SensMat

Deliverable D2.7

Final version of requirements

WP	2	Large-scale survey of evolving needs, barriers, standards, etc.
Task	2.3	Questionnaire and survey
Sub-task	2.3.4	Final version of the requirements

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[1] Dissemination level: **PU** = Public, **CO** = Confidential, only for members of the consortium (including the Commision Services), **EU-RES** = Classified Information: RESTREINT UE, **EU-CON** = Classified Information: CONFIDENTIEL UE, **EU-SEC** = Classified Information: SECRET UE

[2] Type of the deliverable: **R** = Report, **ORDP** = Open Research Data Pilot, **ETHICS** = Ethics requirement, **DEM** = Demonstrator, pilot, prototype, **DEC** = Websites, patent filings, videos, etc, **O** = Other

[3] Creation, modification, final version for evaluation, revised version following evaluation, final

Deliverable abstract

As part of Sub-Task 2.3.4, CNRS-C2RMF transcribes museums need into a final version of requirements. From the international, regional framework and standards recommendations (D2.2; D2.3), survey results and partners inputs (D4.1; D5.2), specifications concerning technical functionalities of devices and treatment modalities of the platform may be drawn.

In order to be a systematic remedy in daily decisions and preventive care actions, Sensmat solution must be able to receive both information filled by users and sensors data. The objective is to find a satisfactory compromise between product quality and price. Requirements are based on following criteria:

- Needed driven;
- User centered and user-friendly;
- Ease the exploitation of various data;
- Curated (trustworthiness of the information given).

Table of contents

1. Contextualization of the requirements: purpose and objectives

Project presentation

The SensMat project aims to set up innovative solutions for preventive care actions of cultural heritage through sensing tools and data treatment platform.

Preventive conservation (PC) regroups indirect care actions in the scope of preserving cultural heritage to insure its transmission. It intervenes in all areas that can have an impact and effect on the integrity of a collection, an object or a work of art, and ultimately threaten its existence or the meanings on which its heritage value is based[4].

WP2 intends to formalize the needs of end-users (museums) in technical requirements for tools and software manufacturers. Sub-task 2.3.3, *Interpretation and transformation of questionnaire in requirements* aims to produce technical, economic, ergonomic and aesthetical requirements according to:

- **International, regional framework and standards recommendations** (D2.2, D2.3);
- **Survey results** (D2.5), illustrating museums practice and needs in terms of preventive conservation policy as well as their expectations to provide solutions easing their everyday actions;
- **Strategic preventive conservation orientation for daily operations**: preventive conservation professionals are shifting from fixed thresholds to much more adaptable and/or tolerable limits. These parameters must include historical climate, building performance and geographical and seasonal criteria. It influences the functionalities required since they must be editable by the end-user according to various factors and stakes, he/she must take into account. The devices and the software tool must help the calculation and monitoring of these parameters while giving guidelines on best practices to be used;
- **Partners inputs**: through the release of D4.1 *Definition of sensors to be used in the Specification,* we were able to expand the first version of D2.6 *First version of the requirements* into a final version (D2.7) that includes much more solutions as proposed by the partners.

From these inputs, we were able to draw three criteria:

- **Need driven;**
- **User-centered and user-friendly**;
- **Curated data exploitation**.

[4] Center of Research and Restauration for Museums of France (C2RMF), *Vademecum of preventive conservation*, 2013 edition, available in French : https://c2rmf.fr/sites/c2rmf.fr/files/vademecum_cc.pdf : *La conservation préventive intervient sur l'ensemble des domaines qui peuvent avoir des incidences et des effets sur l'intégrité d'une collection, d'un objet ou d'une œuvre d'art, et menacer à terme son existence et la perte des significations qui fondent leur valeur patrimoniale.*

Criteria's impact on requirements and expectations

i. Need driven

In order to fit the needs at best, two survey campaigns (D2.5) have been organized and their results show that organic materials are the first concern of museums. The reaction of organic material to stressing environment in short time span makes them identified as the most sensitive materials to preserve. Consequently, organic collections should be the most monitored ones. Due to limited resources and specialized staff, there is a lack of data exploitation. The following barriers have been identified:

- **Lack of human resource**: the general reduction of team effort and work shifts leads to the hierarchization of emergency actions daily rather than the study of environmental factors (unless catastrophic events) that may be time consuming.
- **Lack of technical knowledge**: because of the complexity of the data produced by the sensors currently on the market (often raw numbers, possibly graphic charts), small and medium sized museum staffs often drop their exploitation. They are not able to make a coherent link with the environmental impact this has on the collections. As a consequence, when sensors are set in the rooms, they may not be calibrated and often left for months or years without being exploited.

The expected use for the sensors involves the monitoring of environmental parameters on a long-time basis, mainly in storage and permanent spaces of exhibition. The objective is to monitor these environmental parameters before they become degradation factors for the collections.

ii. User centered and user-friendly

Surveyed professionals outlined the difficulties they face analyzing raw environmental data – which can lead to bias in diagnostic and deficiency in mitigation procedures. The information must be easily accessible. As a solution to this objective, we determined that sensors are meant to indicate a type of environment according to the following key functionalities – these functionalities are integrating a strategic orientation in PC daily practices we are eager to implement in the museums:

- **Indicate and inform on the degree of adequacy between an environment and the needs of the collection**. No quantitative precision is expected but a qualitative overview, allowing to monitor degradation factor through environmental levels of alert documenting the risks involved for the collections. The objective is to give a tool of condition assessment for the collection manager.
  For instance, and given the complexity of pollutants measurement interpretation, it has been settled, with the Institute of Corrosion (P11-FR), to alert the museum professionals according to the corrosiveness classes measured.
  Similarly, we aim to target the stability of climatic parameters (RH, T): we established that no thresholds are relevant if they do not take into account the historical climate[5] of the

[5] The term is defined in standard EN15757:2010, *Conservation of cultural property – Specifications for temperature and relative humidity to limit climate-induced mechanical damage in organic hygroscopic material* as the accumulated threats, original climate and conservation conditions an artefact is used to. The objective

artefact, the building performances, the seasonal variations and the available mitigation tools. To encourage a larger vision of these parameters and facilitate the reading of the data, we propose that the software shows simultaneously a graphic representation of the data and compare it to the thresholds defined in the environmental policy and an annual average.

- **Connect these data to modelling data in order to predict, document and prevent on-going and future alterations:** the aim is to document the typology of alterations faced by the collection manager as a component of decision-making tools.

The survey highlighted the absence of interconnection between the sensors commonly used in the museums, forgetting about the synergetic effect of degradation factors.

iii. Curated data exploitation

The operating line of actions must be curated by the professional deontological framework. The decision-making tools will be able to encourage behaviors fitting the expectations of preventive actions conveyed in international standards. Within the missions of the museum and its staff, the tools must fit for three main tasks, depending on the exploitation level:

- **To provide an environmental study of the building** and acknowledge the imponderable constraints which will shape conservation protocols. It also records the historical environment for documentation purposes and preservation actions adequacy;
- **To monitor degradation factors and the state of conservation**, either to document the condition of the collections for reports purposes or to help in prioritizing care actions, on a daily basis or in the scope of intervention protocols;
- **Define a strategic environmental policy** to insure a suitable environment for permanent display (corresponding to the conserving missions of the museum[6]) and/or temporary exhibitions (and therefore economic activities of diffusion).

The objective is to transcript behaviors into statistics and find solutions enabling to integrate these stakes as technical solutions. The surveys showed that many museums aren't in capacity to assess their needs or to formulate solutions that would help them optimize the use of sensors. We therefore had to propose solutions to fill the gaps left by the surveyed professionals. Several solutions would help to exploit the results of monitoring campaigns:

- **Help in defining suitable environmental extrema,** taking into account the institution constraints;
- **Visualization of colored ranges** according to the degree of suitability of the environment for the sensitivity of artifacts;

is to document this historical environment and better respect the consequent sensibility and/or fragilities. The objective is to extend the use of the word to other degradation factors.

[6] The International Council of Museums (ICOM) defines the museum and its missions as following: *A museum is a non-profit, permanent institution in the service of society and its development, open to the public, which acquires, conserves, researches, communicates and exhibits the tangible and intangible heritage of humanity and its environment for the purposes of education, study and enjoyment.*

- **Risk cartography**: zoning, identification and prioritization of the areas and affected collections;
- **Production of weekly reports**: historical environment, yearly variations, historical dose of illuminance. It would allow a better documentation for state reports.

The main issues raised concerning the diffusion of the information given with SensMat tools and platform should be able to fulfil the data exploitation failure in most institutions because of a lack of time, staff and technical knowledge. The data treatment scheme needs to be able to give information about the condition of the collections within a specific environment and draw both projections and decision-making tools. To that end, the platform needs to be fed from both sensors data and information filled by the user to contextualize the analysis scheme. This information must be able to produce easily relevant statistics. Therefore, we need to anticipate the information we need to have to produce as exhaustive view on the collection condition and environment. Indeed, this information need to be ranked and classified in order to produce content and statistics to ensure a follow-up of the collections and preventive action performed. The objective could be to target a web-scale interoperability through the utilization of shared thesaurus.
Also, two query modes should be able to make the information available and match the expectations of such a tool:

- The alerts of concerning data, going beyond the recommendations of the environmental policy (from the platform to the collection manager).
- The interrogation of the data in order to explain an alteration (from the collection manager to the platform).

These two query modes respectively match two major situations in which the collection manager will interrogate the platform. In the first case, we need an alert to prevent a degradation that may not be visually detectable yet or to predict the alteration phase (see ii.User centered and user-friendly) an artefact is risking to evolve in. The second situation corresponds to a visually observed degradation on which the staff needs documentation: its origin and the predicted evolution.
We need the platform to integrate a risk analysis methodology compatible with a short-term projection in order to feed state reports of Facility Reports with condition assessments details, both filled out by the sensors data and the daily observations on the collections. The objective is to make the observation (state condition) and the environment (the conservation conditions) coherent, in order to hierarchize the decision-making tools.

2. Technical specifications

In order to prioritize the needs expressed, we have used a scale from 1 to 4. The color code is to be find next to every functionality.

4	**Essential**	Strong influence if the element is present, strong influence if it is absent ⇨ **Determining**
3	**Basic**	Does not increase satisfaction if present, increase dissatisfaction if absent ⇨ **Minimum required**
2	**Gain**	Increases satisfaction if present, does not increase dissatisfaction if absent

		⇨ **Excellency**
1	**Secondary**	Neutral impact whether present or absent
X		No particular priority: indication

This scale may be used by the partners to assess the solutions they will propose. It can be used as a Key Performance Indicator (KPI) when evaluating the relevance of the solutions.

- **Sensors requirements**

	Compounds	Functionality	Priority level
Devices material requirements	***Battery and alimentation***	Average autonomy: 1 year and half	
	Aesthetic	Discreet/neutral colors	**X**
	Presentation	Wall-mounted (fixating holes) Self-presenting	**X**

		Functionality	Priority level
Sensors communication	***Measurement***	Standard EN 16893:2018 recommends one measurement point per hour. For vibration sensors: average number of cycles and their amplitude per hour. Automatic interrogation mode.	
	Treatment	• Possibility to configure thresholds and extrema • Ranking of the data according to the thresholds	
	Archiving data	Automatic on 5 years is satisfying (standard EN 16893:2018 recommends an indefinite archiving in a readable format).	

- **Climate: hygrometry and temperature**

	Requirements, propositions, solutions
Measurement ranges	T°C : -5°C to 40°C RH: 10% up to 90%
Measuring accuracy	T°C : 2°C RH : 2%

- **Light**

	Requirements, propositions, solutions
Measurement ranges	- Standard EN TS 16163 : from 10lx to 10 000lx - UV: 50-500µW/lumen
Measurement accuracy	Long term drift <1%FS per year

- **Pollutants, VOCs and airborne particle concentration**

Source	Requirements, propositions, solutions[7]
Corrosion	- Indicates a corrosiveness class (based on international standards): alarm on the level of corrosiveness - Electrical resistance measurement on copper and silver samples
VOCs	- Limit of detection <40ppb - Accuracy within ±10% - Response time <6min - Low cross-sensitivity to relative humidity

Particle number concentration detection[8]	- PM10: qualitative objective 30µg/m^3 (annual average)
	- PM2.5: European Union objective fixed on a 20µg/m^3 (annual average)
	- Applied sensor
	  ○ Mass concentration range: 1 to 1000 µg/m^3
	  ○ Mass concentration resolution: 1 µg/m^3
	  ○ Accuracy: ±10%
	  ○ Response time: Min. 1s
	- 500/cm^3 for airborne particle PM2.5, PM10, black carbon, organic carbon

- **Vibrations and shocks**

	Requirements, propositions, solutions
Measurement ranges	0 to 16g 0 to 265m/s^2
Measurement accuracy	±(0.1g + 5% v.m.) ±1/1/1 m/s^2
Resolution	0.1g 1m/s^2

3. Software functionalities and data treatment

	Functionality		Priority level
Software functionalities	***Interoperability***	Web-scaled interoperability: shared thesaurus	
	Editability	• Edition by the end-user • Programmer follow-up	
	Query modes	• Alarms of thresholds overtaking • Collection follow-up on existing alterations	

[7] Based on WP4, First attempt for sensor's specifications – Approaches process scenario (08/04/2019)

[8] PM10 and PM2.5 sampling and measurement: standard EN12341 :2014, *Ambient air – standard gravimetric measurement for the determination of the PM10 or PM2.5 mass concentration of suspended particulate matter*

	Alarms	• Edition of a weekly report on environmental adequacy with the thresholds • Cartography of data collected	
	Output formats (currently in surveyed museums)	.xlsx PDF EZV File .ttd CSV	**X**
	Data archiving	Automatic, 5 years	**X**

- **Monitoring and decision-making tools**

In order to produce relevant decision-making tools, the platform must be able to register the following aspects as a risk analysis methodology in order to document alterations:

A: Endangered: risk of loss of the object or even part of the collection; requires urgent curative conservation action.
B: Medium: integrity threatened; would require curative conservation intervention in the medium to long term.
C: Satisfactory: stable condition, would require conservation-restoration to improve legibility.
D: Very good: can be exhibited as is, possibly dusting;

In addition, we must consider the evolution of an alteration and the cumulative consequences, until its irreversibility (from the data of the sensors and WP3 Multiscale modelling):

A: Rupture phase: loss of the object's original properties.
B: Plastic phase: accumulation of degradation without return to normal.
C: Elastic phase: degradation then return to normal without affecting the object.
D: Stable.

Also, a time evaluation of the notification of the alteration is necessary. This information has to be filled by the user as an interaction with the platform. When they observe a degradation, they need to document with the platform data.
This risk analysis is applicable to per item and per degradation factor.

The platform must be able to provide weekly reports containing:

- Graphic illustrations of each environmental parameter monitored,
- Risk analysis results,
- Cartography (2D and 3D) of the environmental adequacy thanks to a colorimetric chart.

To document properly these information, two levels of alarms must be calibrated:

- 1 alarm calculated on specific thresholds: the calculation may be automatic but the data is provided by the user in order to respect the specificity of each institution policy. The calculations are explained in the following paragraphs, specifically explained per each environmental parameter.
- 1 alarm must be raised taking into account the cumulative effect of these environmental parameters, thanks to risk analysis (see par. “Monitoring and decision-making tools below) and WP3 results for the alteration modelling.

- **Climate data treatment**

Treatment of the data: type of ranking for treatment and analysis of the data (categories the user has to be able to fill in for the analysis).

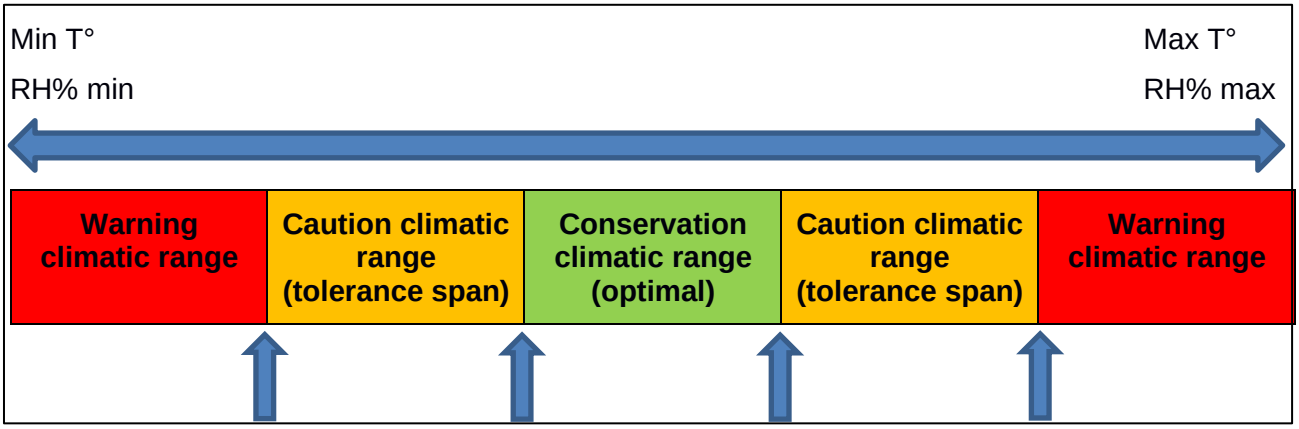
What is being monitored is the dynamic evolution of T/RH, through: speed of variation, cycles duration, repetition frequency. Indeed, the aim of environmental policy must be the avoidance of fluctuations, short term cycles and strong and rapid variations of T and RH[9]. To rank the data and set the alarms, the determination of a climatic range target is necessary through:

- The calculation of three averages to rank the data: annual, monthly, seasonally,
- The definition if short-term fluctuation.

Both will be compliant with standard EN15757:2010 methodology.

From the calculated thresholds, the following information should be filled in automatically:

Conservation climatic range	No risk of damage; simple monitoring
Caution climatic range	Possible risk of damage; monitoring + corrective action(s) to be considered
Warning climatic range	Definite risk of damage; urgent corrective action



Interval measurement point:	**1 per hour (ex.)**	
Duration (start date/end date)		
Variation characterisation	Temperature (°C)	Relative Humidity (%)

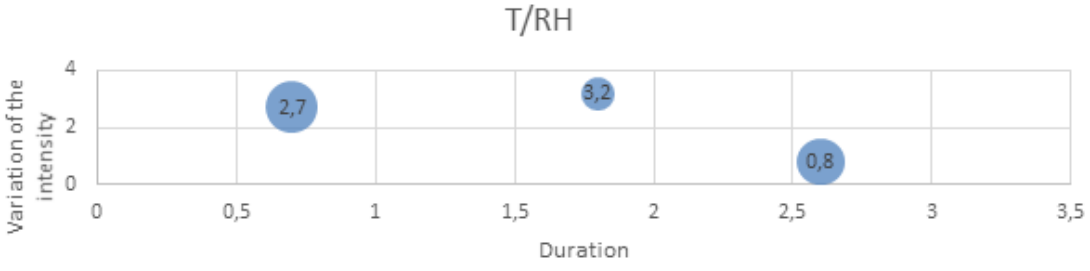
[9] See standard EN15757:2010, *Conservation of cultural property – Specifications for temperature and relative humidity to limit climate-induced mechanical damage in organic hygroscopic material;* Annex A,

Very stable (below…)		
Mainly stable (below…)		
Not stable (above…)		

Variation reference frame	Variation characterization	Temperature (°C)	RH (%)
For 1 day	*Very stable below…*		
	Fairly stable below…		
	Unstable above…		
1 day to 1 week	*Very stable below…*		
	Fairly stable below…		
	Unstable above…		
1 week to 1 month	*Very stable below…*		
	Fairly stable below…		
	Unstable above…		
1 month to 6 months	*Very stable below…*		
	Fairly stable below…		
	Unstable above…		
6 months to 1 year	*Very stable below…*		
	Fairly stable below…		
	Unstable above…		

Also, end-user will need a graphic representation of environmental adequacy, depending on the thresholds calculated, with separated clusters of points and the share of each measurement point, to have a dot density. An example of the graphic representation targeted is shown in the Figure below.

Figure 1: example of the graphic representation with point cluster and dot density



The objective is to have an idea of the repartition of the amount of data collected within the caution and the conservation climatic range. The amount of data measured within a certain climatic range will indicate the degree of adequacy of the climatic environment.

- **Light data treatment**

The devices need to alert on light's dangerous impact: standard EN TS 16163 (Table 2 and 3) gives thresholds according to the level of sensitivity of the collections' materials. The annual dose that must be the deciding element of a light policy towards the object because of the cumulative effect of light-induced degradations. The intensity of light and the duration of exposure are the two elements the platform must calculate.

The sensor and the platform should be able to give, in real-time, the light range measured.

Calculations for the annual dose of light exposure must take into account to following information:

Sensitivity range	Light exposure[10]	Materials[11]
Not sensitive	No thresholds	Stone, metals, ceramics, glass
Sensitive	600 000 lx.h per year 3 000 hours/year 200lx	Painting, leather, wood, wax, varnishes
Very sensitive	150 000 lx.h per year 3 000 hours/year 50 lx	Paper, textiles, pastel, ivory
Extremely sensitive	15 000 lx.h per year 300 hours/year 50 lx	Feathers, silk, Photographies

The display of numerical data may not be user-friendly as many museums do not have a preventive conservation specialist able to calculate the proper annual dose of lighting per artefact. It is the reason why the numerical data must be paired with an alert according to one of the classes mentioned above.

- **Pollutants/VOCs data treatment**

The corrosiveness of the environment is based on the concept of "lowest observed adverse effect dose" (LOAED) since the cumulative effects of the pollutants are the main issue within preservation actions. The concept of dose, that is to say the concentration of the pollutants and the duration of

[10] According to standard EN 16163:2014

[11] Classification according to standard CIE 157 :2004

exposure, must be calculated as the indicator of a corrosive environment. It would therefore be able to anticipate the ideal exposure time of an object in a given atmosphere monitored by SensMat tools.

- **Corrosiveness classes**[12]

The Institute of Corrosion (P11-FR) uses the following corrosiveness chart to determine the adequacy of the environment:

Figure 2 - Corrosiveness classes according to various sources

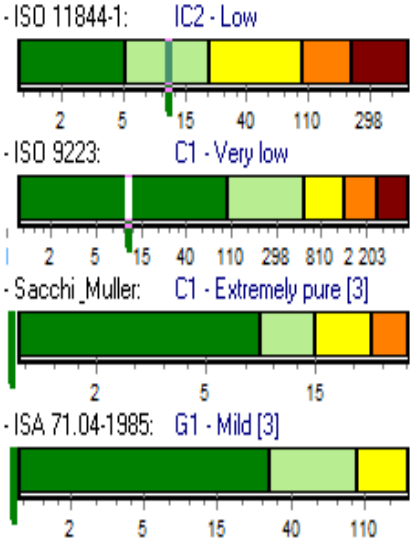


Figure 3[13] - Guidelines on levels of airborne pollutants (Jean Tétreault, Airborne pollutants in museums, galleries and archives, Ottawa, Canadian Conservation Institute, 2003)

Key airborne pollutants	Maximum average concentration for indicated preservation targets, µg m^{-3} (ppb)[14]			Reference average concentration range, µg m^{-3}	
	1 yr	10 yrs	100 yrs	Clean low troposphere	Urban area
Acetic acid	1000 (400)	100	100	0.3–5	0.5–20[15]

[12] https://www.institut-corrosion.fr/wp-content/uploads/2018/03/AirCorr-brochure-v2016.pdf

[13] Source : https://www.canada.ca/en/conservation-institute/services/agents-deterioration/pollutants.html

[14] Preservation target is the length of time (in years) for which the objects can be exposed to the indicated level of pollutants with minimal risk of deterioration. These targets are based on the LOAED of most objects (exclude high risk objects; consult Table 3) and assume that average RH is kept between 50 and 60%, temperature ranges between 20 and 30°C, and the collection is kept clean (if not, the maximum levels of key airborne pollutants for each class of targets may need to be readjusted). These values are not applicable to high risk materials – **ppb** means parts per billion.

[15] Acetic acid levels can be emitted to levels as high as 10,000 µg m-3 in enclosures made with inappropriate materials, such as fresh acid-cured silicone.

Hydrogen sulfide	1 (0.71)	0.1	0.01	0.01–1	0.02–1
Nitrogen dioxide	10 (5.2)	1	0.1	0.2–20	3–200
Ozone	10 (5.0)	1	0.1	2–200	20–300
Sulfur dioxide	10 (3.8)	1	0.1	0.1–30	6–100
Fine particles ($PM_{2.5}$)	10	1	0.1	1–30	1–100
Water vapour	keep below 60% RH[16]			N/A	

- **Vibrations and shocks data treatment**

The vibrations become a degradation factor when the frequency and the amplitude involve a mechanical fatigue on the artefacts. The cumulative effect is crucial for the monitoring. The mass, the fragility of the materials, geometry, flexibility, determine their resistance to these cycles.

Figure 4 - Data from the Canadian Institute of Conservation (as a rough guide)[17]

Examples of museum artifacts	Fragility range (g)
Plaster sculpture	15-25
Unfired clay (raw pieces) and fragile glasswork	25-40
Unfired clay, soft-fired clay, plaster, stucco, glasswork, ceramics	40-60
Oil on canvas (depending on the condition state)	60-115

- **Spatial monitoring sensors**

In order to document the alterations, the data must appear both as photographs and must be able to provide the index of variation and the duration on which it has been observed, following the short-term cycle calculation. If the data is able to fit the four-level scale (see above) of evolution of alteration, it would allow a better documentation on the visually observed alterations.

[16] For permanent collections where the RH has not been kept between 50 and 60%, maintain the historical conditions.

[17] https://www.canada.ca/en/conservation-institute/services/agents-deterioration/physical-forces.html

4. Conclusion

To conclude with, the requirements have been organized in order to give elements on devices material compounds and technical functionalities, including the communication between the various sensors per degradation factors and the analysis grid.

The objective is to find solutions fitting the three criteria (need driven, user-centered and user-friendly, curated data exploitation).

Needs and barriers related to the use and exploitation of sensors and their data has been established by the assessment conducted through the two survey campaigns.

We identified the boundaries of the tools 'utilization on a daily basis in order to ensure a greater impact of the SensMat solutions and to better orientate the resources engaged in the process. Hence decision-making tools will be shaped according to international standards expectations to recreate a coherent operating line of events, depending on the institution.

Technical specifications and functionalities of the software layer are orientated in order to be compliant with both the objectives and the partners propositions.

=== *End of Document* ===