

General methodology for the preventive conservation of cultural heritage buildings

Report of the Project Activity 1.2 (GT.1)

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Abstract

Currently, no systematic policy for the preventive conservation of built cultural heritage exists in the South-West Europe. The existing approaches for inspection, diagnosis, monitoring and curative conservation are often intermittent, unplanned, overpriced and lack a methodical strategy. The HeritageCARE project – monitoring and preventive conservation of historic and cultural heritage – arises in response to this need. Its ultimate goal is the creation of a non-profit self-sustaining entity which will keep supervising the accomplishment of the methodology and the sustainability of the results once the project is concluded.

The present report belongs to the first Group of Activities of the project and aims at outlining the methodology for the preventive conservation of cultural heritage buildings that has been elaborated by the Consortium during the first year of the project.

The report starts with an introduction followed by a general description of the HeritageCare methodology. Thereafter, three sections present in detail the service levels the methodology relies on: Service Level 1 – StandardCare, Service Level 2 – PlusCare, and Service Level 3 – TotalCare. This multi-level system of services represents the core of the HeritageCare *modus operandi* and the Consortium is committing to keep it as affordable as possible to help owners/managers embark on the conservation process of their properties.

The main conclusions drawn from the work carried out hitherto are given at the end of the report together with a brief indication of the forthcoming project activities.

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1 Introduction

Currently, no systematic policy for the preventive conservation of built cultural heritage exists in the South-West Europe (Figure 1). The existing approaches for inspection, diagnosis, monitoring and curative conservation are often intermittent, unplanned, overpriced and lack a methodical strategy. The available financial resources are scarce and they are mostly addressed to listed structures. Besides, owners and stakeholders often conceal an inborn reluctance to invest in preventive conservation and maintenance programs.

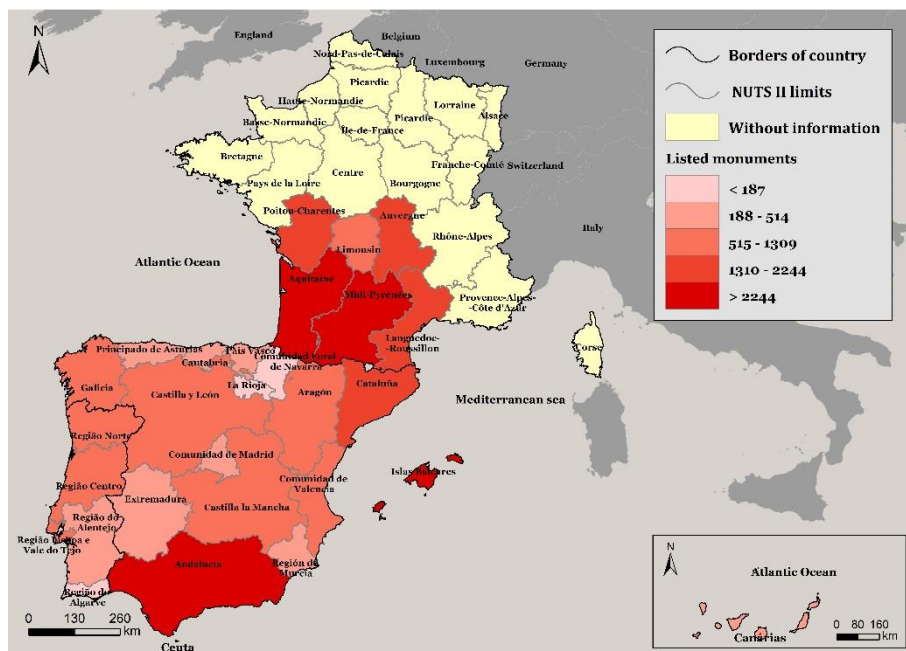


Figure 1: Distribution of built Heritage in the Southwest Europe.

In light of these considerations and driven by the principle “prevention is better than cure”, the HeritageCare project has been launched within the Interreg-SUDOE program co-funded by the ERDF, with the purpose of unfolding an integrated and sustainable strategy for the preventive conservation of built cultural heritage in the South-West Europe. This project involves 3 Countries (Portugal, Spain and France), 8 beneficiary partners and 11 associated partners (Figure 2).

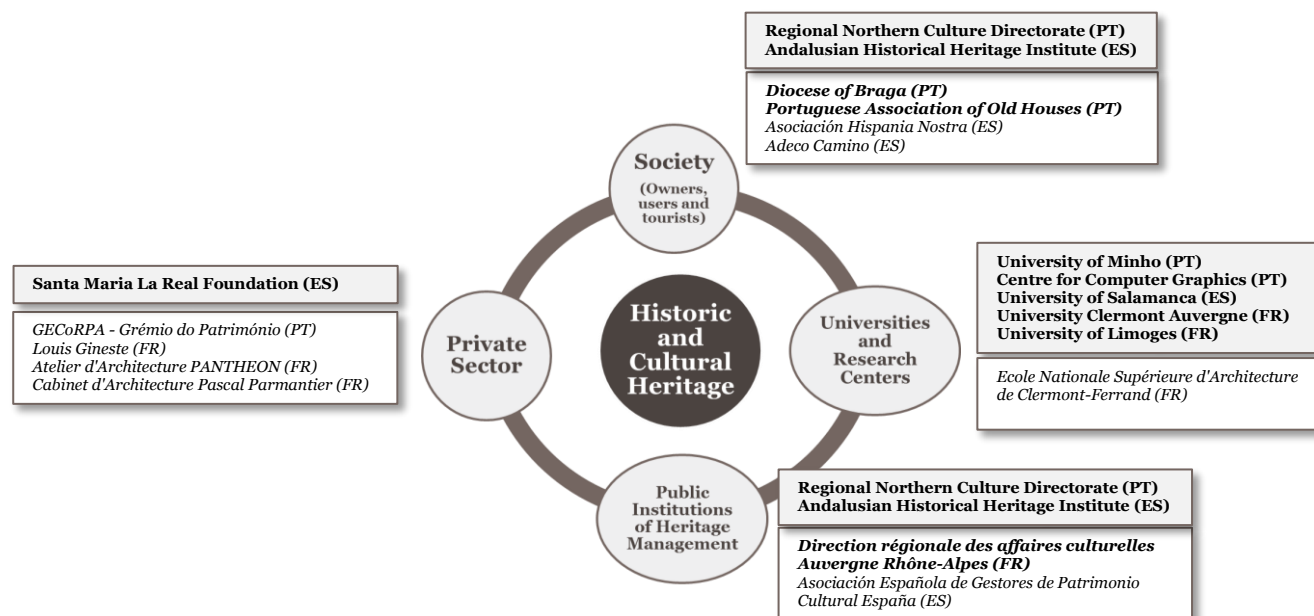


Figure 2: Consortium of the HeritageCare Project.

The ultimate goal of the HeritageCare project is the creation of a non-profit self-sustaining entity which will keep pursuing the accomplishment of the methodology and supervising the sustainability of the results once the project is concluded.

This document belongs to the first Group of Activities of the project and aims at outlining in very general terms the methodology for the preventive conservation of cultural heritage buildings that has been elaborated by the Consortium during past months. The next project activities will allow to test the effectiveness of such a methodology and eventually refine it before proceeding with the development of guidelines and best practice rules.

In detail, the present report is composed by the following sections:

Section 1: Introduction

Section 2: General description of the HeritageCare methodology

Section 3: Service Level 1 – StandardCare

Section 4: Service Level 2 – PlusCare

Section 5: Service Level 3 – TotalCare

Section 6: Conclusions

2 General description of the HeritageCare methodology

2.1 Main goals

The HeritageCare methodology relies on a multi-level system of services for the systematic inspection, diagnosis, conservation and management of the built cultural heritage existing in the South-West Europe. The implementation of the methodology encompasses the integration of advanced tools and technologies which further enhance the quality of the services provided.

In the short-term, HeritageCare sets out to accomplish the following objectives:

- Application and validation of the methodology for preventive conservation of cultural heritage buildings;
- Creation of a 4D database for assets management and information exchange;
- Standardization of methods and tools for maintenance and preventive conservation through the development of guidelines and rules of “*good practice*”.

In the long-term, the HeritageCare mission is to:

- Raise public awareness about the social and economic benefits associated with regular inspections and preventive conservation measures of historic buildings;
- Involve the society, in particular the technical-scientific community, public authorities and institutions as well as the conservation and restoration sector, in order to lead a more efficient and sustainable way for the protection of historical and cultural heritage;
- Connect the general public to heritage by directly engaging them in the conservation process of such valuable assets.
- Create and operate as a non-profit entity to pursue a common not-for-profit goal, that is the monitoring and preventive conservation of built cultural heritage.

2.2 HeritageCare entity and main services

The main challenge of this project is the creation of a non-profit self-sustaining entity that will keep pursuing the HeritageCare mission once the project is concluded.

In legal terms, this entity will be either a charitable trust, an association or a service organization provided with a proper statute and a structured management system with three operating units (one per Country) and one umbrella board composed by a few representatives of each Country. The management structure will be grounded on two pillars: one directive pillar, responsible for the administrative, financial and commercial aspects as well as the coordination of human resources; and one scientific pillar, responsible for leading and overseeing fieldwork and *modus operandi*.

As funds and revenues are necessary for implementing the methodology and providing the relevant services, HeritageCare entity shall work as a subsidized system. Sources of financial support may come from:

- Building annual fees (estimated to be between 50€ to 100€/building);
- Cost of the service level(s) provided (SL1, SL2 and/or SL3);
- Other sources (e.g. public and private institutions; church-related organisations; insurance agencies; enterprises/companies included in the HeritageCare list of certified enterprises; freelances; newsletters subscriptions and advertising; fund-raising events).

It is noted that the designation ‘nonprofit’ does not mean that the organization cannot generate revenues, but rather that the revenues or funds realized in the operation of the entity must be retained for its self-preservation and not used to benefit any members.

The beneficiary and associated partners of the current project shall be the only HeritageCare’s shareholders (or equivalents). The participation/incorporation of other entities and bodies, like governmental organizations, associations of restorers, universities, and the like, will be defined in a later stage. Nevertheless, any association, foundation or council linked to the preservation and conservation of cultural heritage at national and international level, such as ICOMOS, UNESCO and EUROPANOSTRA, shall be involved within the HeritageCare system.

Regardless of the Country, HeritageCare entity shall operate according to a common methodology based on a system of services organised in three levels (Figure 3):

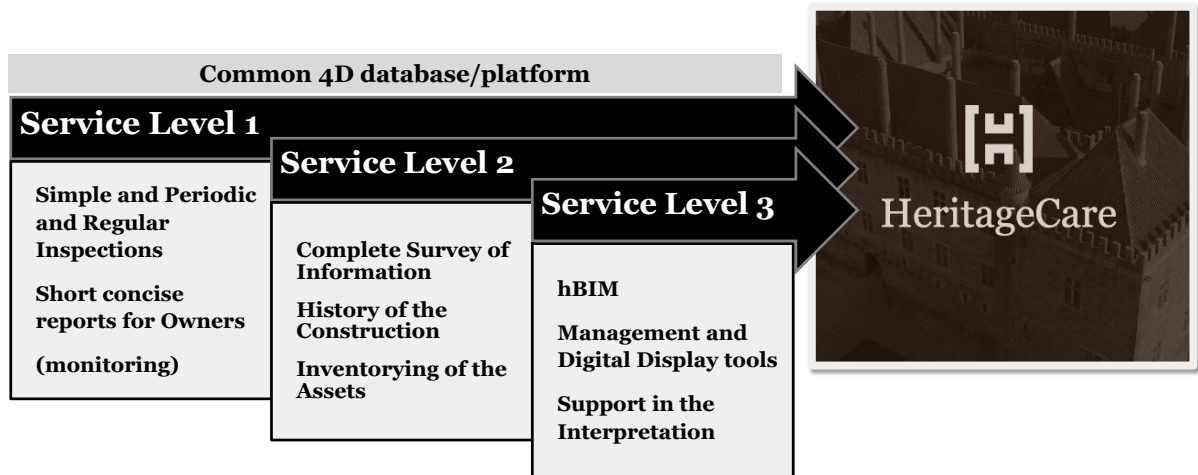


Figure 3: General methodology of HeritageCare

Service Level 1 (SL1): “Clinical picture” of the heritage building over time – Qualified teams perform detailed on-site inspections of the historic fabrics at regular intervals with the aid of specific fillable forms/e-forms.

Service Level 2 (SL2): It includes the SL1 and a virtualization of the heritage building and assets inventory – Complete geometrical surveys of target constructions are carried out by means of 3D recording techniques. Additional information is collected (e.g. results from monitoring activities and ND testing, assets inventory). All information from SL1 and SL2 are integrated and stored in the 4D database.

Service Level 3 (SL3): It includes the SL1 and information integration and management – Digital models of the heritage structures are built, accessed and manipulated through hBIM (historical Building Information Modelling), allowing faster information sharing, better management of heritage buildings, integration between preventive conservation actions and management systems. All information from SL1, SL2 and SL3 are integrated and stored in the 4D database.

All levels provide high-quality services suited to serve the purpose they are conceived for, but fieldwork, tools and final outputs vary for each of them. Hence, different names are associated with the three service levels, depending on their functionality (Table 1).

Table 1: Designation of HeritageCare Service Levels.

Service Level	Designation	Functionality
SL1	StandardCare	Provision of what is essential for the primary health and ordinary maintenance of the heritage building
SL2	PlusCare	Provision of what is necessary for the primary health, ordinary maintenance and thorough screening of the heritage building along with its integrated and movable assets
SL3	TotalCare	Provision of what is necessary for the primary health, ordinary maintenance, thorough screening and enhanced management of the heritage building along with its integrated and movable assets

General remarks and main characteristics of each service level are given in Table 2. A more detailed description follows in the next sections of this report.

Table 2: General remarks for each Service Level.

SL1 StandardCare	<ul style="list-style-type: none"> • SL1 must be simple, feasible, low-cost and should allow a rapid condition screening of the heritage construction • Each heritage building/asset must have an ID card • A historic analysis of the building should be performed prior to on-site inspections in order to get acquainted about construction phases, previous structural interventions, maintenance works, actual use, etc. • Inspections must be carried out by at least two inspectors able to give a general overview of and assess both structure and integrated assets. Based on this first inspection, the real need of having a second inspection with experienced professionals will be evaluated • Climbing techniques are not mandatory but considered a desired tool for inspectors • The time devoted to cleaning and small repair works should not exceed 10% to 20% of the total inspection time • The periodicity of inspections may vary from case to case, depending on the health condition and size of the building, but a time span of 3 years is fixed for 'regular' buildings • The inspections will follow a protocol with a precise checklist of items to inspect which will be also used for the report with recommendations to owners • Re-inspections must repeat the same steps of the first inspection, following the same checklist so as to easily compare current and previous building conditions. The re-inspections should also highlight whether or not owners have followed the recommendations provided by HeritageCare during the first inspection
SL2 PlusCare	<ul style="list-style-type: none"> • Service Level 2 can be only carried out after Service Level 1: SL1 is complementary to SL2 • The main purpose of SL2 is to provide owners and facility managers with detailed info about the geometry and the health condition of their properties in order to orientate preventive actions in a more accurate way (and timely, if problems are detected) • SL2 should include: geometric survey with 3D recording techniques (photogrammetry/laser scanner/back-pack mapping); 3D virtualization and modelling; collection of additional info (historic documentation, assets inventory and inspection, results from monitoring activities and NDTs); information integration from 4D database • Photogrammetric techniques must be used to foster the comparison of the building condition over time. The analysis of data from monitoring systems can further support this comparison • The real need to perform ND tests within SL2 will be evaluated during the development of the project • 3D models built in SL2 should serve only from a geometrical point of view, keeping the integration of information for the digital models in SL3
SL3 TotalCare	<ul style="list-style-type: none"> • Service Level 3 can be only carried out after Service Level 2: SL2 is complementary to SL3, and so is SL1 • SL3 inspections should follow the protocol of inspection of SL1 but with the aid of an AR app using Microsoft HoloLens technology in order to support and ease the inspection procedure • The main goal of SL3 is the correct integration of all information collected from former service levels and the enhanced management of heritage assets through the BIM platform • Interoperability between HeritageCare database and BIM software is a key issue. • A VR navigation tool will be developed to virtually move inside the buildings and visualize the information stored in the database while walking across them. • By leveraging BIM technology, SL3 should streamline the conservation and management process of monumental buildings.

The effectiveness and validity of the HeritageCare methodology for preventive conservation of built cultural heritage will be proven through its application to real case studies to choose among the great variety of heritage buildings spread over the SUDOE territory, e.g. churches, chapels, palaces, castles, ancient buildings, etc. (Figure 4). In detail, the first service level of the methodology will be applied and validated through sixty case-study buildings (twenty per country). Fifteen out of sixty case studies (five per country) will be then selected for the implementation of the second service level of the methodology. Finally, one case study per country will be further exploited to put into practice the third and last level of the HeritageCare methodology. During the project time frame, the implementation of the methodology will have no cost for the end users.

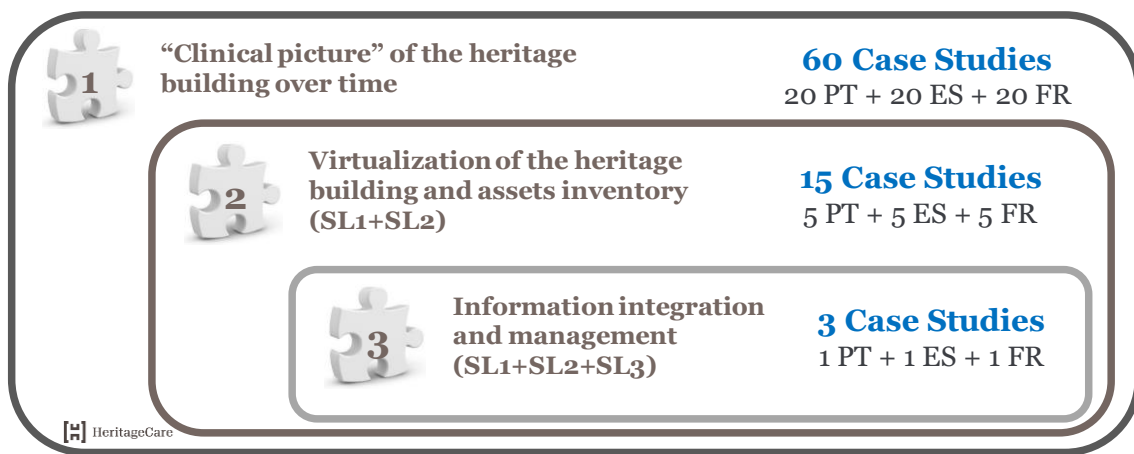


Figure 4. Distribution of HeritageCare case studies by service level.

2.3 End users

Owners and/or Managers of buildings/assets with historical and cultural value (either listed or not, either public or private) can derive great benefits from joining the HeritageCare system. The voluntary participation of owners is considered essential for the implementation of the preventive conservation management system. The non-profit profile for the entity to apply the methodology and services is crucial.

2.4 In case of a problem

In case of a serious/urgent problem, Owners as well as national Heritage Authorities will be timely alerted. Owners will be advised to contact experts to perform additional Inspection and

Diagnosis works and to plan a prompt intervention. They will also be informed about construction companies operating according to the best practices and with recognized experience on conservation, so as to help them seek for a proposal of intervention on their property.

3 Service Level 1 – StandardCare

According to the European Standard UNI EN 16096, the condition survey is the first step to undertake in order to plan appropriate and effective preventive conservation measures on built cultural heritage, thereby minimizing future damage and deterioration processes.

The condition survey is carried out by HeritageCare professionals through on-site inspection(s), appropriately preceded and followed by pre- and post-inspection phases. The three phases form the core of Service Level 1, which can be schematized as follows:

Steps 1st inspection SL1



Steps re-inspection SL1



Next, all progressive stages composing SL1 will be briefly described along with the type of information that shall be assessed step-by-step during each stage. Further details and more exhaustive information are provided in Annex A (reference file: *4D Database SL1 and SL2 V2.xlsx*).

3.1 Prior to inspection

The condition screening of SL1 encompasses a prior-to-inspection phase which aims at collecting all necessary information that will form the basis for the subsequent fieldwork. During this phase, the following groups of information shall be compiled: (1) the first owner's interview; (2) building ID info; (3) management info; and (4) equipment info.

Owner's Interview

The first contact with the owner should be an informal interview where all oral information (or sources of information) about the building and its assets should be collected. During this colloquial meeting, the inspectors shall clarify to the owner what type of works will be carried out by the HeritageCare entity, as well as the expected outputs for him. A very important point is to convince the owner to create the proper conditions for the building accessibility.

Building ID info

This group of information is fundamental to create the IDentity card of the historic building that will be inspected by HeritageCare. Such information may be acquired, for instance, from existing cultural heritage databases, cadastre/land registers, records of previous works, public administrations and authorities, or even from the owner(s). Building ID info comprises:

Object Information

- a) Object code, name, category, overview plan/image;
- b) Address, location, GPS coordinates, cadastral number;
- c) Classification (listed building info, relevant entity, protection status);
- d) Original and current function;
- e) Function periods (visiting/worship times – if the building is open to public);
- f) Inspection periods.

Property Information

- a) Number of Associate (when subscription to HeritageCare system already exists);
- b) Owner/Tenant/Manager's name, address and contact details.

Construction Information

- a) Construction period/date;
- b) Main construction systems, materials, number of floors;
- c) Short building description (appearance, components, constituent materials, finishes);
- d) Short site description (climatic/environmental/geological conditions of the area, interactions with adjacent objects, etc.);
- e) Other technical data.

Map Information

Brief description complemented by schematic sketches of all components and spaces relevant for mapping purposes, namely roofs, façades, floors, rooms.

Management Info

Before inspection, a historic analysis of the building shall be made to get acquainted about previous interventions, ongoing maintenance works, actual use, etc. Source materials may come from existing cultural heritage databases, cadastre/land registers, earlier inventories and conservation plans, inspection reports from national and regional authorities, and the like. In detail, the information listed below shall be assessed at this stage, if available:

Object Information

This information comes from the general object information registered in the Building ID. The only new field here concerns a summary of functional changes that the building object of inspection might have undergone over time.

Construction Information

To foster a better understanding of the built cultural heritage and to ease related management issues, the following information shall be obtained and added to the construction information section of the Building ID:

- a) Architect/constructor/author;
- b) Fabric (entity who paid the construction works);
- c) Historic survey (original drawings, photographs, construction phases, functional and structural alterations, additions, demolitions, bibliographic references);
- d) Short description of previous inspections/interventions/maintenance actions;
- e) Description of interventions/maintenance actions carried out after HeritageCare inspections and recommendations;
- f) Main dimensions of the object (height, ground area, number of floors);
- g) Other useful technical data.

Integrated and movable objects Information

Beyond the information related to the building architecture, basic information associated with the integrated and movable objects found within the fabric shall be gathered and registered. The following items are highlighted:

- a) Significance, age, features, function and materials of integrated and movable objects (main and exceptional);
- b) Bibliographic references;
- c) Other observations.

Equipment Info

A systematic planning stage is fundamental to avoid setbacks while operating on site. All material resources and equipment needed to carry out in situ inspections shall be clearly defined beforehand, depending on the case-study. HeritageCare recommends the following list of equipment for SL1 inspections:

Building/Architecture

Name	Short description	Technical characteristics
Basic survey equipment	paper, pencil, markers, portable work table, meter/rule, laser meter, binoculars, level, ladder (2 to 5 m), small hammer (for sonic tests), brush, scalpel, knife (timber), lamps, flashlights, dust mask, latex and cotton gloves	several
Security equipment	helmets, security shoes, first aid kit, climbing ropes	several
Inspection form	HeritageCare form for StandardCare	Paper form
Tablet	A tablet must be used to run apps to help during inspections	Minimum 32 GB for storage and 4 GB for RAM. Android 6.0
Apps	Apps with inspection form and damage Atlas.	Such as DStretch (decorrelation of the RGB channels of the device used during the e-form), Photosynth or another 360-panorama viewer; off-line options
Building plan	Building plan/sketch to write down info during the inspection	Building plan/sketch to be added on the building ID
Digital cameras	360° digital camera	Light and with long battery life; Synergy between 360° cameras and e-forms
Drone	for inspection of roofs and parts difficult to access	Max take-off weight 4 kg, max wind speed resistance 10 m/s, remote controller
Van	Medium-sized road vehicle for carrying inspection equipment	Fully equipped with ladder, survey and safety equipment, cleaning tools, artificial light, etc.
Telescopic tripod	Lightweight tripod with several sections able to get higher heights than the standard tripods	Several sections (more than 3-4) Aluminium Elements to improve the stability of the system Maximum height: 4-6 m Head compatible with the panoramic and standard tripod heads
Compass	Guidance instrument	n.d.
Portable borescope	Inspection camera	Wi-Fi Portable Endoscope Camera Snake Inspection Video Endoscope for iOS / Android 6pcs Interface Tablet USB 2.0 MP 8.4mm 10M
Power generator	Noiseless air compressor	Noise level: 65 dB Motor: 1,5 Hp- 1.1. Kw- 230 V single-phase

Integrated and movable objects

Name	Short description	Technical characteristics
Latex gloves	Talc free. Disposable, natural, 9.5 inches long and with 4 thousandths of a thickness.	Talc free. Disposable, natural, 9.5 inches long and with 4 thousandths of a thickness.
Nitrile gloves	Material free of latex and chemical residues, non-sterile, talc free, ergonomic, higher calibre, optimum sensitivity, ambidextrous, high strength, blue colour.	Material free of latex and chemical residues, non-sterile, talc free, ergonomic, higher calibre, optimum sensitivity, ambidextrous, high strength, blue colour.
Dust masks	Adjustable nasal bridge: Simple verification of the use of correct protection in the workplace, yellow code: FFP1 according to EN 149: 2001 + A1: 2009, detectable metal.	Adjustable nasal bridge: Simple verification of the use of correct protection in the workplace, yellow code: FFP1 according to EN 149: 2001 + A1: 2009, detectable metal.
Cotton gloves	Made of 100% cotton fabric, with closed cuff adjustable in white colour	Inspection type cotton glove, seamless, protects fingerprints and scratches on the finished product. Size 9 for men and 7 for women
First aid kit		410 x 310 x 100 Weight 6,420 kg.
Safety helmet	Yellow colour, adjustable polyethylene, antiperspirant tape.	Weight 380 gs. Norma CE EN 397
Wash wipes	Double layer, aloe vera and lanolin, special for all types of dirt.	100 washwipes dispenser 280 x 270 mm.
Binocular visor		Available magnifications (Da-2,3,4)

3.2 During the inspection

In situ inspections are performed by at least two professionals with adequate background on materials, construction techniques, damage mechanisms and deterioration processes of both movable and immovable heritage assets. The fieldwork shall be supported by an inspection form/e-form which will allow to perform the condition and risk assessment of the building object of study as well as its single constituent parts. The entries of the inspection form shall include the following items:

Inspection Form for Buildings

1 Roof covering

- 1.1 Function and geometry of coverage
- 1.2 Finishing systems
- 1.3 Junctions and singularities
- 1.4 Chimneys
- 1.5 Roof lights, etc.
- 1.6 Others

2 Roof supporting structure

- 2.1 Structural elements and materials
- 2.2 Supports of structural elements
- 2.3 Others

3 Rain water system (from roof to the bottom)

- 3.1 Gutters
- 3.2 Rain pipes
- 3.3 Sewerage
- 3.4 Others

4 Building envelope

- 4.1 Vertical structural elements
- 4.2 Horizontal and structural elements
- 4.3 Isolated external elements
- 4.4 Masonry anchors, grids and related items
- 4.5 Balconies and terraces
- 4.6 Exterior stairs
- 4.7 Wall copings and parapets
- 4.8 Doors and Windows, including glasses
- 4.9 Outside wall finish
- 4.10 Others

5 Building Interior

- 5.1 Vertical structural elements
- 5.2 Horizontal structural elements
- 5.3 Internal finishing materials
- 5.4 Internal staircases and walkways
- 5.5 Doors and Windows, including glasses
- 5.6 Others

6 Integrated and movable objects

- 6.1 Fixed furniture
- 6.2 Movable furniture
- 6.3 Others

7 Technical installations and equipment

- 7.1 Plumbing systems
- 7.2 Sewage system (dirty waters)
- 7.3 Electricity system
- 7.4 Sound system and networks
- 7.5 Belfries and Tower clocks
- 7.6 Especial machinery
- 7.7 Others

8 Indoor Climate

- 8.1 Relative humidity
- 8.2 Air temperature
- 8.3 Light exposure
- 8.4 Ventilation
- 8.5 Others

9 Prevention and Safety

- 9.1 Seismic Vulnerability
 - 9.1.1 Seismic zone
 - 9.1.2 Irregularities and interactions
 - 9.1.3 Horizontal diaphragms and roofing system
 - 9.1.4 Quality of the structural system and conservation status for seismic behaviour
- 9.2 Lightning protection
- 9.3 Fire protection
- 9.4 Theft and vandalism
- 9.5 Preservation
- 9.6 Others

10 Accessibility and hygiene

- 10.1 Accessibility
- 10.2 Cleaning
- 10.3 Garbage and waist
- 10.4 Animals and insects
- 10.5 Others

11 Site

- 11.1 Pavement and terrain
- 11.2 Enclosure
- 11.3 Biological growth
- 11.4 Others

Condition & Risk Classification

The condition of all construction elements listed above shall be assessed and recorded based on a grading scale system (Table 3) that associates a qualitative/quantitative index to each of the inspected items. Such index shall take into account the type and extent of damage and shall be weighted according to the importance and role played by each element within the building (note that the weighing factor might vary case-by-case). The condition grade of a group of construction components shall correspond to the condition grade of the most damaged part(s) belonging to that group. Finally, depending on the condition and risk assessment of each group of components, an overall evaluation will be provided for the following items:

- 1) Building envelope;
- 2) Building Interior;
- 3) Technical Installations, Prevention & Safety;
- 4) Accessibility, Hygiene & Site.

According to this criterion, the need for urgent remedial measures or additional inspection & diagnosis works will be automatically highlighted.

Table 3. HeritageCare grading system for condition and risk classification.

Class No.	Condition Classification	Symptoms	Urgency Risk Classification	Comments
0	Good	No symptoms	Long term	No immediate actions required Preventive monitoring is necessary
1	Fair	Minor Symptoms	Medium term	The condition of the fabric is not perfect but does not need immediate action Monitoring is necessary to prevent further decay
2	Poor	Moderately Strong Symptoms	Short term	The condition of the fabric is such that it needs timely repair or additional inspection and diagnosis work
3	Bad	Major Symptoms	Urgent and Immediate	Urgent repair is necessary Urgent additional inspection and diagnosis work
NA/NI	Not Accessible	Parts not (safely) accessible	Not Inspected	Parts that are 'not inspected' are either not (safely) accessible for the building inspectors or not visible

On-site Works

During on-site inspections, HeritageCare professionals shall carry out only:

- a) Small cleaning works (e.g. removal of plant/cast, unclog gutters);
- b) Easy repair works (e.g. tile replacement/fixing);
- c) Non-postponable urgent measures (e.g. removal of dangerous detached stones).

Any direct intervention on the building which differs from the ones listed above shall not be performed (e.g. repointing). In presence of significant problems, HeritageCare shall either alert the owners about the necessity for in-depth diagnostics or restrict the access to the building if life-safety requirements are not met. The time devoted by HeritageCare inspectors to on-site works shall not exceed 15-20% of the total inspection time.

3.3 After the inspection

Following the inspection, a back-office work shall be carried out by HeritageCare inspectors in order to check out, upload and store on the database all information collected on site (real-time upload is not available if the inspection e-form is filled in offline). This assortment of data shall be easily accessed, managed, integrated and updated over time. The database will be exploited to feed a web-based platform provided with different user authorizations so that different individuals (e.g. staff members, owners and stakeholders) can access only specific web contents based on their identity.

Owners Report

Main output of the back-office work is the report with recommendations for owners. Based on the inspection outcome, HeritageCare shall elaborate an easy-to-read document to shed light on the state of conservation of the inspected object, along with case-specific maintenance actions to undertake by the owners in the short/medium/long term to prevent further decay. The report shall follow the outline given below:

- Cover page;
- Table of contents (1-2 pages);
- Administrative & building information (one-page short resume of the Building ID);
- Condition assessment (through the grading system) & recommendations for short, medium or long term maintenance of each inspected item (2 pages):

1. Building envelope - including roof and water drainage system;
 2. Building Interior - including indoor climate;
 3. Technical Installations, Prevention & Safety;
 4. Accessibility, Hygiene & Site;
- Track record of preventive conservation actions and schedule of future maintenance actions (one-page graphical representation);
 - Annex 1: Description of identified damages and anomalies according with the checklist/protocol of inspection (max 20 pages);
 - Annex 2: Links to guidelines for good practices on preventive conservation (one page).

Owners Report Layout

The layout of the owners' report shall have the template shown in Figure 5 and provided in the reference file *HeritageCare Owners Report V2.docx*. The header shall always contain the name of the service level performed (e.g. StandardCare for SL1) as well as logo, address and contact details of the HeritageCare entity. The footer shall feature the logos of all beneficiary partners.



Figure 5. Example of layout for owners' report.

Web Content Layout for Owners

Unlike HeritageCare staff, who has full ownership and control over the contents present on the web platform, owners of inspected buildings can only access and download the information related to their own property(ies), namely:

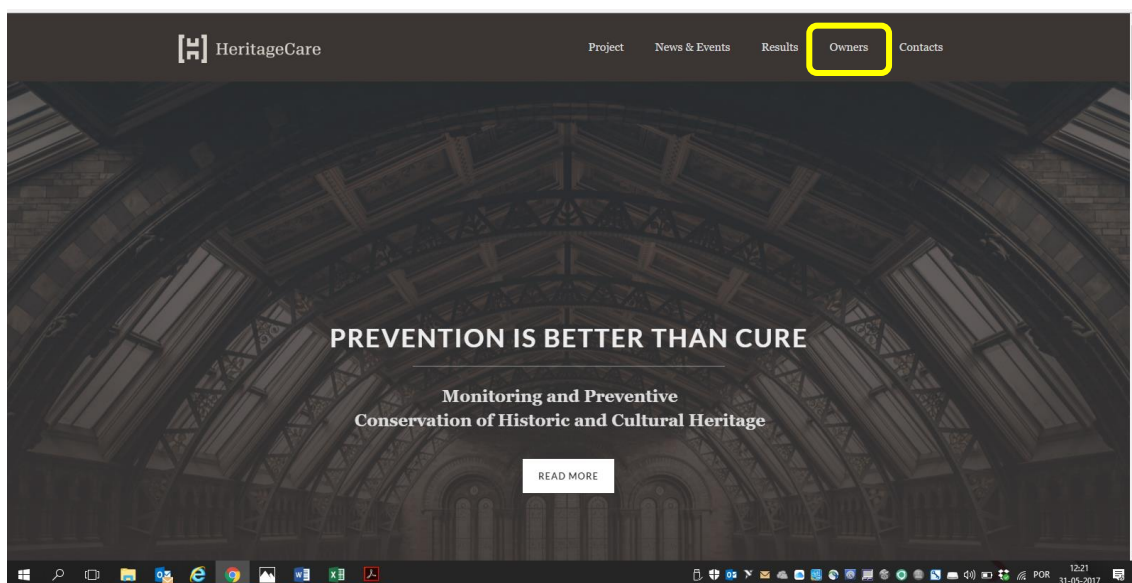
- Short/complete Building ID;
- Historic survey (Management info);
- Reports with condition assessment & recommendations.

Owners are not provided with editing rights on the web contents. Still, specific editable fields and web forms will be made available to them in order to:

- Report to HeritageCare the adopted preventive conservation actions;
- Raise warnings about unexpected events or problems;
- Ask to HeritageCare questions and advices.

Access >

Owners can log in to their restricted area from the navigation menu at the top of the HeritageCare homepage, by clicking on the item '*Owners*'.



Home >

Once logged in and selected the **StandardCare** key, owners will be redirected to a homepage with a short ID of their property, the graphical outcome of the condition assessment with the relevant recommendations, and the editable fields for the owner's feedback.

StandardCare Building Inspection

subscriber

legal protection

Inventory OE

current function

Inspection date

Paços dos Duques de Bragança

Museu do Paço dos Duques de Guimarães

R. Conde Dom Henrique, 4810-245 Guimarães, Portugal

Listed building | Nacional Monument

43084

Museum

31/05/2017, 02/06/2017

Condition Assessment

Building Envelope

Roof Covering	Good condition	Long Term	No immediate action required. Continuous monitoring
Roof Structure	Not Accessible		Condition can not be inspected. Condition not likely to change. However, make sure that there are no visible signs of deterioration.
Rain water system	Poor condition	Short Term	Investigation of drainage system. Check if water is properly drained. Additional inspection and diagnosis work.
Building Envelope	Red condition	Urgent and immediate	Repair is needed. Urgent action required to prevent further damage and deterioration.

Consequences

- The roof structure might be severely affected
- Water infiltration can happen in the building
- One unknown area of building can be a surprise

Recommendations

- [Urgent]** Three broken tiles on the roof must be replaced
- [Short]** Biological colonization should be checked to avoid problems with the drainage system
- [Medium]** Owner should make accessible the north part of the roof

Owner's Feedback

Report a preventive conservation activity

Ask a Question or Doubt

Report a Warnings to HeritageCARE

Building Interior

Roof Covering	Good condition	Long Term	No immediate action required. Continuous monitoring
Roof Structure	Not Accessible		Condition can not be inspected. Condition not likely to change. However, make sure that there are no visible signs of deterioration.
Rain water system	Poor condition	Short Term	Investigation of drainage system. Check if water is properly drained. Additional inspection and diagnosis work.

Consequences

- The roof structure might be severely affected
- Water infiltration can happen in the building
- One unknown area of building can be a surprise

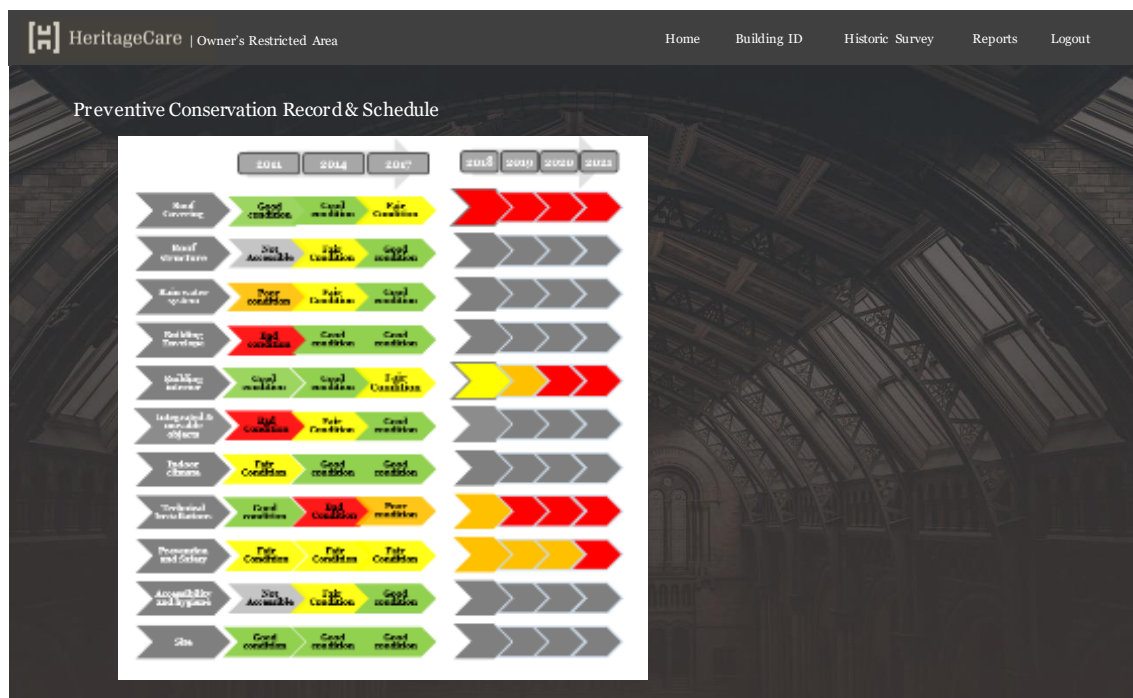
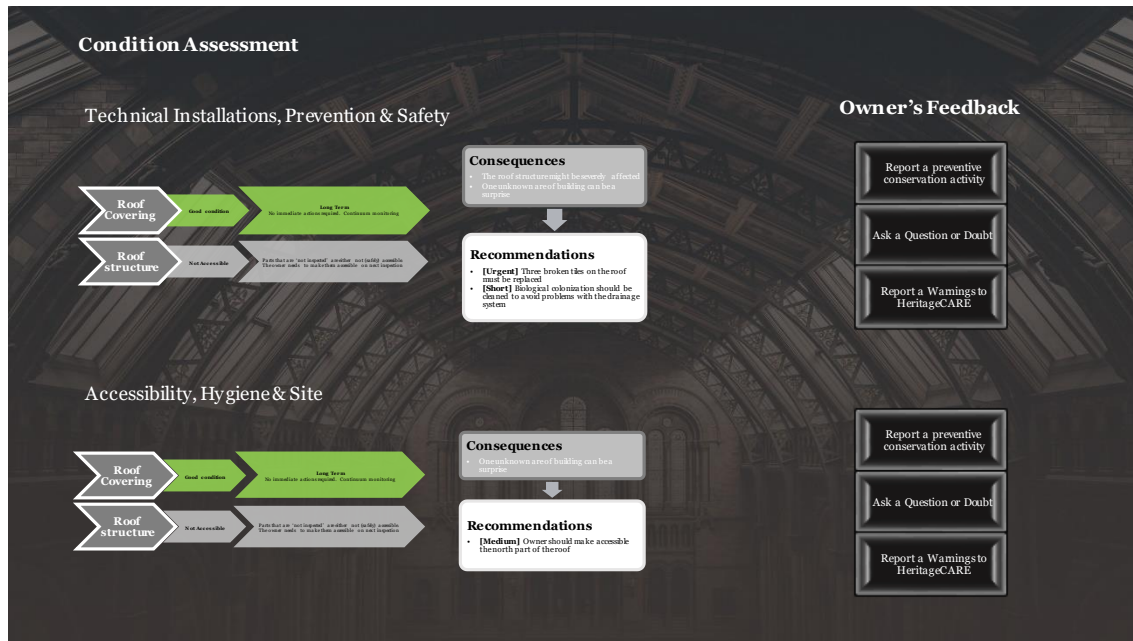
Recommendations

- [Urgent]** Three broken tiles on the roof must be replaced
- [Short]** Biological colonization should be checked to avoid problems with the drainage system
- [Medium]** Owner should make accessible the north part of the roof

Report a preventive conservation activity


Ask a Question or Doubt

Report a Warnings to HeritageCARE



Building ID >

By clicking on the item 'Building ID' of the navigation menu of the restricted area, owners can access and download – via appropriate 'pdf download button' – the complete ID of the building(s) along with their respective map(s).



StandardCare Building Inspection

Building ID


[download pdf](#)

General Object Information

Name and/or category of the object	Text text text ext text text text text text text text text
Address / Localization	Text text text ext text text text text text text text text
Global GPS coordinates	Text text text ext text text text text text text text text
Public or private building	Text text text ext text text text text text text text text
Listed as / Entity	Text text text ext text text text text text text text text
Cadastral matrix number	Text text text ext text text text text text text text text
Original function	Text text text ext text text text text text text text text
Current function	Text text text ext text text text text text text text text
Images	Text text text ext text text text text text text text text
Visiting/functions periods	Text text text ext text text text text text text text text
Inspection periods	Text text text ext text text text text text text text text

Property

Number of Associate	Text text text ext text text text text text text text text
Owner name	Text text text ext text text text text text text text text
Owner Address	Text text text ext text text text text text text text text
Owner phone contacts	Text text text ext text text text text text text text text
Owner e-mail contacts	Text text text ext text text text text text text text text



StandardCare Building Inspection

Building ID

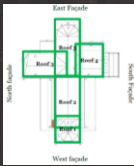
[download pdf](#)

Construction Information

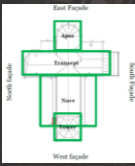
Date/period of construction	Indicate the most precisely possible the date or the period of construction of the building or parts of it
Main Materials	Short description
Main construction systems	Short description
Number of floors	List of the components with a short description (construction, constituent materials and finishes). If the construction/material is not identified, this should be noted and a general description of the visual appearance should be made. It should be agreed in advance which components are the subject of the condition survey. Information about local environmental, climatic and geological conditions of the area, interactions with adjacent objects (other buildings and/or constructions) and any other external influences (e.g., excavations, trees removed)
Short description	
Site Condition	
Other technical data	In case of information that doesn't fit in previous fields

Building maps

Roof plan




Floor plan



[download pdf](#)

Historic Survey >

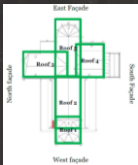
By selecting the menu item ‘*Historic Survey*’, owners can also retrieve information about the construction of their building(s) in terms of materials, techniques, construction period and phases, etc. Again, appropriate download options will be provided for the owners to get the pdf version of this documentation.



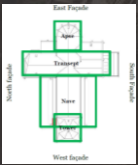
StandardCare Building Inspection

Building maps

Roof plan



Floor plan



download pdf

Historic Survey

download pdf

Construction Information

<i>Fabric</i>	Entity who pays the works/constructions
<i>Architect / Constructor / Author</i>	Name (and maybe a contact)
<i>Date/period of construction</i>	List of the components with a short description (construction, constituent materials and finishes). If the construction/material is not identified, this should be noted and a general description of the visual appearance should be made. It should be agreed in advance which components are the subject of the condition survey.
<i>Short description (*)</i>	
<i>Bibliographic References</i>	
<i>Main Materials (*)</i>	A detailed description about the main materials which constitute the building
<i>Main construction techniques (*)</i>	A detailed description about the construction techniques
<i>Construction Phases (Option A)</i>	With the possibility to link with other databases (see if it's possible to have authorization to use these links)
<i>Construction Phases (Option B)</i>	Detailed description of the (different) construction phases and functional and structural changes. This will reflect the successive changes in the use of the original structure (damages, collapses, reconstructions, additions, demolition, modifications, restoration works, structural modifications and any change). This way it's possible to identify the different

Reports >

Finally, the complete report(s) resulted from HeritageCare inspection(s) can be accessed by owners via the menu item 'Reports' on the top right of the navigation menu. The content of each report is fully available both for online reading and downloading.

Web Content Layout for Stakeholders

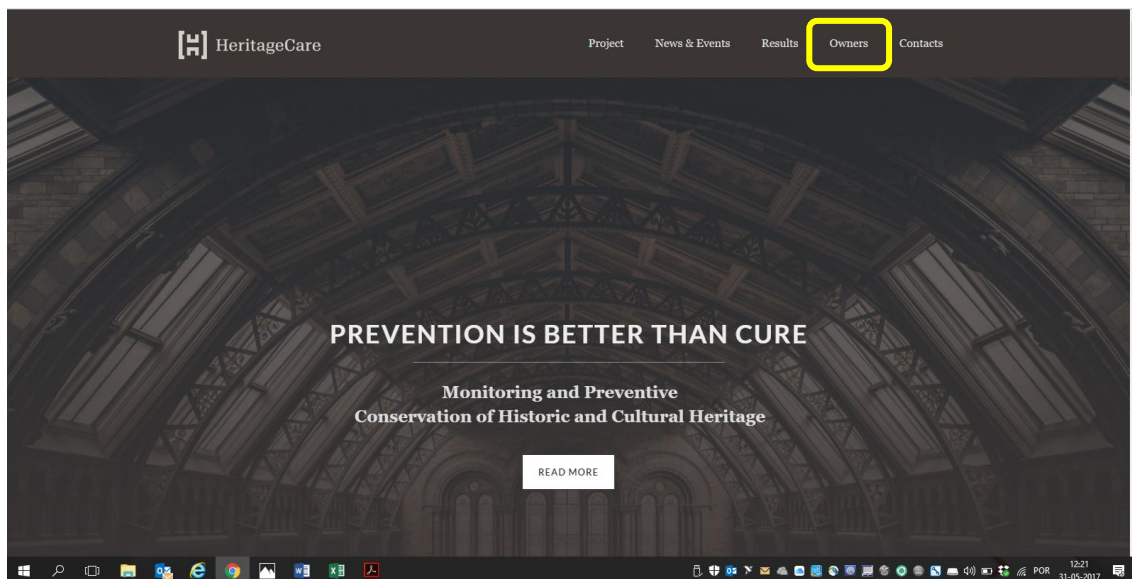
Public authorities, governmental organisations and stakeholders in general shall have authorizations different from owners. What matters to them is to have a broad statistics-based overview that allows for:

- Number, distribution and overall state of conservation of the heritage buildings present over a certain territory;
- List of subscribers (owners) and inspected buildings;
- Track record of subscribers' performance in terms of preventive conservation actions and forecast of building health conditions (warnings);
- Statistics in general.

Stakeholders are not provided with editing rights on the web content, therefore they can only visualize and read online the afore-mentioned information.

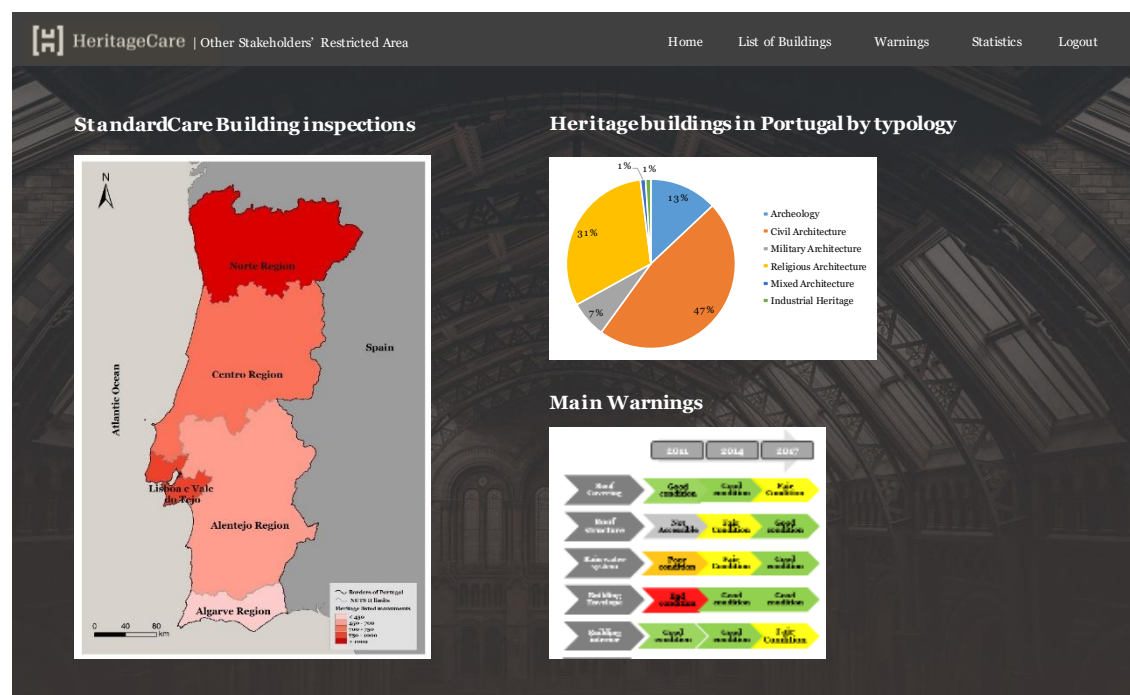
Access >

Stakeholders can login to their restricted area from the navigation menu at the top of the project homepage, by clicking the item '*Owners*' or '*Other Stakeholders*'.




Home >

Once logged in, stakeholders will be redirected to a homepage providing a general picture of the distribution, typology and main warnings of the heritage buildings inspected over a certain territory (Portugal, Spain, France).



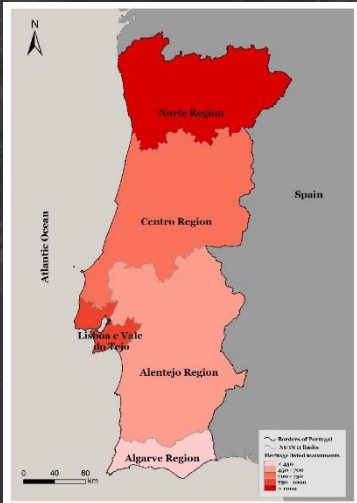
List of Buildings >

By clicking on the item 'List of Buildings' of the navigation menu of the restricted area, stakeholders can access the list of subscribers (owners) along with information concerning current function, status of protection (listed or non-listed building), address and inventory code of the relevant inspected buildings.


HeritageCare | Other Stakeholders' Restricted Area

Home
List of Buildings
Warnings
Statistics
Logout

StandardCare Building inspections



List of Buildings

subscriber	Museu do Paço dos Duques de Guimarães
legal protection	R. Conde Dom Henrique, 4810-245 Guimarães, Portugal
Inventory OE	Listed building Nacional Monument
current function	43084 Museum m
Inspection date	31/05/2017, 02/06/2017

subscriber	Museu do Paço dos Duques de Guimarães
legal protection	R. Conde Dom Henrique, 4810-245 Guimarães, Portugal
Inventory OE	Listed building Nacional Monument
current function	43084 Museum m
Inspection date	31/05/2017, 02/06/2017

subscriber	Museu do Paço dos Duques de Guimarães
legal protection	R. Conde Dom Henrique, 4810-245 Guimarães, Portugal
Inventory OE	Listed building Nacional Monument
current function	43084 Museum m
Inspection date	31/05/2017, 02/06/2017

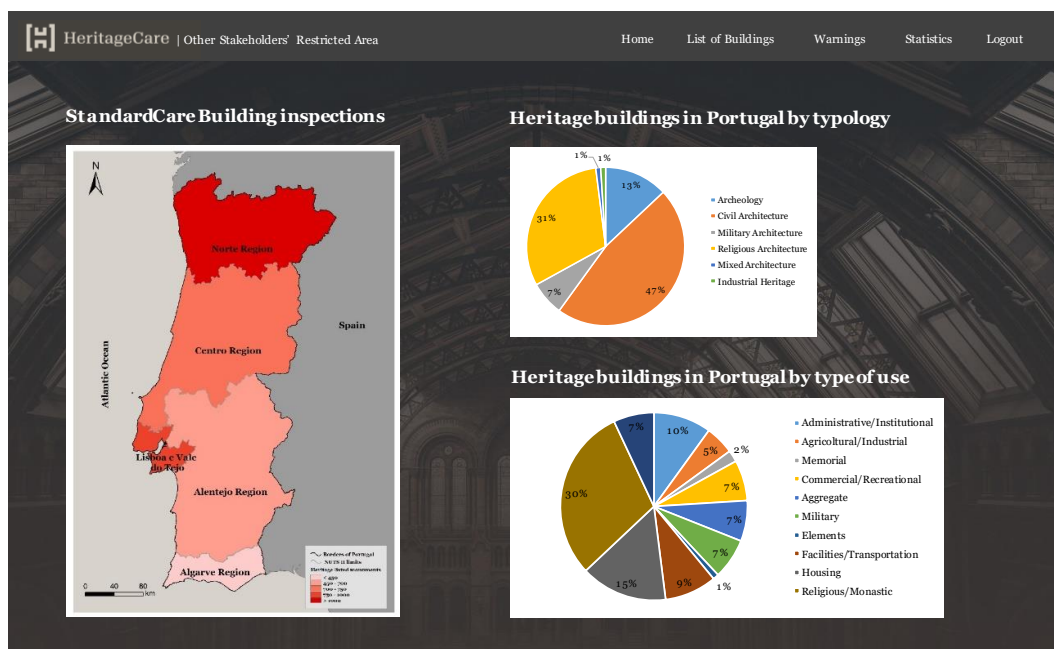
Warnings >

To get acquainted with the state of conservation of the inspected built heritage, stakeholders can select the menu item ‘*Warnings*’ and visualize the track record of the performance of each subscriber in terms of preventive conservation actions undertaken as well as the forecast of the building health condition for the upcoming years.

[illegible]

Statistics >

Finally, detailed statistical information about the number, distribution, typology, use, etc. of the buildings inspected by HeritageCare shall be provided to stakeholders via the specific menu item ‘Statistics’ on the top right of the navigation menu.



Owner's Report feedback

The last stage of SL1 is a meeting/interview with Owner after his report reading. The aim is to analyse his personal feedback about the contents and advices of the report. The inspectors should revise the main conditional assessment and advices until the next inspection. The approximate date of the next inspection should also be fixed.

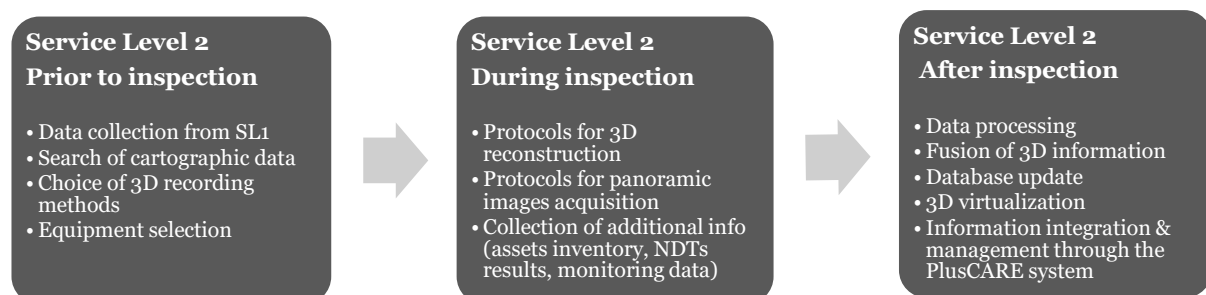
4 Service Level 2 – PlusCare

Service Level 2 is conceived to increase and further detail the level of information of the inspected buildings and related indoor assets, integrating and complementing the information collected in SL1. By leveraging the latest advances in 3D recording strategies, digital replicas of heritage assets are created by HeritageCare professionals and stored into an optimised Geographical Information System (GIS), called **PlusCare**, where potential users can access and retrieve the information acquired at this stage depending on their authorization.

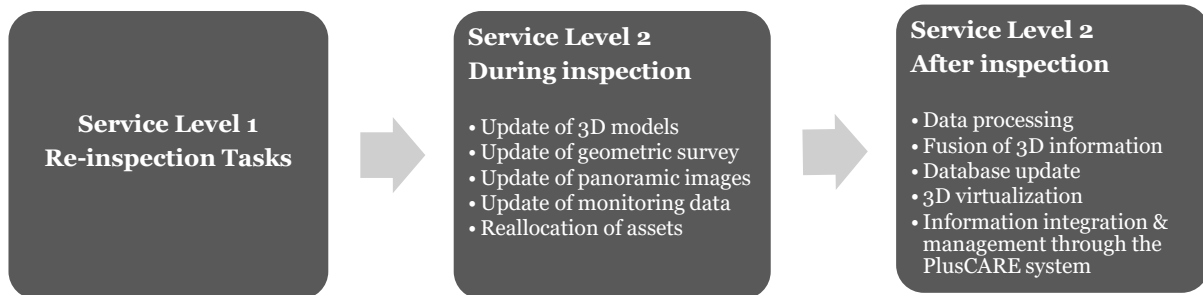
Like SL1, Service Level 2 shall follow a specific protocol of inspection that may vary according to the selected 3D recording procedure. All aspects that need to be taken into account for a successful SL2 inspection shall be addressed beforehand. Hence the necessity of a prior-to-inspection phase before proceeding with the data capturing on-site. The principal steps composing SL2 inspection fieldwork are listed in the chart below, including those related to prior and after inspection phases. To back owners' needs, HeritageCare does commit to keeping SL2 fieldwork as convenient and viable as possible, although more complex and demanding than SL1.

The workflow of SL2 is detailed in the next sections along with the type of information that shall be acquired step-by-step during each phase. More technical information is provided in Annex B (reference file: *Procedures & Tools – Service Level 2.docx*).

Steps 1st inspection SL2



Steps re-inspection SL2



4.1 Prior to inspection

The 3D digitalization envisaged in SL2 requires a prior-to-inspection phase aimed at selecting the best 3D recording strategy for the creation of accurate digital replicas of the inspected buildings along with their related assets. The type of recording method depends on the complexity and size of the parts that need to be digitalized as well as on the outcome that is intended to obtain. Based on the structural typologies featured in the SUDOE space, the following 3D recording strategies are recommended: photogrammetric methods (aerial or terrestrial) based on the Structure from Motion approach; terrestrial laser scanner and back-pack mapping system.

Prior to inspection, the following groups of information shall be compiled: (1) data & info from SL1; (2) cartographic data; (3) 3D recording method; and (4) equipment info.

SL1 Data & Info

This group of information includes all material and data collected prior/during/after SL1 inspections (**StandardCare**). Besides building and management info, there are the outcome of the condition and risk assessment of the inspected heritage buildings as well as the relevant inspection reports with recommendations (see Section 3). This information will represent the starting point for SL2 inspections (**PlusCare**) and will be ultimately integrated with the new data acquired at this stage.

Cartographic Data

Cartographic data are fundamental to get information about location, topographic condition and spatial distribution of the object to be digitalized, thereby allowing to plan properly and in advance the sensor network distribution for the data acquisition. Examples of cartographic data sources are Google Earth, Google Maps or the country's Spatial Data Infrastructure among others.

3D Recording Method

3D recording methods may vary significantly in terms of capabilities, thus it is important to choose correctly the sensor(s) that will be used for the digitalization of the selected object. To assist HeritageCare professionals in this task, the following aspects must be considered and balanced:

- **Resolution:** minimum quantitative distance between two consecutive measurements (linked to the sensor-object distance);
- **Accuracy:** quality (precision) of the data capture;
- **Sampling rate:** ratio between number of samples and time used to capture them;
- **Costs:** cost of the sensor(s), including maintenance, repair and possible rent of additional tools;
- **Operational conditions:** conditions of the environment surrounding the object (e.g. areas featuring poor light conditions require the use of passive sensors);
- **Scale:** dimensions of the heritage buildings/assets;
- **Range:** maximum and minimum range required for the sensors to work properly;
- **Material:** material used to make the building/asset. The recording strategy might differ depending on the material the asset is made of (e.g. photogrammetry is not the most suitable solution when dealing with homogenous texture materials).
- **Final product:** aspect related to the radiometric layers, linked in turn to the geometrical model, needed to understand and read through the Cultural Heritage pieces (e.g. thermographic information, infrared data or RGB colour).

Table 4 indicates the suitability of each recording method based on the afore-mentioned aspects and with relation to the complexity and size of the cultural heritage objects to digitalize.

Table 4: Scoring of different 3D recording methods.

Method	Cultural Heritage objects						Underwater heritage¹
	Large heritage areas	Buildings			Movable assets		
		Outdoor	Indoor		Large-medium scale assets	Small-scale assets	
			Spacious areas	Narrow areas			
Close-range terrestrial photogrammetry	••	•••	•••	•	•••	•••	•••
Close-range aerial photogrammetry	•••	•••	••	‡	‡	‡	‡
Static laser scanner	••	•••	•••	•	••	•	••*
Back-pack mapping	•••	•	••	•••	•	•	‡

Scoring meaning: ••• Highly recommended •• Can be used ••* Can be used but requires the extraction of the piece • Not recommended ‡ cannot be used.

Equipment Info

All material resources and equipment needed to carry out SL2 inspections shall be clearly defined beforehand, grounded on the information assessed above. Besides SL1 basic inspection tools, HeritageCare recommends the following list of equipment for SL2:

Building/Architecture

Name	Short description	Technical characteristics
Telescopic tripod	Lightweight tripod with several sections able to get higher heights than the standard tripods	Several sections (more than 3-4) Aluminium Elements to improve the stability of the system Maximum height: 4-6 m Head compatible with the panoramic and standard tripod heads
GPS receiver	External or in-built device able to register the images captured in a global coordinate system	Able to register the position of the images captured (this position must be added into the image's metadata)
Illumination device	Illumination device useful for situations on which the light conditions are adverse	LED Natural white Diffuse light Portable

¹ Underwater heritage can be considered as a special group, including large heritage areas and moveable assets.

Conductivity meter	A portable tester for measuring conductivity, dissolved salts and temperature	Range: 0/1999 mS/cm Resolution: 1mS/cm Accuracy: 2% full scale Power requirements: 4 x 1,5 V batteries Dimensions: 265 x 29 x 15 mm Weight: 400 gr.
Portable borescope	Inspection camera	Wi-Fi Portable Endoscope Camera Snake Inspection Video Endoscope for iOS / Android 6pcs Interface Tablet USB 2.0 MP 8.4mm 10M
Power generator	Noiseless air compressor	Noise level: 65 dB Motor: 1,5 Hp- 1.1. Kw- 230 V single-phase

PlusCare system

Name	Product	Main functionalities	Examples
Image processing software	Processed image	Processing RAW images Image correction (exposure, white balance, contrast, etc.)	Inkscape (free, open source) ImageJ (free, open source) Photoshop (demo) Adobe Camera Raw (demo)
Stitching software	Panoramic image	Creation of spherical and rectilinear panoramas	Hugin (free) Microsoft ICE (demo) Autopano (demo)
Photogrammetric software	Photogrammetric point cloud	Creation of 3D models based on the Structure from Motion approach	GRAPHOS (free, open source) Photoscan (demo) Pix4D (demo)
Laser scanner software	Laser scanner point cloud	Processing the raw data coming from the laser scanner Alignment Registration Filtering	Faro Scene (demo) Trimble RealWorks (demo) Riscan Pro (demo) GeoSlam desktop Polyworks (demo)
Point cloud software	Merged point cloud	Registration Alignment Cleaning Decimation Texture mapping	Cloud compare (free, open source) Meshlab (free, open source) Geomagic (demo) 3D reshapar (demo) JCR reconstructor (demo)
Flight planning software	Photogrammetric network	Planning the flight Time invested Pixel size Number of captures Height control Hardware compatibility	DJI Go (free) Pix4D capture (free) DJI GS Pro (free) Mission Planner (free) UGCS (free/demo)
Virtual tour software	PlusCare system	Panoramic images Point and polygon hotspots Information linked to URL, pdfs and images Capability to integrate maps Possibility to create custom interfaces	Pano2VR (demo) Krpno (demo) 3D vista (demo)

Integrated and movable objects

Name	Short description	Technical characteristics
Latex gloves	Talc free. Disposable, natural, 9.5 inches long and with 4 thousandths of a thickness.	Sizes: Small, medium and large Resistant to fats and oils. Flexible. Lint free. Comfortable. Ambidextrous. Thickness of 4m FDA Certified for Food Handling
Nitrile gloves	Material free of latex and chemical residues, non-sterile, talc free, ergonomic, higher calibre, optimum sensitivity, ambidextrous, high strength, blue colour.	Sizes: Small, medium and large. Manufactured and processed in accordance with ISO 9001 and quality control system CE BS EN455
Dust masks	Adjustable nasal bridge: Simple verification of the use of correct protection in the workplace, yellow code: FFP1 according to EN 149: 2001 + A1: 2009, detectable metal.	It satisfies the clogging requirements according to EN 149: 2001 + A1: 2009, guarantees a long life of the mask without affecting the breathing facility. Class FFP1-D according to European standard EN 149: 2001-CE
Video Microscope Digital	Laptop, connection and power via PC via USB interface; Supplied complete with "Dino Capture" software, "Amita" table base with flexible arm, integrated micro touch button and 8 white leds with polarization	Allows you to save images or video and carry out measurements. Resolution: 1.3 Mpixels Increases: 10x, 50x, 200x continuous without lens shift Dimensions: 100x Ø 32mm Weight: 95gr.
Work lamp with clip	Consisting of black fiberglass clamp, articulated arm, aluminium parabola treated with epoxidic varnishes and ignition button	Versatility and possibility of hooking of its clamp, has several applications, especially in works. Bulb holder with bulb bulbs E27 max 500W Weight 1.3Kg
Light Bulb	It offers the same amount of light as a 60W halogen Power Rating: A + W Equivalence: 60 KWh / 1000h: 10 Shelf life up to (hr): 30,000	120W with bushing E27 Number of switching cycles: 50,000 Turn-On Time: Instant Amount of mercury (%): 0.12 400Lm IP20 Voltage 220-240V Frequency 50 / 60Hz Class A + Material: Metal, polycarbonate and crystal. Length 120 mm
Light bulb	Incandescent lamp. Operation without reactor, offers the same amount of light as a 60W halogen	Light Wood mixed, 160 w dim bulb. 75X100 mm, pos. Vert. ± 30°, with bushing E27,
Steel clips	Standard Round Tip Model	Stainless steel. Length 14.5 mm
Scalpel with small fixed blade	Essentially cutting or incision instruments with fixed blade, which is generally bent gradually for greater accuracy Fine-pointed, pointed blade used in surgical procedures, dissections, etc.	Stainless steel of length 14 cm, straight or curved blade.
Scalpel Handle # 3	Small, thin-blade, pointed knife instrument used in surgical procedures, dissections, etc.	Stainless steel length 14 cm
Stainless steel blade for Scalpel Knife	Steel pointed blades that are used in procedures of surgery, dissections, etc.	Stainless steel blade # 15

Cotton gloves	Made of 100% cotton fabric, with closed cuff adjustable in white colour	Inspection type cotton glove, seamless, protects fingerprints and scratches on the finished product. Size 9 for men and 7 for women Ambidextrous Also, absorb perspiration. Certification CE, NMX-S-040-1987
Micropops type eppendoorf	Microtubes in polypropylene of high transparency flat cover to write and side band for labels. Special design for working with proteins or nucleic acid amplifications, made of resin, non-reactive	Graduates 100µl, from 0,1 to 0,6 ml. Resistance to centrifugation of 17.000g, dimensions of 30 x 8 mm and autoclave at 121°C and freezing up to -80°C
Zip-lock closure bags with bands	Low density polyethylene.	Size 100 X150 High resistance
Zip-lock closure bags with bands	Low density polyethylene.	Size 120x180 High resistance
Brushes in sterile tubes	Sterile ethylene oxide swabs in round bottom tube.	High resistance, with label-seal with stopper. Tube size Ø 13 x 165mm
Indelible markers	Markers with the possibility of not being deleted from plane of the surface in which they are.	Various colours, and different graduations of tips. The indelible marker is usually made by porous material, such is the case of felt, and its ink are chemicals such as toluene and xylene. Care not to use on assets.
First aid kit		410 x 310 x 100 Weight 6,420 kg.
Safety helmet	Yellow colour, adjustable polyethylene, antiperspirant tape.	Weight 380 gs. Norma CE EN 397
Wash wipes	Double layer, aloe vera and lanolin, special for all types of dirt.	100 washwipes dispenser 280 x 270 mm.
Binocular visor		Available magnifications (Da-2,3,4)

4.2 During the inspection

The inspection fieldwork of Service Level 2 consists of two main tasks: (1) the data acquisition for 3D reconstruction and virtualization of the inspected heritage building and (2) the collection of additional information – when available – concerning both the building and its contents (integrated assets and movable objects). The inspections are performed by at least two professionals with sufficient expertise in geomatic techniques and associated tools (e.g. UAV photogrammetry, laser scanner, back-pack mapping).

Data Acquisition

In order to achieve an accurate 3D reconstruction of the object of study, the data acquisition shall comply with a specific protocol. Depending on the selected recording strategy (see Section 4.1), the following protocols can be used:

Photogrammetric protocols for 3D reconstruction

- a) Parallel protocol (suitable for reconstruction of planar object, such as façades, and for aerial photogrammetry);
- b) Convergent protocol (ideal for the 360 ° reconstruction of movable assets, e.g. statues);
- c) Cross protocol (ideal for detailed reconstructions, for example a column capital).

In most cases, the most suitable solution comes from the combination of several protocols.

Photogrammetric protocols for acquisition of panoramic images

- a) Spherical panoramas (use of full-frame fish-eye lenses or circular fish-eye lens);
- b) Rectilinear panoramas (use of rectilinear lenses).

Photogrammetric protocols are pre-defined. This means that, depending on the object to capture as well as on the level of detail required, specific rules and parameters must be observed, such as the number of captured images, the shot overlap and path, the lens system, the focal length, the exposure triangle (aperture of lens, shutter speed, ISO sensitivity of the sensor), and the like. Detailed information and technical specifications of each protocol are provided in Annex B (reference file: *Procedures & Tools – Service Level 2.docx*).

Laser scanner protocols

Unlike photogrammetric protocols, these protocols are more flexible due to the capacity of the laser scanner to capture the whole scene or at least great part of it. However, HeritageCare recommends to follow some practical rule to optimize the outcome of the data acquisition:

- Operate in good environmental conditions;
- Minimize the number of scanner stations;
- Optimize the position of scanner stations;
- Minimize the number of low intersection angles;
- Avoid obstacles between laser scanner and object;

- Consider the laser safety class (IEC-60825-1²).

Owing to the complexity and size of most cultural heritage assets, several scan stations might be necessary to capture the whole scene. Hence, these stations will be characterized by different local coordinate systems, requiring the use of definite registration methods to combine them into a common coordinate system. Registration methods include:

- a) Cloud-to-cloud strategies (alignment procedure based on station overlaps);
- b) Target-based approach (alignment procedure based on artificial targets).

For more technical information about laser scanner protocols and related registration methods, the reader is referred to Annex B (reference file: *Procedures & Tools – Service Level 2.docx*).

Asset ID Info

This group of information represents the Asset counterpart of the Building ID. The aim is to create a sort of IDentity card of the heritage objects that will be inspected during SL2. This type of information may be acquired from existing cultural heritage databases, asset registers and archives, records of previous conservation works, public administrations and referring entities, or even from the owner himself. Asset ID info comprises:

Asset Identification & Property Information

- a) Name, category, type and sub-type;
- b) Legal category of protection (classification number, referring entity);
- c) Inspection periods;
- d) Owner/Manager's name, address and contact details.

Historical Facts

- a) Construction period/date;
- b) Author and style;
- c) Iconography (identification, description and interpretation of the artwork);
- d) Changes and restorations over time.

² International Electrotechnical Commission. (2014). *Safety of Laser Products–Part 1: Equipment Classification and Requirements*, (Geneva, Switzerland). IEC-60825-1.

Technical Information

- a) Short description of the asset (appearance, constituent materials, etc.);
- b) Manufacturing and decorative techniques;
- c) Dimensions and weight;
- d) Photos;
- e) Relevant documents and bibliographic info.

Location Information

- a) Asset code and location within the building;
- b) Panoramic photo with asset coordinates.

Inspection Form for Assets

Like building inspections, asset inspections shall be supported by an inspection form/e-form which will allow to perform the condition and risk assessment of the asset object of analysis in order to evaluate its state of conservation. The entries of the inspection form shall include the following items:

1 Environmental assessment

- 1.1 Condition 1 (lux, temperature, humidity)
- 1.2 Condition 2 (lux, temperature, humidity)

2 Assessment of the conservation state

- 2.1 Damage 1
- 2.2 Damage 2
- 2.3 Damage 3
- 2.4 Other damages

Condition & Risk Classification

The condition of integrated assets and movable objects found within the inspected buildings shall be assessed and recorded according to a grading scale system (see Table 3, Section 3.2) that associates a qualitative/quantitative index to each of the damages detected on a certain asset. Such index shall take into account the type and extent of damage and shall be weighted depending on the severity of the consequences the asset may be subject to (thus, the weighing

factors might vary case-by-case). The overall condition grade of the asset shall result from the round weighted sum of the single condition grades assigned to the different damages affecting that particular object. Analogously, a simple risk assessment shall be performed to provide a thorough evaluation of the conservation state of the inspected asset and to highlight the need for urgent remedial measures or additional inspection & diagnosis works.

Monitoring and/or NDTs Data

During SL2 fieldwork, besides classifying the integrated and movable assets present in the building, HeritageCare inspectors shall also collect further information and data that can help better evaluate the conservation status of the heritage building so as to address *ad hoc* preventive conservation measures. This information may concern the results from non-destructive tests carried out previously or the data from existing monitoring systems. In the latter case, a specific form shall be filled in while on-site to keep record of the type, location, sensor number, distribution and tracked parameters of the monitoring system(s).

4.3 After the inspection

After the inspection, HeritageCare professionals shall perform a back-office work in order to pass from the raw data captured on field to the final products to upload and store into the **PlusCare** system, also incorporating further information collected on site (assets inventory, data from monitoring activities and ND testing) and integrating the information acquired previously during SL1 inspections. This assortment of data shall be easily accessed, managed, integrated and updated over time. Such database will be exploited to feed a visual block through which different potential users (e.g. staff members, owners and stakeholders) can consult the information created during SL2 depending on their authorization.

Data Processing

Among the final products of Service Level 2 are: (1) the photogrammetric panoramas; (2) the photogrammetric point clouds; and (3) the laser scanner point clouds. The creation process of these outputs shall comply with a precise workflow, whose stages may differ

depending on the adopted 3D recording method (Figure 6). Technical details of the processing work are given in Annex B (reference file: *Procedures & Tools – Service Level 2.docx*).

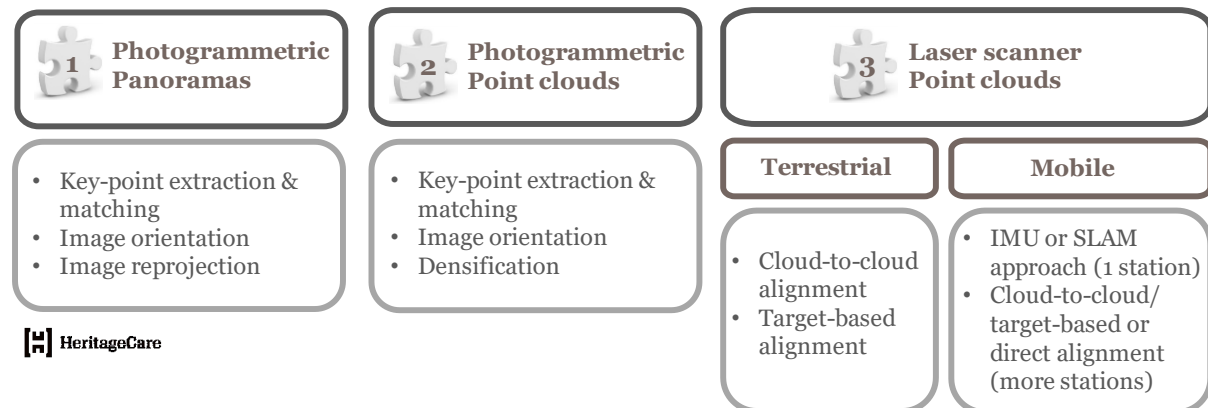


Figure 6. Data processing stages for different recording strategies.

The 3D models originated from the point clouds will also be used to produce 2D drawings of the inspected heritage buildings, namely plans, sections and elevations.

Fusion of 3D Information

The success of recording cultural heritage assets in 3D passes through the appropriate combination of different methods and the correct integration of 3D information coming from multiple sources. The integration of information (registration) can be carried out using one of the approaches listed in Figure 7. Following this phase, optimization strategies are recommended to remove unwanted information from the final point cloud. Blended and optimized all geometrical information captured in the form of point cloud, the last step requires the segmentation of this product into functional parts, e.g. roof, façades and rooms, so as to facilitate their analysis (measures, volume calculations, and the like).

An exhaustive description of the procedures for registration and optimization is provided in Annex B (reference file: *Procedures & Tools – Service Level 2.docx*).

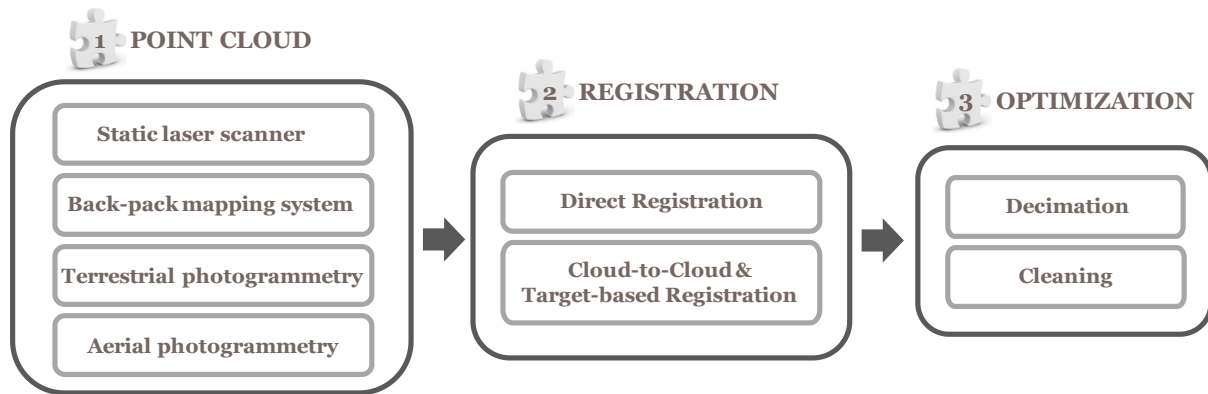


Figure 7. Workflow for the optimal fusion of 3D information.

PlusCare System

The main output of SL2 back-office work is the PlusCare system, an adapted and optimized Geographical Information System (GIS) structured around two basic pillars:

- **A visual block**, integrated by a user-friendly interface composed by 360° spherical panoramas with links to different information associated to pre-defined hotspots (e.g. point clouds info, specific documents and images concerning assets, existing damage mechanisms, possible monitoring systems, etc.);
- **An operating block**, composed by a database able to feed the visual block with the correct information when activating the hot spots.

PlusCare Content for Users

Users: Owners

Unlike HeritageCare staff (expert users), who has full ownership and control over the contents of the PlusCare system, owners of inspected buildings can only access and download the information related to their own property(ies), namely:

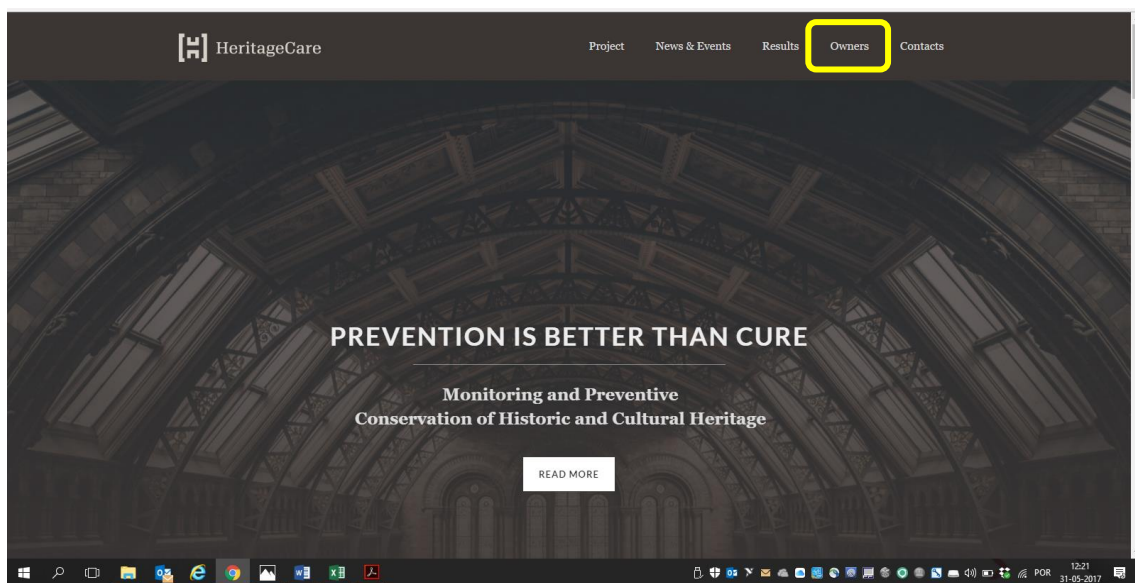
- StandardCare data & info;
- 3D reconstruction and virtualization;
- Additional info about the building and its assets.

Owners are not provided with editing rights on the system contents. Still, specific editable fields and web forms will be made available to them in order to:

- Report to HeritageCare the adopted preventive conservation actions;
- Raise warnings about unexpected events or problems;
- Ask to HeritageCare questions and advices.

Access >

Owners can log in to the PlusCare system through their restricted area, by clicking on the item ‘Owners’ from the navigation menu at the top of the HeritageCare homepage.



Home >

Once logged in and selected the **PlusCare** key, owners will be redirected to a homepage with a short ID of their property followed by the relevant cartographic data with location, topographic condition and spatial distribution of the object. Then, by clicking on each of the items the navigation menu is composed of, owners can have access to the different information collected up to this stage about their property.

The screenshot displays the HeritageCare web interface. At the top, there is a navigation bar with the following items: StandardCARE, Point Clouds, Panoramas, Additional Info, and Logout. The main content area is divided into two columns. The left column features a section titled 'PlusCare Building Inspection' with an aerial photograph of the Avila Cathedral. Below this is a section titled 'Cartographic Data' with a map of the city of Avila, Spain, and a Google Maps icon. The right column is titled 'Avila Cathedral' and contains a table of metadata.

Avila Cathedral	
Object	Avila Cathedral
Legal protection	Listed building Nacional Monument since 1949
Inventory OE	RI-51-0000138
Current function	Catedral and Museum
Subscriber	Plaza de la Catedral, 8, 05001, Ávila, Spain
Inspection date	05/07/2017, 07/07/2017

Below the metadata table, there is a section for 'Location' with the following details:

Location	Avila, Spain
Coordinates	40° 39' N / -4° 41' W
Topographic condition	xxx
Spatial distribution	xxx

To the right of the location details is a 3D wireframe model of the Avila Cathedral.

StandardCare >

All information resulting from HeritageCare inspection(s) for SL1 can be accessed via the menu item 'StandardCare' of the navigation bar. In this area, each owner can retrieve information concerning the complete ID of his building, its construction system, the relevant historic survey as well as the inspection report with recommendations for preventive conservation (see Section 3.3). Such information is fully available both for online reading and downloading.

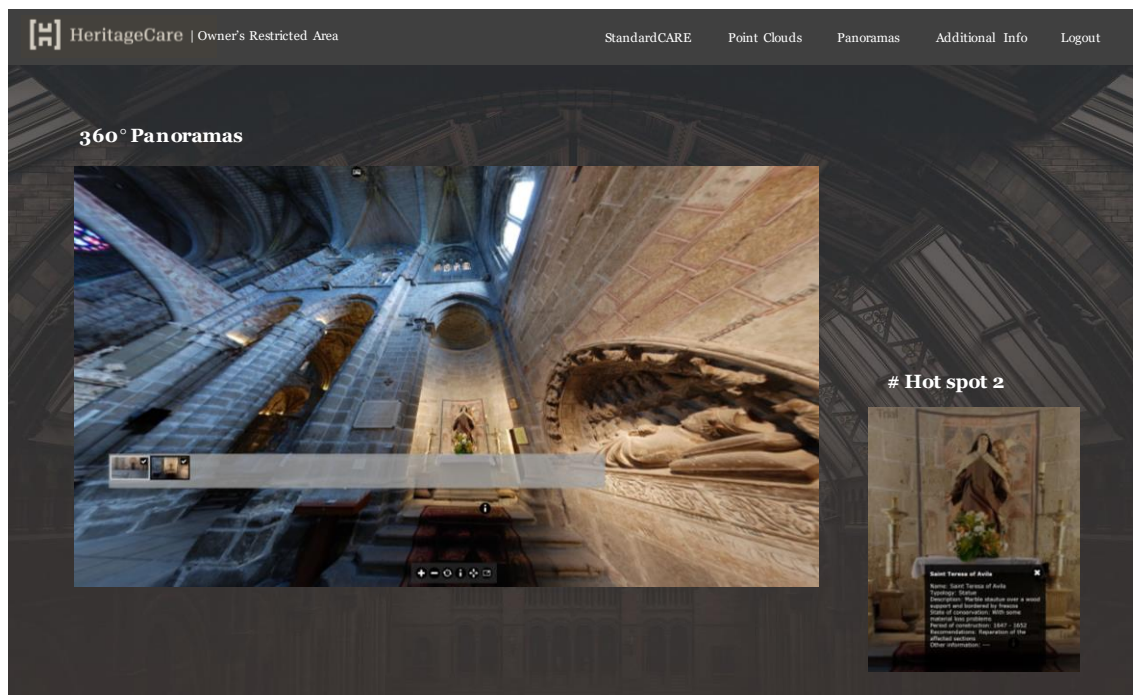
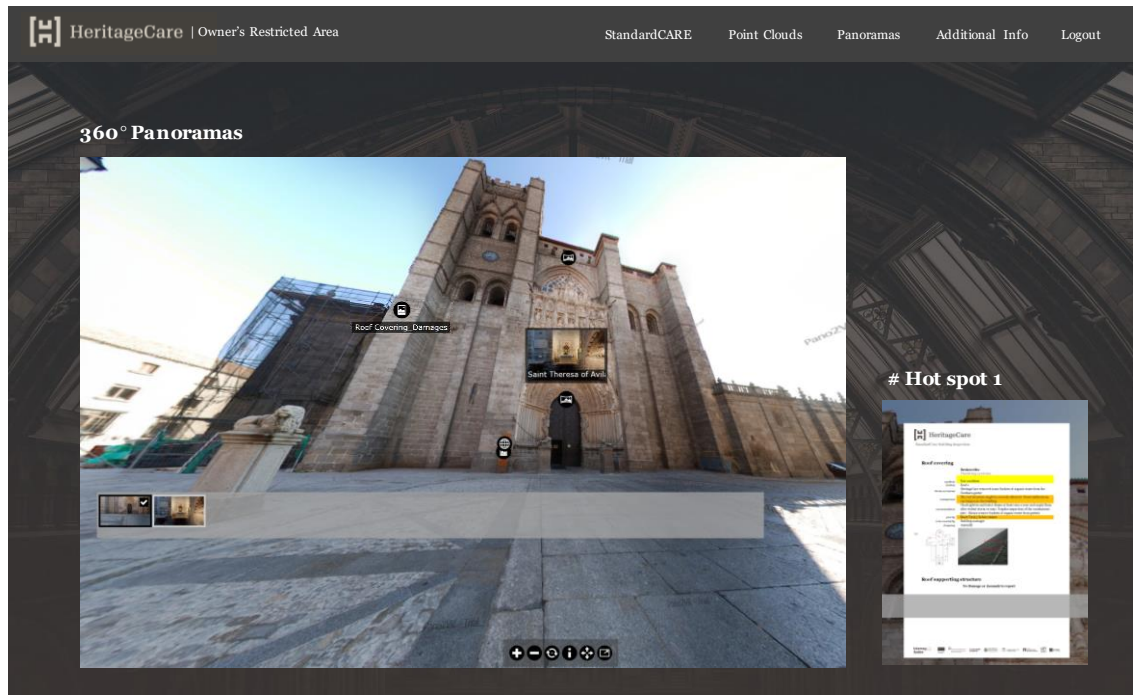
Point Clouds >

By clicking on the item 'Point Clouds' of the navigation menu, owners will be able to visualize the final geo-referenced point cloud of their building along with the respective 3D digital model. Geometric dimensions and 2D technical drawings (plans, sections and elevations) of the building can be extracted directly from the point cloud.

Panoramas >

Through the menu item 'Panoramas', virtual-reality images created by stitching overlapping panoramic photos of the inspected buildings can be appreciated. Owners can explore their properties through full-screen virtual tours that integrate 360° panoramas with hotspots associated to information regarding the valuable assets contained in the buildings, the damage

mechanisms detected during on-site inspections and the data from possible monitoring systems installed for preventive conservation purposes.



Additional Info >

The complete list of integrated assets and movable objects present in the inspected building can be retrieved by clicking on the item 'Additional Info'. In the same area, owners can search

out further data collected by HeritageCare during SL2 inspection activities, such as the results obtained from available NDTs and/or the variation of specific parameters (e.g. temperature and humidity) tracked via already-installed monitoring systems.

Users: Stakeholders

Public authorities, governmental organisations and stakeholders in general shall have authorizations different from owners. What matters to them is to have a broad statistics-based overview about the inspected buildings and their related assets.

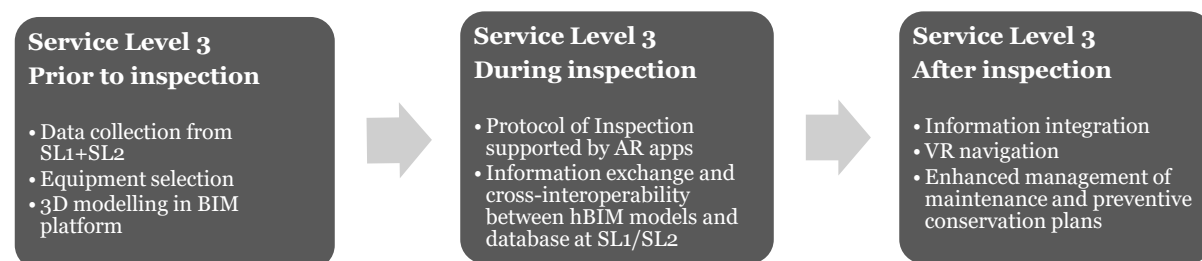
By accessing their restricted area from the navigation menu of the HeritageCare webpage, this type of users will be able to see the point clouds and the 360° panoramas of the inspected buildings, along with general information of the assets contained within them (besides being able to retrieve the SL1 information they are authorized for). For the sake of privacy, stakeholders can just visualize the afore-mentioned contents and they are not provided with editing rights.

5 Service Level 3 – TotalCare

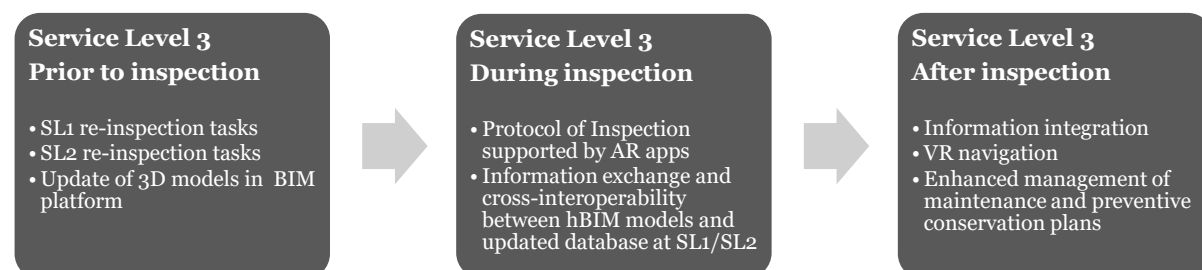
Service Level 3 (SL3) is devoted to the integration and management of information obtained from former service levels into the HeritageCare database, by leveraging the *Building Information Modelling* (BIM) with application to heritage structures – hence the acronym hBIM. Digital representations of the inspected historic buildings will be generated, accessed and manipulated by HeritageCare professionals through this intelligent 3D model-based process. Historic building information models (hBIMs) can be extracted, exchanged and networked to support decision-making regarding maintenance and preventive conservation actions on built assets.

The principal steps composing SL3 inspection phases are summarized in the chart below. The detailed description of each phase follows in the next sections.

Steps 1st inspection SL3



Steps re-inspection SL3



5.1 Prior to inspection

The augmented reality (AR) based inspection of SL3 requires a prior-to-inspection phase aimed at collecting all information necessary for the creation of the BIModel along with the definition and specification of the type and level of development (LOD) of the BIM objects representing the physical elements of the inspected heritage building, namely doors, columns, walls, roofs, etc. Thus, to guarantee the success of the inspection task, the following groups of information shall be assessed and finalized beforehand: (1) data & info from SL1 and SL2; (2) equipment info; and (3) 3D modelling in BIM platform.

SL1 + SL2 Data & Info

This group of information embraces all material and data gathered during SL1 (StandardCare) and SL2 (PlusCare) by applying the respective inspection protocols, as described in Section **Error! Reference source not found.** and Section **Error! Reference source not found.**. This information will form the basis for SL3 inspection activities (TotalCare) and will be integrated and periodically updated into the HeritageCare database in order to feed the BIModels created at this stage.

Equipment Info

The tools and appliances needed to perform the activities envisaged for SL3 shall be defined in advance so as to speed up the 3D modelling in BIM platform as well as the subsequent inspection tasks. Besides SL1 and SL2 inspection equipment, HeritageCare recommends the following items for SL3:

Table 5. Software required for the creation of the BIModels.

Name	Product	Main functionalities	Examples
BIM manager	BIM model		Autodesk Revit 201X
3D modeler	FBX model	Reworking of geometric model to be used within the HoloLens	3DS max 201X

Table 6. Hardware required for SL3 inspections.

Name	Short description	Technical characteristics
Microsoft HoloLens	Smart glasses providing high quality mobile augmented reality	
Power bank	Complementary battery for HoloLens	QC 3.0 output charge is the minimum to be compatible with HoloLens

3D Modelling in BIM Platform

This information concerns the digital representation of physical and functional characteristics of the historic buildings that will be inspected by HeritageCare. The generation of these digital models is carried out with a 3D model-based process, called Building Information Modelling (BIM). Traditional building design was largely reliant upon two-dimensional technical drawings (plans, elevations, sections, etc.), whereas BIM goes further beyond 2D and covers more than just geometry. Properties of building components, integrated assets, spatial relationships, geographic information, light analysis, are only a few examples of the aspects covered by BIM.

The 3D model created in BIM is an assembly of “objects” made with an architecture software (HeritageCare will use Autodesk REVIT software) carrying geometry, relations and parametric attributes (e.g. positional data, dimensions, manufacturer's data, algorithms describing form and so on). According to this parametric logic, the objects are defined as parameters and relations to other objects, thus if an object is amended, dependent ones will automatically adjust to suit. Given the complexity and size of most heritage buildings, two aspects must be carefully taken into account before proceeding with the generation of the BIModel:

- 1) *BIM Object representation*: definition of the attributes/properties necessary to characterize the model elements (BIM objects). Properties are assigned as type or component. Common properties shall be assigned to type and not component³;
- 2) *Level of Development (LOD) specification*: the degree to which the element's geometry and attached information has been thought through – the degree to which the project team members may rely on the information when using the model⁴ (not to be confused with the *Level of Detail* which is essentially how much detail is included in the model element).

³ www.nationalbimlibrary.com/Content/BIMStandard/NBS-BIM-Object-Standard-v1_2_1114.pdf

⁴ www.bimforum.org/lor (LOD Specification 2015)

Once the afore-mentioned aspects are specified, the creation process of the BIModel is almost straightforward.

5.2 During the inspection

The fieldwork of Service Level 3 consists of in situ inspections carried out following the protocol of inspection of SL1, but with the aid of an AR app using Microsoft HoloLens technology in order to support and ease the entire inspection procedure. SL3 inspection shall be performed by at least two professionals with adequate background on materials, construction techniques, damage mechanisms, deterioration processes and with sufficient capabilities for handling and controlling the smart inspection tools that will be used at this stage.

AR-based Inspection

SL3 inspections shall follow the protocol established for SL1 inspections (see Section **Error! eference source not found.**). The added value provided by the TotalCare system in comparison to the first two service levels (StandardCare and PlusCare) consists in the use of an augmented reality (AR) application based on the Microsoft HoloLens that will be developed on purpose to help HeritageCare professionals perform their inspection task.

The AR application shall enable inspectors to visualize the BIModel on top of the real building, letting them interact flawlessly at the parametric object level. In this regard, the AR app requires access to numerous data to be functional. Most importantly, the access to the BIModel, including both the geometric information of the parametric objects (primitive shape and position) and the non-geometric information related to these objects, such as the space where they are contained (room and floor) or any additional information which can prove to be useful to the inspector (e.g. object material, ...). Moreover, the AR app must have complete access to previous inspections information as well as to the damage Atlas contained in the 4D database. Last but not least, access to the GUID (Globally Unique Identifier) table will be critical to allow the application to hook all information to the right parametric objects and therefore contextualize the data correctly.

The Mixed Reality inspection tool (Microsoft HoloLens) shall have a view for detecting and analysing cracks in the walls. This functionality allows the inspector to see a processed field of view, where contours are highlighted and cracks on walls detected and classified according to some extracted metrics (Figure 8). Yet more, a functionality for measuring the Euclidean distance between two visible points in space shall be added to this smart inspection tool so that the inspector would just needs to select the desired points with his gaze or gesture and the tool will automatically determine the length up to a certain precision (it is expected for this functionality to work better in planes than in complex objects).



Figure 8: Cracks on a wall observed through HoloLens.

Information Exchange

Fulcrum of SL3 is to guarantee the interoperability between BIM software and 4D database at SL1/SL2 in order to allow HeritageCare professionals to exploit the amount of information collected about the inspected buildings at any stage of the inspection process. Interoperability allows for information exchange between products or systems without any restrictions. As far as SL3 is concerned, two data formats can be employed to achieve this goal:

- The IFC (*Industrial Foundation Class*) format: open and independent file format with a data model developed to facilitate the interoperability between software platforms in the architecture, engineering and construction (AEC) industry;
- The FBX (*Filmbox*) format: proprietary file format used to provide interoperability between digital content creation applications.

By using one of the afore-specified formats to export the BIModel, HeritageCare database and BIM software will be capable of communicating with each other and exchanging information with no limitation. However, a few differences must be highlighted. The use of the IFC format as input file would allow the AR app to be independent of the adopted BIM software, but would require the use of two additional tools, one to convert the IFC file into a usable 3D model and another one to extract/parse non-geometric information. On the contrary, the use of the FBX

format combined with the predefined schedule tool already available in Revit would provide the AR app with ready-to-integrate elements. In both cases, Revit API offers an easy way to automatize the export process, but this solution only works while using Revit. The two scenarios outlined above are schematized in the data structures below (Figure 9 and Figure 10):

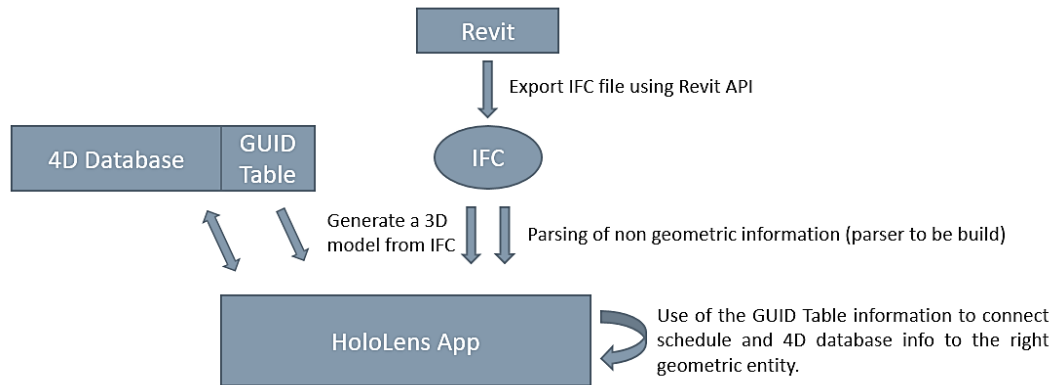


Figure 9: BIM-Database interoperability with IFC export.

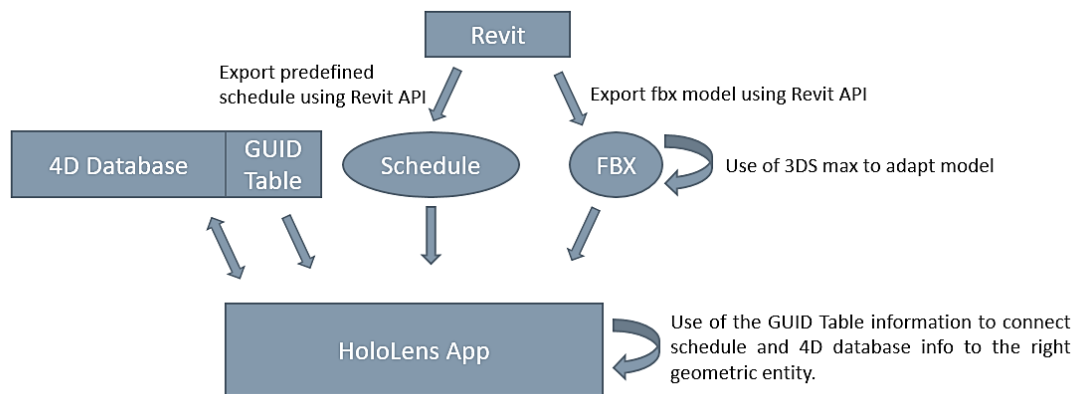


Figure 10: BIM-Database interoperability with FBX export.

5.3 After the inspection

The after-inspection work of SL3 is mainly dedicated to the integration of the information assembled prior /during/after the inspections at the three service levels between BIM platform and HeritageCare database. This database will be exploited to feed a virtual reality application that will allow users to enter and virtually move inside the 3D model, also accessing the information stored in the 4D database. The integration of information is the key to the successful management of any type of heritage building, whether being ordinary and regular or singular and non-conventional.

VR Navigation App

The main output of SL3 back-office work is a simple desktop application for virtual reality (VR) navigation consisting of:

- **A visual part**, composed by the 3D model of the inspected building with precise links to the parametric objects defined in the BIM platform (Figure 11);
- **An operating part**, composed by a database, namely the HeritageCare database, and a query system, allowing users to filter the relevant information to be fed to the visual block when visualizing the objects.
- **A controlling part**, composed by the movements' modalities to move around the model and interactions' modalities to interact with the parametric objects.

Although too detailed for owners and stakeholders, the information displayed during the VR navigation across the historic building will turn out to be extremely useful for the curator in charge of that building. Therefore, the development of this information visualization tool will be focused on heritage curators. It is important to keep in mind that the VR application is meant to support maintenance and preventive conservation plans, so aesthetics is not the main objective, information quality is. Depending on the project advancement, the possibility of porting this application to a more sophisticated VR navigation system can be explored, improving the immersion of users and providing more intuitive control.

Even though for the present project only a few users will have access to virtual reality technology, this solution can still be shown to prove the potential of VR-based tools and convince more owners and stakeholders to join Service Level 3 in the future.

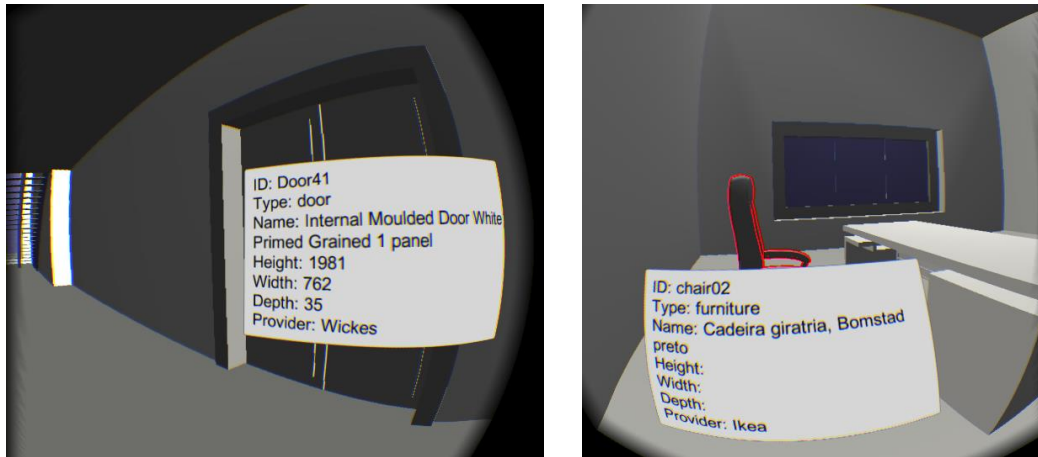


Figure 11: VR demo with BIM information integration.

Information Integration & Management

Fed by the HeritageCare database, the 3D digital models created in BIM platform shall integrate all information collected from the three SLs about the inspected historical buildings, including geographic information, construction components and materials, integrated assets and movable objects, existing damage mechanisms, maintenance and preventive conservation actions, sensor measurements, etc. The correct integration of information will enhance in turn the management of the heritage assets joining the TotalCare system.

Heritage buildings are complex, and so are the BIM data and applications that support them. Notwithstanding, BIM environment does enable faster information sharing, more accurate resolutions, visual representation of potential issues, better integration between preventive conservation actions and management systems, and much more. Supported by hBIM, SL3 will allow HeritageCare professionals to streamline the conservation and management process of cultural heritage buildings, resulting especially useful for owners and managers of large and non-conventional historic structures.

6 Conclusions

This report belongs to the first Group of Activities of the HeritageCare project and focuses on the description of the general methodology for preventive conservation of cultural heritage buildings developed during the first year of the project. After a brief introduction, the key steps of the HeritageCare methodology are outlined along with the main objectives of the project in the short and long term. Next, the three service levels of the methodology through which HeritageCare will operate are described in detail: Service Level 1 – StandardCare, Service Level 2 – PlusCare, and Service Level 3 – TotalCare.

Beyond traditional tools, the HeritageCare methodology will leverage the latest advances in digitization and smart technologies to keep abreast of the times and further enhance the quality of the services provided. Despite that, the Consortium is committing to keep the services as affordable as possible to help owners/managers embark on the conservation process of their properties. The next project activities will be devoted to the implementation of the methodology through real case-study structures to be chosen among the great variety of heritage buildings spread over the SUDOE territory. These case studies will be selected so as to encompass the most representative structural typologies identified in South-West Europe and will allow to test the effectiveness of the proposed approach. Pros and cons will be evaluated and a refinement of the methodology will be planned – if necessary – before proceeding with the standardization of methods & tools for the development of guidelines and rules of “*good practice*”.

Notwithstanding the grand challenges associated with the project, HeritageCARE partnership is jointly working for the successful development of a systematic and integrated strategy that will allow to streamline both conservation and management issues of built heritage in Portugal, Spain and South of France, ensuring the future sustainability of the approach as well as the direct engagement of the society in the preservation process of built environment.

Annexes

A – Service Level 1 additional information

B – Service Level 2 additional information

Annex A – Service Level 1 additional information

4D Database SL1 and SL2 V2.xlsx

Annex B –Service Level 2 additional information

Procedures & Tools - Service Level 2 V4.docx