italy. The portal of the information system is currently reachable at the web address shown in the blue box.

More details about the structure of the information systems and relationships with the other technological systems of the ARCH project can be found in D7.5 “*Interface specification and system architecture*”.

2.2. Data collection

The concept of historic area (HA), as defined in ARCH expands the concept of Historic Urban Landscape (HUL), as defined by UNESCO in 2011, recognizes the dynamic, complex, and interconnected nature if HAs that include diverse social, functional, and economic features. In fact, the exposed elements are intended as people, ecosystems, environmental services and resources, structure and infrastructure, as well as economic, social and cultural assets, which could be adversely affected by climate change and natural hazards [1]. Therefore, the geo-located datasets to characterize the exposed elements of the HAs are taken into consideration in HArIS. In particular, the following elements and features, among others, are analysed: the hydrological and natural systems; the built environment, including its infrastructures; the land use patterns and spatial organization of natural landscapes; the perceptions and visual relationships of the urban landscapes; the people distribution; the social and educative systems; the elements belonging the cultural heritage. Social and cultural practices and values, economic processes and intangible dimensions of heritage in relation to diversity and identity should also be considered.

The historic areas can be viewed as a complex social-ecological system (SES) of people and nature, emphasising that humans must be seen as a part of, not apart from, nature. SES science provides a theoretical framework that conceptualises the environment as an open system consisting of ecological and social processes and domains (cf. Figure 3).

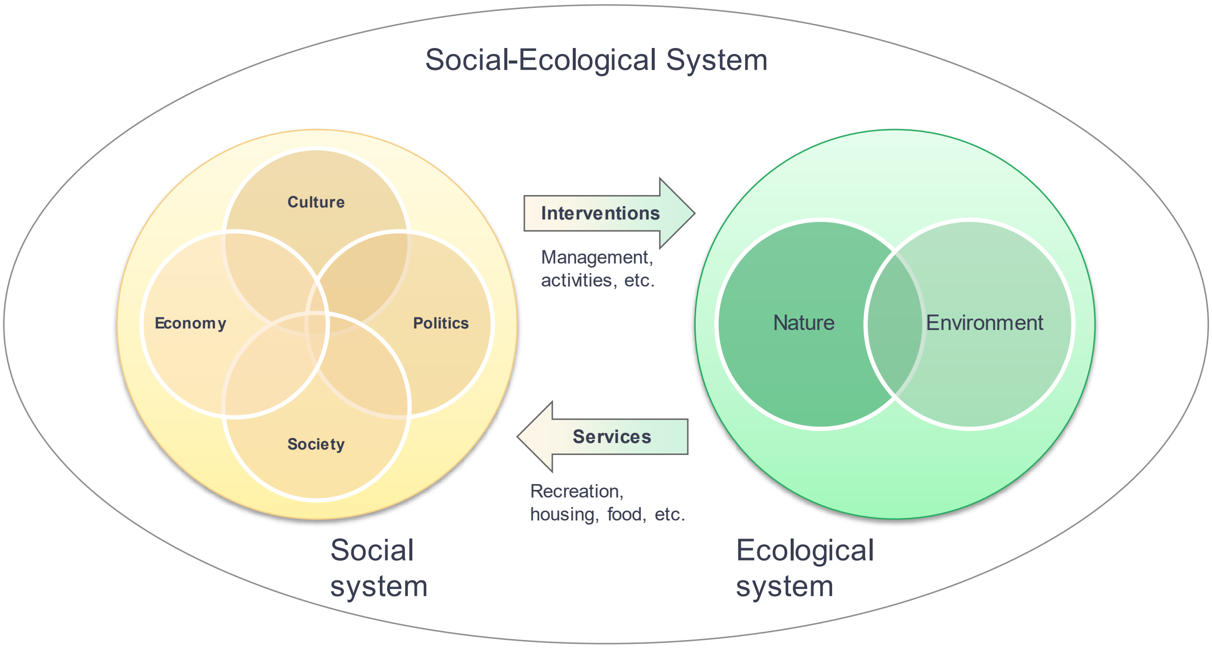

Figure 3: Domains of the Social-Ecological System (adopted from [2] and [3]).

Within a SES, resilience and transdisciplinary concepts are used to frame and influence the integration between social and ecological processes ([2]). Going further, historic areas do not exist on their own, but are embedded in the larger urban area, i.e. historic areas are not just social-ecological systems themselves but are also part of larger social-ecological systems (being this a city, a region, or a larger territorial entity) [4].In this context, the main domains composing the SES have been analysed and georeferenced data and information have been structured in HArIS database. Dataset were collected in HArIS with reference to the domains in Figure 3, which we were able to characterise through geo-localized information. These datasets related to the different historic areas (a summary table is given in Annex 8.1) have been obtained combining different data-providers (such as Open Street Map[1] and Copernicus Land Monitoring Service[2]) or directly involving the partner cities and by consulting the city or national web-portals (cf. Table 1)

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1 https://www.openstreetmap.org/
2 https://land.copernicus.eu/

Table 1: Local WEB portals consulted to obtain useful data for the characterization of the ARCH pilot sites

City	Web-portal	Link
Bratislava	Open Data Bratislava	https://opendata.bratislava.sk/
	Bratislava Map Portal	https://mapy.bratislava.sk/
Camerino	Instituto Nazionale di Statistica (ISTAT)	https://www.istat.it/en/
Hamburg	Hamburg Geo-Portal	https://geoportal-hamburg.de/geo-online/
Valencia	Ajunamente De València Geoportal	https://geoportal.valencia.es/home/
	Geoportal de la Infraestructura Valenciana de Datos Espaciales	https://visor.gva.es/visor/

The main purpose of the data research is to offer elements allowing for the assessment of Key Performance Indicators (KPI). In fact, HArIS is capable to transfer to the ARCH DSS data collected and required for that assessment: i.e. population data (e.g. gender, age, occupation, ethnicity, etc.); location and basic information on critical infrastructures (e.g. transport systems network), strategic buildings (e.g. like hospitals, schools, museums, etc.); hydrological and natural systems (e.g. like waterways, lakes, type of vegetation); position and characterization of the cultural heritage assets; economic data such as number and type of activities, organizations and small-medium enterprises, as well as employed population in occupations. With reference to the domains identified by the SES, the georeferenced layers on the urban scale currently included in HArIS are illustrated in subsections 2.2.1-2.2.3. Moreover, the database, specifically designed to structure and manage the information on the cultural heritage assets, is described in the section 3.

2.2.1. Natural and built environment at urban\local scale

In the framework previously proposed, data have been collected to characterise the natural and built environment in the urban context where the historic areas have been included. In addition, the elements within such local areas were characterised through data and information at building and object scale.

In particular, the following domains have been examined:

- **Natural environment**: the natural features consisting of physical (e.g. water and waterways as in Figure 4) and biological formations; geological and physiographical formations (e.g. geological setting as in Figure 5); natural sites (e.g. vegetation as in Figure 6) or precisely delineated natural areas;

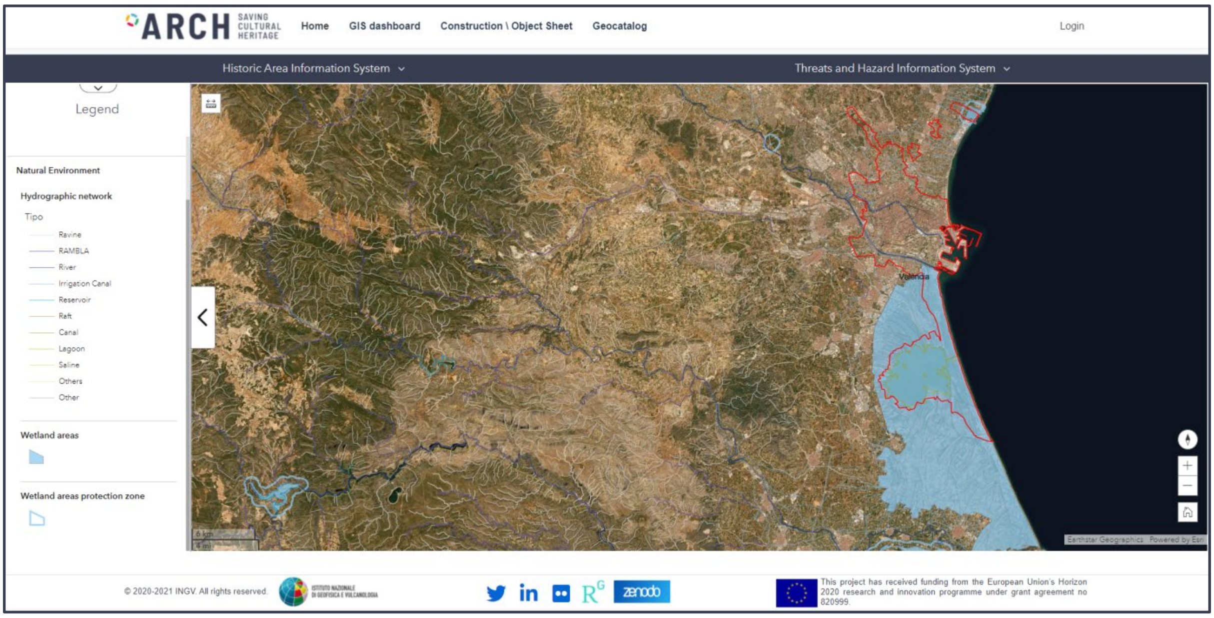

Figure 4: Hydrographic network and wetlands in the area of Valencia

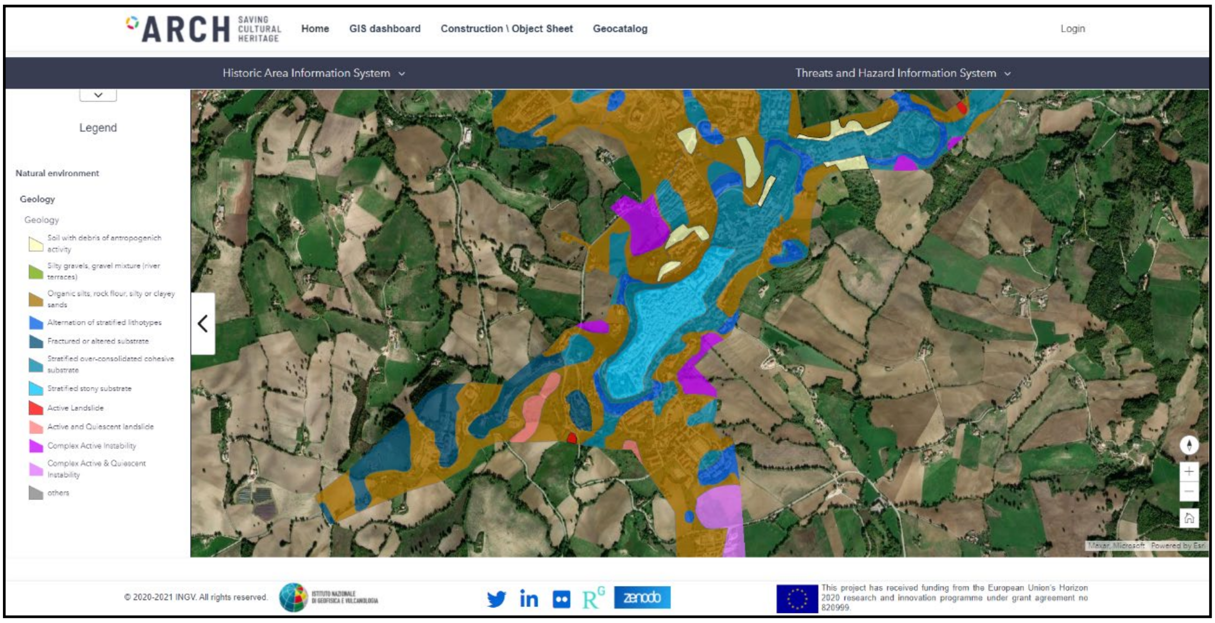

Figure 5 Geological setting of the area around the historic centre of Camerino

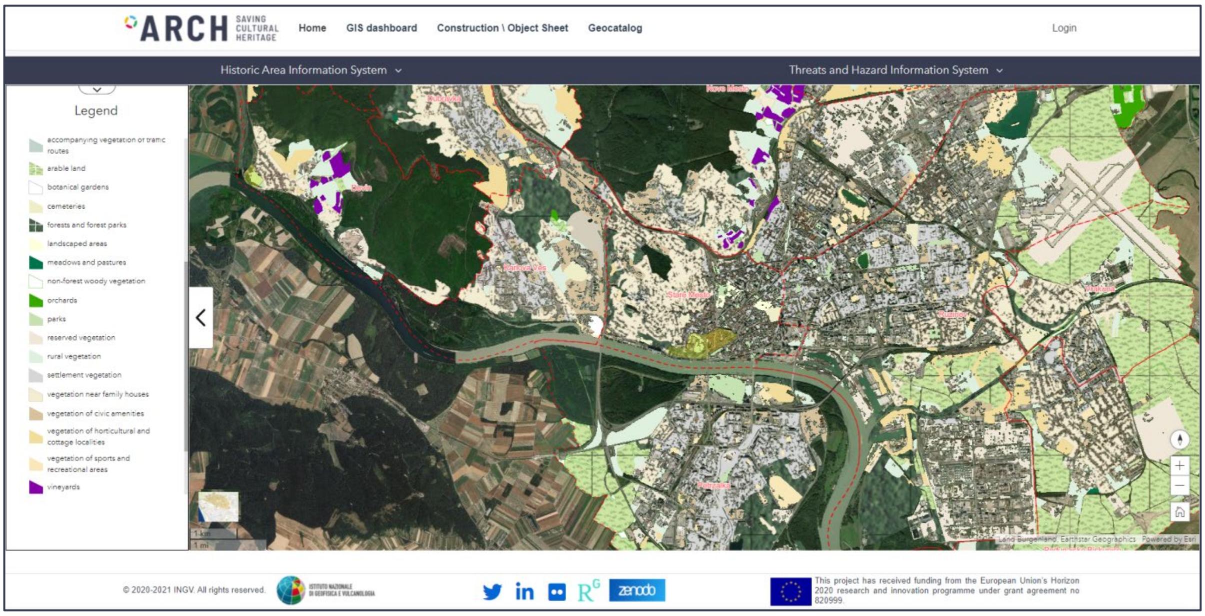

Figure 6: Characteristics of the vegetation in the urban area of Bratislava

- **Built environment** as set and configuration of physical infrastructure (e.g. roads and railways in Figure 7), transport and constructions (e.g. buildings in Figure 8);

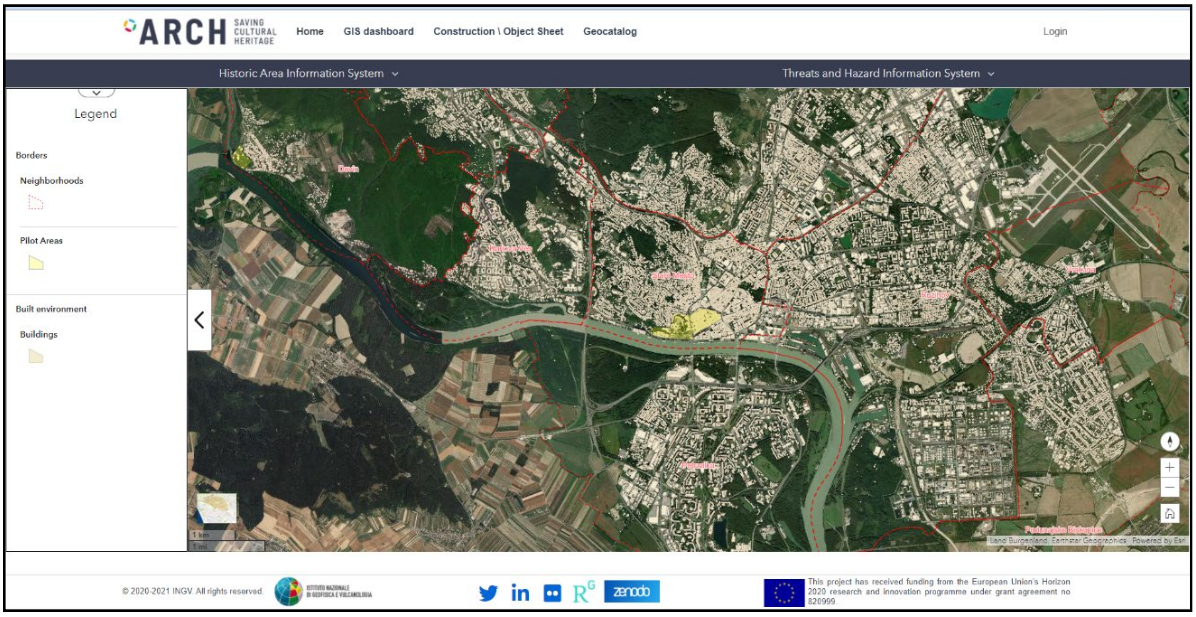

Figure 7: Road communication infrastructure in the urban area of Bratislava

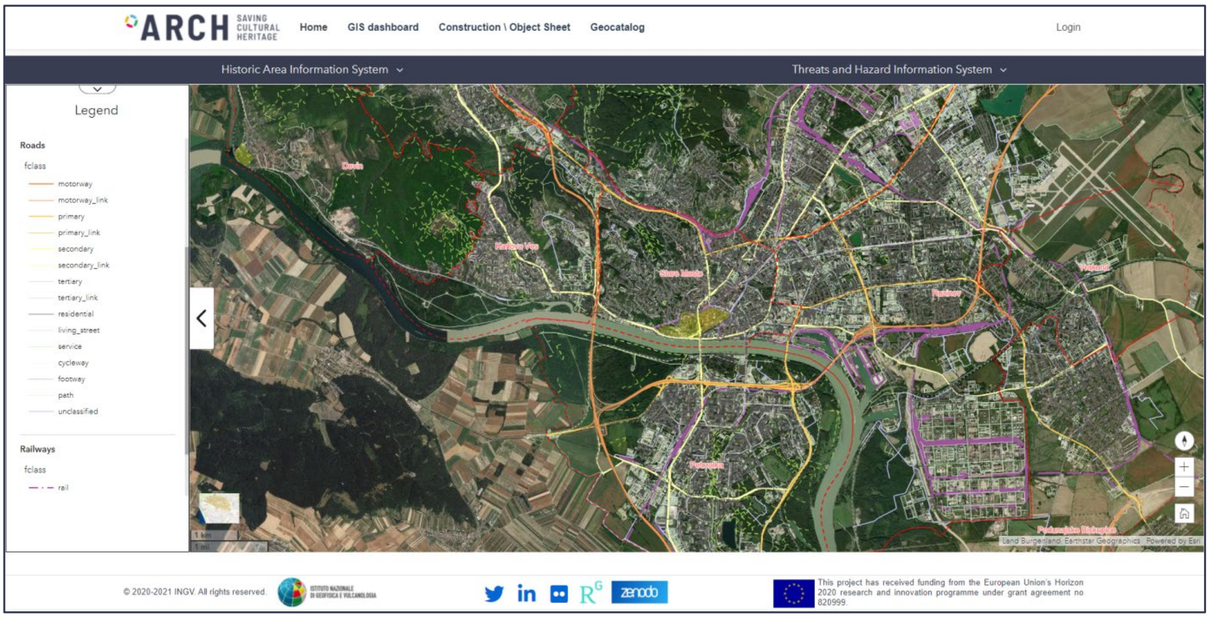

Figure 8: Buildings layer in the urban area of Bratislava

- **Elements of (tangible) cultural heritage** that includes structures and historic places (Figure 9), monuments, artefacts, etc., which are considered worthy of preservation for the future. Since ARCH is mainly focusses on physical heritage, some intangible heritage is also considered, in the form of objects, artefacts and cultural spaces that are associated with practices, representations, expressions, knowledge and skills, which communities, groups and individuals consider also as part of their cultural heritage.

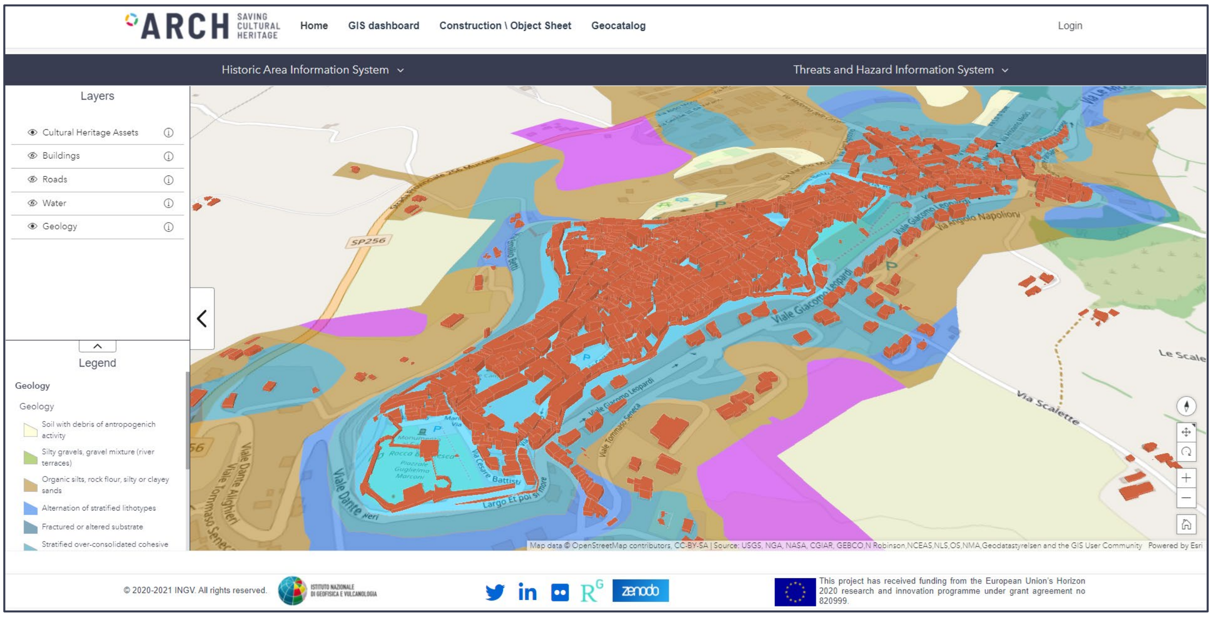

Figure 9: Elements of the cultural heritage in the historic centre of Camerino

2.2.2. Data collection at Cultural Heritage building scale

This subsection is an overview of the data useful to assess the physical vulnerability of exposed elements, also it depending on the hazard. This has represented the guide to the search of the datasets to be collected in HArIS, in order to characterise the vulnerability of cultural heritage assets, providing, in any case, the possibility to include\change information over time. In particular, the hazards in the Table 2 are those that emerged as the most significant from the co-creation process between the technical partners and the cities. The datasets are reported in the Table 2 distinguishing between:

- **Needed data** – those that are necessary to calculate the Vulnerability Index[3] - ;
- **Useful data** – those that are useful to improve the assessment of the Vulnerability Index, which is in any case attributed on the basis of previous data ;
- **Negligible data** – those that allow to further detail the Vulnerability Index, but have a lower weight than the previous ones.

Table 2: Exposed elements to characterise the physical vulnerability with reference to the hazard

Vulnerability factors	Hazards				
	Earthquake	Pluvial\fluvial flooding	Ground instability (subsidence, erosion)	Extreme temperatures	Pollutants
Material and type of the main vertical structural system	**Needed**	Useful	**Needed**	**Needed**	**Needed**
Material and type of the horizontal structural systems: slabs and Roof system	Useful	Useful	Negligible	Useful	Negligible
Material and type of Foundation	Useful	Useful	**Needed**	Useful	Negligible
Construction year (or design code adopted if any)	**Needed**	Useful	Useful	Useful	Useful
Number of floors	**Needed**	**Needed**	Useful	Useful	Useful
Geometrical features	Useful	Negligible	Useful	Useful	Negligible
Interventions on structural system Changes of use or change to the original structural systems (e.g. opening, superimposed floors)	Useful	Useful	Useful	Negligible	Negligible
Quality of Materials	Useful	Useful	Useful	Useful	Useful
State of preservation	Useful	Useful	Useful	Useful	Useful

[3] Vulnerability index: A metric characterizing the vulnerability of a system [1].

Further data that might be peculiar for the vulnerability assessment of a certain hazard are listed in the following sections hazard by hazard.

2.2.2.1. Data for Seismic Vulnerability assessment

The seismic vulnerability of CH items within the historic area, belonging to the Category "Building and Structures" (pages 6-7 in [5], [6]) is performed according to the so-called Microseismical-Mechanical cross-calibrated Method (cf. [7], [8]) that allows for the seismic vulnerability assessment of a differently numerous sets of buildings, from group of buildings, statistically aggregated in a geographical unit, up to single building. According to [6] the seismic vulnerability of single buildings or group of buildings is measured in terms of both a vulnerability index, V, and a ductility index, Q.

As far as single buildings are concerned the vulnerability index V is attributed by considering how different building types (e.g. masonry buildings, reinforce concrete building or timber) might have a different seismic performance and how further constructive or geometric peculiarities of the buildings (such as state of maintenance; plane and vertical regularity the presence of specific constructive, such features like tie-roads) might modify it.

Vulnerability Factors:

- Anti-seismic vernacular devices (e.g. Tie-rods, buttresses, strong wall to wall connection and, horizontal to vertical floor connections, diatonic in leaf walls)
- Characteristics of the foundation site
- Position of the building in the aggregate
- Differences between adjacent buildings (height, discontinuity)

2.2.2.2. Data for assessing Vulnerability to pluvial\fluvial flooding

Damages due to (pluvial and fluvial) flood events can be particularly severe as historic structures are most commonly composed of absorbent building materials, often compromised by age and condition of preservation, which are susceptible to decay and damage as a result of moisture ingress [9]. Therefore, to evaluate the Vulnerability index it would be very useful to know the number of underground floors. This index can be used with the fragility curves, which have been derived at the scale of individual building typology (e.g. [9]-[11]), in order to assess the damage level as function of the flood depth levels.

Vulnerability Factor:

- Presence of underground floors

2.2.2.3. Data for assessing the Vulnerability to subsidence

The cause-effect relationships between building damage severity and Subsidence-Related Intensity (SRI) parameters can be investigated using a probabilistic approach based on empirical or analytical fragility curves [12] and [13]. An application of this methodology is reported in [14].

Vulnerability Factor:

- Characteristics of the foundation site

2.2.2.4. Data for assessing the Vulnerability to extreme temperature and pollutants

Models (dose-response functions) and experimental studies available in literature are able to estimate the damage of a material according to meteorological (e.g. rainfall) and climatic parameters (e.g. temperature) and concentrations of pollutants involved in degradation processes (e.g. [15], [16] and [17] for stone materials; [18], [19] and [20] for blackening of the surface). The dose-response functions, generally expressed in terms of loss material per year, are usually used for the quantification of the degradation of materials that constitute cultural assets [21].

In addition other data regarding vulnerability to the extreme temperature can be related to the heat storage [22] and the morphological peculiarity (e.g. so-called urban canyon) [23]

Vulnerability Factors:

- Material of building façades
- Sky view factor
- Site morphology

2.2.3. Socio-economic domains

The table below reports the main elements (belonging to the different dimensions of HAs, e.g. economic and social domains) for which data (and related attributes) have been analysed and, where available, collated in HArIS to enable the assessment of the exposed elements and their vulnerability. To be highlighted that the aggregation and the spatial distribution of the data often depend on the statistical services which provide them.

The available data are collected either as aggregated data (e.g. percentage % of population in different age ranges) or as disaggregated data (e.g. number # of people in an age range disaggregated by gender) depending on the availability.

Table 3: Exposed elements to characterise the social-economic vulnerability

Vulnerability Factor	Element	Attribute
	Local Population	
Social Structure	Foreigners	Age, gender, ethnicity, education, disability marriage status, their total population and/or its percentage, social participation as volunteers.
	Tourists	
Economic Status	Local population	Income, unemployment\employment status, Insurance, poverty
	Organisations	Sectors, activities, employees, revenue
	Schools	
	Hospital and health system	
Community	Other public facilities (churches, museums, theatres, galleries, cinemas, live musical, etc.)	Number, level, surface occupied, etc.
	Historical and cultural parks	
	Emergency services	

2.2.3.1. Data to assess social indicators

Population and demographic data that describe and differentiate a local community have been collected in HArIS aiming to allow the characterisation of social indicators identified in the international literature. In particular for the society characterization data has been collected to evaluate community well-being, demography (Figure 10), social cohesion and welfare, education (Figure 11), recreational, cultural and tourist places.

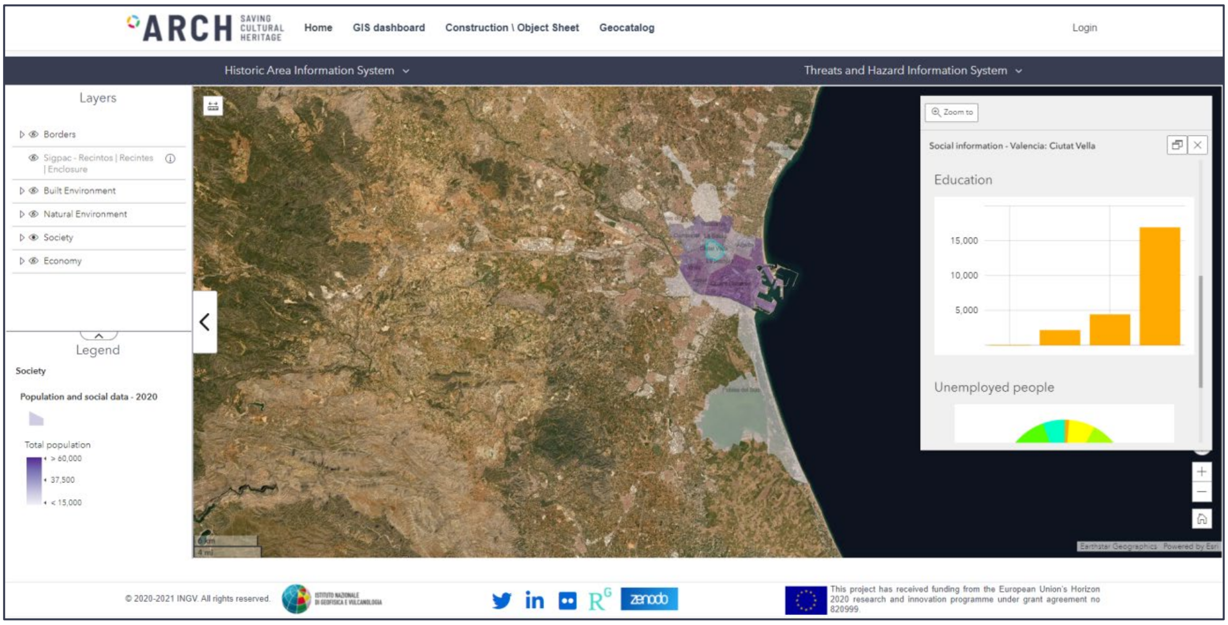

Figure 10: Total population statistics relating to districts of Valencia

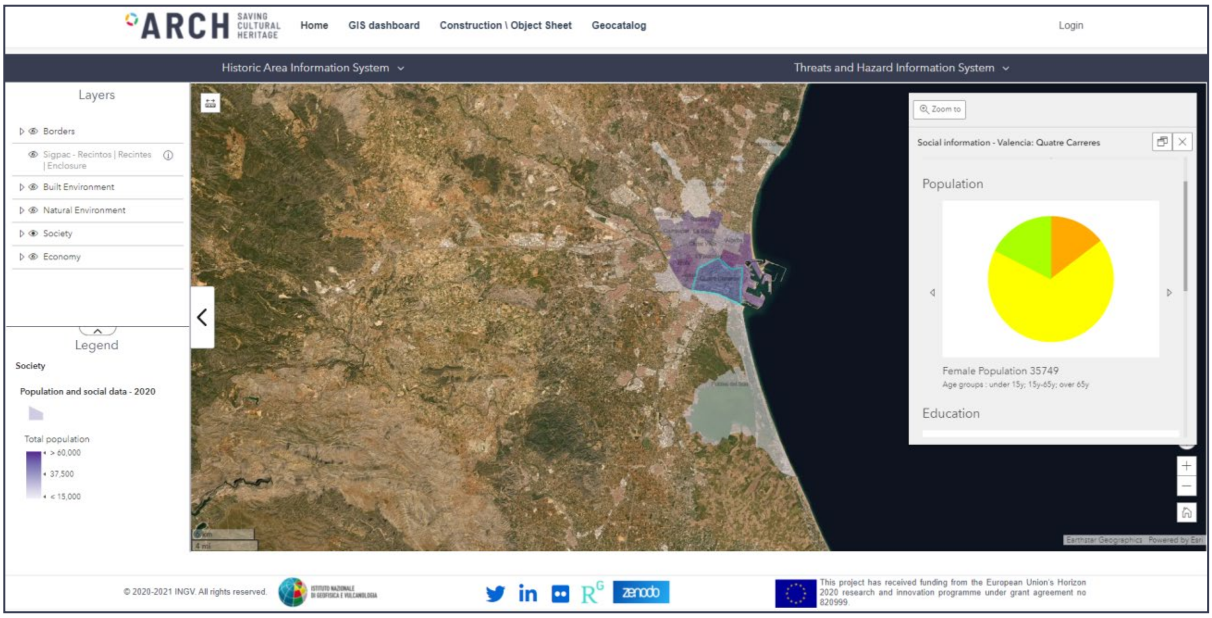

Figure 11: Education level and unemployment statistics related to districts of Valencia

2.2.3.2. Data to assess economic indicators

Data has been collected in HArIS also to characterise the economic sectors: primary (forestry, agriculture, etc.), secondary (manufacturing) (Figure 12) and tertiary (services) (e.g. Figure 13). Moreover, land use\land cover products have been included in the information system (Figure 14), in order to identify the functional use of the areas.

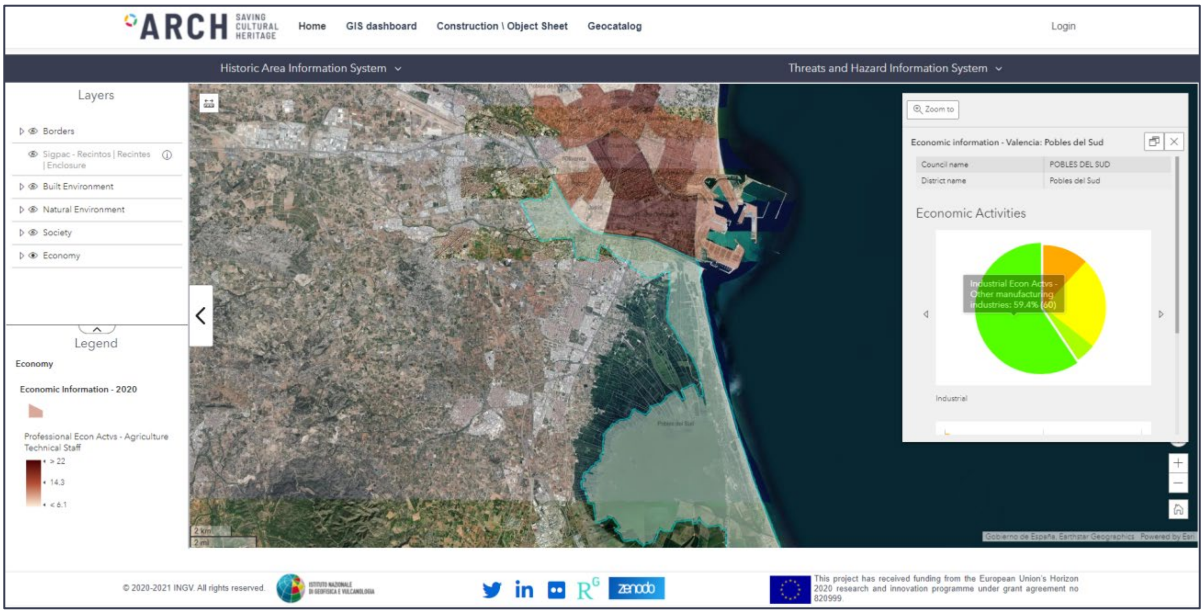

Figure 12: Commercial activities statistics concerning Valencia areas

As for the sector classification, different countries uses different classification systems, e.g. Italian National Institute of Statistics (ISTAT) in Italy adopts Italian Classification of Economic

Activity (ATECO)[4], whereas economic indicators from Agenda2030|Cultures[5] refers to the International Standard Industrial Classification of Economic Activities (ISIC) and International Standard Classification of Occupations (ISCO), therefore the preference in ARCH will be to harmonise national classifications to the international standards adopted by Agenda2030|Cultures, so that data and assessment done in terms of economic indicators can be comparable. This can be done by mapping the correspondence between the national classifications (e.g. ATECO for Italy) and the aforementioned ISIC and ISCO international classification.

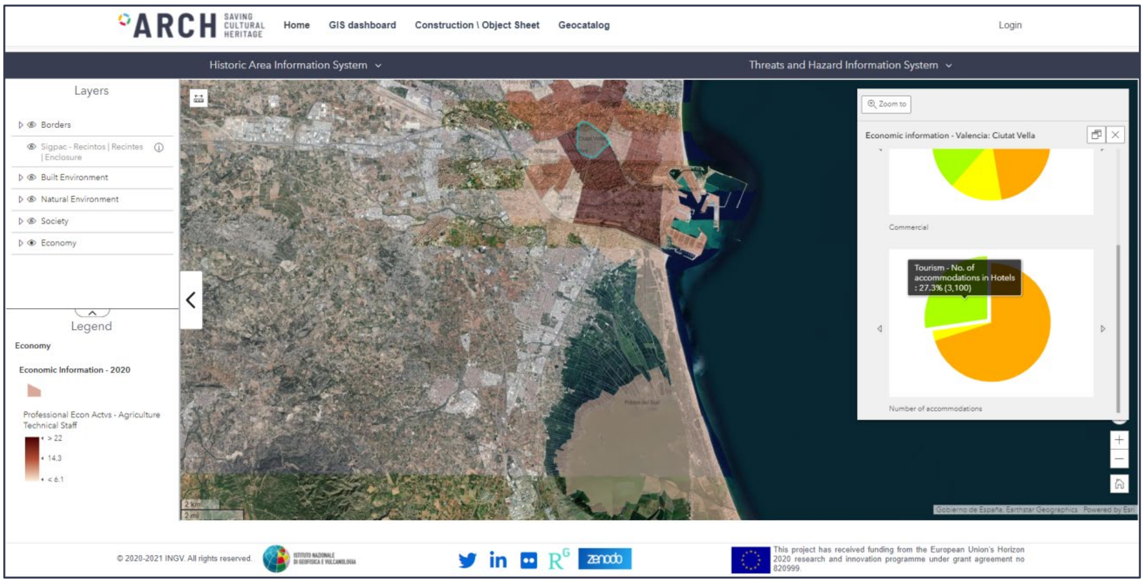

Figure 13: Number of hotels bookings statistics concerning Valencia areas

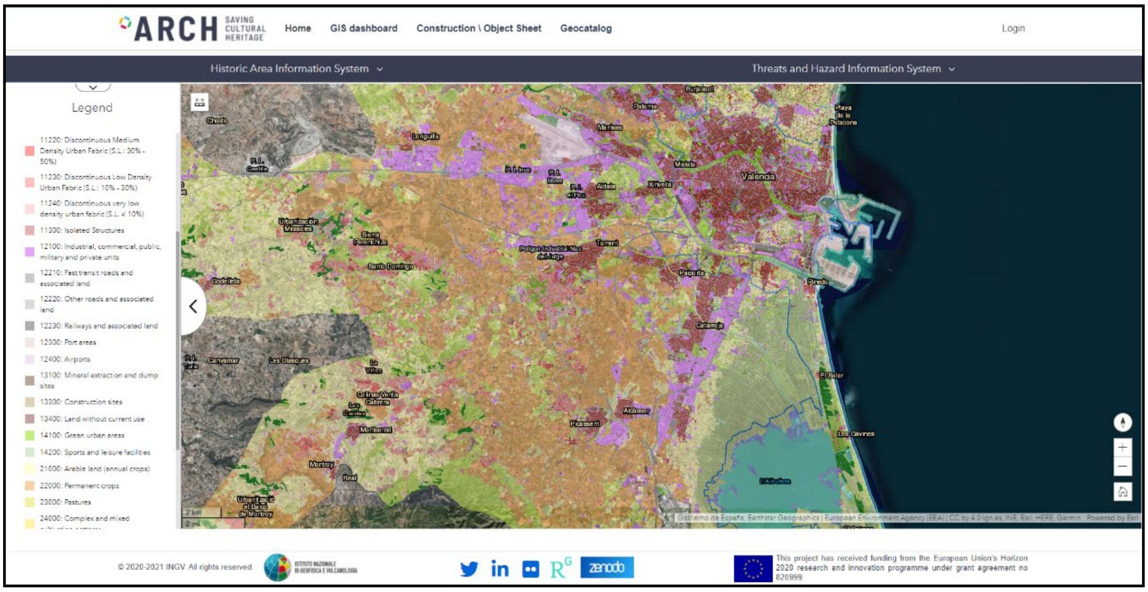

Figure 14: Land Use and Land Cover in HArIS from Copernicus Land Monitoring Services for Valencia areas.

4 https://www.istat.it/en/methods-and-tools/classifications
5 https://whc.unesco.org/en/culture2030indicators/

2.2.3.3. Data to assess the strategic facilities for the community

In practice, schools, hospitals, and other emergency services are considered strategic and essential elements for the community, e.g. when examining the Emergency Limit Condition (ELC)[6]. By definition, the ELC represents the limit condition for which, after the seismic event, an urban settlement loses all its functions (including residence) and preserves only the operation of most of the strategic functions for emergency management, their accessibility and connection with the territorial context. In general, strategic buildings, emergency areas, and the main links between the elements and the territorial context, as well as their interactions with the interfering elements, are identified [24]. However, the idea of ARCH is to include also the elements related to the cultural services (Figure 15), such as museums, cinemas, sport facilities, parks, etc., which should be of significant value in increasing community resilience; in fact, to better recover and reconstruct, the activities related to cultural elements should be considered essential.

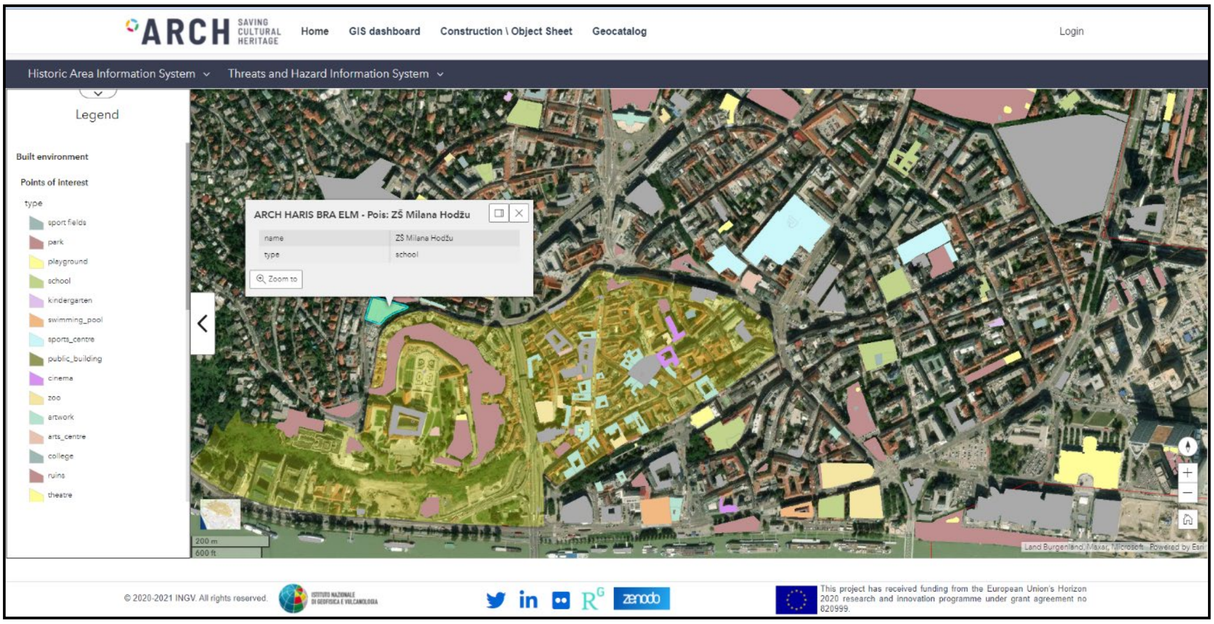

Figure 15: Elements to characterise the community (e.g. schools, parks, museums, etc.)

[6] Emergency Limit Condition (ELC) introduced by the Italian Government Ordinance (OPCM n. 4007/2012), in accordance with Law n. 77/2009.

3. Database of HArIS

To manage data related to the single assets of the cultural heritage, understood as constructions and objects - movable and immovable artefacts - in the HA, and also to make the authorised users able to update information over time, a specific database has been designed with the main purpose of structuring and storing data and information. In particular, starting from experience already accumulated within the ITA PON MASSIMO project[7], and also analysing similar products or procedures aimed to disaster prevention and risk management from previous EU projects (e.g. RESCult[8], HERACLES[9]), the database was built to acquire datasets collected by project partners or those already available at pilot cities and their stakeholders. The references to characterise geometry, nature and use of the construction are based on the technical guidelines and Unified Modelling Language (UML) provided by INSPIRE for buildings[10]. In addition, to guarantee the flexibility and interoperability with other potential systems, the database was designed to be modular, so any new fields of information could be included also later on. Moreover, some fields have been added, though data was not complete for selected buildings, to make authorised users able to include them as soon as available. In the following paragraphs, a database structure is described with reference to two parts characterising constructions and objects.

3.1. Database of the assets in the Historic Area

As mentioned in Section 2.1, HArIS and THIS have the same development concept and will be integrated with each other, so that users can easily access both, the tools that provide information on the elements of the historic area, and the ones relating to hazard indicators. However, the databases are specifically designed to allow the storage and management of the different types of information. The idea is that the databases must be dynamic components of the information systems, thus permitting the interaction from authorised people (technical partners or cities) to insert new available information (or make changes to already stored datasets). Therefore, a specific database has been designed with the main purpose to collect the datasets related to the heritage assets in the historic areas. Figure 16: shows the functional scheme of this database. The structure has been adapted in order to combine the need for structuring available data, arising from cities (or their stakeholders), and the requests for information, from technical partners, also taking into account that the datasets may be incomplete (information available only for some assets) or not currently available, but reachable over time. In addition, the structure of the single tables and the connections among them have been defined to make the collected information on the assets and objects in historical areas understandable.

Details about the tables and their specific fields are reported in the next subsections (3.1.1 and 3.1.2) and the Annex 8, respectively. The way on how to make changes or new insertions to datasets is reported in section 4.3. Wherever possible the constructions have

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7 PON MASSIMO project: https://ponmassimo.rm.ingv.it/portal
8 RESCult project: https://www.rescult-project.eu/publications-downloads/
9 HERACLES project: http://www.heracles-project.eu/
10 INSPIRE Data Specification on Buildings: https://inspire.ec.europa.eu/id/document/tg/bu

been identified by mean of the cadastral reference, and different types of information has been included: position and geometry; building nature and current use; structural characteristics; material properties; indices to characterise the architectural, historical, artistic, and social values. The functional scheme of the database is reported in Figure 16:and with constructions as blue boxes and objects as orange ones.

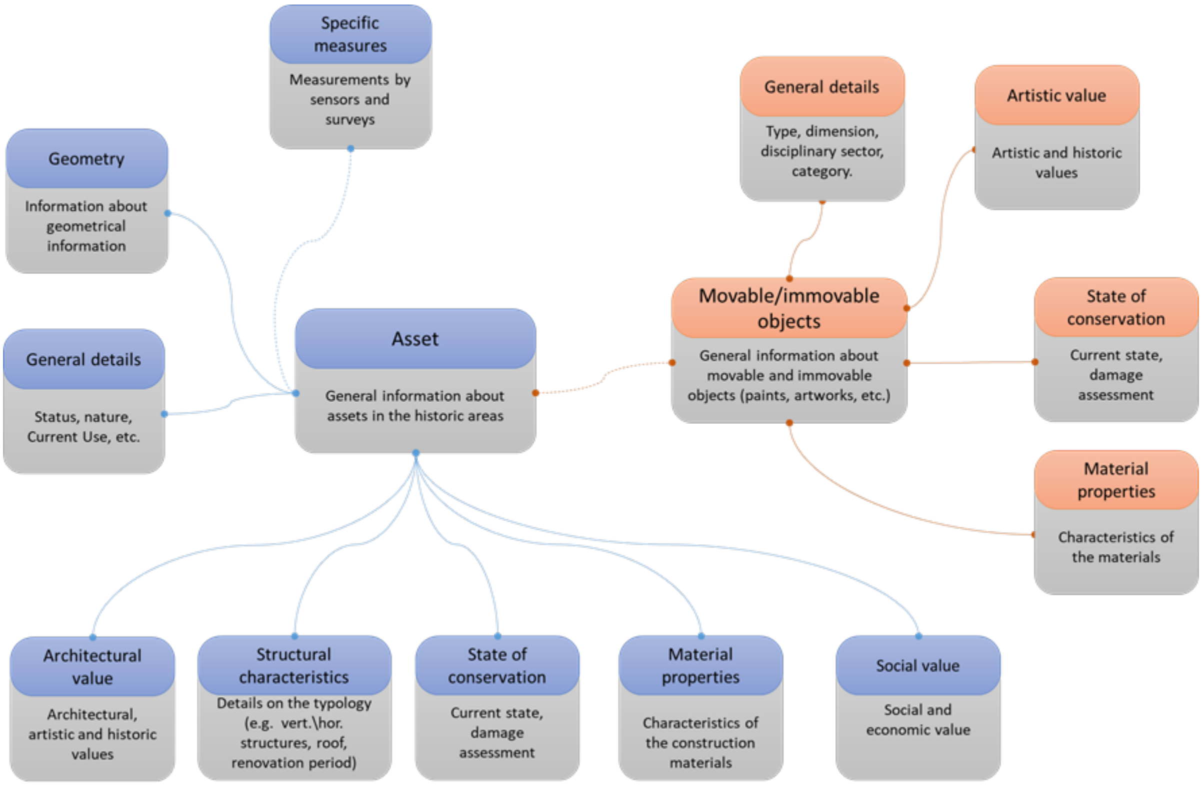


Figure 16: Functional scheme of the HArIS database for the characterization of the heritage assets.

The database has been filled for Camerino analysing the AeDES forms[11], used in Italy for damage assessment, short term countermeasures and evaluation of the post-earthquake usability of ordinary buildings, and the other surveys performed immediately after the 2016-2017 seismic sequence in Central Italy. In addition, a specific survey has been performed to characterise the wall structure of typical buildings in the historic centre (e.g. Figure 17). In fact, 44 wall panels were analysed. In the other cases, information to characterise the heritage assets is obtained directly by the partner cities or by consultation of the open city web-portals (cf. Table 6), also taking into account the specific hazards to be evaluated, as it emerged from the co-creation process.

Another specific section of the database was designed to characterise also the movable and immovable objects in the historic areas, with the possibility to store different type of information (cf. orange and grey boxes in Figure 16:): position and sizes, type of artwork, descriptive details, artistic value, state of conservation, material properties. Furthermore, an object can be directly linked to an asset, if the latter is also the hosting site of the artwork or a potential shelter during an emergency phase. In this case, specific data have been collected

[11] https://www.scribd.com/document/452060857/Scheda-AEDES-pdf

in particular for the case of Camerino from the involvement of the stakeholders responsible for the management of this type of assets. However, all cities will be able to change and insert new heritage objects and information will be automatically updated in the database for the vulnerability (and exposure) analyses.

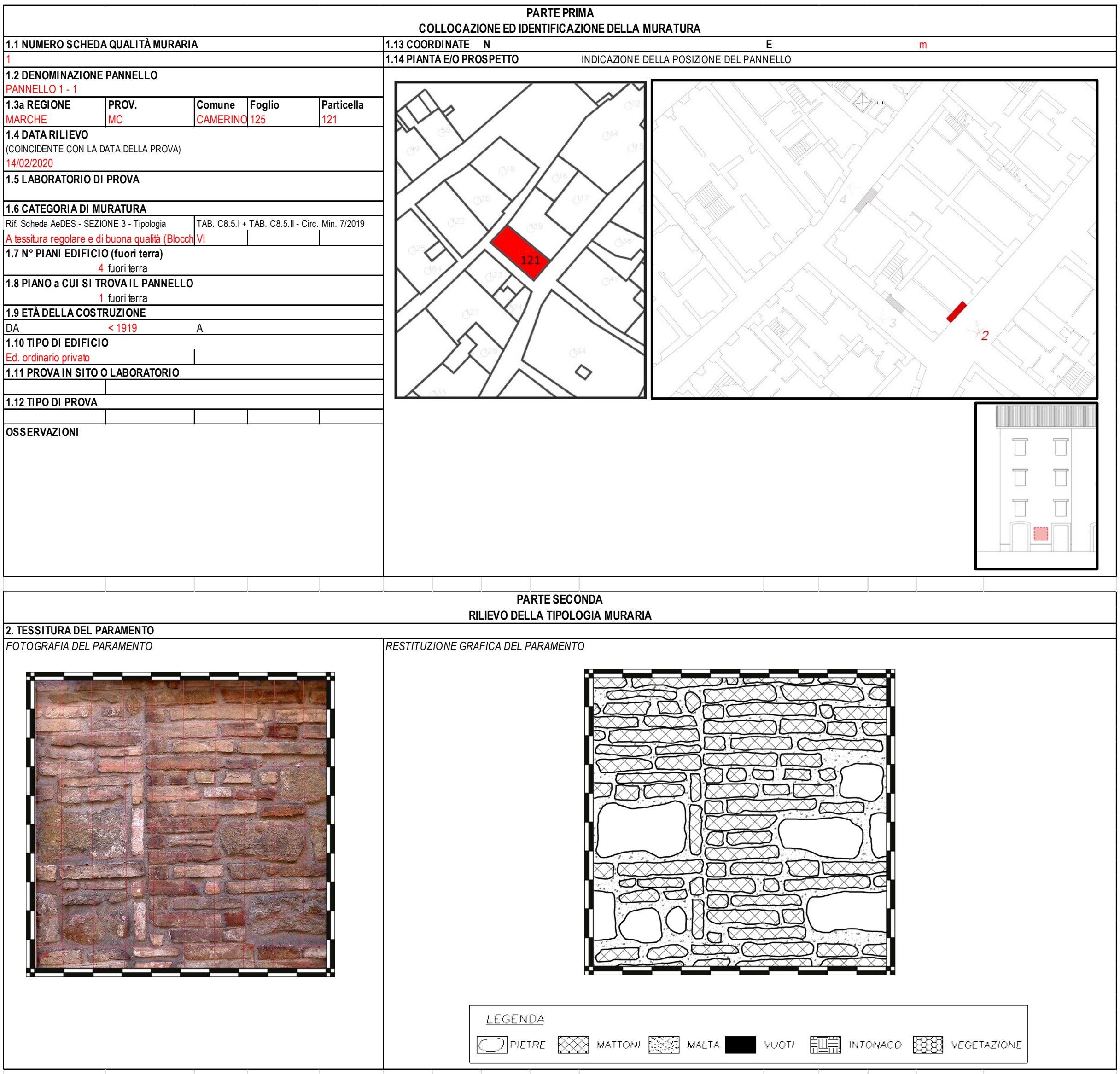


Figure 17: Extract from a survey report relating to the wall structure of the Camerino buildings

The data structure containing the main section that links to other related ones was designed to meet the demands from technical partners for being able to effectively analyse and manage information coming from cities partners. The tables were filled with the information already available from the partners or extracted and structured from existing dataset. Nevertheless, taking into account the dynamic nature of the information acquisition process (i.e. often datasets are not immediately available or, in any case, information is not homogeneous for all the heritage assets, moreover, some types of information could change over the time), the block structure has been defined to ensure a high degree of flexibility, with the possibility to choose if adding single fields to one of the tables or including another block without changing the overall structure. In practice, the same structure has been conceived for the assets and the objects allowing to connect them, as example if the assets are also the storage or exhibition area of the movable or immovable object (cf. Figure 18). The information about objects, as well as being a support to the management of these elements of the cultural heritage, has a direct impact on the assessment of the exposure to the risks.

3.1.1. Structure for the CONSTRUCTION database

The database for managing information about assets consists of different tables in order to group information related to the blocks in Figure 18. The CONSTRUCTION table represents the core (blue box in Figure 18), to which a single building or different parts of a building can be connected, and each of them can be characterised by a specific nature and a current use (orange boxes in Figure 18).

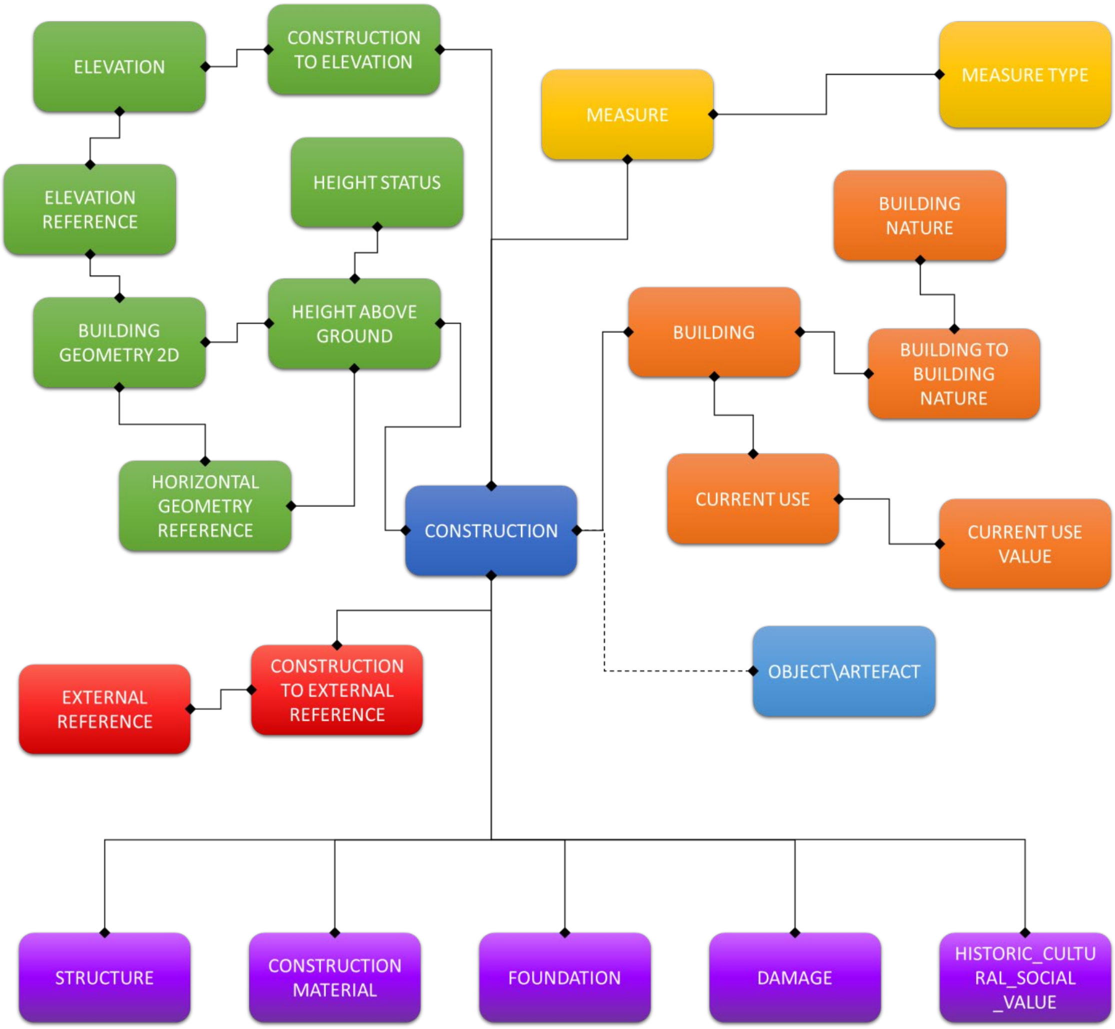


Figure 18: Structure of the database for the constructions in HArIS

The position, geometry and shape of the assets need to be assigned to each construction (green boxes in Figure 18). In addition, the characteristics of the asset can be stored with reference to the composition structural elements, construction materials, foundation and state of damage (purple boxes in Figure 18); moreover, coefficients can be assigned to represent the social, cultural and historical value of the assets, at least for those that make up the "identity of the Community" and that give a sense of belonging. In other words, these coefficients could be used to quantify the intangible values intrinsic to tangible assets, for example through the elaboration of interviews or questionnaires to people as is being done for the main assets in the HA of Camerino. To each construction it is possible to link external references (red boxes in Figure 18), such as images, technical drawings and any other associated information in digital form (e.g. models, BIM data, sensors, controllers etc.), as well as results of surveys and monitoring (yellow boxes in Figure 18) that can be reached by connecting to the elements, if they are stored in the information systems of ARCH or via external web links, if they are in an external repository. Finally, the asset can take on the function of container or shelter for movable/immovable objects; in that case it is possible to link it to the tables relating to the objects. Details on the fields contained in each table are reported and described in the Annex 8.2.1.

3.1.2. Structure for the OBJECT database

The Figure 19 shows the structure of the database to store information about movable\immovable objects in the historic areas. The characteristics of the objects, such as name, description, size, disciplinary sector, storage area, are included in the table OBJECT (cyan box in Figure 19). On the other hand, STORAGE_AREA identifies building hosting one or more heritage objects - (green box in Figure 19), if this is registered in the CONSTRUCTION table of the asset database (see previous sub-paragraph) or, in any case, the position of the object by latitude and longitude, if this is outdoors or stored on a site not already included in ARCH database. In addition, elements in STORAGE AREA can be identified also as shelter, in case the building is a temporary warehouse, so it is possible to identify location of the object also during an emergency phase. This could be also used to identify buildings that might be used e.g. as “cooling spaces” for people during a heatwave.

The movement of an object, due for example to an exhibition in another place or a religious function, is traceable through the EVENT table (purple box in Figure 19). Moreover, any action necessary to keep the object in good condition (e.g., repair, cleaning, etc.) can be reported in the INTERVENTION table (red box in Figure 19). Finally, any digital document or external reference on the web can be linked to one of the previous tables through the ATTACHMENT table (yellow box in Figure 19). Details about fields contained in each table are reported and described in Annex 8.2.2.

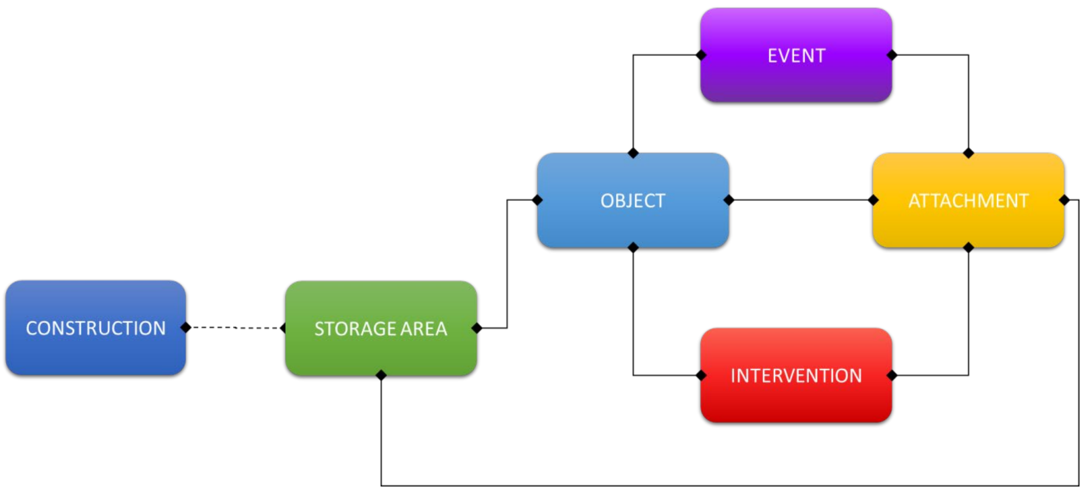


Figure 19 Structure of the database for the objects in HArIS

4. Web tools and operational guide

To make the data and information accessible to users, as already described in D7.5 *“Interface specification and system architecture“* and graphically reported in Figure 19, three tools have been developed:

- **GIS Dashboards** enabling users to obtain information by location-based analytics, using intuitive and interactive data and maps to be viewed on a single screen.
- **Building/Object Sheets** to query and visualise structured data included in the database, for example providing information about assets and objects in the historic areas; these web-sheets will be used also for editing and data entry performed by authorised users.
- **3D model viewer** to visualise the three-dimensional models of assets and objects, also enabling users to extract a subset of three-dimensional data.

Three tools are interconnected, such that the user can use the GIS dashboard to navigate different information levels and through links can get access to electronic sheets and the 3D viewer. The overall design of the information system platform of ARCH follows specific guidelines to allow an easy understanding for the users, and to facilitate the accessibility to all functionalities. The GUI is designed to be easy-to-use by non-expert users and users not familiar with GIS applications as it targets not only CH professionals, but also any employee that deals with the protection of the CH.

4.1. How to access information systems

In this section, these tools (version v1.2021) are presented and a quick user manual is illustrated. Currently, the landing page of the information systems (Figure 20) can be reached to the web link [http://www.cs.ingv.it/ARCHPortal/.](http://www.cs.ingv.it/ARCHPortal/)

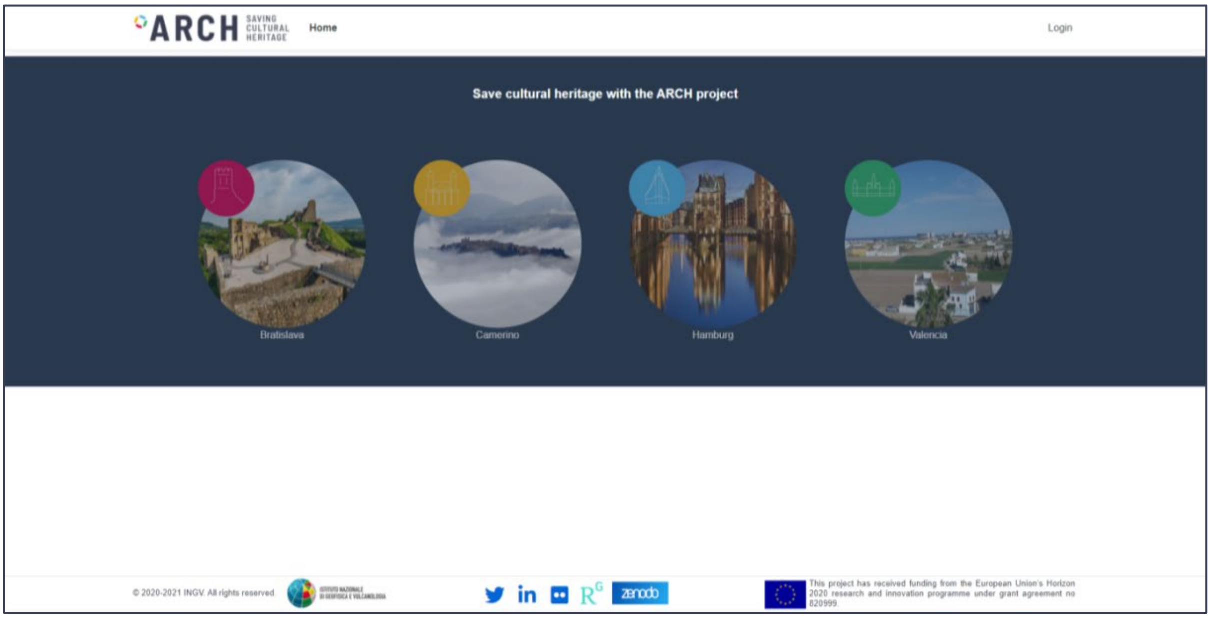


Figure 20: Front page of the Information System platform

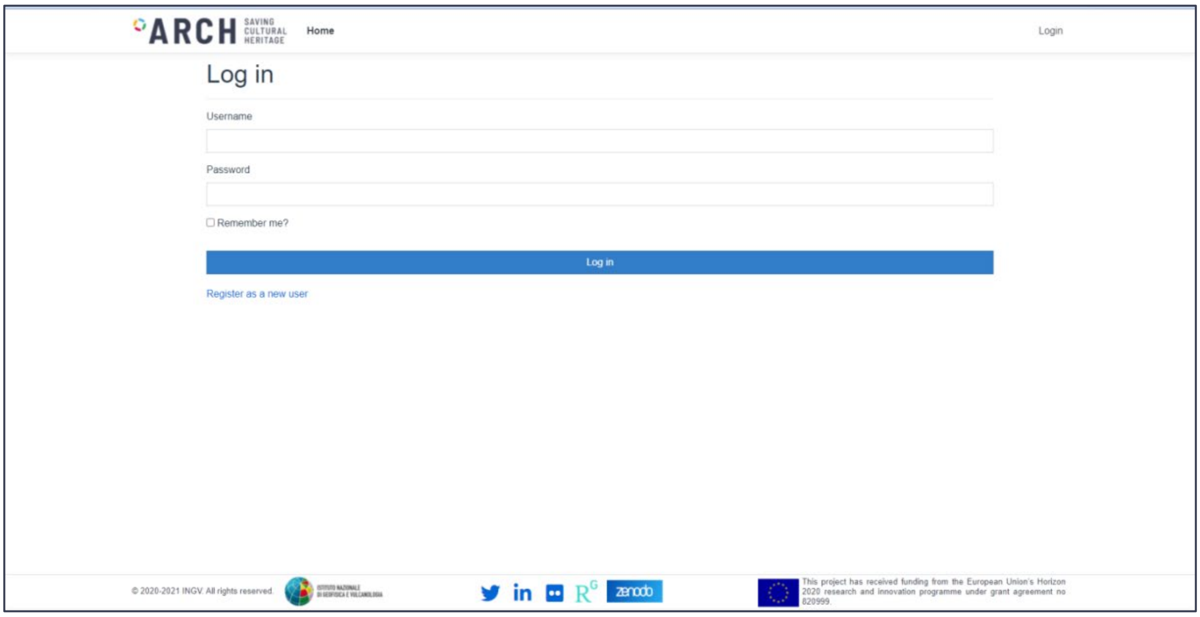


Figure 21: Login to the information systems

After clicking on the button at the top right in the landing page, the user can login (Figure 21), if registered, otherwise she\he can request the registration of a new account (Figure 22), that will be managed by INGV before granting it. This control process is necessary as the authorised user has access to all functionalities; with the possibility also of modifying information concerning the assets of her\his own historical area. However, the unregistered user can have access in consultation mode to all public information contained in the systems.

Currently all pages in HArIS are available without registration, and the login is used only to modify the information; however, specific details on the assets may later be made available only after the user registration.

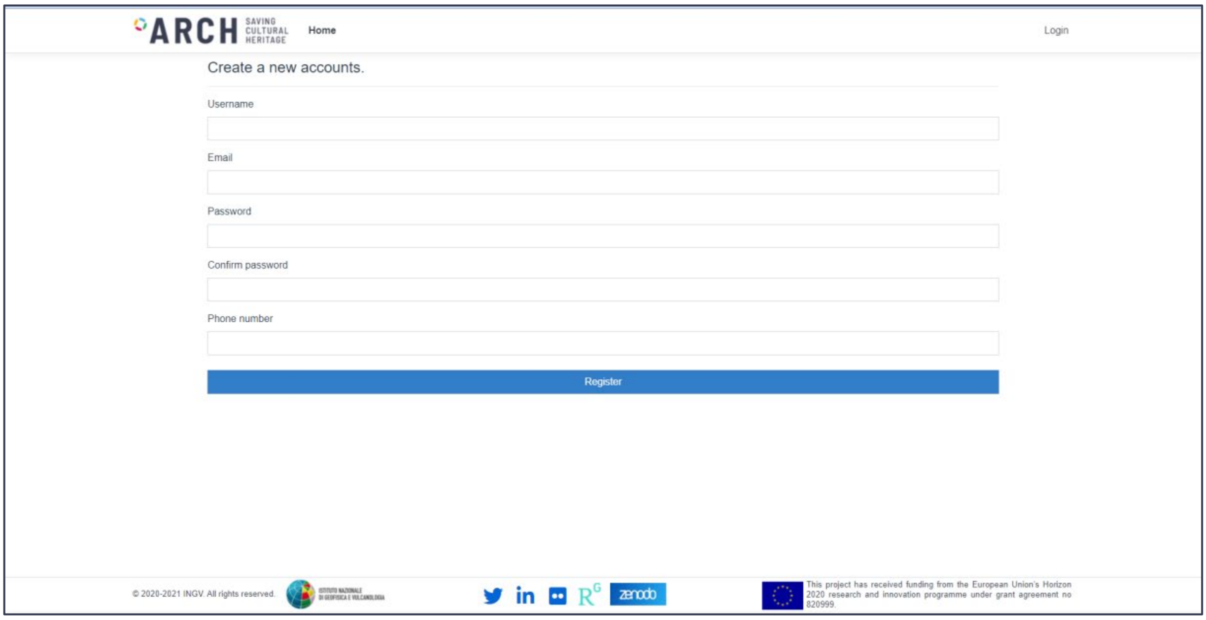


Figure 22: Registration of new account

Figure 23: GIS dashboard of HArIS (example for the case of Hamburg)

In the landing page, the image of the city lights up when the mouse pointer is positioned over it and, at this point, the corresponding GIS dashboard (Figure 23) is loaded with a simple click. Once this new page has been loaded, a menu in the header (1 in Figure 23) allows accessing to the tools of the information platform, always remaining available so that the user can easily change her\his choice. This menu reports the follow link:

- "Home" to return to the landing page and choose another city;
- "GIS dashboard" to obtain the tool to query the cartographic layers (Section 4.2);
- "Construction\Object Sheet" to consult the information on the assets (Section 4.3);
- "Geocatalog" to browse and search metadata and link related to GIS web-services and datasets in HArIS and THIS. This functionality is being developing in Task 4.4 and will be described in Deliverable 4.4 "Knowledge information management system for decision support", including how services and data can be reached by other systems.

4.2. GIS Dashboard

The GIS dashboards allow users to query and visualise the cartographic layers on built and natural environment, the position of the heritage assets, but also the social-economic information available in the ARCH repository or, directly, through external services.

The main page of the GIS dashboard is reached directly from the landing page of the information systems (Figure 20) as soon as the city was chosen. Once GIS Dashboard tool is loaded, two drop-down menus appear (2 in Figure 23) in order to choose different available products related to HArIS and THIS. In particular, all pages in HArIS have the same structure, as example the map GUI related to the information on the HA (Hamburg in Figure 23) can be divided into three main areas:

- **Map panel** (③ in Figure 23), where the information layer on the map is displayed and, by clicking on the features, the information windows are opened; the map can be navigated using a mouse, however the zoom, orientation and return to the initial view can be managed using the buttons at the bottom right. The map can be enlarged by making the left boxes (④ and ⑤) disappear using the arrow button.

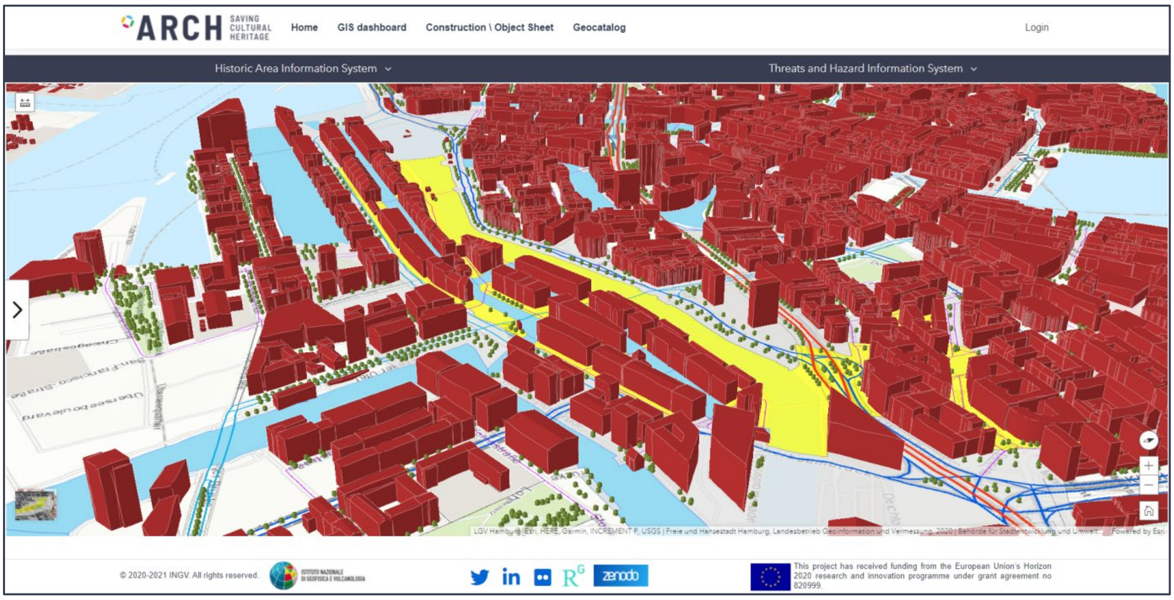


Figure 24: GIS dashboard 3D map of HArIS (example for the case of Hamburg)

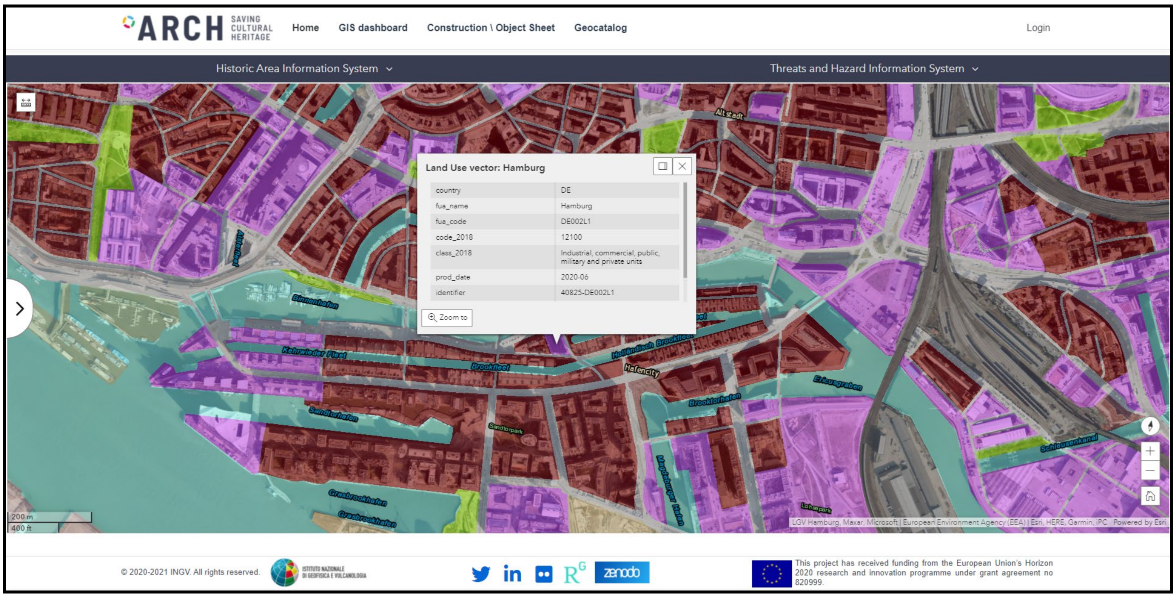


Figure 25: Land Use and Land Cover in HArIS obtained from Copernicus Land Monitoring Services (example for the case of Hamburg).

- **Layers panel** (④ in the Figure 23), where the information layers can be activated (or deactivated) to be displayed (or made to disappear) from the area in the Map Panel

- **Legend panel** (5 in the Figure 23), where information about each active layer is illustrated, this area can be extended with the arrow button to allow the user to have a view of more represented elements.
- **The button to switch on the 3D map** (6 in the Figure 23), with representation of the terrain model and the height of the elements of the cultural heritage (Figure 24) or the whole urban elements, where this information is available.

The other informative maps can be obtained through the drop-down menu (2 in the Figure 23), such as the land use\land cover in the urban area (Figure 25). By clicking on an element of the map opens a popup with the main features and information about it.

4.3. Electronic sheets

The electronic sheets allow user to visualise and update information about constructions and objects in the historic areas. The user can have access to the information stored on the database in two ways:

- by clicking on the feature in the map of the CH assets (Figure 26) and then on details in the pop-up (Figure 27), thus the sheet relating to the element opens up directly in another window (Figure 28).

Figure 26: Electronic sheet of the GIS dashboard for accessing the construction data

- by clicking on "Construction / Object Sheet" on the menu in the header (1 in the Figure 23) the construction list appears (Figure 29), and then the user can select "Objects" (or "Construction") from the menu immediately below. Once the user has chosen what to query, she\he can search for a specific item using the icon at the top right and filtering by: construction name, address, sheet and parcel. In addition, a specific sheet can be opened through the button (Figure 29) or, directly, in edit mode using button (Figure 29). In any case, it is possible to pass in edit mode by clicking the "edit" button directly in the sheet.

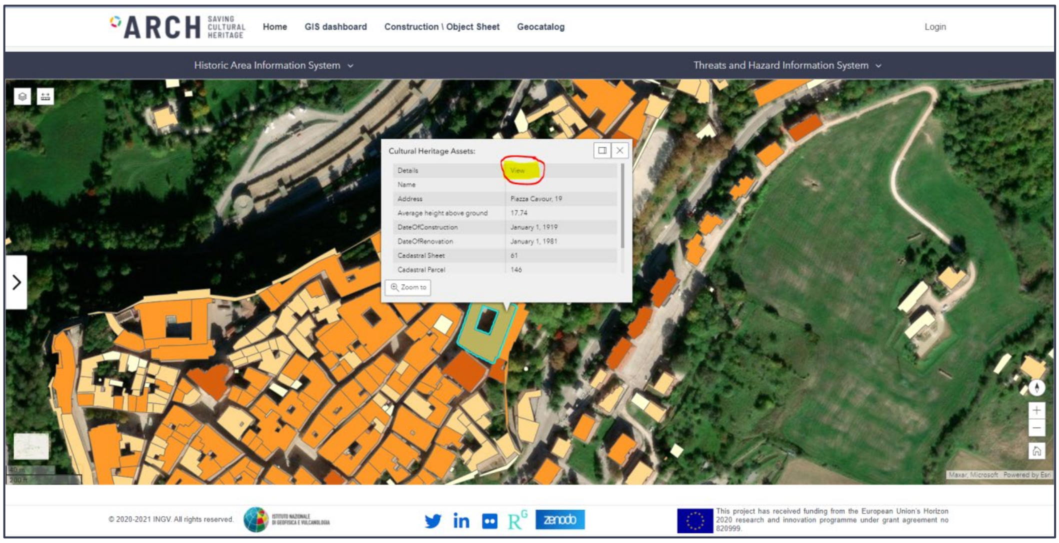


Figure 27: selection of a specific construction in the electronic sheet of the GIS dashboard.

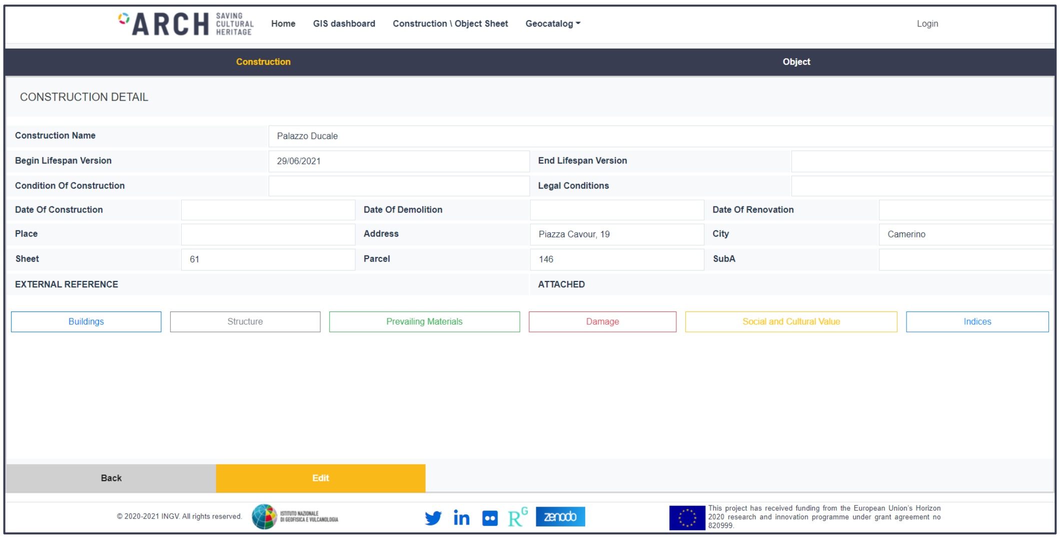


Figure 28: Link to a related sheet when accessing the construction electronic sheet of the GIS dashboard.

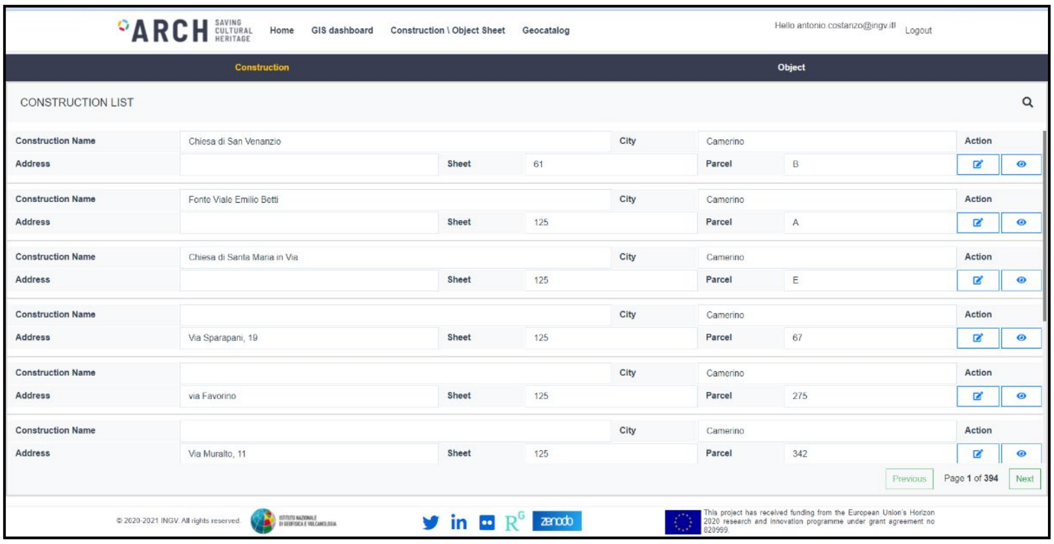


Figure 29: List of the constructions

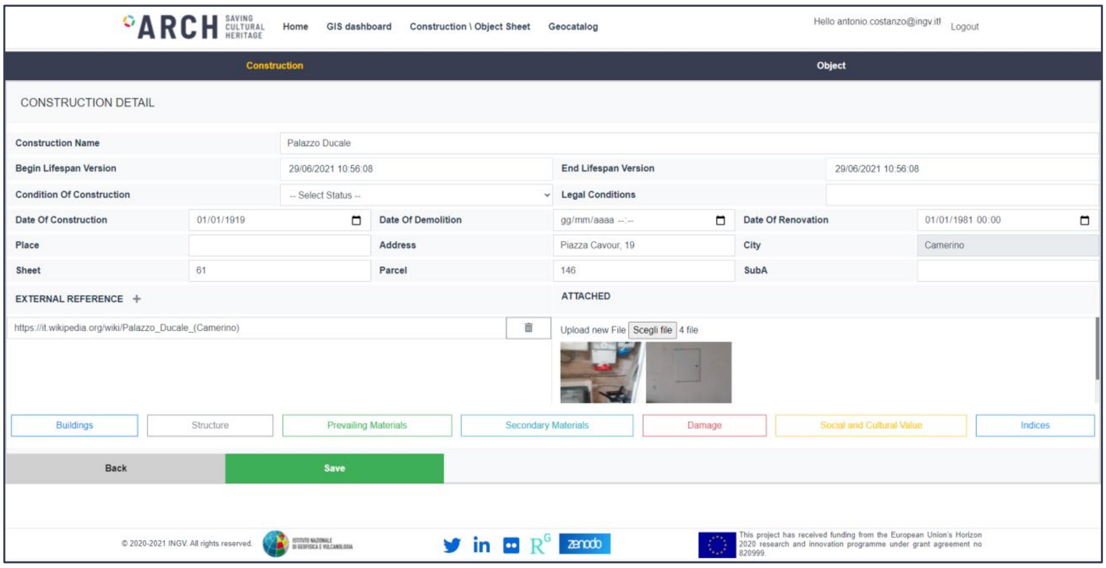


Figure 30: General view of the electronic construction sheet.

Once a construction electronic sheet is loaded, the overall info can be viewed (Figure 30). The tabs in the lower part of the window can be used to obtain available info about:

- buildings which compose the construction
- the structure and its components
- prevailing materials
- damage framework
- coefficients representing historical, aesthetic, social, religious and recreational value
- Summary indices about the quality of construction materials, social-cultural value and usability classification assigned to the construction

After logging in, the user can operate in edit mode in order to change fields in the tabs of the sheet or include web links and attachments (e.g. pictures, technical drawings, reports) related to the asset (Figure 31). At the end, the same attachments are available to be viewed on the web-browser or downloaded (as the technical drawings in Figure 32).

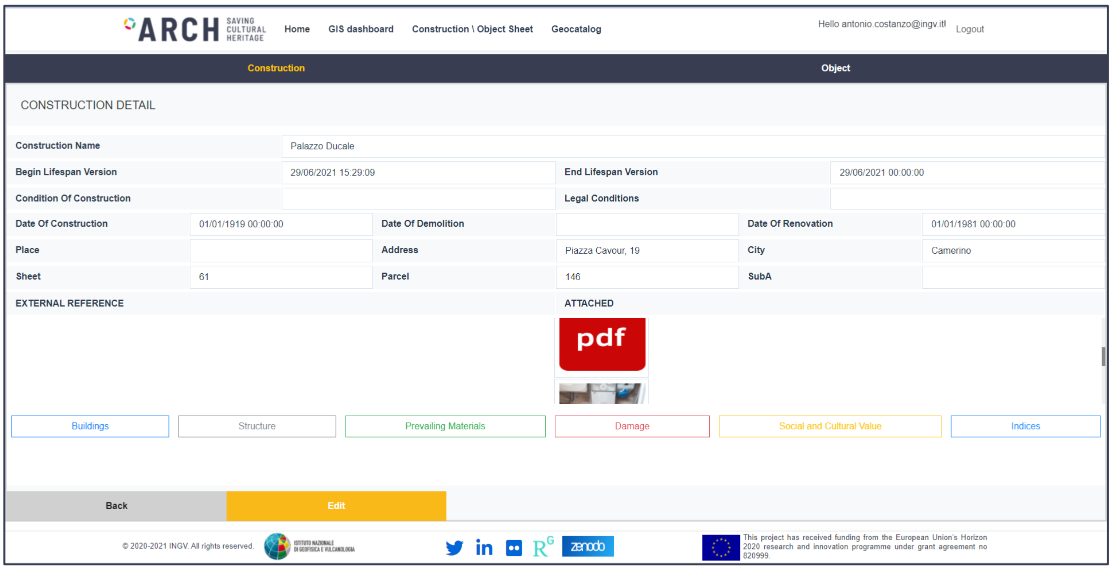


Figure 31: Edit mode of the electronic construction sheet.

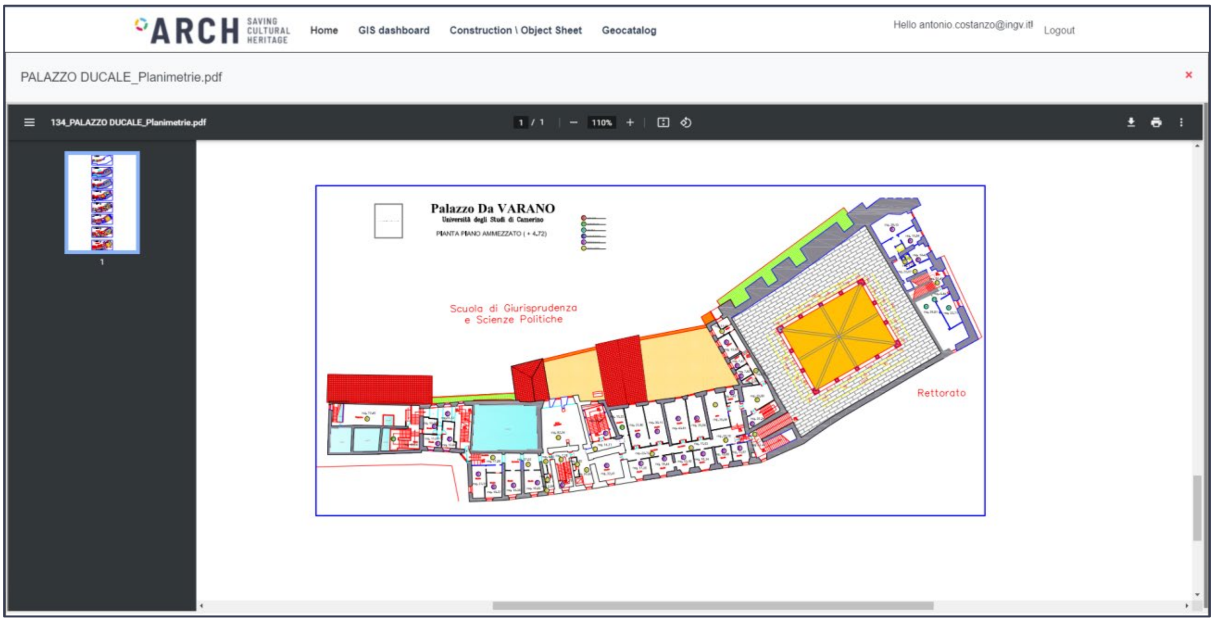


Figure 32: Visualization of an attachment in the electronic construction sheet: view.

Instead, to reach the object list, the user needs to choose "Object" from menu. In this case too, the user clicks the button (Figure 33) to obtain the information sheet in view mode (Figure 34a) or, directly, button (Figure 33) to access in edit mode (Figure 34b). It is possible to pass from view mode to the edit mode directly with the button "Edit" (Figure 34a). At this point, it is possible to make changes to the fields or to insert a web link and upload a file. After saving it, the user can obtain the information directly from the sheet (e.g. the picture in Figure 34c). In addition, the logged user can also add a new event (Figure 35a) or a necessary intervention (Figure 35b) related to the specific object, it simply by filling the respective tables.

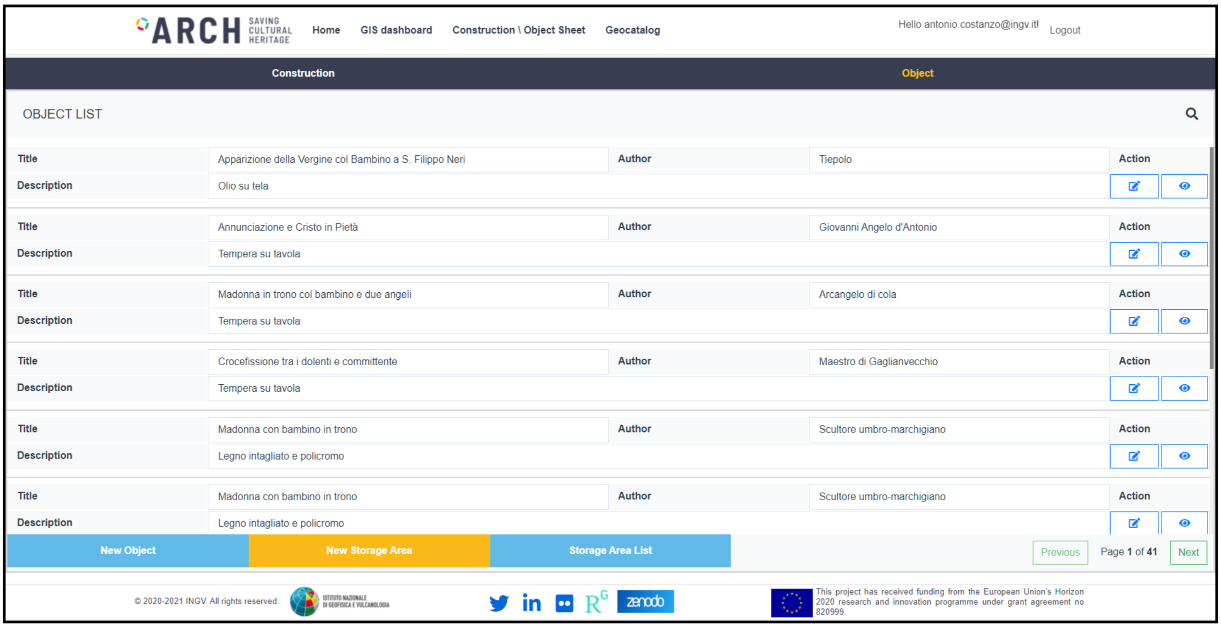
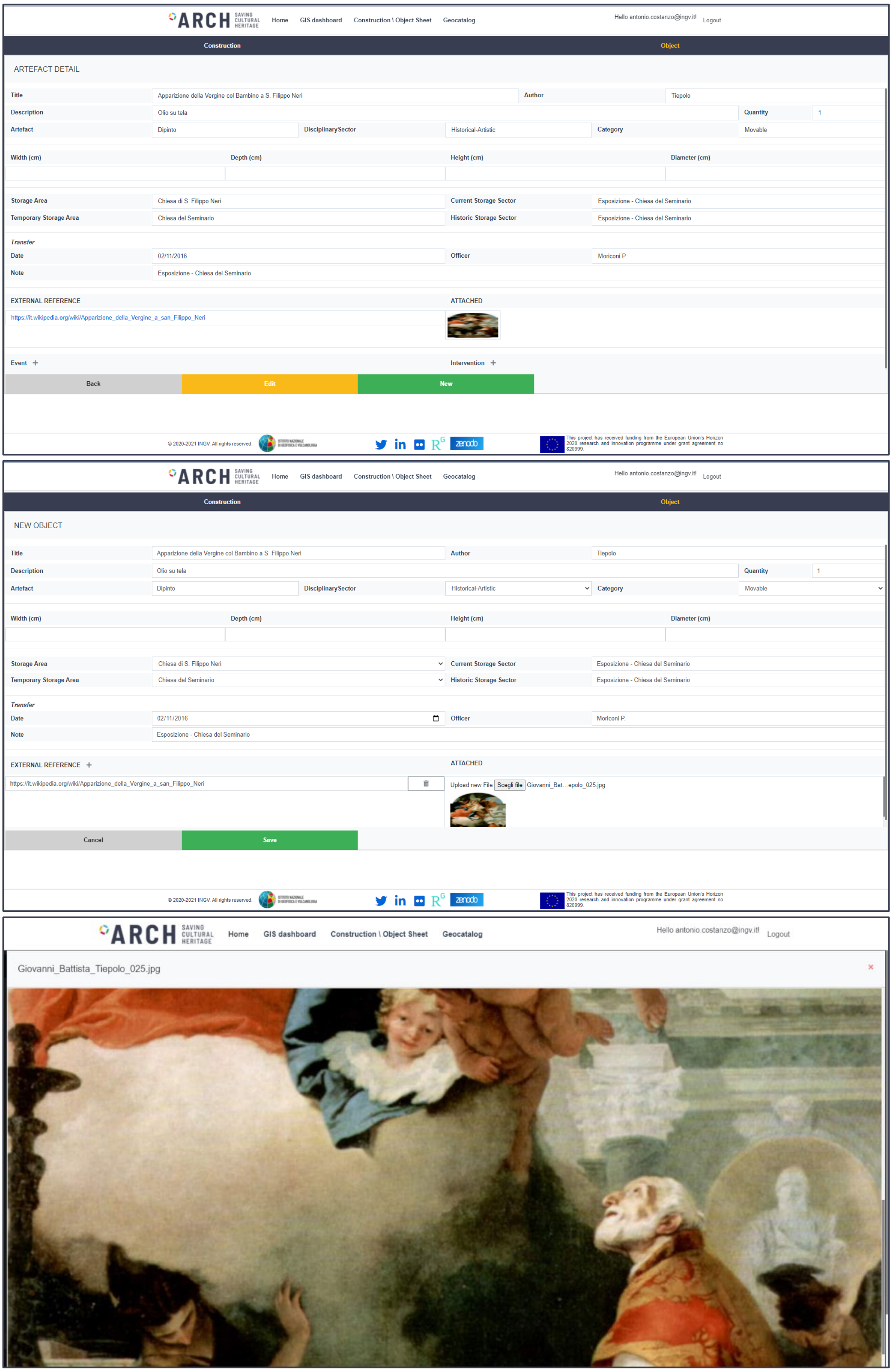


Figure 33: List of the objects for accessing the Electronic Sheet: in view and edit mode.

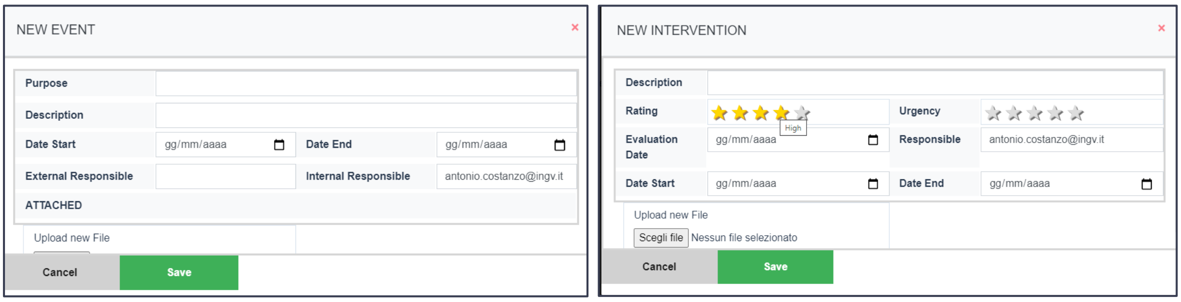


(a)

(b)

(c)

Figure 34: Object Electronic Sheet: view (a) and edit mode (b), and visualization of an attachment (c).

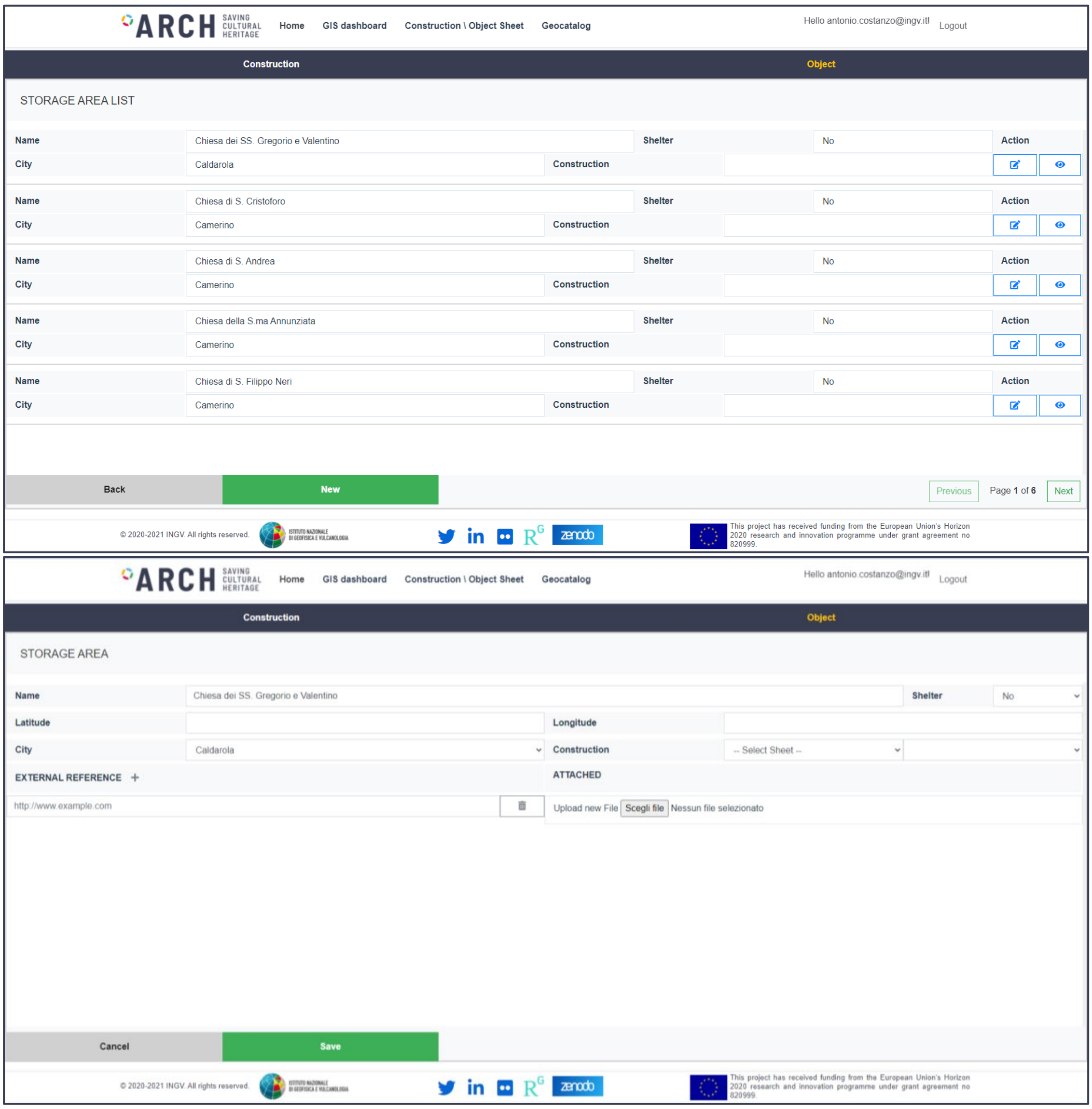


(a) (b)

Figure 35: Object Electronic Sheet: windows to include a new event (a) and a necessary intervention (b).

Using links, which are shown at the bottom of the object list (Figure 33), the user can also:

- insert a new object filling the table in Figure 34
- consult the list of the storage areas (Figure 36a)
- Insert a new storage area (Figure 36b) to be linked as container or shelter to the objects



(a)

(b)

Figure 36: List of the storage areas (a) and table to insert a new one (b).

4.4. 3D viewer

The 3D viewer is a specific web application to visualise point clouds and meshes related to the cultural heritage object, in order to have a realistic view in three-dimensional space. In addition this tool can be used as support to extract specific information or to make measurements directly on the constructions and objects, which can be queried in 3D mode. This viewer will allow managing models also supporting any further analyses in the next tasks of the project.

In the electronic sheet, the icon appears if a 3D model is available for the element (cf. Figure 37). Once the user clicks on the icon, the viewer opens the model in a new window depending on whether it is a point cloud or a mesh.

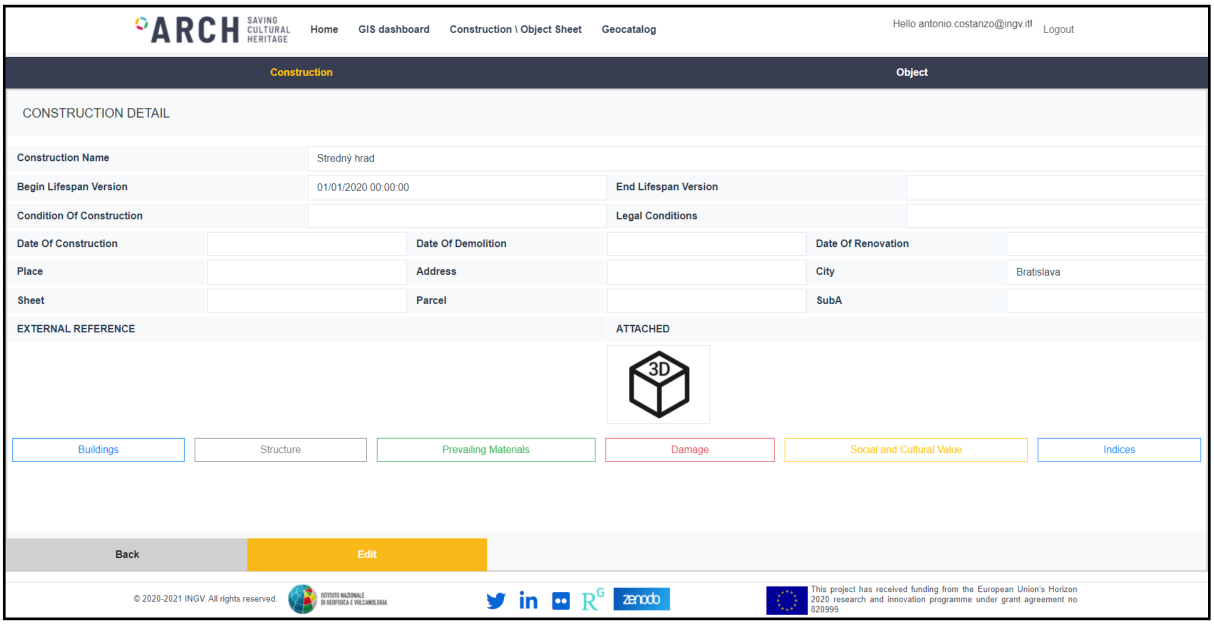


Figure 37: Electronic Sheet of a construction with a related point cloud

The point clouds allow obtaining very dense information – although discontinuous - so a high resolution can be obtained and details can be identified (e.g. crack in the masonry façade or imperfections in the plaster of the paintings); in this case the view is based on the Potree open-source Web-based Graphics Library[12] . The user is enabled to manage the model, navigate and make measures (Figure 38) through the menu in the upper left part of the window. Moreover, another viewer already developed in the PON MASSIMO project[13] (Figure 39), based on the Babylon.js[14] library, has been improved and integrated into this tool of the information system, in order to manage also the representation of objects by means of meshes. It allows to navigate continuous models with the possibility to turn on\off the different parts and to include markers to which specific information can be linked.

[12] https://github.com/potree/potree
[13] https://ponmassimo.rm.ingv.it/portal/
[14] https://www.babylonjs.com/

Figure 38: 3Dviewer for point clouds.

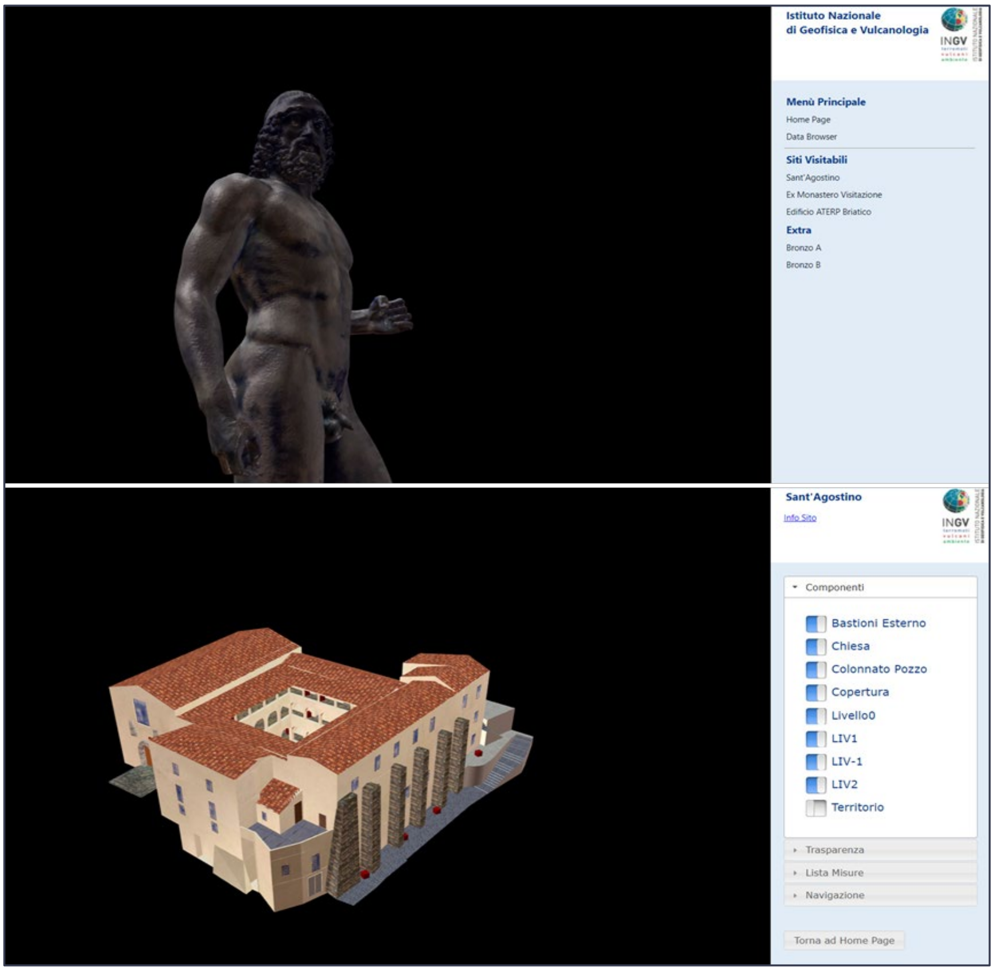


Figure 39: 3Dviewer for meshes developed in PON MASSIMO (after [25]) and included in the ARCH platform.

5. 3D models and deterioration analysis

The ARCH project develops digital technologies that directly employ 3D object models. They are produced from different types of both visual and penetrating scanning, which individually provide only a partial view of the object and hence they need to be integrated into a single model of the object, showing both its external shell as well as each of the material layers. Subsequently, those models are expected to be used for realistic reproduction using 3D novel printing techniques, going far beyond the current state of the art and hence putting stress on the flexibility of 3D model definitions, in this way new features, e.g. occlusions, reflections and touch, to mention just few of them, could be reproduced realistically. Lastly, evolution of the 3D models will be required through morphing techniques, such that the artificial ageing process could be realistically simulated. The latter one will make use of experiences and rules established through speeded-up ageing of sample materials from Scan4Reco project.

In order to support all those types of 3D processing, it was necessary to investigate existing 3D model formats in view of determining the most suitable for both the multi-layer modelling, flexible enough to offer ways of adding new features required for printing and ageing. The results of such analysis have been outlined below, starting from the list of known 3D formats, leading to the identification of the most suitable that will be used as common 3D format in the project. Since 3D model formats are used in the architecture for several specific needs (permanent storage, exchange between components, communication with external ones), formats presented in this chapter, are mostly related to import/export and interfaces among project components, whereby internal data structures might vary depending on the specific needs of each of the component in the project architecture.

5.1. Specific Requirements on 3D Model Representation

In terms of specific impacts that the described ageing procedure implies on the 3D model format, most commonly adopted definitions are readily suitable to provide necessary data. The most important parameters are vertex coordinates and vertex colours, preferably triangular meshes, as well as material definition including additional parameters regarding the chemical composition of the physical material and its roughness (i.e. statistical surface depth variation). Although currently not implemented, future considerations for dynamic (temporal) environmental parameters like wind speed and direction, atmospheric humidity and pressure will be also considered to provide more realistic assessment of the future evolution of the object shape and material changes to object surface.

5.2. Common 3D model representation for ARCH

The commonly accepted formats for use in ARCH become OBJ[15] and FBX[16] as well as 3MF[17], in addition to all point cloud formats accepted already by THIS platform. The first one

[15] http://www.martinreddy.net/gfx/3d/OBJ.spec
[16] https://code.blender.org/2013/08/fbx-binary-file-format-specification

is from one side the most commonly used, while being resistant to inconsistencies among various software than other formats. The 3MF format, even that still under development, shows a potential to become very flexible and future proof, especially that the 3MF consortium is willing to accept our suggestions for extensions to it.

A comprehensive review of existing 3D model formats with analysis of their suitability for representing historical objects and their spatial and temporal analysis has been performed by RFSAT in an earlier SCAN4RECO project[18] from the perspective of universality (ability to be used without conversions among vast number of software applications), interoperability (ability to be imported and used without loss of information) and flexibility for extensions (ability to add more features) to fit the needs of the ARCH project. The analysis in SCAN4RECO combined with needs arising from ARCH pilot sites has led to the following conclusions:

- Common 3D model format: the same 3D format should be used among project components such that to avoid translations, that might potentially lead to changed model representations and hence losses of information. Initially, the OBJ and FBX formats are most universal and flexible for extension to fit the needs of ARCH project.
- Water-proof 3D models are essential, i.e. without holes and undefined spaces/areas. This is a necessary condition for 3D models to be 3D printed correctly. This is also a condition for being able to perform integration from multiple 3D scans and then additional processing e.g. for simulated future deteriorations, etc.
- Integration of 3D scans may face problems when areas are overlapping. Hence, a detection of overlaps needs to be performed prior to integration, in simplest approach by performing weighted averaging, i.e. placing a common boundary to mid-ways between the overlapping areas using individual 3D scan accuracy as a weighting factor.

A common model-based supports both commonly used 3D object geometry and material definitions, with extra support for new features related to new optical surface characteristics, dynamic object properties and their subsequent printing. It describes the set of elements which define the content and structure of XML documents for storing the ARCH results, namely global and local scanning of a cultural heritage object, as well as metadata about the physical object's characteristics.

5.3. Approach to Diagnosis of Geometric Deformation

The use of HArIS decision support offers added value in cultural heritage for preventive conservation purposes. One of the most common purposes is material aging. Material aging has a significant effect on the realistic rendering of artwork objects. Small deformations of the surface structure, colour or texture variations contribute to the realist look of artwork objects. These aging effects depend on material composition, object usage, weathering conditions, and a large number of other physical, biological, and chemical parameters. The 3D geometry

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17 http://3mf.io/specification/
18 https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5b9e747ff&appId=PPGMS

combined with multispectral material analysis provides quantitative measurements of the surface texture and roughness as well as significant deformations and cracks, which is used to obtain information about material changes over the time in terms of its surface deformation. In this work we focus on local deformations due to corrosion/erosion and finally cracks mainly by modelling the behaviour of displacements locally. Using the described simulation algorithms cracks that may appear or expand in the future will be timely detected by decision support diagnosis module and appropriate conservation and protective techniques can be applied.

Deep learning provides a powerful method to interpret large quantities of data automatically and relatively quickly. Deterioration is often multi-factorial and difficult to model deterministically due to limits in measurability, or unknown variables. Deploying deep learning tools to the field of material degradation is a natural fit to the field of historical object analysis for assessing risks of continuing damage to object of important historical and cultural value. Review of the current research in deep learning for detection, modelling and planning for material deterioration is driven by budget reductions, increasing safety and increasing detection reliability. Researchers make string progress, though several challenges remain, not least of which is the development of large training data sets and the computational intensity of many of these deep learning models.

5.4. Implementation of Detection of Geometric Deformation

The concept architecture of the system developed by RFSAT for automated scanning and analysis of cultural heritage objects and structures for various types of deficiencies is shown in Figure 40.

Figure 40: RFSAT automated 3D scanning and analysis of degradations to Cultural Heritage

It contains a Ground Station with a range of supported UAS/UGV/UUV drones that can be operate either manually (legal requirement) and automatically for capturing visual material (image and/or video) which can be then used to build 3D models of the objects and perform automated, neural-network assisted analysis for detection of various types of defects, from cracks to discolorations and physical damages. A physical architecture of the system from Figure 40 is shown in Figure 41.

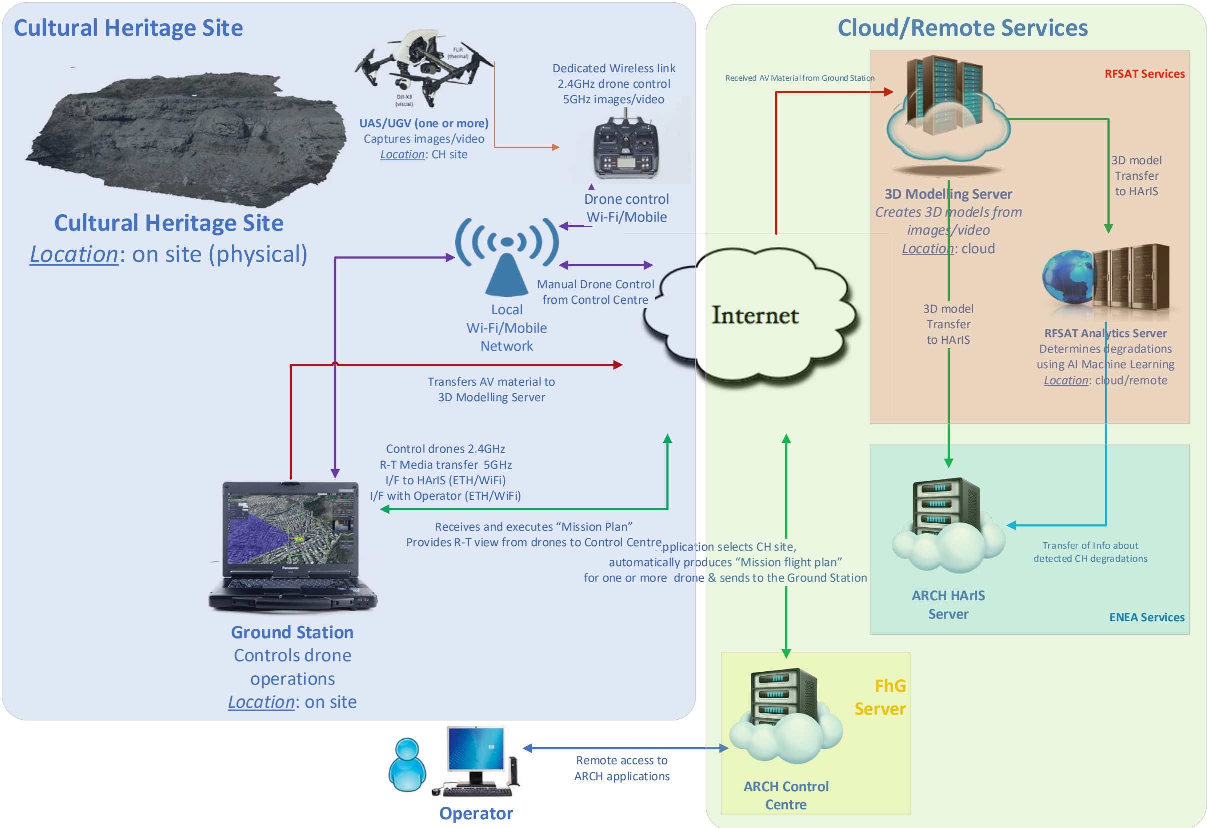


Figure 41 Physical architecture of RFSAT automated 3D scanning & analysis of degradations

The 3D modelling is mainly based on 3D photogrammetry and employs two different engines, depending on application, one being PIX4D engine that operated on a dedicated RFSAT multi-GPU server, while Autodesk engine offers capability of using cloud processing engine. An API for using both serves has been developed by RFSAT for assisting integration into custom applications built with Microsoft Visual C++ 2019 IDE.

The analytics algorithm uses Machine Learning and Artificial Intelligence methods and thus requires prior teaching using example images of similar defects. Results from both RFSAT servers can be then transferred to HArIS for further processing and visualisation by end user. It distinguishes among system parts that physically reside at different physical locations:

- Physical site of the Cultural Heritage, where the following components are located:
  - **Ground Station**, installed on a Panasonic Toughbook with on Win10 aimed to:
    1. receive flight plans (file) from RFSAT app on the ARCH Control Centre
    2. launch & operates drones in automated mode to execute flight plan mission

3. acquire visual material (images & video) of the CH site from various angles
4. send visual material to RFSAT 3D Modelling Server (see below)
5. send directly (option) visual material to RFSAT Analytics Server (see below)

  - **Drones** e.g. UAS (aerial), UGV (ground) and UUV (underwater) along with either their **Remote Controller** (preferable for extended control distance, communicating with drones using e.g. DJI Lightbridge 2 for up to 5km) and/or mobile devices with custom application and connected to drones via Wi-Fi (limits distance to less than 300meters in open space)
  - **Local wireless network access point** and/or cellular access network to ensure reliable network connectivity among parts of the system at CH site

- Remote and/or cloud-based services:
  - **RFSAT 3D Modelling Server**: operates in two (selectable) modes, as cloud services or on a multi-GPU parallel processing server installed at RFSAT offices. Two engines are available: PIX4D and Autodesk. An API written in MS-VCPP2019 has been developed to enable integration of 3D modelling into custom applications.
  - **ARCH Control Centre** (with embedded RFSAT application): expected to be provide by FhG and allow access to and integrate all ARCH services. The RFSAT application will allow selection of the CH site and based on its structure to derive a flight plan for drones such that to acquire required audio-visual material, as required for performing 3D modelling and/or image-based analysis of degradations to CH structures. Semi-automatic approach will assist users in building a mission plan.
  - **RFSAT Analytics Server**: based on images acquired from drones of the CH site (optionally also the 3D models of the site from RFSAT 3D Modelling Server) will perform AI-based and Machine Learning driven analysis of the images and/or 3D model to determine type, location and significance of degradations of CH object. This server operates on an embedded UP2 PC running Linux with Intel Movidius VPU employing neural network co-processor for faster data analysis.
- End-user location:
  - **User Terminal**: used by end users to access ARCH applications from ARCH Control Centre from any remote site. It can be either a workstation/laptop, tablet or smartphone

Note that all system components communicate using TCP-IP networking protocol. Components of the RFSAT system offer API for integrating its functionalities into custom applications developed with MS Visual C++ 2019. Mobile applications (e.g. drone control) run on Android operated terminals and/or mobile phones.

5.4.1. Material degradation due to ageing from pollution combined with climate

Material aging has a significant effect on the realistic rendering of cultural heritage objects, irrespective of small tangible ones, large structures or natural reserve areas. Small deformations of the surface structure, colour or texture variations contribute to a realist look of artwork objects. The distinctive crack patterns observed in many materials arise due to small-scale interactions among elastic strain, plastic yielding, and material failure. Stress gradients can be very large near the crack tip where the stress field often approaches singularity. Modelling the effect of aging is a computationally intensive task. Therefore, tools are needed to expedite the aging simulation/emulation process. Several types of textures may be used to improve rendering. However, this process requires intensive user interaction which may not correctly capture subtle micro-deformations.

Material aging related visual effects are important for capturing realistic effects in computer generated images. Simulating and rendering such phenomena results in images which have a much higher degree of realism. In this work we focus on local deformations due to corrosion/erosion and finally cracks mainly by modelling the behaviour of displacement locally by studying the artificial aging process of sample plates. Geometry analysis methods provide quantitative measurements of the surface texture and geometrical in continuities that can be associated with cracks and other deformations, which is used to obtain information about material changes over time in terms of its surface behaviour.

The ARCH project addresses also effects of ageing on various materials. RFSAT took advantage of earlier experimental results from SCAN4RECO project in determining future evolution of the model containing such materials in their simulations. Deep-learning algorithms and neural networks applied to Machine Learning were used to provide future prediction based on images of real samples taken at different time intervals. In case of RFSAT two methods have been used and compared. One directly worked on images of real aged samples. The alternative method focussed more on the analysis of actual physical effects of ageing, physicochemical reactions with the environmental elements (e.g. gases and liquids), combined with environmental parameters (e.g. pressure, temperature and humidity) having direct impact on actual speed of deteriorations through changes to material composition, such as reactions of metals with oxygen, ionised particles of different reactive atoms and their compounds, such as anhydrides that combine with water and form acids.

5.4.2. Example for bronze historical objects

On metal, patina is a coating of various chemical compounds such as oxides, carbonates, sulphides, or sulphates formed on the surface during exposure to atmospheric elements (oxygen, rain, acid rain, carbon dioxide, sulphur-bearing compounds), a common example of which is rust which forms on iron or steel when exposed to oxygen. On metals it often forms a thin passivation layer when exposed to atmosphere, although under extreme environmental conditions it may lead to erosion of the top layers of the metal, leading to loss of material, pitting etc. In our analysis we have focussed on bronze, although it could be easily extended and applied to other types of materials. In the first instance, we also considered short term ageing, which is unlikely to lead to deep physical erosion, extending it later to more physical effects of metal erosion.

In contrast to common perception, the natural colour of bronze is gold and not dark-brown (actually due to patina) and it is accredited to its high content of copper, often in the range of 90%. Other colours from brown, to green, red and even blue are results of chemical reactions of copper with various chemicals, some of them being environmental, but often also man-made by e.g. artists wishing to achieve certain type of effect. Therefore, initial analysis needs to determine whether patina has already been applied on purpose and in such a case if it has been protected e.g. by layers of wax. This will directly impact the future evolution of the patina under certain environmental conditions.

Different chemicals react with the bronze to achieve different colours. From man-made patinas, one of the most common ones is Liver of Sulphur which results in a golden-brown to almost black colour. Other ones include Ferric Nitrate (golds, browns and reds) and Cupric Nitrate (greens and blues). They are commonly used by artists in layers to achieve a variety of artistic effects. Historically, Liver of Sulphur has been the patina of choice for most sculpture for the rich chocolate brown colour most people are familiar with. In the late 1800's and early 1900's, August Rodin experimented with different chemicals that would result in different colours. Rodin would layer green patina over a base coat of brown to achieve a marbleized effect that became known as Rodin green. Nevertheless, most private commission sculptures are still done using more traditional browns.

In natural environments, one of the most important issues concerning the use of copper is the chemical reaction between copper and other materials. Chemical reactions are responsible for corrosion, staining, and even the green patina that develops on copper surfaces over time. The green patina forms naturally on copper and bronze, and usually consists of varying mixtures of copper chlorides, sulphides, sulphates and carbonates (most of which are monitored through THIS subsystem for ARCH pilot sites), depending upon environmental conditions such as sulphur-containing acid rain. The process is, therefore, faster in some metropolitan, marine, and industrial areas, where higher concentrations of pollutants exist. When acidic moisture comes in contact with exposed copper surfaces, it reacts with the copper to form copper sulphate. The acid is neutralized during the reaction with the copper. This patina eventually covers the surface and adheres tightly to it, thus providing a protective layer against further weathering, and as a result also the patina type of “ageing”. Such a process is very slow and can take many years to fully cover bronze with green patina (Figure 42).

In clean air rural environments, the patina is created by the slow chemical reaction of copper with carbon dioxide and water, producing a basic copper carbonate. In industrial and urban air environments containing sulphurous acid rain from coal-fired power plants or industrial processes, the final patina is primarily composed of sulphide or sulphate compounds. A patina layer takes many years to develop under natural weathering. Buildings in damp coastal/marine environments will develop patina layers faster than ones in dry inland areas.

The digital simulated ageing has been performed and validated on the example of bronze sample. Instead of using associated memory techniques based on neural networks, image morphing techniques have been applied, whereby from known curve of changes from object at the start time through intermediate phases until end time were determined for similar patterns (at custom size of neighbourhood areas) in the original sample image. When ageing an unknown object, similar patterns are searched for and morphed to produce future prediction of the object’s appearance.

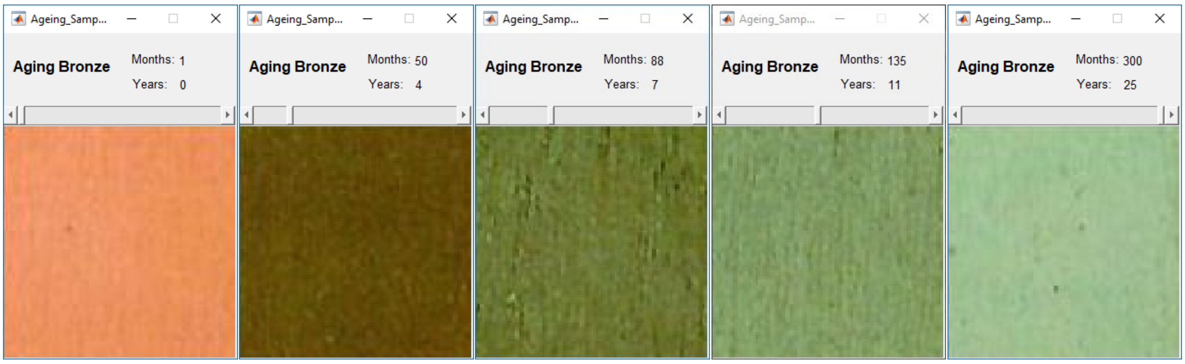


Figure 42: Simulated bronze ageing by morphing using database of artificially aged samples.

Simulations have been performed using Matlab image processing toolbox. The changes to the object texture have been achieved by applying the morphing algorithm directly to the texture of the 3D model. In the alternative approach, physical properties of the material and chemical compounds produced during ageing have been considered. The ageing effects over long period of time for uniform bronze sample are presented in Figure 42. It shows close resemblance to results of forced artificial ageing with high heat under controllable conditions.

Figure 43: Simulated patination of bronze (left) in 5 and 25 years by morphing from real data

For illustration similar algorithms have been applied to the test bronze statue, a copy of San Giorgio made by Donatello in about 1415, which has been exposed to weathering effects over the past few years in Florence. Estimated age of the patina has been determined to be between 17 and 20 years (Figure 43). The patination is visible only on parts of the object, indicating that some protection has been applied that worn out throughout the years. Assuming that whole object now lacks protective layer, the future predicted evolution of the patina until it covers the whole surface of the object and isolates the metal from further patination was estimated at 10-15 years. Images from simulations at increasing time intervals, considering slowing down of patination as it progresses, shown in Figure 44.

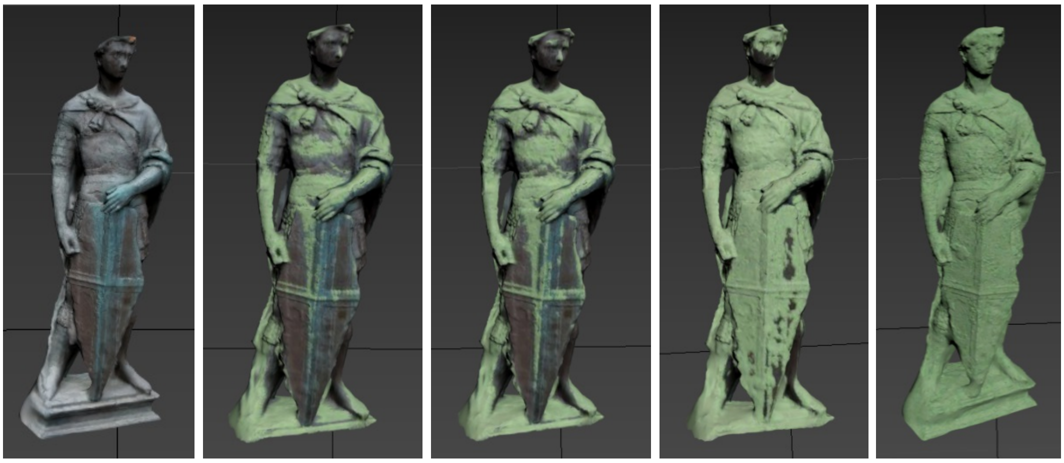


Figure 44: Simulated formation of patina on St Giorgio statue in 10, 15, 20 and 25 years

Since patination is strongly related to various parameters that are difficult to predict over long period of time including weathering, environmental pollution etc, real effect will most likely differ from predictions, though the latter one may provide best-case approximation and indication when and what type of protection, cleaning or restoration process needs to be applied to extend the objects' lifetime.

5.4.3. Deep Learning Technologies

Recent advances in Artificial Intelligence (AI) alongside the development of cheaper more powerful Graphical Processing Units (GPUs), has been driven by the collection of massive data sets via the Internet, novel learning architectures and programming languages. Deep Learning methods are being used to automate the detection of degradation, improve modelling of materials durability and assist decision making by analysis of large sets of degradation data. The true power of Deep Learning arises when the computer is able to discover its own interpretation of the data, often leading to faster and more accurate predictive power than hand-crafted algorithms.

Deep learning models are trained to be able to interpret the input data in a useful way. Simply put, models are initialised with random weights, and example inputs are fed through the network. The difference between the target labels and the model outputs is then measured as the error. The contribution of each neuron to the error is determined using backpropagation, and the weights are updated to reduce the error. This process is repeated until a set number of iterations are completed, or the error is reduced to an acceptable level, and the model adequately interprets the input data into the desired output. The whole process is termed Stochastic Gradient Descent (SGD), although there are several variants in use that employ different methods to increase the speed of converging on a solution. To set up the training phase there are several so-called hyper-parameters that affect the speed of convergence, including the number of iterations to train with, the learning rate (i.e. how large of a step to take with each iteration), and the specific calculation of the error signal. Selecting an appropriate measurement of error is important and depends on the problem space, within the literature the error is also referred to as the 'cost' and the 'loss'.

Detection of degradation is necessary to allow intervention prior to failure; undetected deterioration can lead to catastrophic failure in extreme cases. Direct detection involves measuring change in materials that are detectable in ambient conditions, for example visual presence of corrosion products, cracks and changes in dimensions. Indirect detection requires the application of an excitation signal for which the response of the material can be measured to indicate deterioration, for example ultrasonic thickness testing may reveal loss of wall thickness in pipes. Both direct and indirect detection methods are commonly used, providing complementary functions. Typically, direct detection is used to focus indirect detection efforts to areas of distress.

5.4.4. Direct detection of degradations

Research by the European project MINOAS (Marine Inspection Robotic Assistant System) has demonstrated the effectiveness of a simple Artificial Neural Network (ANN) for corrosion and crack detection using a micro-aerial vehicle in ships ballast tanks [26]. Using traditional computer vision techniques to produce inputs related to colour and texture to various ANNs comprising one hidden layer. The analysis determined that the optimum configuration consisted of 34 inputs and 37 neurons, achieving accuracies of 74 to 87%. This hybrid computer vision + ANN approach may be necessary with shallow networks that are unable to learn to discern higher order features, such as texture. Colour information was provided to the network by filtering hue and saturation values; and texture information by processing the distribution of neighbouring pixel intensity. Thus, the approach does not exploit the true power of deep learning, i.e. allowing the computer to determine the best representation of the input data to achieve the task. It is likely that these models overfit the limited training data of ship ballasts, although this is appropriate for the task at hand, transferring this approach to other environments and subjects may require significant rework. The experiences from MINOAS have driven the analogous development in ARCH to provide drone-based degradation detection systems for historical objects and structures for ARCH pilot sites.

An interesting review of deep learning models and traditional computer vision systems for corrosion detection has been done in 2016 [27]. The deep learning architecture utilised transfer learning of the AlexNet model architecture to identify low level features like edges. The AlexNet model incorporates five convolutional layers, and consists of ~650,000 neurons. Even with a small data set of 3,500 images it was demonstrated that Deep Learning outperforms computer vision with total accuracies of 78% and 69%, respectively. Unfortunately, neither accuracy would be considered equivalent to human performance, measured as 88–95% when tested on the ImageNet Large Scale Visual Recognition Challenge (ILSVRC) [28]. The authors posit that a computer vision system could augment Deep Learning to improve classification accuracy further. The model also requires images to be downsized to 256 × 256 pixels, discarding some (perhaps significant) available information. Image classification for the presence of corrosion at the accuracy achieved would however still require humans to review nearly all data captured.

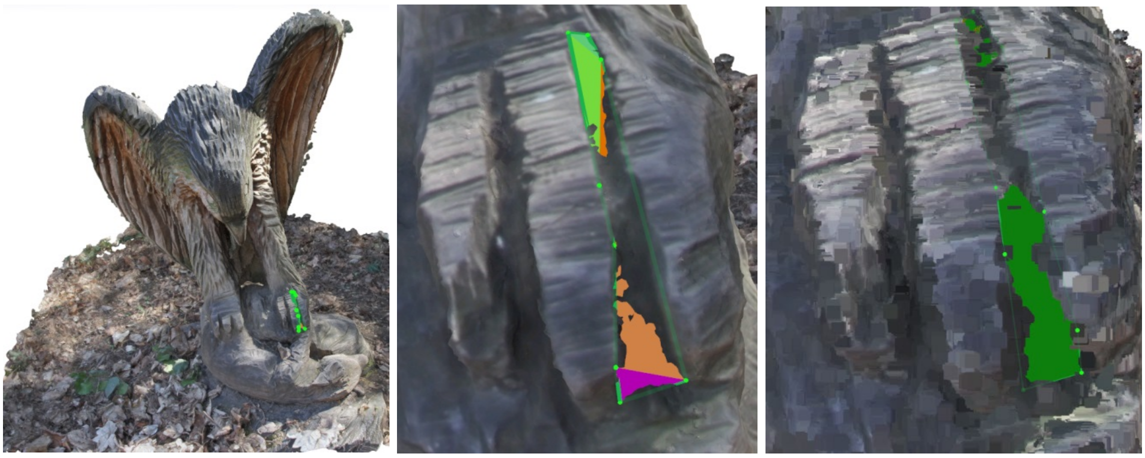
Since cracks are one of the most important structural surface damages to monuments, concrete structures, buildings, and roads, it has been the main focus of the work on Deep Learning techniques in ARCH. Manual measurements of crack irregularities are difficult and need for more expertise. The detection of crack requires careful attention to the following issues: crack length, width, multiple cracks, location, orientation and depth. Hence, subject to availability of sufficiently large training data set, it becomes a great solution for any cultural heritage curator.

5.4.5. Implementation

The proposed approach focusses on detection of cracks, measuring their shapes, performing classification and recognition of the detected defect. First images are captured from autonomous drone with either DSLR camera or embedded raster and/or multispectral cameras, served as input. Since possibility of performing real flights over real historical objects has been impossible over the recent year due to COVID restrictions, simulations have been performed whereby existing models exhibiting structural degradation have been re-scanned digitally, thus producing a set of images used for testing the implementation.

The images are first pre-processed to remove the noise. Their enhanced versions are processed with canny edge detector and Bottom Hat Transform (BTH). The edge detector detects the crack with less noise and BHT extract the dark regions. Then shape parameters of the cracks are extracted. The Discrete Wavelet Transform (DWT) is used to extract the fine details of the crack. The output from DWT is applied to Gray-Level Co-occurrence Matrix (GLCM) method. GLCM is the texture extraction method and it compares the pairs of co-occurrence pixel in an image. Contrast, correlation, homogeneity and variance features can be extracted from the GLCM. These features are used as a set of features for the classification of crack as normal or crack image.

The classical approach to detection of cracks and other physical/geometrical discontinuities using Machine (Deep) Learning technologies from one side offers an opportunity for identification of problems in presence of complicated textures that is very complex using deterministic methods. On the other hand, most of such approaches are based on analysis of raster images (often grey scaled for better contrast) and hence permitting only surface shape (boundary) estimation, with little or no insight into the depth of the structural deficiency, often as important for determination of the seriousness of the problem as the external size. In this context current Machine Learning approaches applied to cultural/historical objects and structures have little applicability.



a b c

Figure 45: Hybrid detection of cracks (a) step 1 using Machine Learning, (b) 3D model analysis

On the other hand 3D models built to sufficiently high precision to perform an analysis of the depth and the structure of the physical deficiency, would require extremely large image resolution and very big number of images to cover the whole object if 3D photogrammetry was used and/or lengthy process of 3D modelling or laser scanning the whole object. This would be both impractical from data processing perspective as well as would require extremely long processing times to come up with even reasonably useful information.

The approach proposed by RFSAT for ARCH would be to combine the advantages of both approaches to leverage the speed and accuracy with precision and accuracy. Our proposal is to perform Machine Learning analysis to find the cracks and establish their rough boundary (Figure 45b) before performing in-situ 3D analysis using deterministic analysis of the 3-dimensional structure of the physical deficiency at very precise location (Figure 45c).

The example presented in the figure above uses a 3D model example provided by PIX4D of an eagle statue, built via 3D photogrammetry with a high-resolution raster camera. We trained the system to identify a narrow separation in the right paw as a crack. The 2D surface of the "crack" was estimated as 0.62 m^2, while the 3D volume of the "crack" as 0.0.139 m^3. This corresponds to an average depth of a "crack" of only 2.2cm, quite negligible in this case since the width was nearly 20cm. The common issue with assessing severity of the structural loss of surface integrity is the structure of the crack, also to be able to distinguish it from intended changes to 3D surface of the object, common for e.g. sculptures, but also for buildings and other structures. Commonly cracks are losses of material smoothness and so they can show a sharp change in angle between faces of the 3D model around the crack, commonly close to 90 degrees. Therefore, before quantifying the size and depth of the crack, we perform a 3D validation of the area around the crack to measure angles between nearly faces. In eth example above the maximum angles between connected faces were less than 45 degrees, thus implying intended change of the shape in the sculpture. This analysis uses a custom software and uses an FBX Software Development Kit (SDK) [19] from Autodesk for Microsoft Visual Studio 2019. Similarly, other types of structural deficiencies can be also assessed via volumetric analysis of the 3D model around the area enclosing the identified defects. Note that volumetric analysis does not need to be explicitly aligned with the edge of recess in a 3D model.

Similar types of analysis will be performed in the next months on actual images and 3D models of objects and structures from ARCH pilot, which has been till now not possible due to travel restrictions imposed over the COVID outbreak period. This is expected to be conducted during the remainder of the project if and when travel restrictions will allow visiting pilot sites to acquire necessary images and build models of the sites from aerial surveillance data using autonomous aerial systems from RFSAT.

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[19] Autodesk FBX SDK 2020: https://www.autodesk.com/developer-network/platform-technologies/fbx-sdk-2020-0

6. Conclusions

By considering historic areas as a complex Social-Economic System, different domains have been analysed. The georeferenced information has been selected and structured in the Historic Area Information System with reference to the built and natural environment, the cultural heritage elements and the social-economic context. Data and information to characterise the heritage assets and to assess their state are provided in order to support the subsequent vulnerability analyses (e.g. WP5), also taking into account that these indicators depend on the potential hazards.

A specific relational database has been developed with the main purpose of storing information on a building / object scale on heritage assets and of relating the information to each other, allowing authorised users to make additions and changes.

Three specific tools have been designed and implemented to allow access to the dataset:

- GIS Dashboards enabling users to obtain info using intuitive and interactive maps;
- Building/Object electronic sheets to query structured data included into the database;
- 3D Viewers to navigate three-dimensional models produced for buildings and objects.

In addition a methodology has been developed for automated acquisition of 3D models from automatically operated drones, followed by automated 3D model creation, leading to the Machine Learning processing of information for automated analysis and detection of structural and material degradations, employing neural-network co-processing for both more accurate and faster processing.

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8. Annex

8.1. Table of the datasets included in HArIS

This table lists the geo-located datasets, currently, inserted in the repository\database of HArIS. Nevertheless, other information could be included or modified in the next months of the project (e.g. Socio-Economic indicators not yet included).

Domain	Element	ARCH cities			
		Bratislava	Camerino	Hamburg	Valencia
Natural Environment	Vegetation	X	X	-	X
	Geology	-	X	X	X
	Water and waterways	X	X	X	X
Built Environment	Buildings	X	X	X	X
	Road infrastructures (Roads, Railways, etc.)	X	X	X	X
	3D City Model	X*	X*	X**	-
Cultural Heritage Assets	Construction (and Objects)	X	X (X)	X	
	Crops				X
Social structure	Social indicators (population, education, etc.)	X+	X+		X++
Economic status	Economic indicators (activities, employed people)		X+		X++
Community (Facilities)	Hospital and health system, schools, university, etc.	X	X	X	X
	Other public facilities (museums, theatres, etc.)	X	X	X	X
	Emergency services (firefighters, police, etc.)	X	X	X	X
Functional areas	Land Use\Land Cover	X°	X°°	X°°	X°°

* 3D model of HA – Level of Details (LoD) 1 by CityGML; ** 3D model of the whole city – LoD2 by CityGML

\+ dataset related to the last census (2011); ++ last available dataset (2020)

° CORINE Land Cover inventory (https://land.copernicus.eu/pan-european/corine-land-cover)

°° Urban Atlas inventory (https://land.copernicus.eu/local)

8.2. Tables of the Construction\Object DB

This annex represents the guide to all the tables, with the relative fields, that make up the database of HArIS, according to the structures showed in sections 3.1.1 and 3.1.2 both for constructions (section 8.2.1) and objects (section 8.2.2). In particular, the fields that can be modified through the Construction\Object Sheet (as indicated in section 4.3) are described, as well as those that define the values that some of the fields can assume, and the others that allow the connection between the information.

8.2.1. Tables of the CONSTRUCTION database

8.2.1.1. CONSTRUCTION

Attribute	Value Type	Definition
OBJECTID	ObjectID	ID of the element in the table
BeginLifespanVersion	DateTime	Date and time at which this version of the spatial object was inserted or changed in the spatial data set.
EndLifespanVersion	DateTime	Date and time at which this version of the spatial object was superseded or retired in the spatial data set.
ConditionOfConstructionRef	ConditionOfConstructionValue	see label in ConditionOfConstructionValue table
DateOfConstruction	DateOfEvent	Date of construction.
DateOfDemolition	DateOfEvent	Date of demolition.
DateOfRenovation	DateOfEvent	Date of last major renovation.
Name	GeographicalName	Name of the asset
LegalConditions	Ineger	Public, Private, Public private partnership
Place	Text	Place
Address	Text	Address
CityRef	Integer	Reference to the Cities
Sheet	Integer	Cadastral Sheet
Parcel	String	Cadastral Parcel
SubA	String	Cadastral subaltern\subordinate

8.2.1.2. CONSTRUCTION_TO_ELEVATION

Attribute	Value Type	Definition
OBJECTID	ObjectID	ID of the element in the table
ConstructionId	integer	Reference to the CONSTRUCTION table
ElevationId	Integer	Reference to the ELEVATION table

8.2.1.3. CONSTRUCTION_TO_EXETERNAL_REFERENCE

Attribute	Value Type	Definition
OBJECTID	ObjectID	ID of the element in the table
ConstructionRef	Integer	Reference to the CONSTRUCTION table
ExternalReferenceRef	Integer	Reference to the EXTERNAL_REFERENCE table

8.2.1.4. BUILDING

Attribute	Value Type	Definition
OBJECTID	ObjectID	ID of the element in the table
CurrentUse	Current use	Activity hosted within the building. This attribute addresses mainly the buildings hosting human activities
NumberOfBuildingUnits	Integer	Number of building units in the building. A BuildingUnit is a subdivision of Building with its own lockable access from the outside or from a common area (i.e. not from another BuildingUnit), which is atomic, functionally independent, and may be separately sold, rented out, inherited, etc.
NumberOfDwellings	Integer	Number of dwellings
NumberOfFloorsAboveGround	Integer	Number of floors above ground
ConstructionRef	Integer	Reference to the CONSTRUCTION table

8.2.1.5. BUILDING_GEOMETRY_2D

Attribute	Value Type	Definition
OBJECTID	ObjectID	ID of the element in the table
BuildingRef	Integer	Reference to the BUILDING table
HorGeomEstimatedAccuracy	Real	The estimated absolute positional accuracy of the (X,Y) coordinates of the building geometry. Absolute positional accuracy is defined as the mean value of the positional uncertainties for a set of positions where the positional uncertainties are defined as the distance between a measured position and what is considered as the corresponding true position.
HorGeomReference	HorizontalGeometryReferenceValue	Element of the building that was captured by (X,Y) coordinates.
ReferenceGeometry	Boolean	The geometry to be taken into account by view services, for portrayal.
VerGeomEstimatedAccuracy	Real	The estimated absolute positional accuracy of the Z coordinates of the building geometry. Absolute positional accuracy is defined as the mean value of the positional uncertainties for a set of positions where the positional uncertainties are defined as the distance between a measured position and what is considered as the corresponding true position.
VerGeomReference	ElevationReferenceValue	Element of the building that was captured by vertical coordinates.

8.2.1.6. BUILDING_NATURE

Attribute	Value Type	Definition
OBJECTID	ObjectID	ID of the element in the table
BuildingNatureLabel	BuildingNatureType	Values indicating the nature of a building.
BuildingNatureDescription	BuildingNatureDescription	Description of the nature of a building.

8.2.1.7. BUILDING_TO_BUILDING_NATURE

Attribute	Value Type	Definition
OBJECTID	ObjectID	ID of the element in the table
BuildingRef	integer	Reference to the BUILDING table
BuildingNatureRef	integer	Reference to the BUILDING_NATURE table

8.2.1.8. CURRENT_USE

Attribute	Value Type	Definition
OBJECTID	ObjectID	ID of the element in the table
CurrentUseValueRef	CurrentUseValue	Reference to the CURRENT_USE_VALUE table
Occupants	Integer	Number of potential occupants
Percentage	Integer	The proportion of the real world object, given as a percentage, devoted to this current use.

8.2.1.9. CURRENT_USE_VALUE

Attribute	Value Type	Definition
OBJECTID	ObjectID	ID of the element in the table
CurrentUseValueLabel	CurrentUseValue_Label	Refer to CurrentUseValue table
CurrentUseValueDescription	CurrentUseValue_Description	Refer to CurrentUseValue table

8.2.1.10. STRUCTURE

Attribute	Alias	Value Type	Definition
OBJECTID		ObjectID	ID of the element in the table
ConstructionRef		integer	Reference to the CONSTRUCTION table
Name	Name	text	Identification
Additional notes	Notes	text	notes on the considered building
B1	Nr Storeys	integer	Number of storeys (including basements)
B2	Nr Basements	integer	Number of basements
B3	Average storey height [m]	integer	Average storey height
B4	Average storey surface [m]	integer	Average storey surface
B5	Construction/renovation period	Integer (1..8)	Period of construction or period relative to last important renovation [1=<1919, 2=1919-1945, 3=1946-1961, 4=1962-1971, 5=1972-1981, 6=1982-1991, 7=1992-2001, 8=>2002]
B6	Nr storeys above ground	integer	Number of storeys above ground

Attribute	Alias	Value Type	Definition
B7	Position in Aggregate	integer	Building position (in the aggregate) 0=isolated 1=internal building, 2=extreme building, 3=corner building 4=other
B8	Regularity in plan	Integer	1 = Not Regular 2 = Regular
B9	Structure	Integer	0 = Masonry 1 = Reinforced Concrete Frame 2 = Reinforced Concrete Wall 3 = Steel Frame 4 = Wood Beams 5 = Iron Beams 6 = Cast Iron Coated
C0_1	StructureTypology T1 [%]	Real	Percentage of the prevailing typology of vertical/horizontal structures. The following fields contain information about the building typology according to AEDEs form (post-earthquake survey). Reference document https://www.eeri.org/wp-content/uploads/Italy/EUR%2022868%20(2007)%20Field%20Manual%20for%20post-earthquake%20damage%20assessment.pdf
C0_2	T1-Vertical Structures	integer	Vertical Structures (prevailing typology) 1=unknown 2=Irregular layout or bad quality/without tie rods or tie beams 3=Irregular layout or bad quality/with tie rods or tie beams 4=Regular layout and good quality/ without tie rods or tie beams 5=Regular layout and good quality/with tie rods or tie beams
C0_3	T1-Horizontal Structures	Integer	C0-3 T1-Horizontal Structures integer (1,…,6) Horizontal structures (prevailing typology) 1=Unknown 2=Vaults without tie rods 3=Vaults with tie rods 4=Beams with flexible slab 5=Beams with semirigid slab 6=Beams with rigid slab) X
C0_4	Structure Typology T2 [%]	Real	Percentage of the secondary typology (derived as 100-C0-1) of vertical/horizontal structures

Attribute	Alias	Value Type	Definition
C0_5	T2-Vertical Structures	Integer	VerticaVertical Structures (secondary typology) 1=unknown 2=Irregular layout or bad quality/without tie rods or tie beams 3=Irregular layout or bad quality/with tie rods or tie beams 4=Regular layout and good quality/ without tie rods or tie beams 5=Regular layout and good quality/with tie rods or tie beams l Structures (secondary typology)
C0_6	T2-Horizontal Structures	Integer	HorizontalHorizontal structures (secondary typology) 1=Unknown 2=Vaults without tie rods 3=Vaults with tie rods 4=Beams with flexible slab 5=Beams with semirigid slab 6=Beams with rigid slab) structures (secondary typology)
C0_7	Isolated columns	Integer	Presence of isolated Presence of isolated columns 0=no, 1=yes columns
C0_8	Mixed structures	Integer	Presence of a mixed structure typology 1=frame over masonry 2=masonry over frame 3=masonry and frame in parallel
C0_9	Strengthening	Integer	Presence of strengthened masonry 1=injections or unreinforced plasters 2=reinforced masonry of reinforced plasters 3=other or unknown strengthening
C0_10	Roof	Integer	Roof 1=thrusting heavy 2=non thrusting heavy 3=thrusting light 4=non thrusting light
C1_1	Material M1 [%]	Real (0-100)	Percentage related to the prevailing typology The following fields contain information about the masonry survey campaign. There are 2 prevalent types that will be weighted according to the percentage of presence. (reference document to be included)
C1_2	M1-Masonry Typo	Integer (1..7)	Prevailing typology Code for field 2.2 TYPOLOGY in MQI Form 1=stone 2=brick 3=semi-hollow bricks (<45%) 4=hollow bricks (>45%) 5=tuffs elements 6=mixed masonry 7=other

Attribute	Alias	Value Type	Definition
C1_3	M1-Brick courses	Integer (1,..,6)	Prevailing typology Code for field 2.3 BRICK COURSES in MQI Form 1=present at a fixed distance 2=present at variable distance 3=present (other material) 4=present (brick) 5=present (RC) 6=absent
C1_4	M1-Listed Masonry	Integer (1,..,2)	Prevailing typology Code for field 2.4 LISTED MASONRY in MQI Form 1=absent 2=present
C1_5	M1-pinning stones	Integer (1,..,3)	Prevailing typology Code for field 2.5 PINNING STONES in MQI Form 1=absent 2=present (brick) 3=present (stone)
C1_6	M1-Horizontal Joint	Integer (1,..,3)	Prevailing typology Code for field 2.6 HORIZONTALITY OF BED JOINT in MQI Form 1=not fulfilled 2=partially fulfilled 3=fulfilled
C1_7	M1-Vertical Joint	Integer (1,..,3)	Prevailing typology Code for field 2.7 STAGGER PROPERTIES OF VERTICAL JOINTS in MQI Form 1=Aligned vertical joint (NF) 2=Partially staggered vertical joints (PF) 3=Properly staggered vertical joints (F)
C1_8	M1-Elements	Integer (1,..,8)	Prevailing typology Code for field 3.1.1 STONE/BRICK ELEMENT in MQI Form 1=sandstone 2=limestone 3=hardstone 4=tuff 5=bricks 6=unfired bricks 7=RC 8=other
C1_9	M1-Origin	Integer (1,..,5)	Prevailing typology Code for field 3.1.2 ORIGIN OF THE STONE/BRICK in MQI Form 1=local excavation 2=river bed 3=quarry 4=artificial product 5=other

Attribute	Alias	Value Type	Definition
C1_10	M1-Processing	Integer (1,..,4)	Prevailing typology Code for field 3.1.3 STONE/BRICK PROCESSING in MQI Form 1=no processing 2=rounded or pebble stonework 3=natural square block 4=artificial square block
C1_11	M1-Conservation	Integer (1,..,4)	Prevailing typology Code for field 3.1.4 CONSERVATION STATE OF STONE/BRICK in MQI Form 1=good 2=decent 3=poor 4=very bad
C1_12	M1-Shape	Integer (1,..,7)	Prevailing typology Code for field 3.1.5a STONE/BRICK SHAPE in MQI Form 1=pebbles 2=erratic blocks 3=slabs 4=rubble 5=artificial square blocks 6=blocks 7=square blocks
C1_13	M1-Regularity Class	Integer (1,..,3)	Prevailing typology Code for field 3.1.5b STONE/BRICK REGULARITY in MQI Form 1=Not fulfilled 2=Partially fulfilled 3=Fulfilled
C1_14	M1-Dimension	Integer (1,..,3)	Prevailing typology Code for field 3.1.6a STONE/BRICK DIMENSION in MQI Form 1= stones dimension < 20cm 2=stones dimension 20-40 cm 3=stones dimension > 40 cm
C1_15	M1-Dimension Class	Integer (1,..,3)	Prevailing typology Code for field 3.1.6b STONE/BRICK DIMENSION REGULARITY in MQI Form 1=Not fulfilled 2=Partially fulfilled 3=Fulfilled
C1_16	M1-Mortar function	Integer (1,..,3)	Prevailing typology Code for field 3.2.1 MORTAR FUNCTION in MQI Form 1=bedding 2=facework 3=filling

Attribute	Alias	Value Type	Definition
C1_17	M1-Mortar Consistency	Integer (1,..,5)	Prevailing typology Code for field 3.2.2 MORTAR CONSISTENCY in MQI Form 1=dusty mortar 2=weak mortar 3=medium quality mortar 4=good quality mortar 5=other
C1_18	M1.Mortar Colour	Integer (1,..,12)	Prevailing typology Code for field 3.2.3 MORTAR COLOR in MQI Form 1=whitish 2=ivory white 3=light grey 4=grey 5=dark grey 6=beige 7=grey – ochre 8=ochre 9=hazelnut 10=light brown 11=brown 12=pinkish
C1_19	M1-Mortar Aggregate Colour	Integer (1,..,5)	Prevailing typology Code for field 3.2.4 (MORTAR) COLOR OF THE AGGREGATE in MQI Form 1=whitish 2=ivory white 3=light grey 4=grey 5=dark grey 6=beige 7=grey – ochre 8=ochre 9=hazelnut 10=light brown 11=brown 12=pinkish
C1_20	M1-Mortar Aggregate Type	Integer (1,..,3)	Prevailing typology Code for field 3.2.5 (MORTAR) TYPE OF AGGREGATE in MQI Form 1=sand 2=gravel 3=fine gravel
C1_21	M1-Mortar Aggregate Shape	Integer (1,..,2)	Prevailing typology Code for field 3.2.6 (MORTAR) SHAPE OF THE AGGREGATE in MQI Form 1=rounded 2=edgy

Attribute	Alias	Value Type	Definition
C1_22	M1-Joint Regularity	Integer (1,..,3)	Prevailing typology Code for field 3.2.7° (MORTAR) BED JOINT REGULARITY in MQI Form 1=Not Fulfilled 2=Partially Fulfilled 3=Fulfilled
C1_23	M1-Joint Dimension	Integer (1,..,2)	Prevailing typology Code for field 3.2.7b (MORTAR) BED JOINTS DIMENSION in MQI Form 1=thin 2=thick
C1_24	M1-Mortar Quality Class	Integer (1,..,3)	Prevailing typology Code for field 3.2.7 QUALITY OF THE MORTAR in MQI Form 1=Not Fulfilled 2=Partially Fulfilled 3=Fulfilled
C1_25	M1-NTC Class	Integer (1,..,8)	Prevailing typology NTC 2019 - Circolare classification, Tab. C8-5-1 1=Irregular stone masonry (pebbles, erratic, irregular stones) 2=Uncut stone masonry with facing walls of limited thickness and infill core 3=Cut stone with good bonding 4=Irregular soft stone masonry (tuff, limestone, etc.) 5=Regular soft stone masonry (tuff, limestone, etc.) 6=Dressed rectangular (ashlar) stone masonry 7=Solid brick masonry with lime mortar 8=Semi-solid brick masonry with cement mortar

8.2.1.11. CONSTRUCTION MATERIAL

Attribute	Alias	Value Type	Definition
OBJECTID		ObjectID	ID of the element in the table
ConstructionRef		integer	Reference to the CONSTRUCTION table
D0_1	Prevalent Material	text	Type of prevalent material of the construction
D0_2	Plaster	Real (0..1)	Percentage of Plaster
D0_3	Sandstone	Real (0..1)	Percentage of Sandstone
D0_4	Limestone	Real (0..1)	Percentage of Limestone
D0_5	Plaster	Real (0..1)	Percentage of plaster
D0_6	Brick	Real (0..1)	Percentage of Brick
D0_7	Other Materials	Real (0..1)	Percentage of Other Materials

Attribute	Alias	Value Type	Definition
D1_1	M1-Carbonate Content	Integer (0,1)	Prevailing typology (according to typology considered in C1-1 – C1-25) Quality index relative to the chemical-physical parameter n.1 CARBONATE CONTENT BY CALCIMETRY 0= 0-10% 1=>10%
D1_2	M1-Salt Content	Integer (1..5)	Prevailing typology Quality index relative to the chemical-physical parameter n.2 SOLUTE SALT CONTENT BY CONDUCTIMETRY, measured according to UNI11087 and classified as follow 1=(>20%), 2=(10-20%), 3=(10-6%), 4=(3-6%), 5=(<3%)
D1_3	M1-Porosity	Integer (1..3)	Prevailing typology Quality index relative to the chemical-physical parameter n.3 MORTAR POROSITY BY PHISISORPTION POROSIMETRY 1=(>40%) 2= (20-40%), 3=(<20%)
D1_4	M1-Granulometry	Integer (1..4)	Prevailing typology Quality index relative to the chemical-physical parameter n.4 GRANULOMETRIC ANALYSIS BY THIN SECTIONS, classified according to CNR NorMsL12/83 guidelines (in Italian) 1= homogeneous (1 class) 2= almost homogeneous (2 classes) 3= almost heterogeneous (3 classes) 4= heterogeneous (>3 class)
D1_6	M1-Dimension MQI	Vector (dim.3) of reals (0..10)	Prevailing typology MQI score for STONE/BRICK DIMENSION (values between 0 and 10, 3 fields for vertical, orthogonal, coplanar behaviour)
D1_7	M1-Strenght MQI	Vector (dim.3) of reals (0..10)	Prevailing typology MQI score for STONE/BRICK STRENGHT (values between 0 and 10, 3 fields for vertical, orthogonal, coplanar behaviour)
D1_8	M1-Mortat MQI	Vector (dim.3) of reals (0..10)	Prevailing typology MQI score for QUALITY OF MORTAR (values between 0 and 10, 3 fields for vertical, orthogonal, coplanar behaviour)
D1_9	M1-Masonry MQI	Vector (dim.3) of reals (0..10)	Prevailing typology MQI score for MASONRY(values between 0 and 10, 3 fields for vertical, orthogonal, coplanar behaviour)

Attribute	Alias	Value Type	Definition
D1_10	M1-Masonry Category	Vector (dim.2) of integers (1..3)	Prevailing typology MASONRY overall CATEGORY 1=category A, 2=B, 3=C, 3 fields for vertical, orthogonal, coplanar behaviour
D1_11	M1-Mechnical Prop [N/mmq]	Vector (dim.3) of reals	Prevailing typology MECHANICAL PARAMETERS EVALUATION of the MASONRY (3 fields for compressive strength, shear strength and modulus of elasticity) [N/mmq]
D3	MQI-Average	real (0,..,1)	Average MQI - Overall average quality index to be used as a parameter of the vulnerability model (weighted average between the 2 types of masonry of the minimum die and MQI indices). If not available, the reference average value is assigned

8.2.1.12. FOUNDATION

Attribute	Alias	Value Type	Definition
OBJECTID		ObjectID	ID of the element in the table
ConstructionRef		integer	Reference to the CONSTRUCTION table
E1	Site Morphology	integer (1,..,4)	Site morphology 1=crest 2=sleep slope 3=mid slope 4=plan
E2	Foundations	integer (1,..,4)	Damage to the foundations 1=Absent 2=produced by earthquake 3=worsened 4=pre-existent

8.2.1.13. DAMAGE

Attribute	Alias	Value Type	Definition
OBJECTID		ObjectID	ID of the element in the table
ConstructionRef		integer	Reference to the CONSTRUCTION table
F1_2	Damage Floors	Integer (0,333)	Damage to the structural components: floors Score as F1-1
F1_3	Damage Stairs	Integer (0,333)	Damage to the structural components: stairs Score as F1-1
F1_4	Damage Roof	Integer (0,333)	Damage to the structural components: roof Score as F1-1
F1_5	Damage Partition	Integer (0,333)	Damage to the structural components: infill-partitions Score as F1-1
F1_6	Pre-existing Damage	Integer (0,333)	Damage to the structural components: Pre-existing damage Score as F1-1

Attribute	Alias	Value Type	Definition
F1_1	Damage Vertical Structures	Integer (0..333)	Damage to the structural components: vertical structures Code consisting of 3 integers: The first position (hundreds) describes the extension of very heavy damage, The second position (tens) describes the extension of medium severe damage, the third one (units) describes the extension of slight damage Extension is described by the following code 0= no damage or negligible damage 1=extension >2/3 2=1/3<extension <2/3 3=extension <1/3 (ordered as in AEDES form) e.g. 002 (or 2)=slight damage with extension between 1/3 and 2/3 110 = very heavy damage with extension<1/3 and medium damage with extension<1/3
F2_1	Damage Coverings	Integer (0,1)	Damage to the no structural components: falling of plaster, coverings, false ceilings 0=absent 1=present
F2_2	Damage Tiles Chimneys	Integer (0,1)	Damage to the no structural components: falling of tiles, chimneys Score as F2-1
F2_3	Damage Eaves	Integer (0,1)	Damage to the no structural components: falling of eaves, parapets Score as F2-1
F2_4	Damage Objects	Integer (0,1)	Damage to the no structural components: falling of internal or external objects Score as F2-1
F2_5	Damage Hydraulic	Integer (0,1)	Damage to the no structural components: damage to hydraulic or sewage systems Score as F2-1
F2_6	Damage Electric/gas	Integer (0,1)	Damage to the no structural components: damage to electrical or gas systems Score as F2-1
F3	Usability Classification	integer (1,..,6)	Usability classification 1=usable building 2= usable with countermeasures (temporary unusable) 3=partially unusable 4=requiring more detailed investigation (temporary unusable) 5=unusable 6=unusable for external risk

8.2.1.14. SOCIAL_CULTURAL_HISTORICAL_VALUE

Attribute	Alias	Value Type	Definition
OBJECTID		ObjectID	ID of the element in the table
ConstructionRef		integer	Reference to the CONSTRUCTION table

G1	Historical Value	Real (0..10)	Historical value
G2	Cultural, aesthetic and symbolic value	Real (0..10)	Cultural, aesthetic and symbolic value
G3	Social value	Real (0..10)	Social value
G4	Religious, Spiritual value	Real (0..10)	Religious, spiritual and commemorative value
G5	Recreational value	Real (0..,10)	Recreational value
G6	Other value	Real (0..10)	Other value
G7	Socio-Cultural Index	Real (0..1)	Index value for estimating a loss. If this information is missing, the reference value 0.5 is assigned

8.2.1.15. ELEVATION

Attribute	Value Type	Definition
OBJECTID	ObjectID	ID of the element in the table
ElevationReferenceRef	ElevationReferenceValue	Refer to ELEVATION_REFERENCE_VALUE table
ElevationValue	Real	Value of the elevation.

8.2.1.16. ELEVATION_REFERENCE

Attribute	Value Type	Definition
OBJECTID	ObjectID	ID of the element in the table
ElevationLabel	ElevationReferenceValue_Label	see ElevationReferenceValue table
ElevationDescription	ElevationReferenceValue_Description	see ElevationReferenceValue table

8.2.1.17. HEIGHT_ABOVE_GROUND

Attribute	Value Type	Definition
OBJECTID	ObjectID	ID of the element in the table
BuildingRef	integer	Reference to the BUILDING table
HeightReference	ElevationReferenceValue	Element used as the high reference.
LowReference	ElevationReferenceValue	Element as the low reference.
HeightStatus	HeightStatusValue	The way the height has been captured.
Value	Length	Value of the height above ground.

8.2.1.18. HEIGHT_STATUS

Attribute	Value Type	Definition
OBJECTID	ObjectID	ID of the element in the table
HeightStatusLabel	HeightStatusValue_Label	see label in HeightStatusValue table
HeightStatusDescription	HeightStatusValue_Description	Refer to HeightStatusValue table

8.2.1.19. HORIZONTAL_GEOMETRY_REFERENCE

Attribute	Value Type	Definition
OBJECTID	ObjectID	ID of the element in the table
HorizontalGeometryLabel	HorGeoReferenceValue_Label	refer to HorGeoReferenceValue table
HorizontalGeometryDesc	HorGeoReferenceValue_Description	refer to HorGeoReferenceValue table

8.2.1.20. MEASURE

Attribute	Value Type	Definition
OBJECTID	ObjectID	ID of the element in the table
MeasureType	integer	Reference to the MEASURE_TYPE table
MeasurementDate	Date	Date of the measure
ConstructionRef	integer	Reference to the CONSTRUCTION table
Marker3D	integer	Reference to the Marker3Dvalue table

8.2.1.21. MEASURE_TYPE

Attribute	Value Type	Definition
OBJECTID	ObjectID	ID of the element in the table
MeasureTypeLabel	MeasureTypeValue_Label	see label in MeasureTypeValue table
MeasureTypeDescription	MeasureTypeValue_Description	Refer to MeasureTypeValue table

8.2.1.22. BuildingNatureValue

Label	Description
arch	A man-made structure in the form of an arch.
bunker	A facility, partly underground, intended for or used by the military either for location of command/control centres or for troop encampment.
canopy	An overhead roof providing shelter to things below. Canopies may be free standing frameworks over which a covering is attached or may be linked or suspended to the outside of a building.
caveBuilding	A space hosting human or economic activity which is usually enclosed within rock with the addition of man-made exterior walls and which may contain structures comparable to the interior structures of freestanding buildings.
chapel	A Christian place of worship, usually smaller than a church.
castle	A large ornate or fortified building usually constructed for the purpose of a private residence or security.
church	A building or structure whose primary purpose is to facilitate the catholic or orthodox cult.
dam	A permanent barrier across a watercourse used to impound water or to control its flow.

Label	Description
greenhouse	A building that is often constructed primarily of transparent material (for example: glass), in which temperature and humidity can be controlled for the cultivation and/or protection of plants.
lighthouse	A tower designed to emit light from a system of lamps and lenses.
mosque	A building or structure whose primary purpose is to facilitate the Muslim cult.
shed	A building of light construction, which usually has one or more open sides, that is typically used for storage.
silo	A large storage structure, generally cylindrical, used for storing loose materials.
stadium	A place or venue for sports, concerts or other events and consists of a field or stage either partly or completely surrounded by a structure designed to allow spectators to stand or sit and view the event.
storageTank	A container usually for holding liquids and compressed gases.
synagogue	A building or structure whose primary purpose is to facilitate the is religious cult.
temple	A building or structure whose primary purpose is to facilitate the meeting of a religious sect.
tower	A relatively tall, narrow structure that may either stand alone or may form part of another structure.
windmill	A building which converts the energy of the wind into rotational motion by means of adjustable sails or blades.
windTurbine	A tower and associated equipment that generates electrical power from wind.
Column	An upright pillar, typically cylindrical, supporting an arch, entablature, or other structure or standing alone as a monument.
Monastery	A building occupied by a community of monks living under religious vows.
Obelisk	A tapering stone pillar, typically having a square or rectangular cross section, set up as a monument or landmark.
Palace	A large and impressive building forming the official residence of a ruler, pope, archbishop, etc.
Trilithon	A megalithic structure consisting of two upright stones and a third across the top as a lintel.
Triumphal Arch	A monumental structure in the shape of an archway with one or more arched passageways
Groups buildings	Groups of separate or connected buildings
Historical nucleus	Historical nucleus
Monumental sculpture and painting	Works of monumental sculpture and painting
Gardens	Parks and gardens
nature human work	Combined work of nature and humankind
Archaeological finds	Archaeological finds
Archaeological sites	Archaeological sites

8.2.1.23. ConditionOfConstructionValue

Label	Description
declined	A construction cannot be used under normal conditions, though its main elements (walls, roof) are still present.
demolished	A construction has been demolished. There are no more visible remains.
functional	A construction is functional.
projected	A construction is being designed. Construction has not yet started.
ruin	The construction has been partly demolished and some main elements (roof, walls) have been destroyed. There are some visible remains of construction.
underConstruction	A construction is under construction and not yet functional. This applies only to the initial construction of the construction and not to maintenance work.
underRenovation	A construction is under renovation and not yet functional.

8.2.1.24. CurrentUseValue

Label	Description
residential	A building (or building component) is used for residential purpose.
individualResidence	A building (or building component) hosts only one dwelling.
collectiveResidence	A building (or building component) hosts more than one dwelling.
twoDwellings	A building (or building component) hosts two dwellings.
moreThanTwoDwelling	A building (or building component) hosts at least 3 dwellings.
residenceForCommunities	A building (or its component) hosting a residence for communities.
agriculture	A building (or building component) is used for agricultural activities.
industrial	A building (or building component) is used for secondary sector activities (industrial).
commerceAndServices	A building (or building component) is used for any service activities. This value addresses the buildings and building components dedicated to tertiary sector activities (commercial and services).
office	A building (or building component) hosts offices.
trade	The building (or building component) hosts trade activities.
publicServices	A building (or building component) hosts public services. Public arteria services provided for the benefit of the citizens.
ancillary	A building (or building component) of small size that is used only in connection with another larger building (or building component) and generally does not inherit the same function and characteristics as the building (or building component) it is linked to.
religious	A building (or building component) hosts religious activities.

8.2.1.25. ElevationReferenceValue

Label	Description
aboveGroundEnvelope	The elevation has been captured at the level of the maximum extent of the above ground envelope of the construction.
bottomOfConstruction	The elevation has been captured at the bottom of the usable part of the construction.
entrancePoint	The elevation has been captured at the entrance of the construction, generally the bottom of entrance door.
generalEave	The elevation has been captured on one of the meeting lines between the roof and the walls.
generalGround	The elevation has been captured on one of the meeting lines between the construction and the ground.
generalRoof	The elevation has been captured anywhere on the roof.
generalRoofEdge	The elevation has been captured on one of the roof edges.
highestEave	The elevation has been captured on the highest meeting line between the roof and the walls.
highestGroundPoint	The elevation has been captured on the highest point of the meeting lines between the construction and the ground.
highestPoint	Elevation has been captured at the highest point of the construction, including the installations, such as chimneys and antennas.
highestRoofEdge	The elevation has been captured at the highest roof edge level of the construction.
lowestEave	The elevation has been captured on the lowest meeting line between the roof and the walls.
lowestFloorAboveGround	The elevation has been captured at the level of the lowest floor above ground.
lowestGroundPoint	The elevation has been captured on the lowest point of the meeting lines between the construction and the ground.
lowestRoofEdge	The elevation has been captured at the lowest roof edge level of the construction.
topOfConstruction	The elevation has been captured at the top level of the construction.

8.2.1.26. HeightStatusValue

Label	Description
estimated	The height has been estimated and not measured.
measured	The height has been (directly or indirectly) measured.

8.2.1.27. HorGeoReferenceValue

Label	Description
aboveGroundEnvelope	The building horizontal geometry has been captured using the above ground envelope of the building, i.e. the maximum extent of the building above ground.
combined	The building horizontal geometry has been obtained from the combination of the geometries of its building parts with the geometries of the building parts using different horizontal geometry references.
entrancePoint	The building geometry is represented by a point located at the entrance of the building.
envelope	The building horizontal geometry has been captured using the whole envelope of the building, i.e. the maximum extent of the building above and underground.
footPrint	The building horizontal geometry has been captured using the footprint of the building, i.e. its extent at ground level.
lowestFloorAboveGround	The building horizontal geometry has been captured using the lowest floor above ground of the building.
pointInsideBuilding	The building horizontal geometry is represented by a point located within the building.
pointInsideCadastralParcel	The building horizontal geometry is represented by a point located within the parcel the building belongs to.
roofEdge	The building horizontal geometry has been captured using the roof edges of the building.

8.2.1.28. MeasureTypeValue

Label	Description
OTH	Unknown
3DM	3D Model
PDF	PDF file
TXT	Text file
PIC	Picture
LSC	Laser Scanning
IRT	IR Thermographic image
CAD	Technical drawing CAD
STM	Static monitoring
DYM	Dynamic monitoring
HYM	Hyperspectral analysis on construction materials
SCL	Sclerometer Test
SNC	Sonic Test
UTS	Ultrasonic test

8.2.2. Tables for the *OBJECT* database

8.2.2.1. OBJECT

Attribute	Value Type	Definition
OBJECTID	Object ID	
SheetRef	Integer	Reference to the existent identification
StorageAreaRef	Integer	Reference to STORAGE_AREA table defining a container
ShelterAreaRef	Integer	Reference to STORAGE_AREA table defining a shelter in emergency phase
CurrentStorageArea	text	Current Storage Sector
HistoricStorageArea	text	Historic Storage Sector
Title	text	title or subject of the artefact
Quantity	Integer	Quantity of the elements
Description	Text	Description of the object\artefact
Author	Text	Author of the object\artefact
Diameter	Double	diameter dimension in cm
Width	Double	width dimension in cm
Depth	Double	depth dimension in cm
Height	Double	height dimension in cm
Category	Integer (1..3)	1 movable 2 immovable (3 intangible)
DisciplinarySector	Integer (1..10)	1 archaeological 2 architecture 3 landscape 4 ethnoanthropological 5 photographic 6 musical 7 naturalistic 8 numismatists 9 scientific-technological 10 historical-artistic
Artefact	TypeArtefact	1 painting 2 wall painting 3 sculpture 4 religious object 5 decoration
Officer	text	Officer
Note	text	Note
Date	date	Date from which the object is in the current position

8.2.2.2. STORAGE_AREA

Attribute	Value Type	Definition
OBJECTID	Object ID	
CityRef	Integer	Reference to the city
ConstructionRef	integer	Reference to the CONSTRUCTION table
Name	text	Name of the storage area
Longitude	double	Longitude
Latitude	double	Latitude
Shelter	Integer (1..2)	1 Conventional storage 2 Shelter (storage in emergency phase)

8.2.2.3. EVENT

Attribute	Value Type	Definition
OBJECTID	Object ID	
ArtefactRef	Integer	Reference to the OBJECT table
Purpose	text	Purpose of the movement of the objects
Description	text	Description of the event for which the object will be moved
DateStart	date	Start date of the event
DateEnd	date	End date of the event
ExternalResponsible	text	Responsible internal to the city\stakeholder
InternalResponsible	text	Responsible internal to the city\stakeholder

8.2.2.4. INTERVENTION

Attribute	Value Type	Definition
OBJECTID	Object ID	
ArtefactRef	Integer	Reference to the OBJECT table
Rating	integer (1..5)	Rating assigned to the intervention on the artefact: 1 very low 2 low 3 medium 4 high 5 very high
Urgency	integer (1..5)	Urgency assigned to the intervention on the artefact: 1 very low 2 low 3 medium 4 high 5 very high
EvaluationDate	Date	Evaluation Date of the intervention

Attribute	Value Type	Definition
DateStart	Date	Start date of the intervention
DateEnd	Date	End date of the intervention
Responsible	Text	Responsible of the intervention
Description	Text	Description of the intervention

8.2.2.5. ATTACHMENT

Attribute	Value Type	Definition
OBJECTID	Object ID	
TableName	TableName	Reference to the table: - OBJECTS - INTERVENTION -...
ID_ref	Integer	Refence to the ID of the table TableName
File	Text	Path + filename