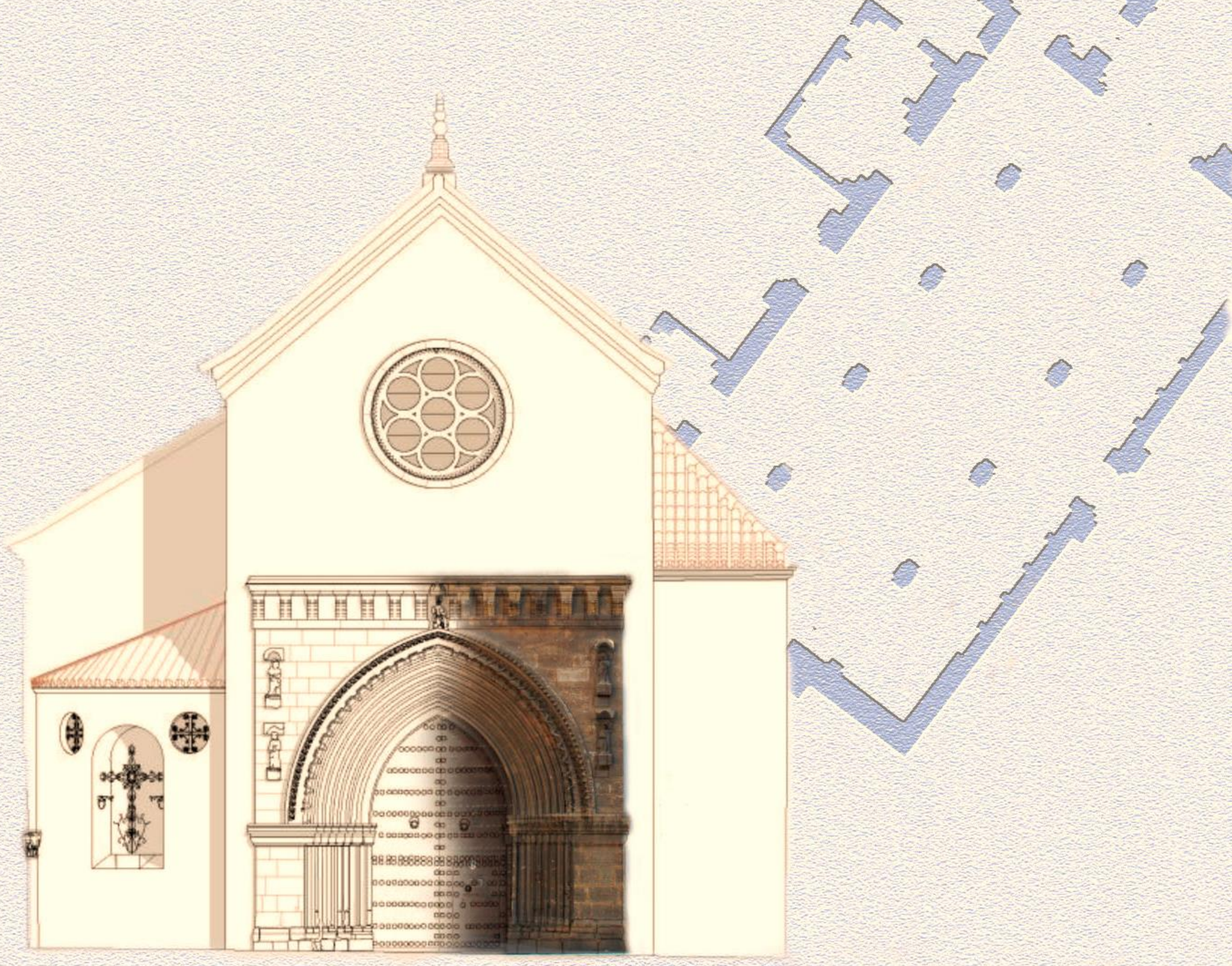
Preventive Conservation and Emergency Rehabilitation of Heritage Buildings through Research on Hazards and Vulnerability to Climate Change and natural and man-made disasters

USER MANUAL

<u>Software ART-RISK COOPERATION 3.0</u>



Seville, May 2020

Research Project on Preventive Conservation and Emergency Rehabilitation of Heritage Buildings through Research on Hazards and Vulnerability to Climate Change, Natural and Man-made Disasters (File No: UPO-03)

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http://www.investigacionenconservacion.es/index.php/proyectos-pnic/2088-pnic2016-03-art-risk-inteligencia-artificial-aplicada-a-la-conservacion-preventiva-de-edificios-patrimoniales

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In application of Law 3/2007, of 22 March, for the effective equality of women and men, any mention in these guidelines of persons, groups, etc., whose gender is masculine, will refer to the neutral grammatical gender, including, therefore, the possibility of referring to both women and men.

Table of Contents

1. Introduction. Art-Risk Project

The assessment of the state of conservation of heritage buildings is an interdisciplinary scientific practice based on knowing the symptoms, anomalies and/or pathologies that cultural assets present in order to design an intervention plan that fulfils their needs as much as possible. In relation to this discipline, **preventive conservation** studies the risks of heritage buildings, i.e. it aims to ascertain the threats and the probability of their occurrence (**hazards**), the current state of conservation (**vulnerability**) to **assess risk as a function of vulnerability and threats** to the asset. The aim is therefore to minimise possible future degradation and thus prolong the useful life of the movable or immovable property under analysis.

The **Art-Risk** project '*Artificial intelligence applied to the preventive conservation of heritage buildings*' (BIA2015-64878-R) has been funded by the Ministry of Economy and Competitiveness and the European Regional Development Fund, with the key objective of designing computational tools based on artificial intelligence models to promote decision-making focused on the preventive conservation of historical heritage. Meanwhile, the Preventive Conservation and Emergency Rehabilitation of Heritage Buildings through Research on Hazards and Vulnerability to Climate Change, Natural and Man-made Disasters project (File No: UPO-03), funded by the Ministry of Development and Housing of the Regional Government of Andalusia, has achieved the internationalisation of the tool so that it can be applied internationally.

During these projects, an interdisciplinary team composed of architects, conservator-restorers, chemists, biologists, geologists, historians, archaeologists, building engineers, computer engineers, pharmacists, mathematicians, etc. worked on new vulnerability and hazard analysis procedures. The team has developed tools based on the experience of experts from different disciplines in the heritage conservation sector. Expert opinions have been systematically and repeatedly collected using the DELPHI forecasting method, so that decision-making is supported by interdisciplinary scientific criteria. The end result is tools for conservation and intervention decision-making that minimise the risk of heritage loss when there is a large number of heritage buildings to be conserved.

These new procedures use a multi-scenario approach to analyse risk. Environmental and climate change hazards can be assessed, together with the level of use of the building and its static-structural hazards, using historical data relating to the functional lifetime of the building.

During the projects, several tools and models have been developed and improved, ART-RISK 1, ART-RISK 2 and ART-RISK 3, applicable to different construction methodologies (churches, walls and bastions, contemporary buildings, etc.) as well as different settings (Spain, Portugal, Chile, Colombia, Cuba, Peru, etc.).

The Art-Risk methodology has been validated and presented to the scientific community through different papers and articles with references on the project's website.

In this document, we present the registered software **Art-Risk Cooperation 3.0 (Andalusian territory intellectual property registration number SE-967-19 for the Spanish version)**, that is free to use, which helps decision-making for the preventive conservation of a group of heritage buildings, and is useful in policies of land use planning, urban planning and managing historic heritage. This tool features the innovation of including a transversal vision that includes the heritage, urban, architectural and cultural value, the analysis of the environmental surroundings and the socio-demographic situation of the site. All this allows the user to make a decision on intervention priorities based on objective criteria, which facilitates the conservation of heritage elements.

The currently version (**Art-Risk Cooperation 3.0**) has been designed and tested for churches in Spain, Colombia, Cuba and Peru, and can be used everywhere in any country.

For more information on the Art-Risk Project, please visit the website:

https://www.upo.es/investiga/art-risk/

And about the Cooperation Project:

https://www.upo.es/investiga/art-risk/proyecto-cooperacion/

2. Art-Risk Cooperation 3.0 software

2.1. The ART-RISK 3 model

The **Art-Risk 3** software is a tool designed for the preventive conservation of heritage buildings that is built on artificial intelligence (Xfuzzy 3.3). The software is designed to compare a list of buildings and rank them according to their conservation requirements.

This free software consists of manual data entry by the user. These inputs are divided into six groups, as defined in Figure 1. This classification is based on two essential concepts when assessing a property: hazard and vulnerability. According to UNESCO,[1] risk is the product of hazard and vulnerability. Threats are phenomena that may cause damage or disruption to cultural assets. This factor is sometimes replaced by the term hazard,[2] which refers to the likelihood of a threat occurring. Hazards can be natural or human-induced, such as in the case of an earthquake or armed conflict. Vulnerability is the susceptibility or responsiveness of cultural property to hazards, so vulnerability relates to the degree of intrinsic weakness of the cultural asset. Finally, the service life depends on the hazards, vulnerability and management of the building in terms of maintenance.

These variables have been combined following the formula shown in Figure 2, in which the inference relationships are established by consulting experts using the DELPHI model.[3]

To use this software, a previous inspection visit to the buildings under study is required, along with finding the data for the environmental variables in different databases and an assessment by the technician/s in charge of the analysis.

To use this software, training on the tool and sharing criteria of buildings is recommended.

[1] UNESCO (2014) Gestión del riego de desastres para el Patrimonio Mundial, pp.8-9.
[2] H.S. Stovel (2009) Programa de Desarrollo de Capacidades para el Caribe para el patrimonio mundial (CCBP), Módulo 3, Gestión de la preparación ante el riesgo. UNESCO, p.6.
[3] Astigarraga, E. (2002). El método Delphi. San Sebastián: Unviersidad de Deusto.

Vulnerability	Geotechnics Built environment Constructive System Roof design Conservation
Anthropogenic hazard	Changes in population Occupancy
Cataloguing of the property	Heritage Value Value of moveable assets
Maintenance	Maintenance
Static-Structural Hazards	Ventilation Facilities Overload Fire risk Structural modifications
Environmental Risks	Medium precipitation Erosion by rainfall Thermal stress Frost
Natural hazards	Seismic hazard Flood hazard

Figure 1: Art-Risk Cooperation 3.0 software input variables based on the type of variable. The user must assess and input these variables.

For each building that is evaluated, the tool returns 3 output data to the user much like a calculator:

1. Vulnerability assessment of the property
2. Assessment of identified environmental hazards affecting preventive conservation
3. Functionality index assessment

These assessments make it possible to prioritise the buildings under study according to conservation needs.

Based on the assessment of the seismicity of the area and flooding, a number of recommendations are given in section 7 of this manual.

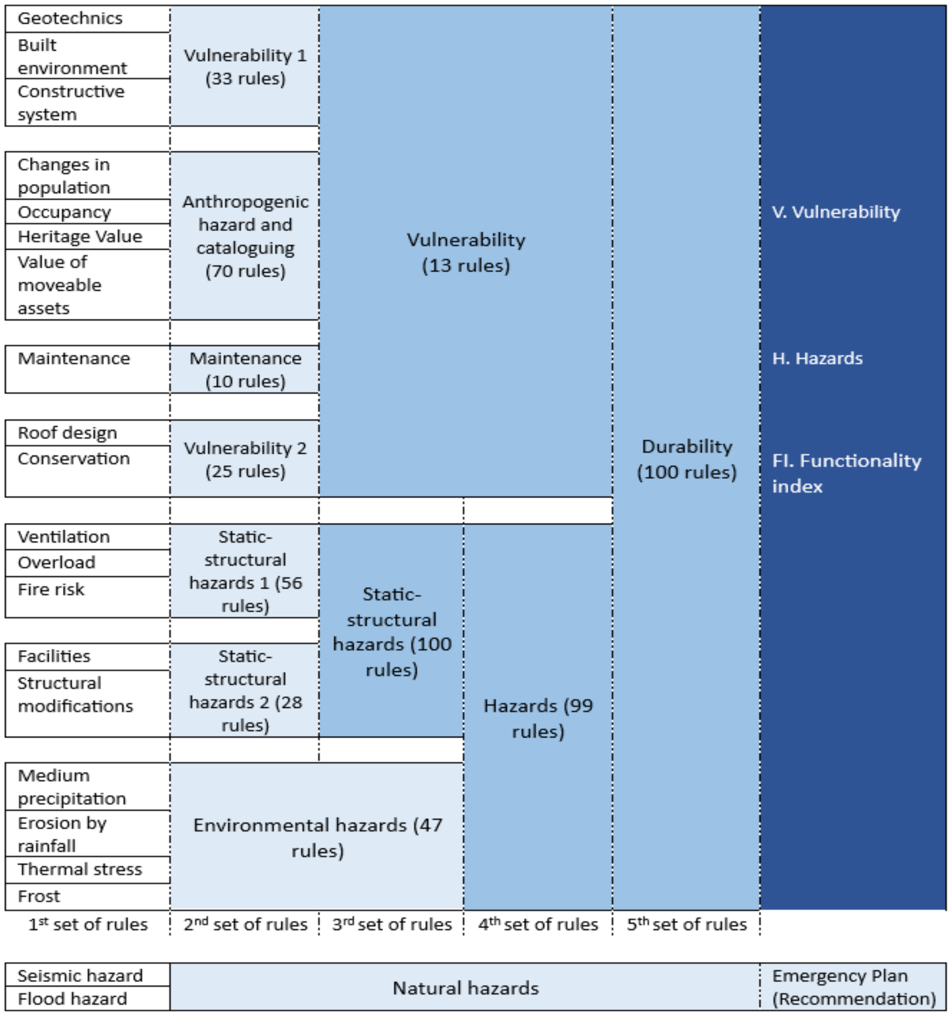


Figure 2: Structure of the relationship and hierarchy between variables of the Art-Risk Cooperation 3.0 methodology.

2.2. The computer interface

The software can be accessed via the following link:

https://www.upo.es/investiga/art-risk-service/art-risk3e/index_en.html

The user interface consists of 4 main pages: introduction, user guide, the tool itself and contact form (Figure 3).

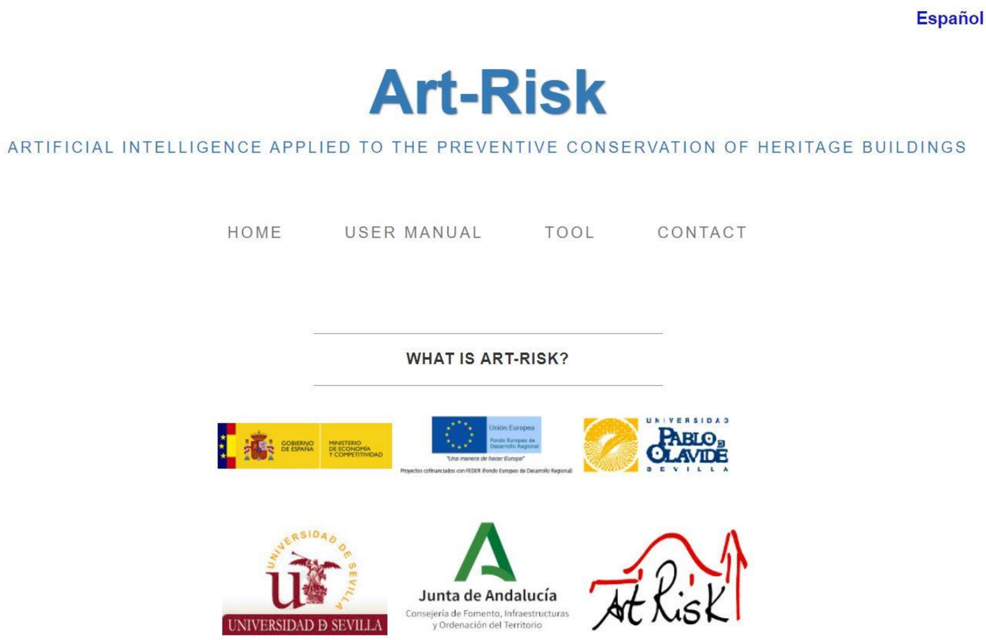


Figure 3. Art-Risk Cooperación 3.0 application homepage

To start the analysis of a building, click on the ‘Tool’ tab. This screen displays 19 numerical input variables (Figure 4) with values ranging from 1.0 (most favourable value) to 5.0 (most unfavourable value).

Manually enter the values of the system variables. To facilitate the assessment of these variables, we recommend reading section 3 (Input variables). Ranking and assessment mode of this manual.

Finally, click on the ‘Submit’ button in the ‘Results’ section to obtain the vulnerability, hazard and functionality index. If, once you have obtained the result you need to change the value of any of the variables entered manually, you can do so and press the ‘Submit’ button again. The results obtained are automatically updated. The ‘Clear all’ button resets all variables and clears the last results obtained. Select it only when you have finished the assessment of one building and want to start assessing the next building.

For the interpretation of the results, see section 4 (Output variables) of this manual.

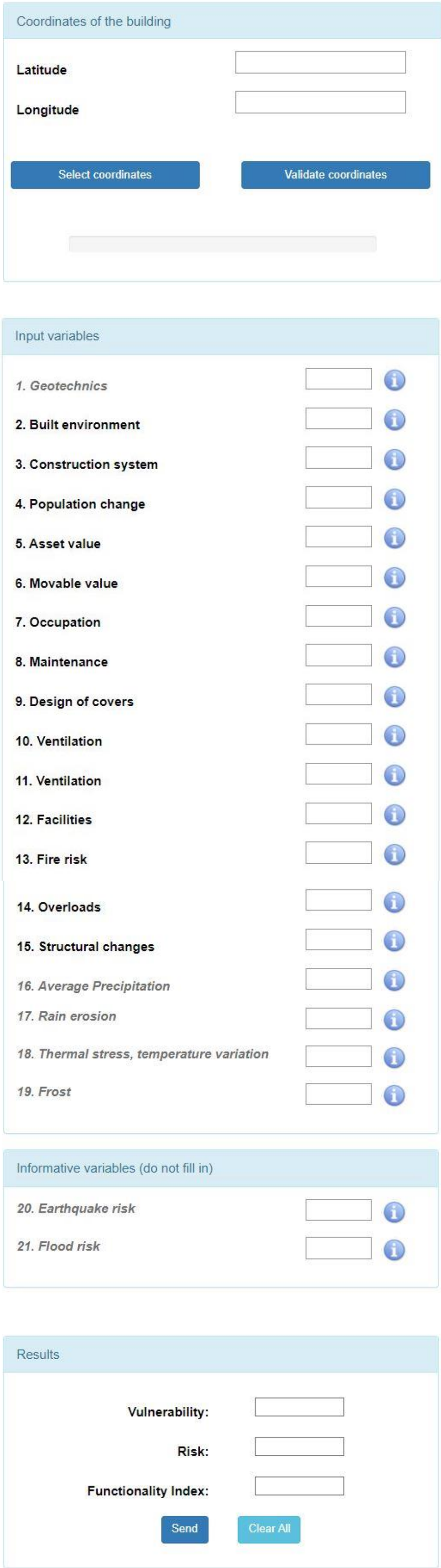


Figure 4. Main tool consisting of 19 manual input variables and the resulting values (vulnerability, hazard and functionality index).

3. Input Variables. Ranking and assessment mode

The Art-Risk Cooperation 3.0 software application supports a total of 19 manually entered variables. The following tables show the qualitative and quantitative definition of each of them, as well as a brief description to facilitate their understanding and assessment.

We recommend taking a training courses and reading this section carefully to understand it before working with the tool to be able to assign the values objectively.

Vulnerability
1. Geotechnics
Five criteria have been established to classify building conditions according to the terrain in each area.

Quantitative assessment	Description of the input parameters
1.0 Favourable	Optimal ground conditions in terms of stability
2.0 Acceptable	Favourable ground conditions in terms of stability
3.0 Medium	Acceptable ground conditions
4.0 Regular	Unfavourable ground conditions
5.0 Unfavourable	Very unfavourable ground conditions

Additional comments:

As an example, the classification made for Spain is presented, according to the general geotechnical map made by the Geological and Mining Institute of Spain in 1974, with a scale of 1:200,000.

The criteria selected to establish the construction conditions are lithological, geomorphological, hydrological and geotechnical (bearing capacity, seating and various geotechnical), classified into 5 different areas:

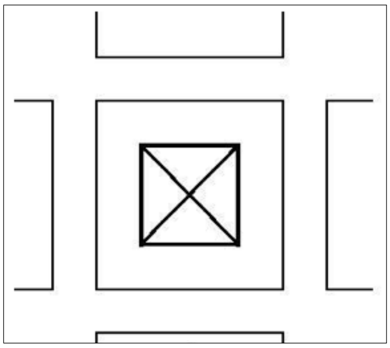
- Area 1 - Land with optimal building conditions.
- Area 2 - Land with favourable building conditions.
- Area 3 - Land with acceptable building conditions.
- Area 4 - Land with unfavourable building conditions.
- Area 5 - Land with extremely unfavourable building conditions.

In each country, users should establish an equivalent table using the available data related to soil stability.

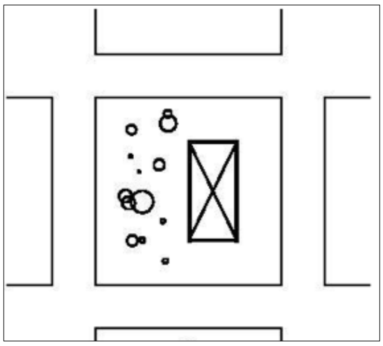
Vulnerability
2. Built environment
Five classification criteria have been established according to the organic growth, extensions, substitutions, aggregations and divisions that have conditioned and modified the state of the partition walls of the heritage buildings. To a greater or lesser extent, this can lead to accessibility problems and easements of all kinds.

Quantitative assessment	**Description of the input parameters**
1.0 Favourable	Building without surrounding constructions
2.0 Acceptable	Building without surrounding constructions, but there could be gardens or trees
3.0 Medium	Buildings with a building attached their party wall
4.0 Regular	Buildings with two buildings attached to their party walls
5.0 Unfavourable	Buildings with at least three buildings attached to their party walls and difficult access

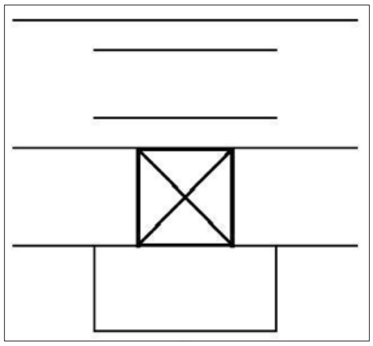
Graphical description



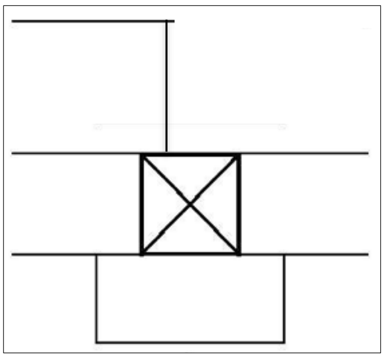
Rating of 1,0



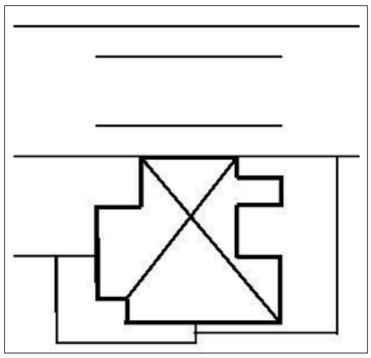
Rating of 2,0



Rating of 3,0



Rating of 4,0

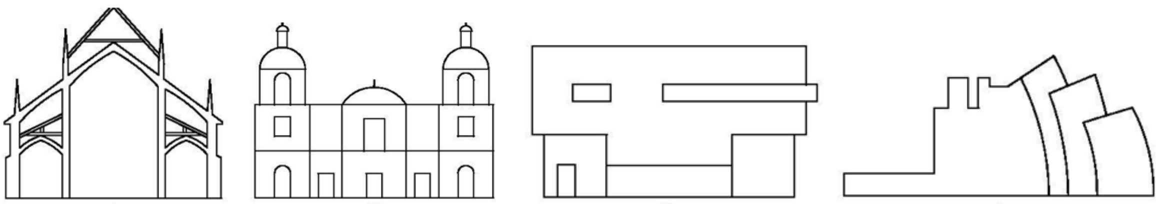


Rating of 5,0

Vulnerability
3. Constructive system
Five classification criteria have been established based on the number of building systems. The constructive system is understood as the set of functional and constructive requirements throughout the useful life of a building: structural, façade, walls, roofs, interior layout, finishes, etc. The greater the number of constructive systems, the more vulnerable the building becomes.

Quantitative assessment	**Description of the input parameters**
1.0 Favourable	Highly homogeneous constructive system
2.0 Acceptable	Homogeneous constructive system
3.0 Medium	Heterogeneous constructive system
4.0 Regular	Constructive system with some complex framework
5.0 Unfavourable	Constructive system with a large amount of complex framework

Graphical description



Best rating (1,0) → Worse rating (5,0)

<table>
<tr><th>Additional comments:</th><th>Additional comments:</th></tr>
<tr><td colspan="2">A highly homogeneous constructive system is one that uses the same material throughout the construction, guaranteeing compatibility, and employs simple and stable architectural forms. As more material typologies or more complex architectural forms are used, building systems tend to become more heterogeneous and with more complex frameworks.</td></tr>
</table>

Anthropic Hazards
4. Changes in population
Increases or decreases in population influence the number of people directly related to the property. In general, declines in population mean fewer resources and monuments being abandoned, thus potentially leading to building deterioration. Five classification criteria have been established based on changes in the population.

Quantitative assessment	**Description of the input parameters**
1.0 Favourable	Growth greater than 15%
2.0 Acceptable	Variations between 0% and 15%
3.0 Medium	Variations between -5% and 0%
4.0 Regular	Decline between -10% and -5%
5.0 Unfavourable	Population decline below -10%

Additional comments:

Population changes should be calculated over a time span of at least 5 years.

Turruncún (La Rioja, Spain).

Example of a municipality that has suffered a decrease in population.

Teruel (Aragón, Spain)

Example of a municipality that has experienced population growth.

Anthropic Hazards
5. Heritage Value
Five classification criteria have been established according to the degree of legal protection and/or the social, cultural and/or liturgical significance of the building.

Quantitative assessment	**Description of the input parameters**
1.0 Favourable	Very high historical value, which is recognised with some special level of protection.
2.0 Acceptable	Tall building, more than 100 years old
3.0 Medium	Medium construction quality
4.0 Regular	Low, poor construction quality
5.0 Unfavourable	Very low, of no artistic historical interest

Additional comments:
We recommend consulting the cataloguing of the properties under study.

Cataloguing
6. Value of movable assets
Five classification criteria have been established based on the property's contents. This value is based on the degree of legal protection, or its social, cultural and liturgical significance.

Quantitative assessment	**Description of the input parameters**
1.0 Favourable	Very high-value movable assets
2.0 Acceptable	High-value movable assets
3.0 Medium	Medium-value movable assets
4.0 Regular	Low-value movable assets
5.0 Unfavourable	Very low-value movable assets

Additional comments:
We recommend consulting the cataloguing of the properties under study.

Cataloguing
7. Occupancy
Five classification criteria have been established based on the degree of occupancy of the building and the level and number of activities carried out within in

Quantitative assessment	Description of the input parameters
1.0 Favourable	Very high level of activities in the building (daily activities)
2.0 Acceptable	High level of activities in the building (weekly activities)
3.0 Medium	Medium level of activities in the building (monthly activities)
4.0 Regular	Low level of activities in the building (some sporadic annual activity)
5.0 Unfavourable	No activities in the building (no yearly activities)

Maintenance
8. Maintenance
Five classification criteria have been established based on the scheduled actions that have an impact on the good state of conservation of the building, including whether there is technical staff in charge on a permanent basis.

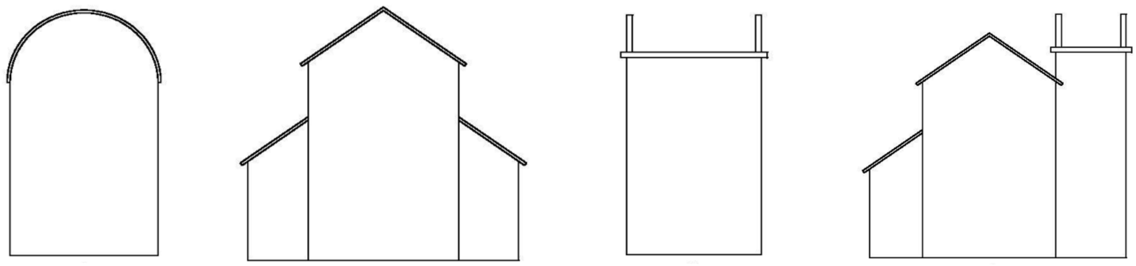
Quantitative assessment	Description of the input parameters
1.0 Favourable	There is a maintenance plan, short/medium term actions scheduled and there is personnel in charge
2.0 Acceptable	There is a maintenance plan, short/medium term actions scheduled and no personnel in charge
3.0 Medium	There is a maintenance plan, no short/medium term actions scheduled and no personnel in charge
4.0 Regular	There is no maintenance plan, no short/medium term actions scheduled and no personnel in charge
5.0 Unfavourable	Building without resources for maintenance

Additional comments:
We recommend consulting building maintenance personnel and/or building users and/or owners. Check the state of conservation of the roof and water drainage, cleaning of roofs and bell towers, capillary damp, interior condensation, walls, cracks and fissures, etc.

Vulnerability
9. Roof design
Five classification criteria have been established based on the degree of difficulty of water drainage on roofs, which generally depends on constructional and geometrical modifications over time. The vulnerability of the building is highly conditioned by the speed with which roof water is drained and the simplicity of the design.

Quantitative assessment	**Description of the input parameters**
1.0 Favourable	Very fast water drainage
2.0 Acceptable	Fast water drainage
3.0 Medium	Normal water drainage
4.0 Regular	Slow water drainage
5.0 Unfavourable	Very slow or complex water drainage

Graphical description:



Best rating (1,0) → Worse rating (5,0)

Additional comments:
For the assessment of this variable, you must take into account all the roofs of the building and how they interrelate with each other. Five levels of complexity of the roofs have been established based on how water is drained: Level 1 (Favourable): The roofs are sloping and there are no meeting points. Level 2 (Acceptable): The roofs are sloping and there are some meeting points. Level 3 (Medium): The roofs are sloping, but there are several meeting points. Level 4 (Regular): The roofs feature flat surfaces. Level 5 (Unfavourable): The roofs feature flat surfaces and many meeting points.

Vulnerability
10. Conservation
Five classification criteria have been established based on the different parts that make up the building (facade, party walls, roofs, foundations, structure, installations, accessibility, etc.) and their level of conservation.

Quantitative assessment	Description of the input parameters
1.0 Favourable	Optimal conservation
2.0 Acceptable	Normal conservation
3.0 Medium	Requires conservation
4.0 Regular	Requires significant conservation
5.0 Unfavourable	Abandoned building

Additional comments:
We recommend that the general inspection and assessment be carried out by specialist technicians. This section requires a joint evaluation of the elements of the building (facade, party walls, roofs, foundations, structure, installations, accessibility, etc.) and their level of conservation...

Static-Structural Hazards
11. Ventilation
Natural ventilation of buildings reduces water condensation problems. Five classification criteria have been established based on the ventilation of the building, taking into account the actual possibilities and use of the building. The analysis must include all areas.

Quantitative assessment	**Description of the input parameters**
1.0 Favourable	There is permanent natural cross ventilation in all areas of the building
2.0 Acceptable	There is permanent natural cross ventilation in some areas of the building
3.0 Medium	There is only permanent natural cross ventilation when the building is in use
4.0 Regular	There is no permanent natural cross ventilation in the building
5.0 Unfavourable	Completely closed-off or abandoned building

Additional comments:
Natural cross ventilation implies that there are windows, doors or other systems on all facades of the building that open daily and allow the building to be ventilated. This is the best possible condition.

Static-Structural Hazards
12. Facilities
Five classification criteria have been established based on the degree to which the facilities meet current standards for water supply and sanitation, electricity and active fire protection.

Quantitative assessment	**Description of the input parameters**
1.0 Favourable	All facilities are compliant and operational
2.0 Acceptable	Some facilities are compliant and all are operational
3.0 Medium	Some facilities are compliant and some are operational
4.0 Regular	No facilities are compliant and some are operational
5.0 Unfavourable	No facilities are operational

Additional comments:
Inspections should be carried out by specialists trained in this type of survey. We also recommend meeting with the owners or those responsible for the maintenance of the building.

Static-Structural Hazards
13. Fire risk
Five classification criteria have been established based on the likelihood of a fire occurring, and the potential speed and intensity of spread.

Quantitative assessment	Description of the input parameters
1.0 Favourable	Non-flammable structure and low fire load
2.0 Acceptable	Non-flammable structure and medium fire load
3.0 Medium	Flammable structure and low fire load
4.0 Regular	Flammable structure and medium fire load
5.0 Unfavourable	Flammable structure and high fire load

Additional comments:
The presence of any wooden structure, pillars, beams, coffered ceilings, etc., as well as altars and movable goods are valued. This section also takes into account the presence of curtains, tapestries, etc. that can easily spread fire. Five risk levels have been established based on the materials used: Level 1 (Favourable): Buildings made of stone or other non-combustible material, which do not have wooden elements such as altarpieces, benches, etc. Level 2 (Acceptable): Buildings made of stone or other non-combustible material, which have some wooden elements such as altarpieces, benches, etc. Level 3 (Medium): Buildings with combustible construction elements, such as wooden beams, but without other wooden elements such as altarpieces, benches, etc. Level 4 (Regular): Buildings with both combustible construction elements and some goods made of this material, such as altarpieces, benches, etc. Level 5 (Unfavourable): Buildings with a multitude of construction elements (beams, coffered ceilings, columns, etc.) and goods (wooden altarpieces, tapestries, benches, etc.) made of combustible materials.

Static-Structural Hazards
14. Overload
Five classification criteria have been established based on the use of the spaces, both by people and the facility, furniture and equipment, which affect the durability of the building.

Quantitative assessment	Description of the input parameters
1.0 Favourable	Use overloads are lower than the original ones
2.0 Acceptable	Use overloads are the same as the original ones
3.0 Medium	There are new overloads of different use than the original ones that generate a medium load
4.0 Regular	New overloads resulting in high additional weight
5.0 Unfavourable	New overloads of use resulting in heavy additional weight, e.g. warehouse space

Additional comments:

You should know and/or analyse the evolution of the building over time, mainly in relation to changes in use that would imply a change in the transmission of static loads and loads maintained over long periods of time.


An example of a changes in loads is the transformation of one of the galleries of the old ablation courtyard of the Great Mosque of Seville (Patio de los Naranjos of the current cathedral), which housed the Chapter and Columbine Library from 1563. In this case the overload is not only caused by the architectural remodelling, but mainly by the weight of the volumes and incunabula stored there.

Static-Structural Hazards
15. Structural modifications
Five classification criteria have been established based on the extensions or reforms of any type carried out throughout the building’s lifespan and have partially or substantially changed the initial load for which the building was planned and constructed.

Quantitative assessment	Description of the input parameters
1.0 Favourable	No changes have been made
2.0 Acceptable	Small symmetrical and balanced modifications aimed at strengthening the original structure
3.0 Medium	Large symmetrical and balanced modifications
4.0 Regular	Disorderly modifications of minor organic growth
5.0 Unfavourable	Large modifications with no organisation

Additional comments:

Structural modifications are generally detrimental to the pre-existing structure, transferring new burdens to the heritage building. They are related to building extensions, organic and unplanned structural modifications, as well as properties attached to the outer walls of heritage buildings.

An example of a structural modification due to the opening of a new door in the epistle aisle of the Church of Santiago (Seville, Spain) in the second half of the 20th century.

Environmental threats
16. Medium precipitation
Five classification criteria have been established based on the amount of rainfall per unit area (m^2)

Quantitative assessment	Description of the input parameters
1.0 Favourable	Very low risk (< 600 mm)
2.0 Acceptable	Low risk (600 mm - 750 mm)
3.0 Medium	Medium risk (750 mm - 1000 mm)
4.0 Regular	High risk (1000 mm - 1200 mm)
5.0 Unfavourable	Very high risk (> 1200 mm)

Additional comments:

We recommend consulting verified databases with at least the last 10 years of records.
In Spain, data have been acquired from the Iberian Climate Atlas of the State Meteorological Agency (Ministry of Environment and Rural and Marine Affairs, Spain) and the following areas have been defined according to average precipitation: 5 areas:

- Area 1 – Rainfall below 600 mm/m^2
- Area 2 – Rainfall between 600 and 750 mm/m^2
- Area 3 – Rainfall between 750 and 1000 mm/m^2
- Area 4 – Rainfall between 1000 and 1200 mm/m^2
- Area 5 – Rainfall above 1200 mm/m^2

In each country, users should establish an equivalent table with available data related to average precipitation or use the classification system set out in this manual.

Environmental threats
17. Erosion by rainfall
Five classification criteria have been established based on the rainfall intensity. Brief rainfall, generally of moderate or heavy intensity, often accompanied by wind.

Quantitative assessment	Description of the input parameters
1.0 Favourable	Minimal risk areas (< 7)
2.0 Acceptable	Low risk areas (7 - 8)
3.0 Medium	Medium risk areas (8 - 9)
4.0 Regular	High risk areas (9 - 10)
5.0 Unfavourable	Maximum risk areas (> 10)

Additional comments:
Rainfall erosion has been calculated based on the rainfall index, which is calculated as the ratio of the rainfall intensity in one hour to the average rainfall intensity in 24 hours. The use of verified sources is recommended to calculate the torrential rain index. For Spain, the data was obtained from the Regulation 5.2-IC of the Road Surface Drainage Regulations (Ministry of Public Works, Spain). Based on these values, five different areas have been established: • Area 1 – Less than 7 • Area 2 – Between 7 and 8 • Area 3 – Between 8 and 9 • Area 4 – Between 9 and 10 • Area 5 – More than 10 In each country, users should establish an equivalent table with available data related to the torrential rain index or use the classification system established in this manual.

Environmental threats
18. Thermal stress
Variable related to temperature variations in a short period of time

Quantitative assessment	Description of the input parameters
1.0 Favourable	Minimal risk (< 6)
2.0 Acceptable	Low risk (6 – 7)
3.0 Medium	Medium risk (7 – 8)
4.0 Regular	High risk (8 – 10)
5.0 Unfavourable	Very high risk (10 – 12)

Additional comments:

We recommend consulting verified databases with at least the last 10 years of records. The daily temperature variation is obtained from the annual average value of the difference between the daily extreme temperatures (maximum and minimum) recorded during the year. For Spain, the values were taken from the thermal oscillation map of the National Geographic Institute.

Five areas have been established based on this value:

- Area 1 - The difference is less than 6 degrees Celsius.
- Area 2 - The difference is between 6 and 7 degrees Celsius.
- Area 3 - The difference is between 7 and 8 degrees Celsius.
- Area 4 - The difference is between 8 and 10 degrees Celsius.
- Area 5 - The difference is between 10 and 12 degrees Celsius.

In each country, users should establish an equivalent table with available data related to thermal stress or use the classification system established in this manual.

Environmental threats
19. Frost
Fenómeno meteorológico que produce un descenso de la temperatura ambiente a niveles A meteorological phenomenon that causes the temperature to drop below the freezing point of water.

Quantitative assessment	Description of the input parameters
1.0 Favourable	Minimal risk (< 10 days)
2.0 Acceptable	Low risk (10 days - 20 days)
3.0 Medium	Medium risk (20 days - 80 days)
4.0 Regular	High risk (80 days - 125 days)
5.0 Unfavourable	Maximum risk (> 125 days)

Additional comments:

We recommend consulting verified databases with at least the last 10 years of records.
Depending on the average annual number of days with minimum temperature below 0 degrees Celsius, 5 areas have been established:

- Area 1 - Less than 10 frost days per year.
- Area 2 - Between 10 and 20 frost days per year.
- Area 3 - Between 20 and 80 frost days per year.
- Area 4 - Between 80 and 125 frost days per year.
- Area 5 - More than 125 frost days per year.

For Spain, the data was obtained from the document Risk Maps: frost and hours of cold in peninsular Spain (period 2002-2012) of the Spanish State Meteorological Agency (Ministry of Agriculture, Food and Environment, Spain).
In each country, users should establish an equivalent table with available data related to frost days or use the classification system established in this manual.

Natural hazards
20. Seismic hazard
Probability of an earthquake occurring in a specific geographical area during a given time interval and involving ground accelerations.

Quantitative assessment	Description of the input parameters
1.0 Favourable	Minimal risk areas (< 0.04 g)
2.0 Acceptable	Low risk areas (0.04 g – 0.08 g)
3.0 Medium	Medium risk areas (0.08 g – 0.12 g)
4.0 Regular	High risk areas (0.12 g – 0.16 g)
5.0 Unfavourable	Maximum risk areas (> 0.16 g)

Additional comments:

We recommend you consult verifiable databases.

The data must be calculated by the user as this variable only appears automatically for buildings located in Spain. In this case, we used the seismic hazard map of the Seismic Resistant Construction Standard: General Part and Building (NCRS-02) of the Ministry of Public Works (Spain).

Five areas have been established based on the seismic acceleration expressed in gravity (g).

- Area 1 – Less than 0.04 g
- Area 2 – Between 0.04 and 0.08 g
- Area 3 – Between 0.08 and 0.12 g
- Area 4 – Between 0.12 and 0.16 g
- Area 5 – More than 0.16 g

In each country, users should establish an equivalent table with available data related to seismic hazards or use the classification system established in this manual. In section 4 on Output variables, you can find a table of recommendations based on the assessed value.

Natural hazards
21. Flood hazard
It's defined as water occupying areas that are normally free from water, due to overflowing rivers, torrents, torrential rains, etc.

Quantitative assessment	Description of the input parameters
1.0 Favourable	Minimal risk areas. (No flooding).
2.0 Acceptable	Low risk areas. (Return period 500 years)
3.0 Medium	Medium risk areas. (Return period 100 years)
4.0 Regular	High risk areas. (Return period 50 years)
5.0 Unfavourable	Maximum risk areas. (Return period 10 years)

Additional comments:

We recommend you consult verifiable databases.

The data must be calculated by the user as this variable only appears automatically for buildings located in Spain. For this, we used the data provided by the National Flood Mapping System of the Ministry of Agriculture and Fisheries, Food and Environment (Spain). Five areas have been defined based on the return period; their delimitation is expressed according to the following classification:

- Area 1 - Territory with a return period greater than 500 years. Delimitation of 26.9% of main watercourses and 3.5% of all watercourses.
- Area 2 - Territory with a return period of 500 years. Delimitation of 22.3% of main watercourses and 2.9% of all watercourses.
- Area 3 - Territory with a return period of 100 years. Delimitation of 33.3% of main watercourses and 4.4-5% of all watercourses.
- Area 4 - Territory with a return period of 50 years. Delimitation of 36.2% of main watercourses and 4.7% of all watercourses.
- Area 5 - Territory with a return period of 10 years and areas defined as watercourse. In each country, users should establish an equivalent table with available data related to flooding or use the classification system established in this manual. In section 4 on Output variables, you can find a table of recommendations based on the assessed value.

4. Output variables

The interpretation of each value obtained in the 'Results' section is described below:

Vulnerability	Actions
Low Vulnerability (<35)	The building is in excellent condition.
Medium Vulnerability (75-35)	The building has certain pathologies and conditions that should be studied in depth.
High Vulnerability (>75)	The building is in a poor state of conservation.

Hazard	Actions
Low Hazard (<35)	Acceptable level of environmental hazards
Medium Hazard (75-35)	Medium level for external environmental hazards.
High Hazard (>75)	High level for external environmental hazards.

Functionality index	Actions
High functional life (>75)	Optimum conditions of functionality.
Medium functional life (75-35)	Periodic inspections are required to ensure an acceptable level of functionality by specialist technicians.
Low functional life (<35)	Unacceptable level of functionality.

The overall assessment of the building should be made by comparing the values obtained for each variable. The following table shows possible value combinations, as well as some recommendations to improve the conservation of the cultural property under study, although the assessment and associated data are required.

Don't forget that this methodology is designed to be applied to a group of buildings and not to individual buildings.

Vulnerability	Hazard	Functionality index	Recommendations
			According to the inspection carried out, the building is in good condition and is not subject to significant external hazards during the assessment. It is advisable to draw up a preventive maintenance and conservation plan with annual monitoring. The assessment and vulnerability calculation should be updated in case of changes or interventions. It is advisable to reassess the building every 10 years, or after disasters such as flooding, fire, earthquakes, etc.
			According to the inspection carried out, the building is in a good state of conservation, but it is recommended that specific measures be taken to reduce the main agents of environmental degradation through a Preventive Conservation Plan with annual monitoring and to improve the maintenance of the building and its facilities The assessment and vulnerability calculation should be updated in case of changes or interventions. It is advisable to reassess the building every 5-10 years, or after disasters such as flooding, fire, earthquakes, etc.
			According to the inspection carried out, the building is in optimum conservation conditions, but it is subject to a high level of environmental hazards according to the model studied. It is advisable to take specific measures to reduce the agents of environmental degradation by means of a Preventive Conservation Plan with annual monitoring. The assessment and vulnerability calculation should be updated in case of changes or interventions. It is advisable to reassess the building every 5 years, or after disasters such as flooding, fire, earthquakes, etc.
			According to the inspection carried out, it is recommended to intervene on the pathologies detected in the medium term (5-10 years). The assessment and vulnerability calculation should be updated in case of changes or interventions. It is advisable to reassess the building every 5-10 years, or after disasters such as flooding, fire, earthquakes, etc.
			According to the inspection carried out, it is recommended to intervene on the pathologies detected in the medium term (5-10 years). It is advisable to implement specific measures to reduce the key agents of environmental degradation by means of a Preventive Conservation Plan with annual monitoring. The assessment and vulnerability calculation should be updated in case of changes or interventions. It is advisable to reassess the building every 5-10 years, or after disasters such as flooding, fire, earthquakes, etc.

Vulnerability	Hazard	Functionality index	Recommendations
Yellow	Red	Yellow	According to the inspection carried out, it is recommended to intervene on the pathologies detected in the medium term (5-10 years). The building is subject to a high level of environmental risks according to the model studied. It is advisable to take specific measures to reduce the agents of environmental degradation by means of a Preventive Conservation Plan with annual monitoring. The assessment and vulnerability calculation should be updated in case of changes or interventions. It is advisable to reassess the building every 5 years, or after disasters such as flooding, fire, earthquakes, etc.
Red	Green	Yellow	Based on the inspection carried out, it is recommended that an in-depth study be carried out by qualified personnel to check the safety of all the elements that make up the building. A short-term intervention plan (1-2 years) is recommended to ensure the integrity of the cultural property and its functionality. The assessment and vulnerability calculation should be updated in case of changes or interventions. It is advisable to reassess the building every 1-2 years, or after disasters such as flooding, fire, earthquakes, etc.
Red	Yellow	Yellow	Based on the inspection carried out, it is recommended that an in-depth study be carried out by qualified personnel to check the safety of all the elements that make up the building. A short-term intervention plan (1-2 years) is recommended to ensure the integrity of the cultural property and its functionality. It is advisable to implement specific measures to reduce the key agents of environmental degradation by means of a Preventive Conservation Plan with annual monitoring. The assessment and vulnerability calculation should be updated in case of changes or interventions. It is advisable to reassess the building every 1-2 years, or after disasters such as flooding, fire, earthquakes, etc.
Red	Yellow	Red	Based on the inspection carried out, it is recommended that an in-depth study be carried out by qualified personnel to check the safety of all the elements that make up the building. A short-term intervention plan (1-2 years) is recommended to ensure the integrity of the cultural property and its functionality. It is advisable to implement specific measures to reduce the key agents of environmental degradation by means of a Preventive Conservation Plan with annual monitoring. The assessment and vulnerability calculation should be updated in case of changes or interventions. It is advisable to reassess the building every year, or after disasters such as flooding, fire, earthquakes, etc.

Vulnerability	Hazard	Functionality index	Recommendations
			Based on the inspection carried out, it is recommended that an in-depth study be carried out by qualified personnel to check the safety of all the elements that make up the building. The building requires urgent intervention (1 to 2 years), as well as reducing the main agents of environmental degradation through a preventive conservation plan.

As for the Seismic and Flood Hazard values, assessed based on the instructions provided in section 3 Input Variables, Ranges and Assessment Mode, we advise the following:

Value	Recommendation
5	Draw up an emergency plan and perform annual drills.
4	Draw up an emergency plan and performing annual drills is recommended.
3	Draw up an emergency plan and perform drills at least every two years.
2	Draw up an emergency plan based on the benefits of implementing a system that minimises the consequences of a disaster.
1	According to the model studied, no special actions are necessary for seismic or flood hazards.

5. Contact form

For any questions or clarifications you can contact the Art-Risk Project team through the 'Contact' tab (Figure 5). The fields 'name and surname' and 'email' are mandatory. You can write your query in the 'message' section. Once you have filled in the form, enter the validation code and click on the 'submit' button.

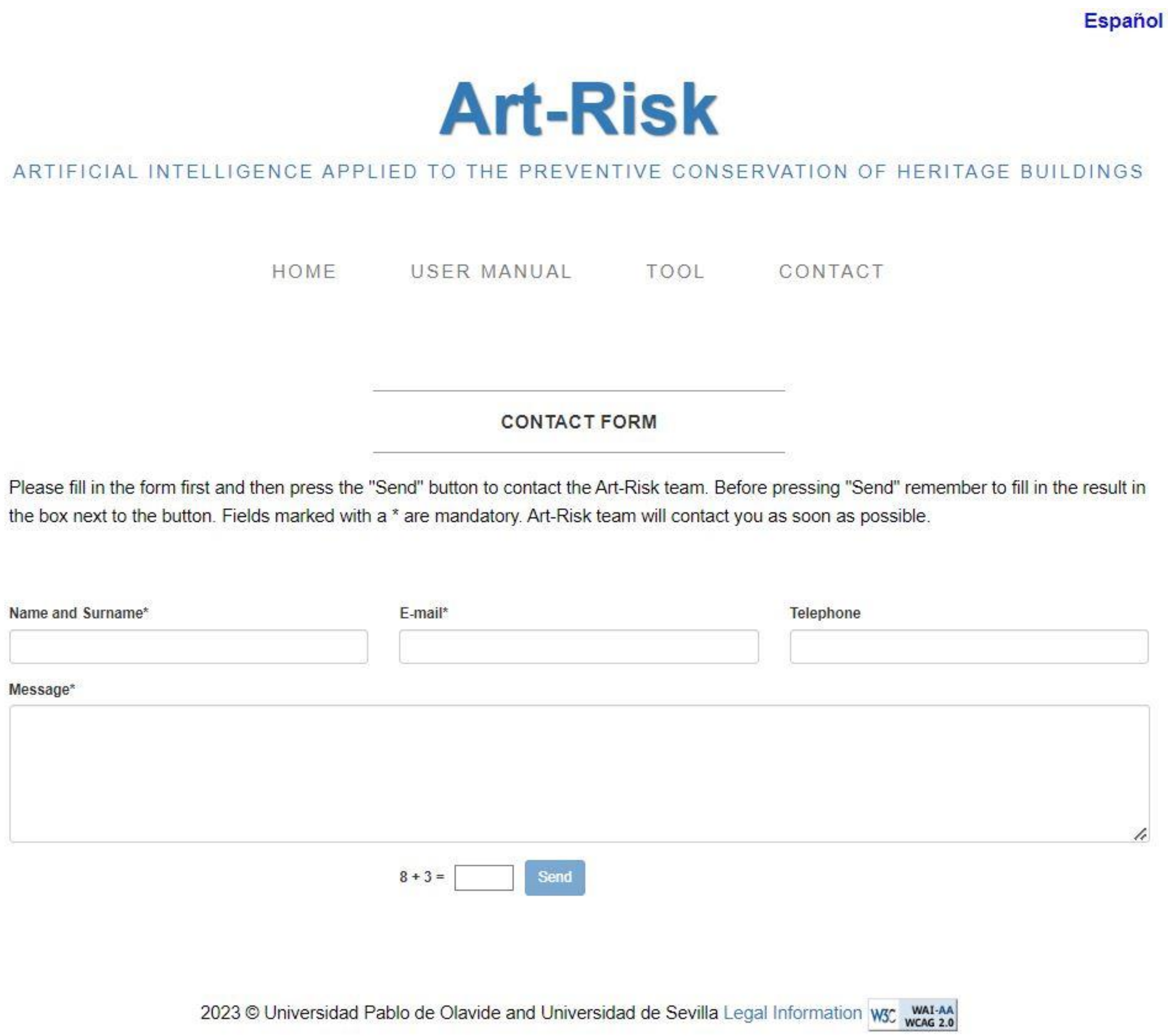


Figure 5. Contact page.

You can also get in touch by email: mportcal@upo.es

6. FAQs

- On what kind of devices is it possible to use the Art-Risk Cooperación 3.0 software?

  The web interface is adapted for use on mobile devices with small screens (tablets and mobile phones). This makes it easier to assess a building on site.

- Is an internet connection required to use the Art-Risk Cooperación 3.0?

  This software application is located on a web server and therefore requires an internet connection. If you do not have an internet connection during the inspection visit, we recommend you use the form in Annex 1 for data collection, and enter the data into the application when you have an internet connection.

- Do you need to download any files to use this tool?

  The Art-Risk Cooperación 3.0 application works online via a web link, so there is no need to download any files to your device.

- Does it cost anything to use Art-Risk Cooperación 3.0?

  Art-Risk Cooperation 3.0 software is free so there are no costs associated with its use. We only ask that you cite the project in your reports and acknowledgements if you use the tool, as detailed below: Art-Risk project (BIA2015-64878-R, RETOS project of the Ministry of Economy and Competitiveness and the European Regional Development Fund).

- Can the model be adapted to the specific characteristics of the type of assets I manage?

  If you would like us to customise the tool to your asset management needs, please contact us via the contact form or by email (mportcal@upo.es). Once the requirements have been established, we will send you a quote.

- Could automatic input of variables related to the location of the building be set up?

  The use of GIS technology allows the customisation of the tool for the automatic input of variables related to the location of the building under study. The variables that can *be automated based on their geo-referencing are: Geotechnics, Average precipitation, Rainfall erosion, Thermal stress or temperature variation and Frost. Two new variables related to natural hazards could also be included: seismic hazard and flood hazard. These variables would have two output variables in which a series of recommendations are made based on the hazard. If you need this option, you can request information via the contact form or by email (mportcal@upo.es).*

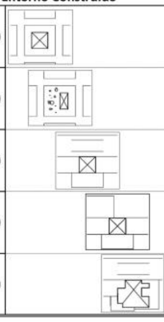
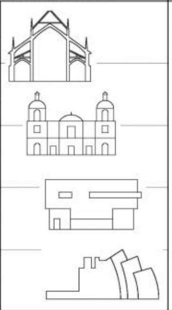
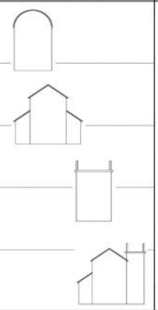
- Is the data stored?

This interface acts as a calculator, but in future updates data storage and visualisation will be possible. If you need this option, you can request a quote via the contact form or by email (mportcal@upo.es).

ANNEX 1

Recommended model form for manual data collection in technical inspections. It includes the 21 input variables for each building to be assessed. Please remember to enter the data into the tool afterwards.

Inspected building: ____
Date: ____
Technician in charge: ____

I. VULNERABILIDAD									
Geotecnia		Entorno Construido		Sistema Constructivo		Diseño de Cubierta		Conservación	
1,0	Muy favorable	1,0		1,0		1,0		1,0	Conservación óptima
2,0	Favorable	2,0		2,0		2,0		2,0	Conservación normal
3,0	Aceptable	3,0		3,0		3,0		3,0	Necesita conservación
4,0	Desfavorable	4,0		4,0		4,0		4,0	Necesita una importante actuación de conservación
5,0	Muy desfavorable	5,0		5,0		5,0		5,0	Edificio en estado de abandono

II. RIESGOS ANTRÓPICOS				III. CATALOGACIÓN				IV. MANTENIMIENTO	
Modificación de la población		Valor patrimonial		Valor mueble		Ocupación		Mantenimiento	
1,0	> 15%	1,0	Muy alto, Bien de interés Cultural (BIC), protegids	1,0	Gran valor	1,0	Muy alta	1,0	Plan de Mantenimiento, acts. programadas a corto/medio plazo y personal encargado
2,0	0% a 15%	2,0	Alto, edificio con edad superior a 100 años	2,0	Alto valor	2,0	Alta	2,0	Plan de Mantenimiento, acts. programadas a medio/corto plazo, no hay personal encargado
3,0	-5% a 0%	3,0	Media calidad constructiva	3,0	Medio valor	3,0	Media	3,0	Plan de Mantenimiento, no acts. a medio/corto plazo, no personal encargado
4,0	-10% a -5%	4,0	Bajo, escasa calidad constructiva	4,0	Bajo valor	4,0	Baja	4,0	No Plan de Mantenimiento, no actuaciones a corto/medio plazo y no personal encargado
5,0	< -10%	5,0	Muy bajo, sin ningún interés	5,0	Muy bajo valor	5,0	Edificio sin actividad	5,0	Edificio sin recursos para acciones de mantenimiento

V. RIESGOS DE ESTÁTICO - ESTRUCTURALES									
Ventilación		Instalaciones		Sobrecargas de uso		Riesgo de fuego		Modificación estructurales	
1,0	Existen ventilación natural cruzada y permanente en todos los espacios	1,0	Todas las instalaciones están conforme a norma y en funcionamiento	1,0	Sobrecargas de uso son menores a las originales	1,0	Estructura incombustible y baja carga de fuego	1,0	No se ha producido ninguna modificación
2,0	Existe ventilación natural cruzada en algunos espacios	2,0	Algunas instalaciones están conforme a norma y todas funciona	2,0	Sobrecargas de uso son igual a las originales	2,0	Estructura incombustible y media carga de fuego	2,0	Modificaciones simétricas y equilibradas de pequeña entidad tendentes a reforzar la estructura original
3,0	A veces existe ventilación natural cruzada cuando el edificio está en uso	3,0	Algunas instalaciones están conforme a norma y funcionan	3,0	Existen nuevas Sobrecargas de uso a las originales	3,0	Estructura combustible y baja carga de fuego	3,0	Modificaciones simétricas y equilibradas de gran entidad
4,0	Sólo existe ventilación cruzada en ningún caso	4,0	Nada está conforme a norma y algunas funcionas	4,0	Nuevas Sobrecargas que originan un gran peso adicional	4,0	Estructura combustible y media carga de fuego	4,0	Modificaciones desordenadas de crecimiento orgánico
5,0	No existe ventilación cruzada en ningún caso	5,0	Las instalaciones no están en funcionamiento	5,0	Nuevas Sobrecargas de uso, por ejemplo espacios destinados a uso de almacén	5,0	Estructura combustible y alta carga de fuego	5,0	Grandes modificaciones sin ningún tipo de orden

VI. RIESGOS MEDIOAMBIENTALES							
Precipitación media		Erosión por lluvia		Estrés térmico		Heladas	
1,0	Riesgo muy bajo (< 600 mm)	1,0	Zonas de riesgo mínimo. (< 7)	1,0	Riesgo mínimo	1,0	Riesgo mínimo (< 1 día)
2,0	Riesgo bajo (600 mm - 750 mm)	2,0	Zonas de Riesgo bajo. (7 - 8)	2,0	Riesgo bajo	2,0	Riesgo bajo (1 día - 5 días)
3,0	Riesgo medio (750 mm – 1000 mm)	3,0	Zonas de Riesgo medio. (8 - 9)	3,0	Riesgo medio	3,0	Riesgo medio (5 días - 20 días)
4,0	Riesgo Alto (1000 mm - 1200 mm)	4,0	Zonas de Riesgo alto. (9 - 10)	4,0	Riesgo Alto	4,0	Riesgo Alto (20 días - 60 días)
5,0	Riesgo muy alto (> 1200 mm)	5,0	Zonas de Riesgo máximo. (> 10)	5,0	Riesgo Máximo	5,0	Riesgo máximo (> 60 días)

VII. RIESGOS NATURALES			
Riesgo por sismo		Riesgo de Inundación	
1,0	Zonas de riesgo mínimo. (< 0.04 g)	1,0	Zonas de riesgo mínimo. (No inundables).
2,0	Zonas de Riesgo bajo. (0.04 g - 0.08 g)	2,0	Zonas de Riesgo bajo. (Periodo de retorno 500 años)
3,0	Zonas de Riesgo medio. (0.08 g - 0.12 g)	3,0	Zonas de Riesgo medio. (Periodo de retorno 100 años)
4,0	Zonas de Riesgo alto. (0.12 g - 0.16 g)	4,0	Zonas de Riesgo alto. (Periodo de retorno 50 años)
5,0	Zonas de Riesgo máximo. (> 0.16 g)	5,0	Zonas de Riesgo máximo. (Periodo de retorno 10 años)

Observaciones: