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Innovative and affordable service for PC monitoring of individual Cultural Artefacts during display, storage, handling and transport

Definition of protocols for deployment of sensor node devices I

Deliverable number: D4.2

Version 1.0

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Abstract

Deliverable 4.2, designated "Definition of protocols for deployment of sensor node devices I" within WP4 Task 4.2, is the first of three deliverables (D4.2, D4.9, D4.10) and is focused on general principles for the definition of the Museum Scenario.

This is the first step of the proposed operational procedures to identify the number and location of sampling points in the spaces dedicated to exhibition or storage of cultural objects.

This document is divided into three main parts, as follows: 1) definition of the Museum Scenario; 2) the procedures to associate the museum with the corresponding Museum Scenario; 3) classification of CollectionCare museums. Four Museum Scenarios are described according to the feasibility of taking field measurements and/or to the availability of historical data on air temperature and relative humidity.

Abbreviations and Acronyms Glossary

AP	Air Pollutants
AV	Available
CR	Condition Report
DFA_AAM	Alava Arms Museum of Diputación Foral de Álava
DFA_AFAM	Alava Fine Arts Museum of Diputación Foral de Álava
DX.X	Deliverable number
IEEE	Historical and Ethnological Society of Greece
IVC	Film archive of the Institut Valencià de Cultura
KMKG	Royal Museum of Art and History
L	Light
map	two-dimensional representation of a variable distribution
MR	Mixing Ratio
N/A	Not Available
OALM	Ethnographic Open Air Museum of Latvia
PC	Preventive Conservation
RDC	Rosenborg Castle The Royal Danish Collection
RH	Relative Humidity
T	Air Temperature
TX.X	Task number
Ts	Surface Temperature
UPV	Universitat Politècnica de València
URO1	Sapienza Università di Roma
V	Vibration
WP	Work Package

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1. Introduction

This document is part of the CollectionCare project, Horizon 2020 Grant Agreement number 814624 whose overall aim is to develop an innovative and affordable service for preventive conservation, monitoring of individual cultural objects during display, storage, handling and transport.

The present document is Deliverable 4.2 (D4.2) headed "Definition of protocols for deployment of sensor node devices I" with deadline in month 11 (January 2020) from the start date of the project. Deliverable 4.2 has been drawn up as part of Task 4.2 (T4.2) designated "Characterize/parameterize the installation of the sensing node inside the exhibition space", within Work Package 4 (WP4) named "Design of the Wireless sensing system".

The objective of T4.2 is the definition of operative procedures on the deployment of sensor node devices in spaces dedicated to exhibition or storage of artworks. The devices are designed to monitor ambient microclimate (mainly temperature and relative humidity) that may have direct influence on the deterioration mechanisms of cultural objects. The task is described in Annex 1 (part A) of Grant Agreement n. 814624.

The climate surrounding an object (namely the microclimate or indoor climate) influences the chemo-physical and structural properties of cultural objects that in turn affect the surrounding environment. Thus, the study of the microclimate requires a holistic approach to gain an understanding of the environment, of the artefact conditions and their management. Over the years, indoor microclimate monitoring has become an increasingly common practice to pinpoint the agents causing the deterioration of artworks. In this context, one of the main objectives of the CollectionCare project is to monitor the environmental conditions to which a cultural object is exposed to during exhibition, storage, handling or transport.

Weather stations for climate and meteorological observations must comply with specific requirements set by the World Meteorological Organisation (WMO, 2010). The requirements are related to the sensor's technical features, its location (e.g. the measurements must not be influenced by any obstacles such as buildings, trees and others), as well as to the frequency and timing of the observations.

In the context of microclimate monitoring systems, the current standards provide recommendations only on the choice of the type of sensor devices to be used (EN 15758, 2010; EN 16242, 2012). In contrast, there are neither norms nor guidelines that set out a specific methodology on the most appropriate deployment of sensor nodes in order to have a comprehensive picture of the environmental behaviour in museums.

To date, several studies have addressed the issue on the deploying sensors in indoor environments (Nguyen et al., 2018; Yun, J. and Kim, J., 2013) but none of them specifically focus on microclimate monitoring for the preventive conservation of artwork. Moreover, these works are mostly based on theoretic methods and only take into account applications dedicated to merely spatial fields of the parameters under study, without considering the environmental processes from a combined spatial-temporal perspective. Only few studies, conducted within historic churches, have analysed the effectiveness of the adopted method to identify the sampling points, but without providing clear details on the design method of the sensors' positioning (Aste et al., 2019; Silva et al., 2015; Silva et al., 2020; Varas-Muriel et al., 2014).

The proposed approach focuses on choosing sampling points in the microclimate monitoring (one of the objectives of task T4.2) and benefits from the studies conducted by Sapienza University of Rome (URO1) and Universitat Politècnica de València (UPV) teams as well as from those reported in literature on this topic.

T4.2 will be structured in three phases, as schematised in Figure 1:

1. Definition of the Museum Scenario (documented in Deliverable D4.2).
2. Basic Procedures (to be documented in Deliverable D4.9).
3. Advanced Procedures (to be documented in Deliverable D4.10).

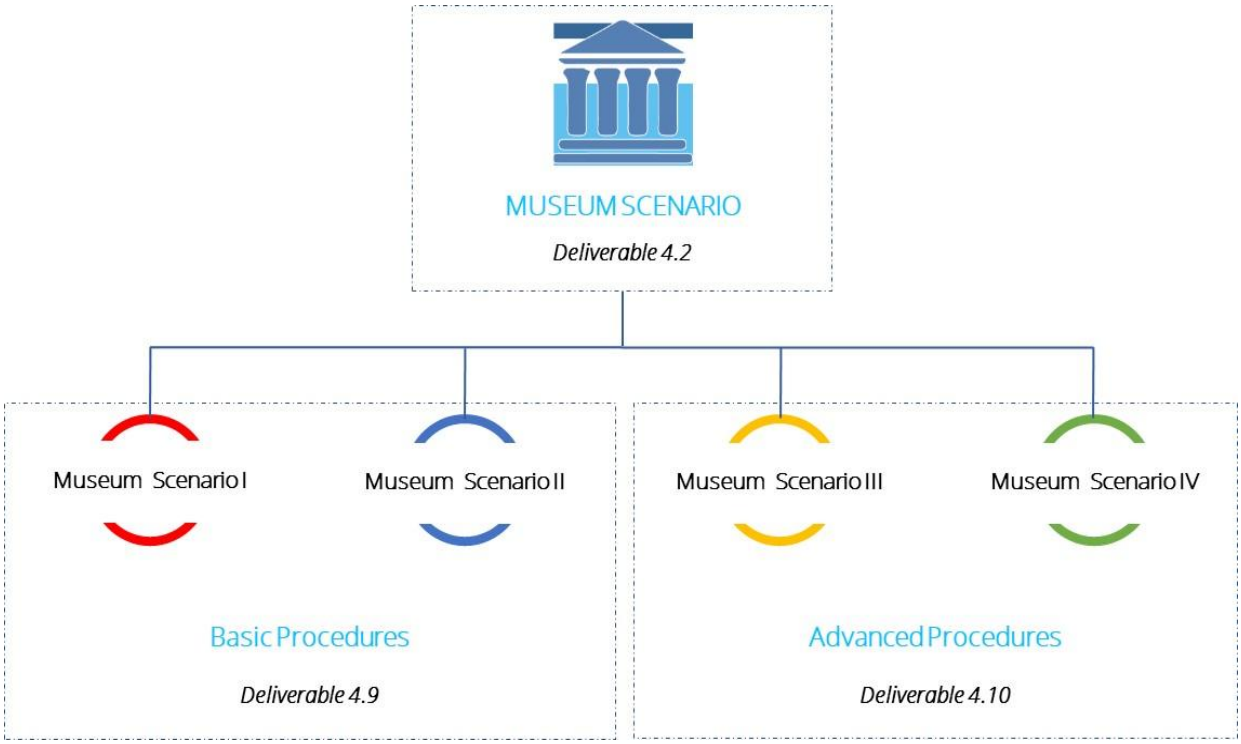


Figure 1. The main phases of task T4.2 of operative procedures on the deployment of sensor node devices

The Gantt Chart in Figure 2 shows the working schedule within each phase of T4.2. Specifically, D4.2 is the first of three deliverables (D4.2, D4.9, D4.10) and aims to provide general principles on the definition of the Museum Scenarios that are related to recurrent contexts of the indoor climate monitoring within museums. This is the first phase of the proposed operational procedures to identify the number and location of sampling points, in order to increase knowledge on a current specific conservation problem of artworks and on their conservation on the long term. Basic and advanced procedures in the deployment of sensors will be described in the subsequent deliverables D4.9 and D4.10, respectively, related to the Museum Scenario.

D4.2 is led by URO1 in collaboration with UPV and will be disseminated at a public level.

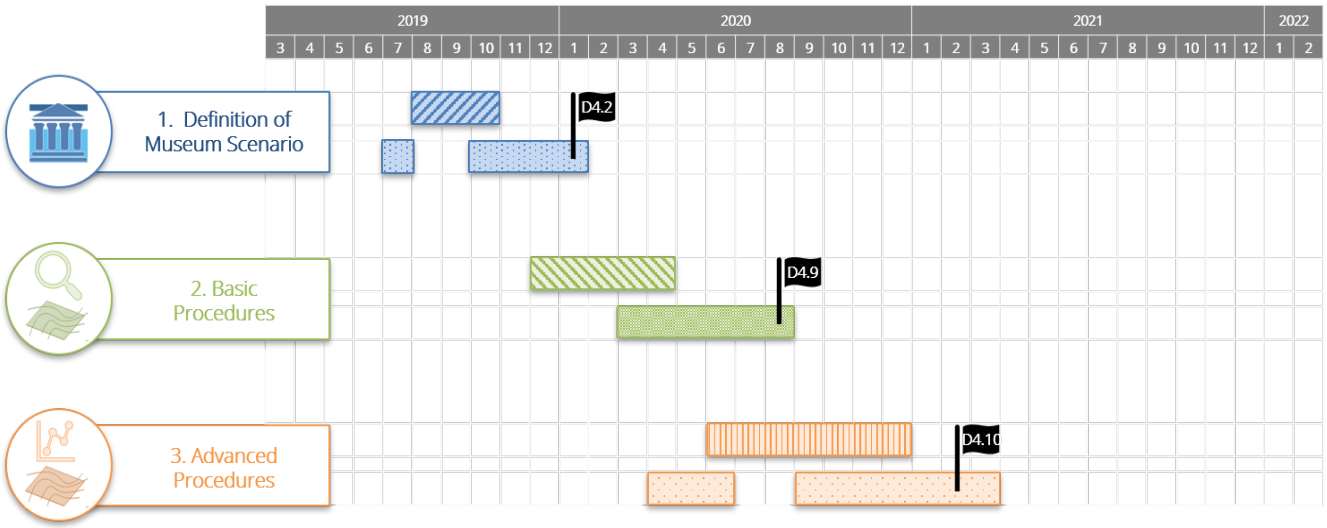


Figure 2. Gantt Chart for each phase of T4.2.

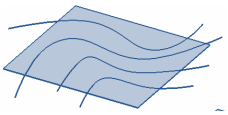
2. Definition of Museum Scenario

When planning microclimate monitoring in museums, the specific aim of the monitoring activity should be the main concept to be understood. After that, the individual objects preserved in the exhibition spaces are taken into consideration. Measurements collected only at a single point could scarcely be representative enough to derive a complete characterization of the environment surrounding several objects.

If there are several sensors, the configuration of their positioning may be in itself a multifaceted task and, in addition, there are no standards or guidelines that provide a precise methodology for their most appropriate deployment.

A good rule of thumb is that sensor nodes are collocated in the proximity of the most climate-vulnerable artworks preserved in the rooms, keeping in mind that the sensors should neither be installed close to any heat and/or radiation sources, nor in proximity of windows and doors.

The starting point of our proposed approach on the deployment of sensor nodes in small-to-medium sized museums is the definition of the Museum Scenario, based on the following issues:



(1) the feasibility of conducting field measurement campaigns for the characterization of the indoor climate in terms of air temperature and relative humidity, as well as of the air-surface interactions;

(2) the availability of historical data of the key ambient variables (mainly indoor air temperature and relative humidity) in one or more rooms in which the cultural objects are preserved or stored.

Issue (1) is focused on field campaigns using portable thermo-hygrometers with the recommended characteristics set out in the current European standards (EN 15758:2010 and EN 16242:2012). Measurements of air temperature (T) and relative humidity (RH) at specific sampling points in exhibition rooms and in proximity to the surfaces of both artworks and walls, are collected (Camuffo et al., 1999). The mixing ratio (MR) of moist air at the same sampling points can be retrieved from T and RH measurements. This way, the spatial distributions of the thermo-hygrometric variables on the horizontal plane can be drawn (namely thermo-hygrometric maps).

This diagnostic approach better highlights areas where gradients of temperature and moisture are located (Fernández-Navajas et al., 2013). Moreover, it allows us to evaluate the location of heat and moisture sources or sinks. In addition, it is possible to visualize the areas affected by external air masses penetrating through open doors or windows that have thermo-hygrometric characteristics different from the internal air (Camuffo, 2019). Thermo-hygrometric measurements close to the external walls can provide the capacity of building buffering against the daily and seasonal fluctuations of outdoor climate.

The key outcome is to show the gradients of temperature and humidity between the surface of the cultural object and the surrounding air, the areas of the surface which are in equilibrium with the environment or if air-surface interactions, in terms of moisture and heat exchanges, are experienced.

Therefore, the basic procedures consist of a visual interpretation of thermo-hygrometric maps to define an initial deployment configuration of the sensor node devices in order to monitor these conditions.

Issue (2) refers to continuous monitoring of air temperature and relative humidity inside the exhibition rooms. If the measurements are taken over a sufficiently long period (at least one calendar year or multiple years), preferably with instruments fulfilling the recommended characteristics set by the European standards (EN 15758:2010 and EN 16242:2012), then it is possible to assess the historic indoor climate (EN 15757: 2010) and to analyse the ambient variability both in terms of the seasonal and daily cycles in each room. The outcome of the analysis allows us to evaluate whether the indoor climate of adjacent rooms may be similar.

Subsequently, the advanced procedures consist of the application of statistic methods to indoor climate data (Siani et al., 2018; Zarzo et al., 2011), which refine the deployment configuration of the sensor node devices by using a proper number of sampling points, whilst guaranteeing the representativeness of the whole environment surrounding the cultural objects.

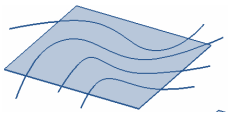
To conclude, the field measurements (1) combined with historic data analysis (2) allow us to further fine-tune the deployment of the sensor node devices.

Based on the above issues, four types of Museum Scenarios have been defined:

- In **Museum Scenario I,** field campaigns cannot be both planned and performed as portable thermo-hygrometric instruments are not available, so the spatial distribution and the gradients of microclimatic parameters remain unknown. Furthermore, microclimate measurements have not been performed either continuously or occasionally. In this case it is not possible to evaluate the historic indoor climate and its variability.
- In **Museum Scenario II,** field campaigns have been conducted and/or can be planned. The observed microclimate values are reported in the horizontal/vertical cross-sections of each rooms, so that the space distribution of moisture and temperature is retrieved. Thus, the visual interpretation of data maps allows us to design an initial configuration of the sensor nodes' deployment. Moreover, microclimate measurements have not been performed, either continuously or occasionally.
- In **Museum Scenario III**, field campaigns cannot be both planned and performed, as portable thermo-hygrometric instruments are not available, so the spatial distribution and the gradients of microclimatic parameters remain unknown. On the contrary, microclimate measurements have been performed either continuously or occasionally in the exhibition rooms.
- In **Museum Scenario IV,** field campaigns have been conducted or can be planned, and microclimate measurements have been performed either continuously or occasionally in the exhibition rooms.

Table 1 summarises the four Museum Scenarios based on the issues (1) and (2).

Table 1. The Museum Scenario schema (N/A= Not Available, AV= available).

 MUSEUM SCENARIO	 THERMO-HYGROMETER FIELD CAMPAIGNS	 TIME SERIES OF MICROCLIMATE OBSERVATIONS
I	No	N/A
II	Yes	N/A
III	No	AV
IV	Yes	AV

3. Evaluation of the Museum Scenario

The starting point of the methodology for an initial deployment configuration of the sensor node devices is the classification of the museum into its corresponding/most suitable Museum Scenario. This classification is based on the recognition of general background information on the museum, its collections and where the cultural objects are preserved. This issue can be derived by the team responsible for microclimate monitoring through on-site visit to the museum and/or gathered through an *ad hoc* questionnaire survey to be filled by the museum's curator together with the professional conservators.

3.1 On-site visit to the museum

Through on-site visit to the museum, the team responsible for microclimate monitoring together with the museum's curator and the professional conservators collect all the background information necessary to characterize the museum, the preserved collections and the internal environmental conditions. Then, the museum will be associated with the corresponding scenario based on all collected information.

The following relevant items are taken into consideration:

(a) building type, based on construction period (Mazzarella, 2015);

(b) floor plans, number of exhibition and/or storage rooms;

(c) orientation of rooms;

(d) mutual positions of exhibition and storage rooms;

(e) climate system used (if any) and type of climate control (temperature, relative humidity);

(f) glazing typology;

(g) microclimate monitoring system (if any);

(h) type of material (or the class of materials that constitute the artwork) that are in exhibition or storage rooms;

(i) state of conservation of the cultural objects.

The items from (a) to (f) have been inspired from the Classification of Climate Control Potential in Buildings suggested by ASHRAE Handbook (2015). Item (g) is included in order to assign the museum to a Museum Scenario. The last two items (h) and (i) are usually provided by conservation condition reports (CR) on cultural objects compiled by the museum conservation staff.

3.2 The questionnaire

In case on-site visits to the museum cannot be carried out, an *ad hoc* questionnaire has been conceived as a useful tool to obtain the background information on the museum needed to assign it to the Museum Scenario. The questionnaire has been developed by URO1 team in collaboration with UPV team.

The questionnaire is organized in four main sections:

(1) general information on the museum, its building and collections;

(2) information on the microclimate measurements and the microclimate system;

(3) knowledge and use of the standards or guidelines on the microclimate for cultural heritage;

(4) comments from the museum.

The questionnaire has been drawn up in Microsoft Excel. Most items and the related answers are shown as drop-down menus or closed questions (i.e. there are only two possible responses, yes/no). Drop-down menus have the main advantages of conserving space and to providing users with a given number of options. Some open-ended questions are highlighted by a grey background. If the respondent does not select any answer, this is interpreted as not available information (N/A).

Section 1 – General information

The main goal of Section 1 (S1) of the questionnaire is to collect general information on the museum (the building and the collection) through three subsections as shown in Figure 3.

	Information on the MUSEUM				
S 1	Name of museum				
	City				
	Country				
	Name of the person in charge of responding to the questionnaire				
	Number of conservation scientists employed in the museum				
	Number of conservators employed in the museum				
	Short description of external climate of the site	(select)			
	Museum BUILDING				
	Type of the building	(select)			
	Energy-saving classification of the building (if any, select one)	(select)			
	The Museum is housed in the whole building	(Y/N)			
	Number of Museum floors				
	Floor area of the Museum	(select)			
	Average height of Museum's rooms	(select)			
	Air conditiong system used	(select)			
	Glazing typology	(select)			
	Number of exhibition rooms				
	Collection storage rooms (if yes, specify size and location)	(Y/N)	(select size)	(select location)	
	Museum COLLECTION				
	Main type of preserved objects	(select)			
	Periodic control by experts on conservation state of artwork	(Y/N)			
	Showcases (if yes, select typology)	(Y/N)	(select typology)		

Figure 3. Section 1 (S1) of the questionnaire: general information on the museum, its building and the preserved collections.

Information on the museum

The purpose of this section is to provide a snapshot of the museum in terms of its geographical location and of the number of conservators/conservation scientists working in the museum. The first six items are defined as free-form survey questions, so the response to these questions is not limited to a set of options. The seventh item is related to the type of external climate affecting the site (Answer options: Mediterranean, humid continental, subarctic climate).

Information on the museum building

Ten items are focused on the museum building. Two building types are taken into account based on the period of their construction (Mazzarella, 2015): historical building (built before 1945); modern building (built after 1945). A third option includes the open-air museum that refers to museums that exhibit collections of buildings and artefacts outdoors. An item concerns the energy efficiency of the building, rated in terms of a set of energy efficiency classes from AA+ (the most energy efficient) to G (the least efficient). The following specific features of the museum building are also requested in order to achieve a satisfactory description of the building museum, e.g. the floor area, the glazing typology, the number of exhibition rooms, etc.

Information on the museum collection

The last items of S1 concern the museum collection in terms of types of cultural objects and showcases. One item asks whether periodic controls on the conservation state of objects are carried out or not.

It is worth noticing that last items are not expected to be compared to any condition reports (CR) provided by the conservation staff. However, they can be useful for the understanding of the potential environmental risks to objects which are preserved in the museum.

Section 2 – Information on the microclimate system

Section 2 (S2) is focused on acquiring greater insights on the monitoring system (if any) of the key indoor environmental variables: air Temperature (T), surface Temperature (Ts), Relative Humidity (RH), Light (L), Air Pollution (AP) and Vibrations (V).

Each respondent selects which microclimate variable is monitored inside the museum. Then, for each of these variables, eleven technical items, grouped into *"Type of the instrument used to measure XXX"*, are designed to show as clearly as possible the different aspects of the monitoring system for conservation purposes. Figure 4 is the screenshot of S2 of the questionnaire for a general microclimate variable (*XXX* stands for the variable's name). This part is repeated for each of the six variables.

	Information on the MICROCLIMATE SYSTEM				
S 2					
	Select the INDOOR CLIMATE PARAMETERS measured and specify starting and ending dates of the monitoring				
	Air Temperature (T)	☐			
	Artwork surface temperature (Ts)	☐			
	Relative Humidity (RH)	☐			
	Air Pollutants (AP)	☐			
	Light (L)	☐			
	Vibration (V)	☐			
	Type of the instrument used to measure XXX				
	Total number of sensors (if you use different sensor model, please fill the column for each sensor model)				
		#1	#2	#3	#4
	Model				
	Manufacturer				
	Sensor	(select)	(select)	(select)	(select)
	Uncertainty/Accuracy	(select)	(select)	(select)	(select)
	Starting date of the monitoring				
	Ending date of the monitoring (if still in operation, specify the date of compilation of the survey)				
	Frequency of observation	(select)	(select)	(select)	(select)
	Method of recording the indoor microclimate data	(select)	(select)	(select)	(select)
	Data analysis and internal report on monitored data	(Y/N)	(Y/N)	(Y/N)	(Y/N)
	Date of the last calibration (if not performed, report to the starting date of the monitoring)				

Figure 4. Section 2 (S2) of the questionnaire: information on the microclimate systems.

The same items are also dedicated to the outdoor climate variables of temperature and relative humidity, if monitored in proximity of the museum. These data can support the evaluation of the influence of the outdoor thermo-hygrometer conditions on the museum indoor climate.

Section 3 (S3) – Other information

Section 3 (S3) provides collated information on the knowledge and application of the European standards or national standards/guidelines concerning microclimate for the preventive conservation of cultural heritage. Three questions are dedicated to this end with closed answers (Y/N), as reported in Figure 5. The last item can be further commented by filling in the grey box with the full reference of other standards or guidelines used by the museum's staff.

S3	**Other information**				
	Do you know European standards about microclimate for cultural heritage and its measurements ?	(Y/N)			
	Are they applied in your museum?	(Y/N)			
	Do you apply alternative national standards or museum guidelines about microclimate (if yes, please specify the name)	(Y/N)			

Figure 5. Section 3 (S3) of the questionnaire: information on the use of European and/or national microclimate standards for Preventive Conservation actions. Y/N stands for yes/no.

Section 4 (S4) – Comments

This last section compiles other relevant information on the museum that are not available in previous items and that users consider useful for the purposes of microclimate monitoring.

4. Scenario classification of the CollectionCare museums

The identification of the scenario to be associated with each of the CollectionCare museums is based on the background information on the museum acquired by on-site visits and/or gathered by *ad hoc* questionnaire filled in by each museum partner.

The questionnaire was submitted to the museum partners in the CollectionCare project at the mid of April 2019 on the Basecamp platform (Basecamp 3). Basecamp is a professional management tool that is used for internal management and communication among CollectionCare partners.

Answers were accepted until the beginning of May 2019. In addition to the questionnaire, the museum partners were asked to provide detailed plans of the museum and to indicate the deployment of sensors if they were in operation. Preliminary results on the museum' answers to the questionnaire are provided in the following sections in order to show the proof-of-concept of the initial phase of the proposed procedure for deployment of sensor node devices.

4.1 CollectionCare museums: geo-localisation

Nine museums have been involved in the CollectionCare project. Two museums were selected to test the prototype sensor node devices: Museo delle Origini (Rome, Italy); Museum of Informatics of the School of Informatics (Valencia, Spain). Seven museums have been chosen as demonstration sites for the validation of basic and advanced sensor node devices.

Table 2 reports information on the geo-localisation and the website addresses of the museums, which are listed following the acronym-alphabetical order. These data have been collected from the first part of Section 1 (S1).

Table 2. General information on the CollectionCare museum sites. The symbol (*) indicates the two test museums.

Acronym	Museum	Country	City	Web address
DFA_AAM	Alava Arms Museum of Diputación Foral de Álava	Spain	Vitoria-Gasteiz	https://armamuseoa.eus/es/
DFA_AFAM	Alava Fine Arts Museum of Diputación Foral de Álava	Spain	Vitoria-Gasteiz	https://web.araba.eus/es/
IEEE	Historical and Ethnological Society of Greece	Greece	Athens	http://www.nhmuseum.gr/en
IVC	Film archive of the Institut Valencià de Cultura	Spain	Valencia	http://ivac.gva.es

KMKG	Royal Museum of Art and History	Belgium	Brussels	https://www.artandhistory.museum/
OALM	Ethnographic Open Air Museum of Latvia	Latvia	Riga	http://brivdabasmuzejs.lv/en/
RDC	Rosenborg Castle The Royal Danish Collection	Denmark	Copenhagen	http://www.kongernessamling.dk/en/rosenborg/
UPV(*)	Museum of Informatics of the School of Informatics	Spain	Valencia	http://museo.inf.upv.es/es/
URO1(*)	Museo delle Origini	Italy	Rome	https://web.uniroma1.it/museoorigini/

(*) test sites

One of the peculiar features of the CollectionCare museums is their geolocalisation heterogeneity. This aspect can be relevant to understand the buffering capacity of the museum building against outdoor environmental conditions. Figure 6 shows the geo-localisation of the museums (black dots on the map together with the museum acronym and logo).

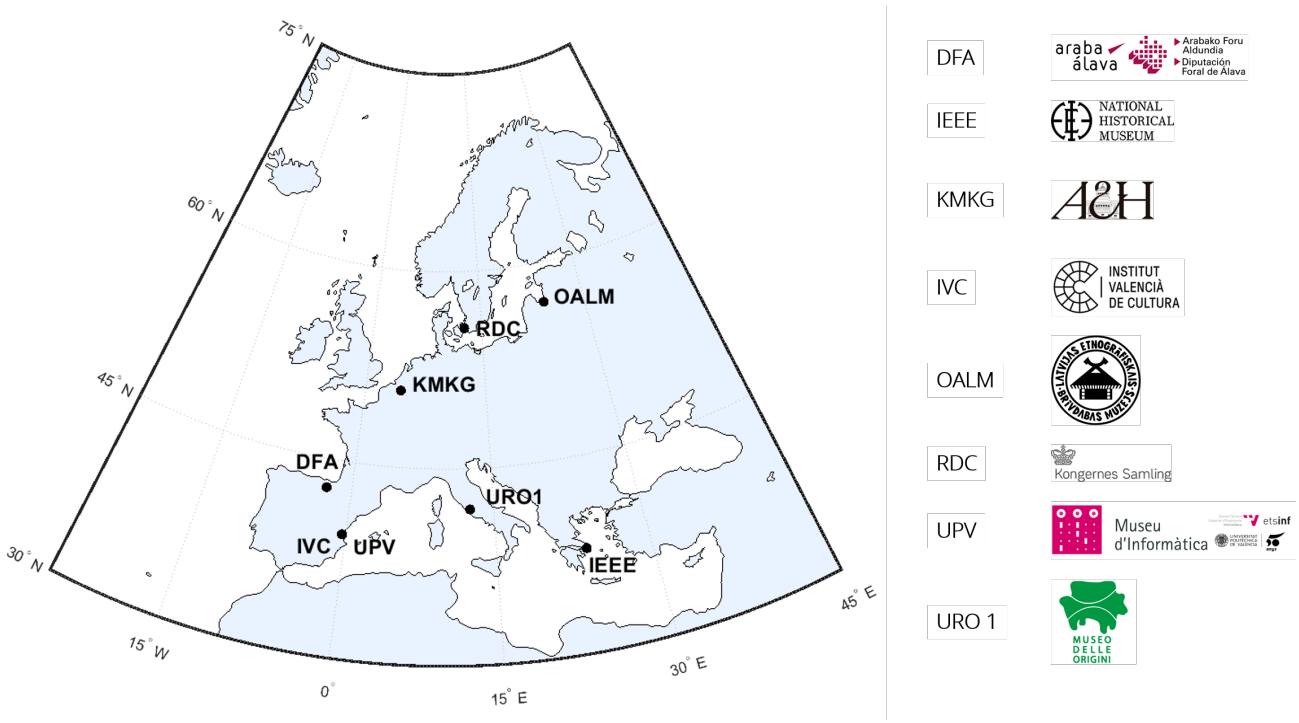


Figure 6. Geolocalisation of the CollectionCare museums with the museum acronym and logo.

The Köppen Climate Classification (http://hanschen.org/koppen/) is used here in order to have an objective and homogeneous assessment of the climate of the sites. The Classification is based on 30-year data (1981-2010) and it is one of the most common climate classification systems utilised by scientists and climatologists to this day.

It can be noticed in Figure 7 that IEEE, IVC, UPV and URO1 are characterized by mild temperate climate with dry and hot (Csa) or warm summer (Csb); DFA, KMKG and RDC are exposed to mild temperate, fully humid climate with warm summer (Cfb); OALM is exposed to snow, fully humid climate with warm summer (Dfb).

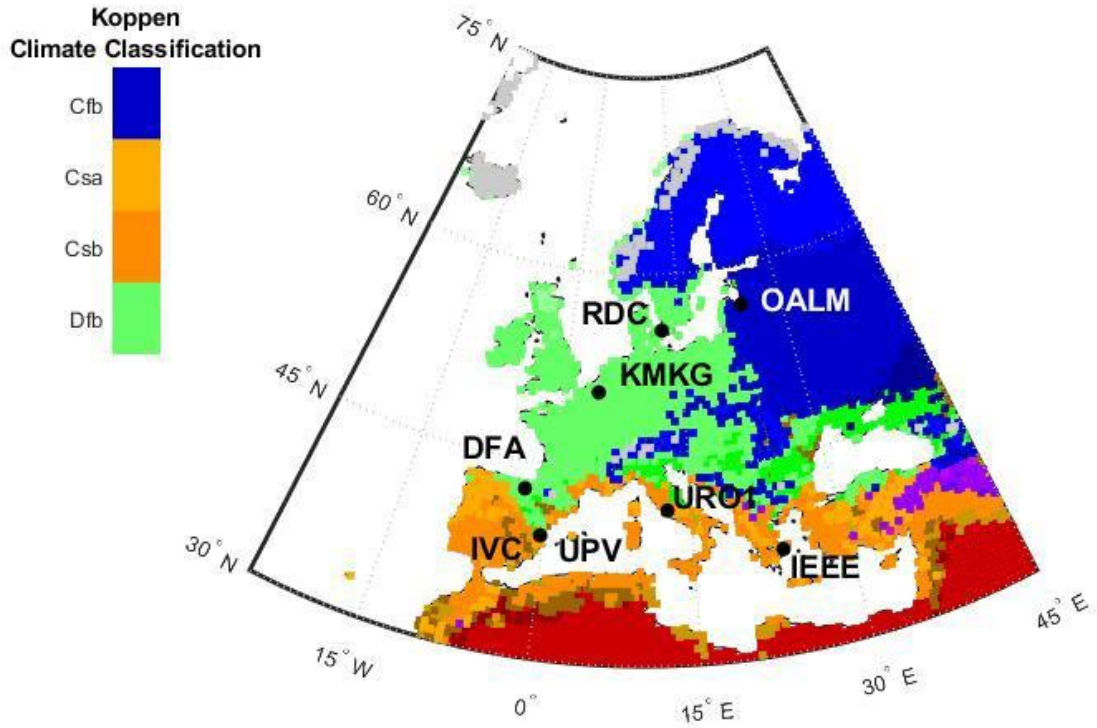


Figure 7. Geolocalisation of the CollectionCare museums on the map with the Köppen Climate Classification. The color bar refers only to the climate classes of the museum sites.

4.2 CollectionCare museums: Information on the microclimate monitoring system

Figure 8 shows a pie chart of the microclimate variables monitored in the CollectionCare museums. In general, seven museums with a microclimate monitoring system collect measurements of air temperature (T) and relative humidity (RH). Visible and UV radiation, general indicated as light (L), are measured only in two sites. None of the museums is equipped with sensors for the measurements of surface temperature (Ts) and vibration (V), whereas air pollutants (AP) are measured only by one museum.

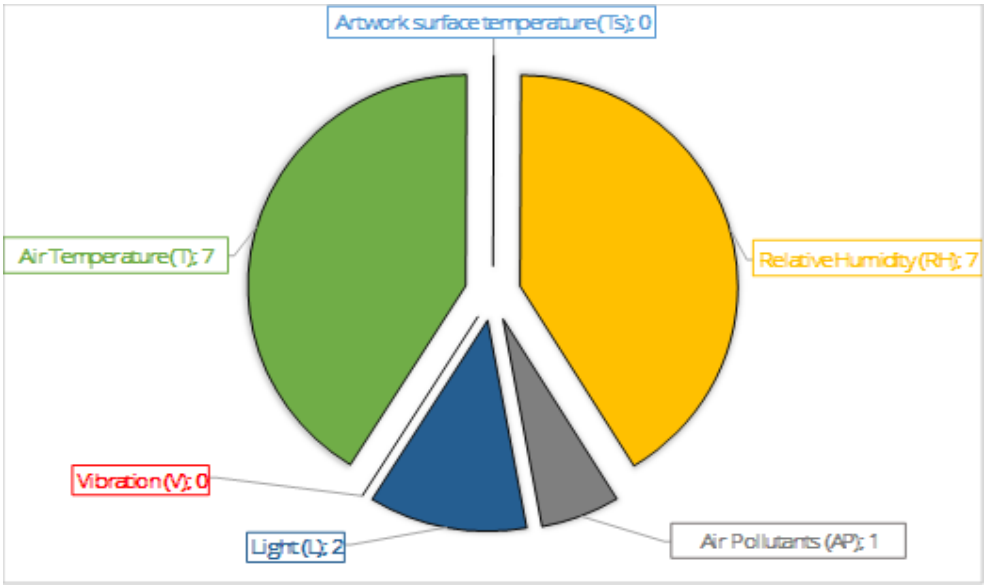


Figure 8. Pie chart of number of the microclimate variables monitored in the CollectionCare museums.

4.3 CollectionCare museums: Museum Scenario

According to Information gathered from the questionnaire a preliminary classification of CollectionCare museums into the corresponding/ most suitable Museum Scenario, is proposed in this deliverable and reported in Table 3.

Table 3. Summary of CollectionCare museums associated with the corresponding/most suitable Museum Scenario.

MUSEUM ACRONYM	MUSEUM SCENARIO	THERMO-HYGROMETER FIELD CAMPAIGNS	TIME SERIES OF MICROCLIMATE OBSERVATIONS
DFA_AAM	III	No	AV
DFA_AFAM	III	No	AV
IEEE	III	No	AV
IVC	III	No	AV
KMKG	III	No	AV
OALM	I	No	N/A
RDC	III	No	AV
UPV	I	No	N/A
URO1	IV	Yes	AV

Figure 9 shows the geo-localisation of the different Museum Scenarios related to the CollectionCare museums. Two museums (OALM and UPV) can be classified as **Museum Scenario I**, since measurements of microclimate variables have not been collected either continuously or occasionally. They are displayed as red square in Figure 9.

None of the museums can be associated to **Museum Scenario II** because the spatial distribution close to the cultural objects and inside the exhibition rooms is not available.

Most of the CollectionCare museums (DFA_AFAM, DFA_AAM, IEEE, IVC, KMKG and RDC) can be classified as **Museum Scenario III** (orange squares on Figure 9). In all these museums microclimate variables have been continuously collected for a long time up to now. However, it is worth noting that only DFA_AFAM, DFA_AAM, IEEE and RDC have provided microclimate data (Deliverable D1.2, confidential report). As IVC and KMKG have not provided data and short records of measurements are available for DFA_AAM, these sites are associated to **Museum Scenario I** in this initial phase.

URO1 site fits the issues of **Museum Scenario IV** (green square in Figure 9).

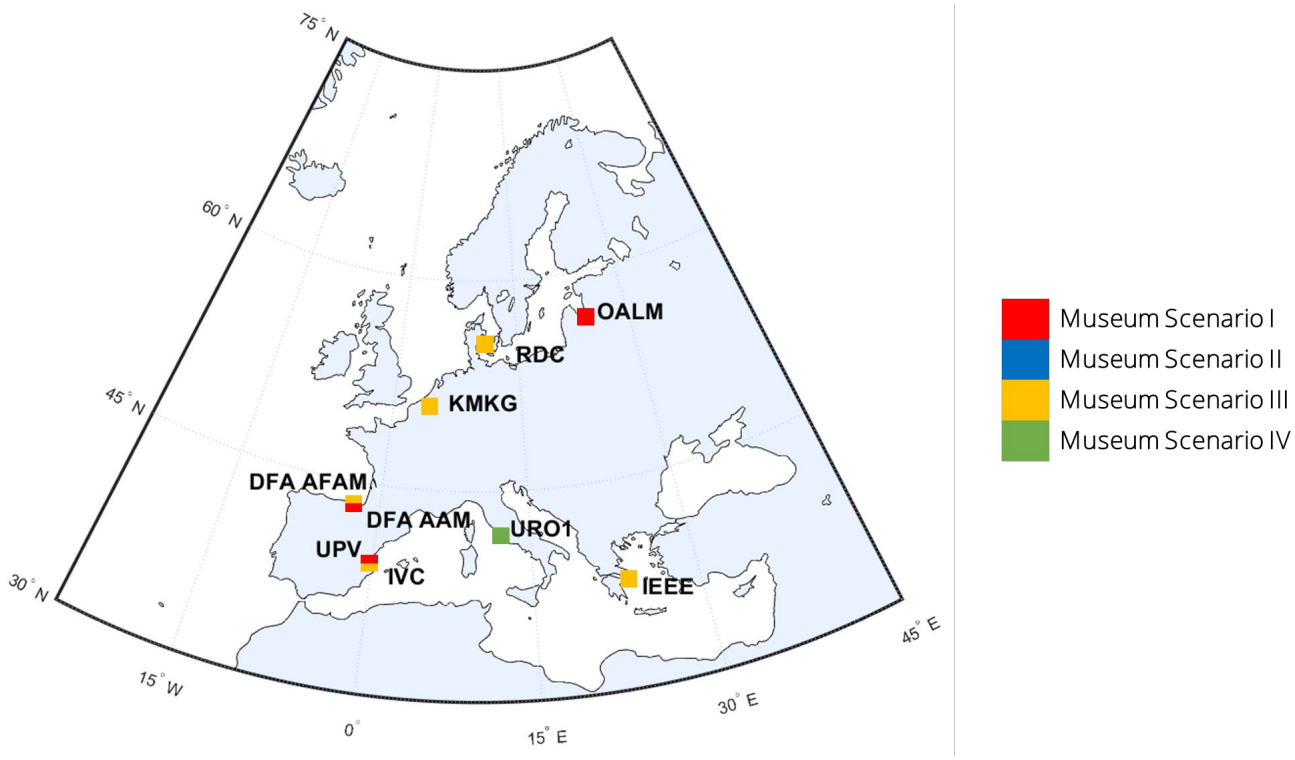


Figure 9. Geo-localisation of the different Museum Scenarios related to the CollectionCare museums.

5. Conclusions

In the definition of protocols for deployment of sensor node devices, several general aspects (exhibition spaces, artworks' location, the surrounding environments etc.) should be considered, with a view to increasing the knowledge of a specific conservation problem of the cultural object, as well as its preventive conservation in the long term.

As a first step of a general protocol for deployment of sensor node devices, four possible museum scenarios have been outlined based on the feasibility of conducting field measurements and/or the availability of historical data on air temperature and relative humidity. As a preliminary result, each CollectionCare museum has been associated with its corresponding museum scenario based on the background information on the museum which can be acquired by on-site visit and/or gathered by *ad hoc* questionnaire.

Deliverables D4.9 and D4.10 will provide more details on the protocols to be followed for deployment of sensor node devices in each Museum scenario associated with the CollectionCare museums. The sensors' site configuration will be also implemented, keeping in mind the needs to place the sensors in close proximity to the climate-vulnerable artefacts preserved in the rooms. In addition, the need to minimise the visual impact caused by monitoring systems for aesthetic reasons will also be considered. Thus, the installation of instruments along the visitors' passageways will be avoided in order to reduce the risk of theft or damage.

Another aspect of the deployment of the sensor node devices that will be analysed, is the evaluation of the indoor signal propagation of wireless sensing system due to different infrastructures, as described in the confidential deliverable D1.4 designated "Definition of technical requirements for wireless communications" and it will be evaluated in Task 4.3. These and other requirements will be discussed and agreed together with CollectionCare museum partners.

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