

Level I (group of heritage assets)
Simplified vulnerability assessment



Establish priorities

Hierarchy of assets

Additional analyses



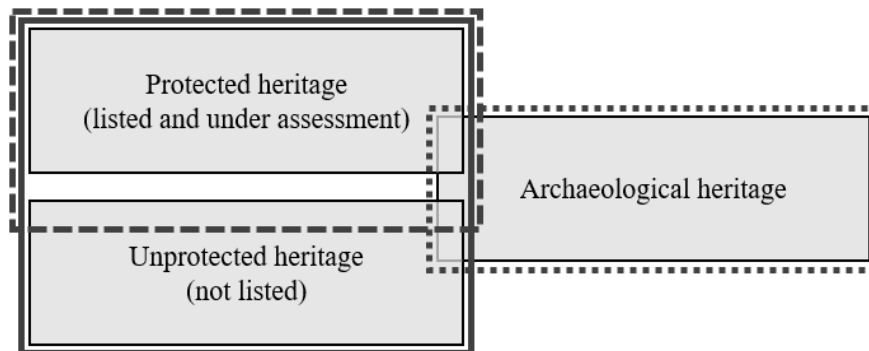
Level II (single heritage asset)
Detailed vulnerability assessment



Level-I Flood risk assessment

- Framework to perform semi-quantitative flood risk assessments to immovable cultural heritage assets in a large region
<https://www.sciencedirect.com/science/article/pii/S1296207419306521>
- Application to mainland Portugal

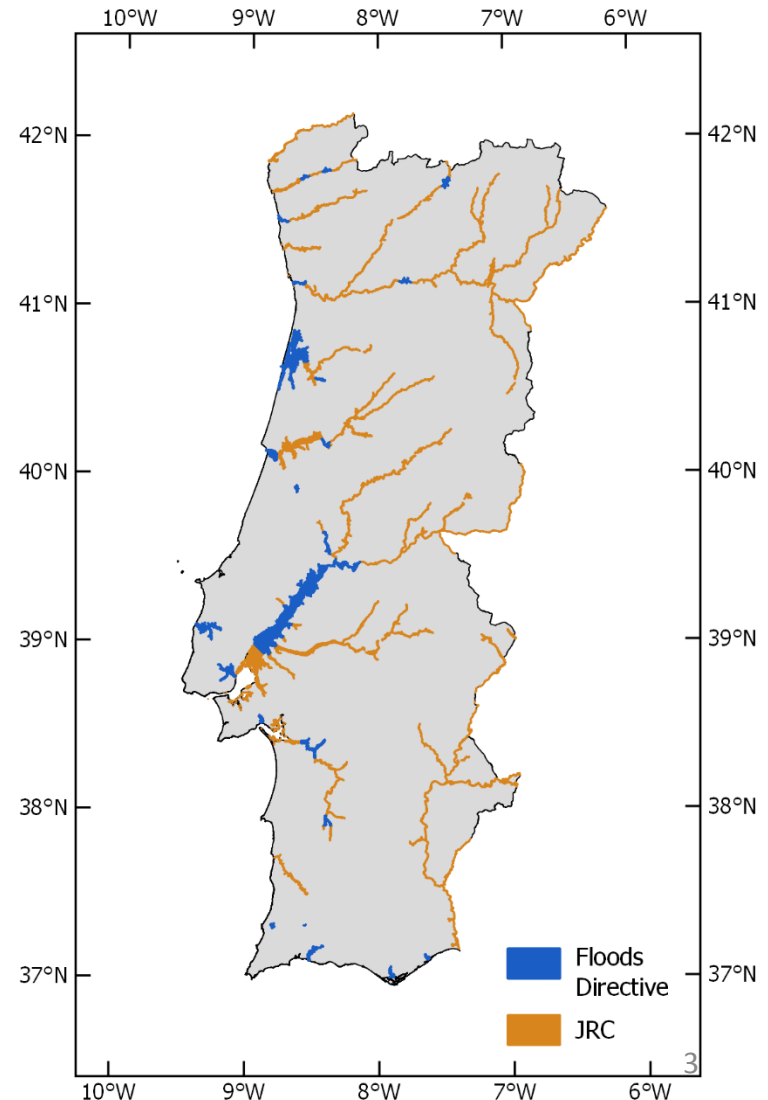
Exposure



Data sources:

- <http://www.patrimoniocultural.gov.pt>
- <http://arqueologia.patrimoniocultural.pt>
- <http://www.monumentos.gov.pt>

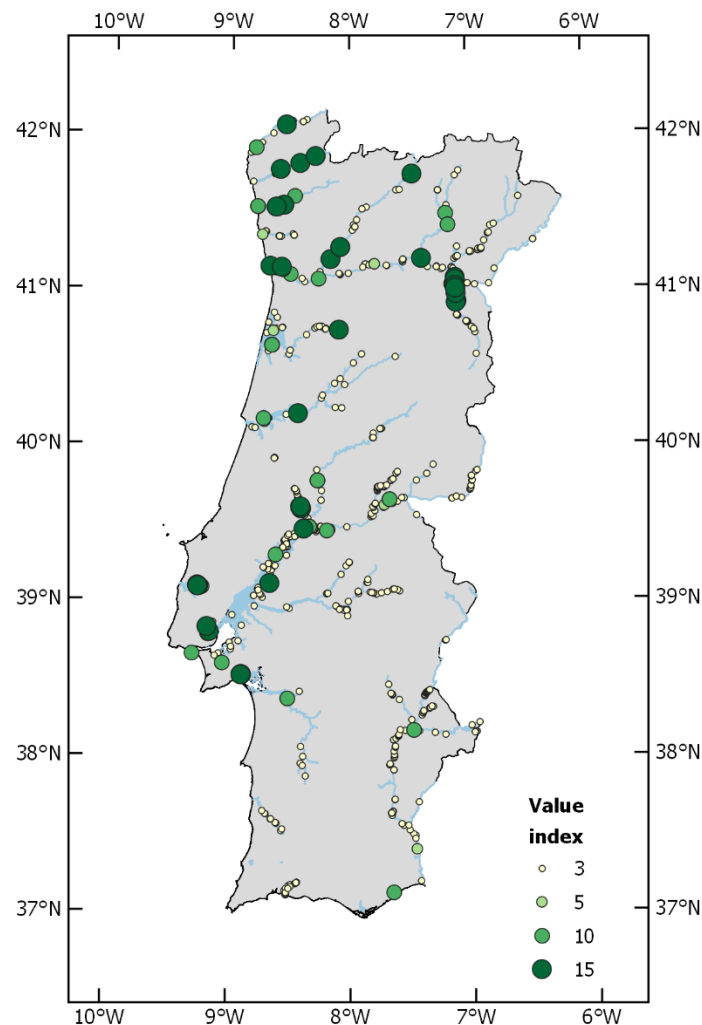
Hazard



Level-I Flood risk assessment

- Listed status of cultural heritage is expected to reflect its overall value
- It is assumed that such status is suitable for establishing relative degrees of value among assets

Status	Value index	Description
World heritage	20	Listed asset with features of exceptional/international significance or that contains elements with a significance beyond national boundaries
National monument	15	Listed asset with features of considerable national significance reflected by its national monument status
Public interest	10	Listed asset with features of national significance though insufficient to grant it national monument status
Municipal interest	5	Listed asset with features of limited/local significance
Under assessment	5	Asset for which the process that grants listed status is currently under assessment
Not listed	3	Asset with features of some significance that was not granted any type of legal protection



Level-I Flood risk assessment

Vuln. class	Designation	Description
A	Buildings with flood-susceptible contents of significant value	Buildings that house contents or collections with elements that are susceptible to flood damage, where those elements have significant cultural value and may not be fully repairable or replaceable because of that damage (due to their material characteristics or uniqueness).
B	Buildings with flood-susceptible contents of limited value	Buildings that house contents or collections with elements that are susceptible to flood damage, where those elements have limited cultural value or may be fully repairable or replaceable because of that damage.
C	Castles and walls	Defensive structures taller than most common constructions, usually built with thick masonry walls and that do not house valuable contents or collections. In cases where these constructions house valuable contents or collections, vulnerability class A or B should be considered instead.
D	Isolated vertical constructions	Slender and often monolithic constructions made of stone or masonry. In some cases, these constructions are built on top of a plinth and are often located in urban squares.
E	Other constructions and buildings	Constructions or buildings that do not house contents or collections of cultural value and do not belong to vulnerability classes A to D. This class includes constructions or buildings that are abandoned or in ruins, but whose configuration can still be almost fully identified.
F	Archaeological sites, remains and ruins	Human-made elements or constructions providing evidence of past activity, relevant to retrace the history of mankind and its relation with the environment. This class includes ruins of constructions whose configuration cannot be fully identified. These elements or constructions are often in stone or masonry, and usually have a low height.
G	Rock art	Artwork done over natural stone found in cave walls or on large blocks in the open air, using painting or engraving techniques. They are assumed to be marginally vulnerable to the actions of flooding.

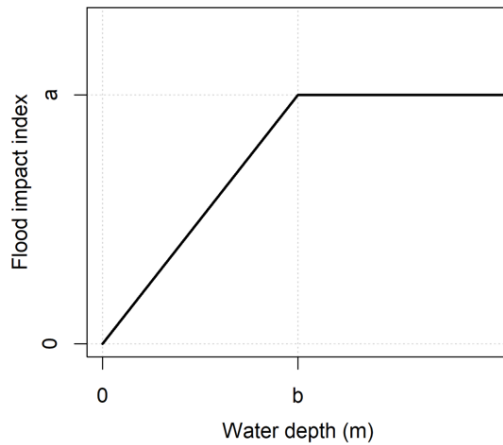
Level-I Flood risk assessment

Vulnerability class



Simplified vulnerability function

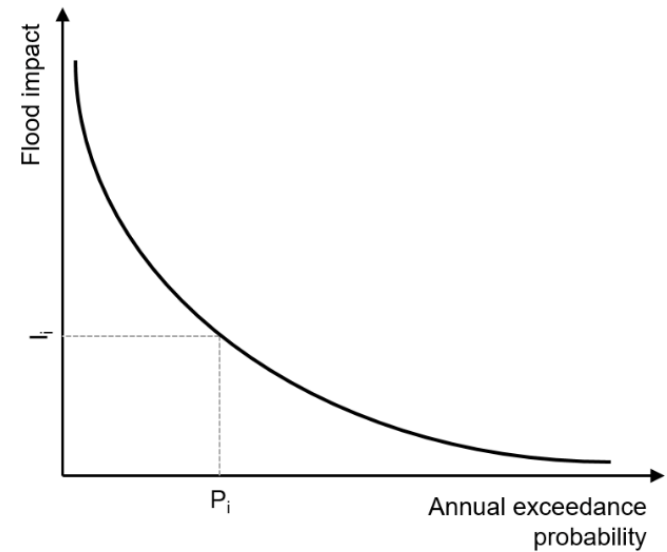
(a)



(b)

Vulnerability class	Parameters	
	a	b
A	5	2.0
B	4	2.0
C	3	5.0
D	3	2.5
E	3	3.0
F	3	0.5
G	2	1.5

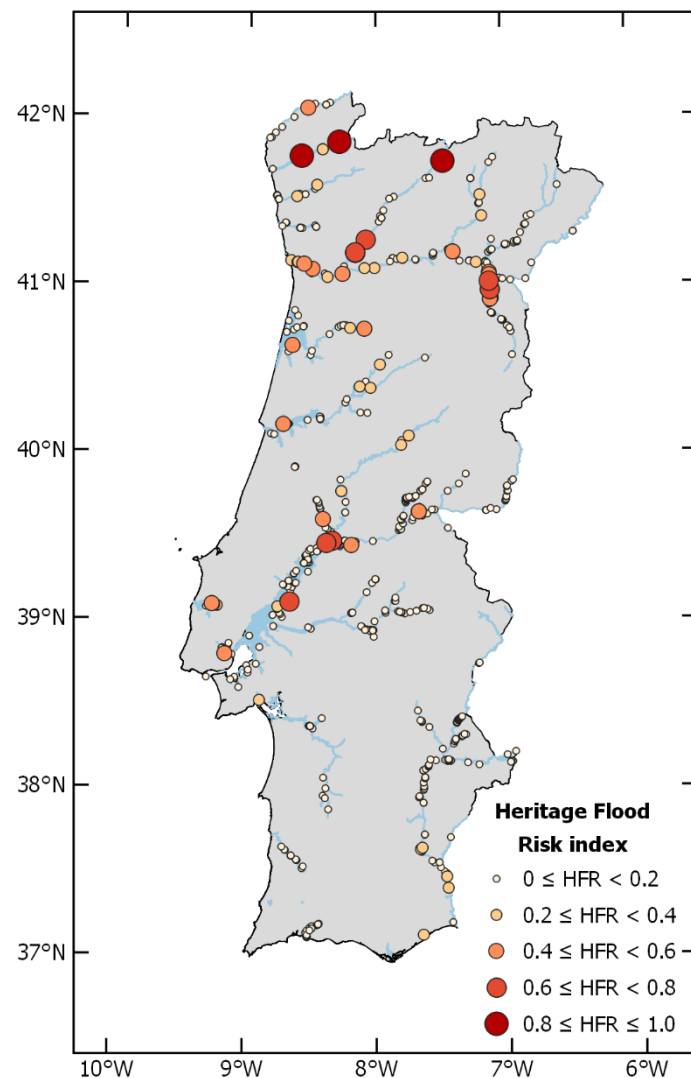
Flood risk index



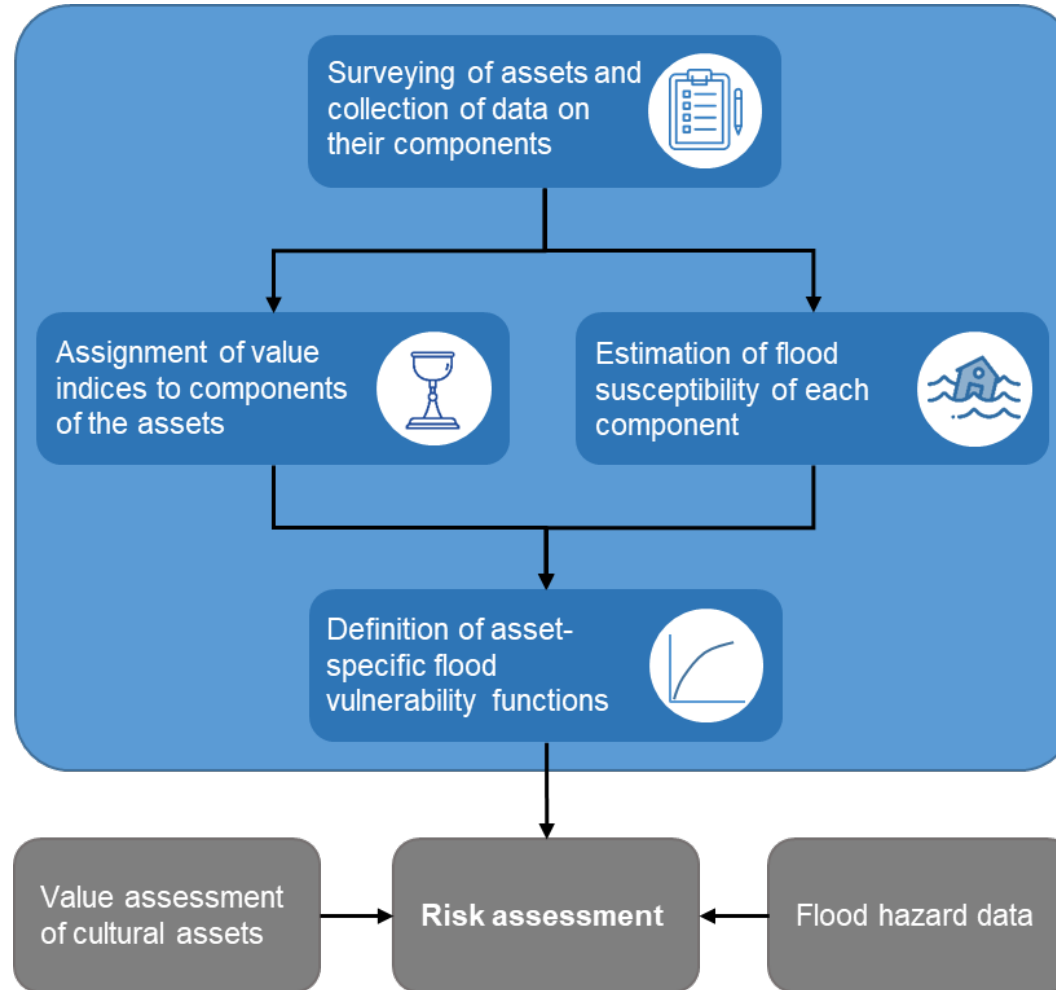
$$HFR = V \sum_{i=1}^{n-1} (P_{i+1} - P_i) \frac{HFI_{i+1} - HFI_i}{2}$$

Level-I Flood risk assessment

ID	Designation	Type	Value index	Vuln. class	Impact index HFI (RP=... yr)			Risk index HFR
					20	100	1000	
1	Mosteiro de Ermelo	Monastery	15	A	5.00	5.00	5.00	1.00
2	Termas Medicinais Romanas de Chaves	Bath house	15	B	4.00	4.00	4.00	0.80
3	Capela do Anjo da Guarda	Chapel	15	B	4.00	4.00	4.00	0.80
4	Convento de São Gonçalo de Amarante / Paços do Concelho / (...)	Convent	15	A	2.48	5.00	5.00	0.79
5	Igreja de Santa Maria sobre o Tâmega / Igreja Paroquial de Sobretâmega / (...)	Church	10	A	5.00	5.00	5.00	0.67
6	Igreja Paroquial de São Nicolau / Igreja de São Nicolau	Church	10	A	5.00	5.00	5.00	0.67
7	Capela de São Lázaro	Chapel	10	A	5.00	5.00	5.00	0.67
8	Igreja da Misericórdia de Constância	Church	10	A	4.90	5.00	5.00	0.66
9	Estação Arqueológica da Quinta de Santa Maria de Ervamoira	Arch. site	15	F	3.00	3.00	3.00	0.60
10	Núcleo Arqueológico de Habitat Paleolítico do Salto do Boi / Cardina	Arch. site	15	F	3.00	3.00	3.00	0.60
11	Pelourinho de São Nicolau de Canaveses / Pelourinho de Marco de Canaveses	Pillory	15	D	3.00	3.00	3.00	0.60
12	Castelo de Almourol	Castle	15	C	3.00	3.00	3.00	0.60
13	Cabeço da Arruda	Shell midd.	15	F	3.00	3.00	3.00	0.60
14	Casa Júlio Resende	House	10	B	4.00	4.00	4.00	0.53
15	Casa dos Arcos / Casa de Camões	House	10	B	4.00	4.00	4.00	0.53
16	Edifício da Capitania do Porto de Aveiro / Antiga Casa dos Arcos	Building	10	B	4.00	4.00	4.00	0.53
17	Ermida de Nossa Senhora do Ameal	Chapel	15	A	1.56	3.08	4.69	0.52
18	Igreja da Misericórdia de Ponte de Lima	Church	10	A	1.87	4.59	5.00	0.47
19	Torres de São Paulo e da Cadeia e o pequeno pano da muralha existente entre as duas torres	Tower	10	B	2.24	4.00	4.00	0.44
20	Piscina de D. Afonso Henriques, das antigas Caldas de Lafões / Termas Romanas	Bath house (ruin)	15	E	0.98	3.00	3.00	0.43



Level-II Flood risk assessment



- Component-Based Flood Vulnerability Modelling for Cultural Heritage Buildings (submitted to International Journal of Disaster Risk Reduction)

Level-II Flood risk assessment

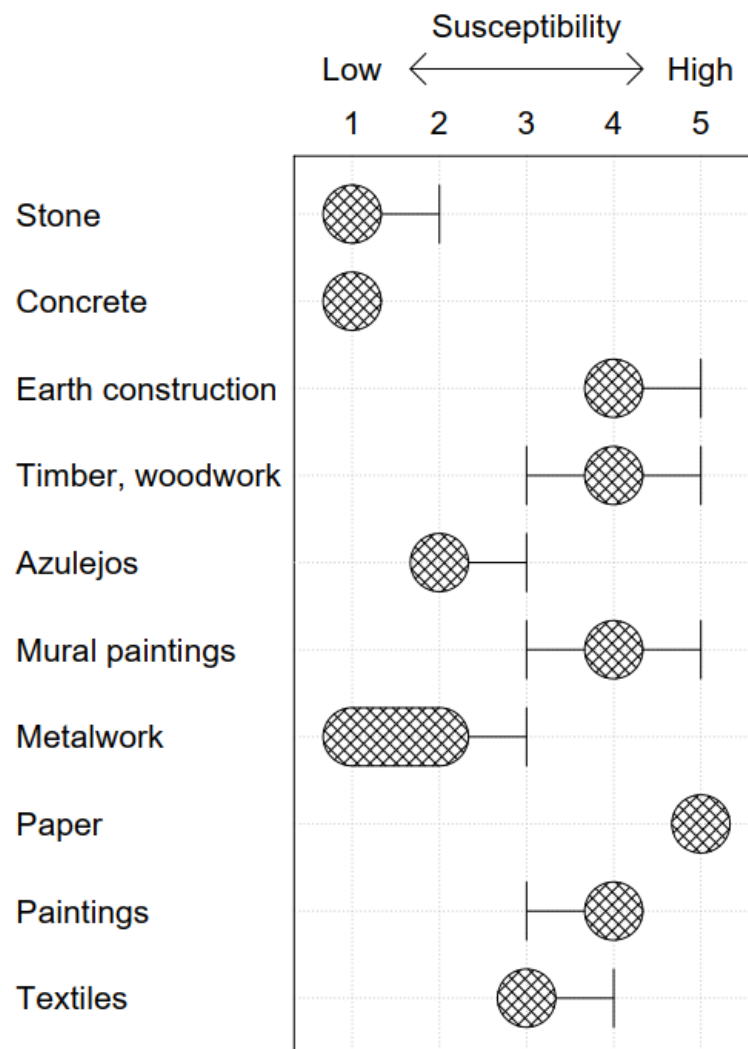
Group	Designation	Common main materials
1. Building	1.1. External walls	Stone, Concrete, Earth, Wood, Clay brick
	1.2. Internal walls	Stone, Concrete, Earth, Wood, Clay brick
	1.3. Basement walls	Stone, Concrete
	1.4. Wall paintings and coverings	Ceramic tilework, Gilded woodcarving, Murals, Decorative plaster
	1.5. Floors	Stone, Wood, Clay tiles
	1.6. Roofs	Concrete, Wood, Clay brick
	1.7. Doors	Wood, Metal
	1.8. Windows and stained glasses	Glass and Wood/Metal
2. Contents	2.1. Main retable and altar	Wood, Gilded woodcarving
	2.2. Other retables and altars	Wood, Gilded woodcarving
	2.3. Altar table	Stone, Wood, Earth
	2.4. Main altar pulpit	Stone, Wood, Metal
	2.5. Nave pulpit	Stone, Wood, Metal
	2.6. Baptismal font	Stone, Metal
	2.7. Statuary	Wood, Metal, Ceramic, Paper pulp
	2.8. Organ	Various
	2.9. Furniture	Wood
	2.10. Light fittings	Metal, Crystal
	2.11. Tombs	Wall, Stone
	2.12. Metal liturgical implements	Gold, Silver, Brass
	2.13. Textile liturgical paraments and implements	Textile
	2.14. Books	Book paper
	2.15. Candlesticks and lamps	Gold, Silver, Brass
	2.16. Porcelains	Porcelain

Level-II Flood risk assessment

Type of material or technique	Potential damage description	Damage influencing factors
Stone	The susceptibility of most common types of stone to flooding is generally low, although some may experience swelling and/or loss of strength. This depends on factors such as their softening coefficient, hydric expansion, and type of mortar.	Negative impacts such as efflorescence and spalling can increase if walls are not properly treated and dried after an event, or due to harsh weather conditions.
Concrete	Concrete is not particularly susceptible to flooding.	Concrete floors may take a long time to dry, which can delay the replacement of floor coverings. This can be alleviated with appropriate above-slab ventilation.
Earth construction	Unbaked earth-wall constructions are highly susceptible to water damage.	Damage will be aggravated if existing external plaster finishes are not well maintained. Earth construction may rapidly erode or collapse if subjected to wetting-drying cycles such as periodic flooding.
Timber and woodwork	Wood generally presents high values of hydric expansion and may swell and distort when wet. It is also susceptible to rot as a result of fungal and insect infestations.	Potential issues with wood may be minimized if it properly ventilated and dried following a flood event. Certain types of wood elements in buildings warrant specific actions, such as draining water behind panelling or removing floorboards to avoid buckling.
Azulejos	Azulejos are typically found in walls, both interior and exterior. Although their tin-glazed surface is largely impermeable, damage such as fissuration or detachment may be triggered by water present in the walls they are attached to.	Susceptibility increases in cases where azulejos remain damp for long periods or if they are exposed to consecutive wetting-drying cycles.
Mural painting	Historic wall paintings, including frescoes, may be damaged through salt crystallisation and efflorescence, detachment of surface layers, and mould growth.	Inadequate drying procedures may aggravate potential flood damages to wall paintings. Potential damage may be minimized resorting to specialized techniques.
Metalwork	Exposure to water will foster corrosion in most metals with the exception of noble metals. Aluminium, bronze, copper, brass or silver objects will not be damaged by immersion in water as long as they are allowed to dry quickly. Iron and steel may rust and expand.	Damage to all types of metalwork can be limited if they are allowed to dry quickly. The presence of salts dissolved in the water can accelerate corrosion considerably.
Paper	Paper is highly susceptible to water. Negative consequences can include rapid development of mould, physical damage, and bleeding of soluble inks and colorants.	Requires swift post-event recovery actions to prevent destruction. Even if treated adequately, which requires expert knowledge, wet books and records generally cannot be fully restored to their pre-damage condition.
Paintings	Exposure to water can cause immediate damage to most paintings, as well as make the artwork more susceptible to subsequent damage. Water can lead to flaking and loss of image layers, as well as expansion, shrinkage and deformation of painting supports such as canvas and wood.	Appropriate drying and specialized post-event treatment is required to reduce negative impacts of floodwater to paintings.
Textiles	Damaged textiles may present colour change, bleeding of dyes, shrinkage, watermarks from migrating finishes, and mould.	Restoration of textiles is generally possible. However, certain contaminants may require textiles to be discarded.

Based on extensive literature review, information from different types of sources is translated into a unified scale of susceptibility for materials commonly found in cultural heritage assets

Level-II Flood risk assessment



Level-II Flood risk assessment

The level of damage at each step is given by

$$f(x) = \sum_i g(x) v_i s_i$$

with

$$g(x) = \begin{cases} 1 & \text{if } x \geq h_i \\ 0 & \text{if } x < h_i \end{cases}$$

where:

- x is the water depth
- i represents each component of the cultural heritage asset
- h_i is the **height at which the component is located** above a reference level (typically the external ground floor level, from which the water depth is also measured)
- v_i and s_i are **their value and susceptibility indices**, respectively.

Level-II Flood risk assessment

Application to
two case studies

(a)



(b)



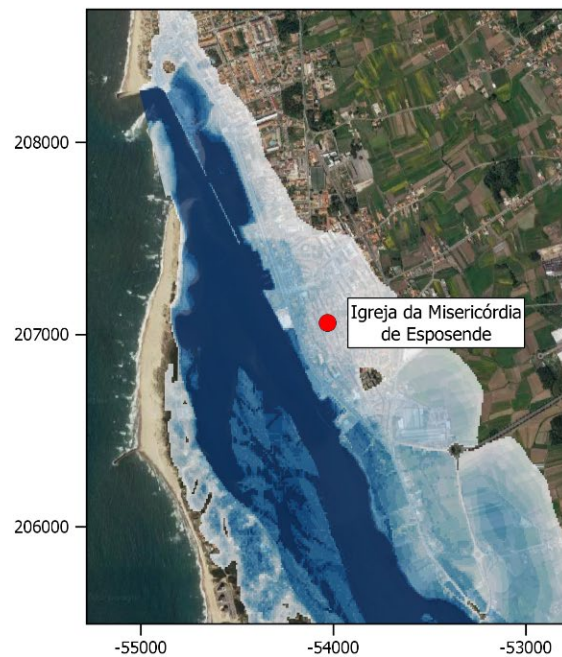
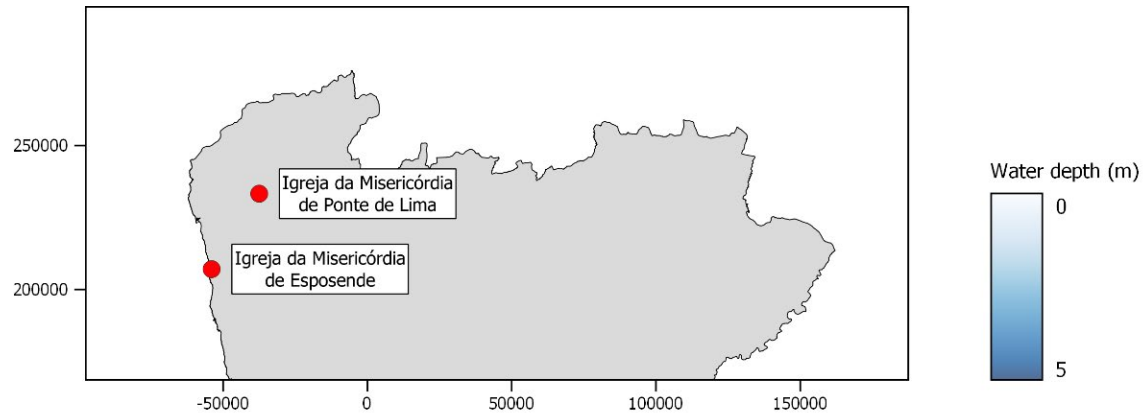
(c)



(d)



Level-II Flood risk assessment

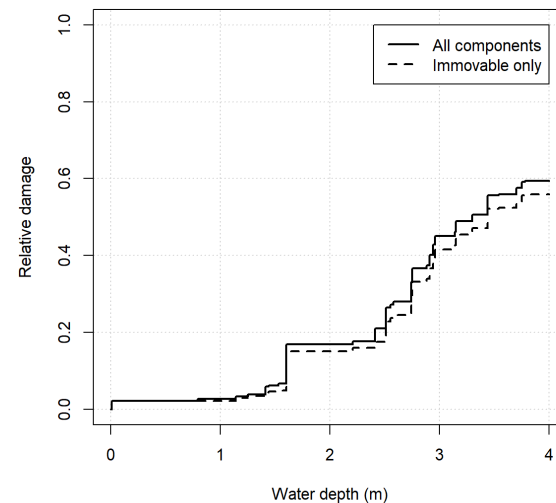
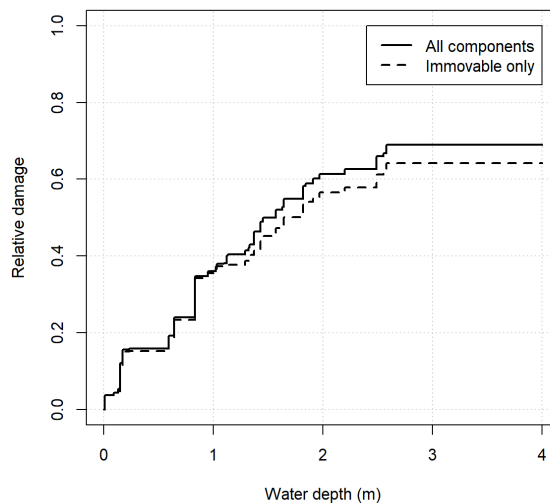


Level-II Flood risk assessment

- Data collection example: main chapel of Esposende church

Component	Move-able	Material family	Material	Height (m)	Value index	Suscept. index
Plinths (set of 2)		Stone	Granite	0.13	1	1
Statue	✓	Wood	Polychromed wood	1.02	3	4
Statue	✓	Wood	Polychromed wood	1.02	3	4
Kneeling benches (set of 2)	✓	Wood	Blackwood	0.13	1	4
Altar table		Wood	Gilded woodcarving	0.64	3	4
Pulpit	✓	Wood	Gilded woodcarving	0.69	3	4
Altar		Wood	Gilded woodcarving	1.29	3	4
Statue	✓	Wood	Polychromed wood	1.64	10	4
Main altar		Wood	Gilded woodcarving	0.64	10	4
Main retable		Wood	Gilded woodcarving	0.64	10	4
Painting		Canvas	Painting on canvas	2.49	10	5
Candlesticks (set of 2)	✓	Wood	Gilded woodcarving	1.84	1	4
Candlesticks (set of 2)	✓	Metal	Brass	1.84	1	2
Jugs (set of 2)	✓	Ceramic	Porcelain	1.84	1	5
Individual benches (set of 4)	✓	Wood	Blackwood	0.64	1	4
Altar side table	✓	Wood	Gilded woodcarving	0.64	3	4
Chair	✓	Wood	Upholstered blackwood	0.64	1	4

Level-II Flood risk assessment



	Return period (years)	Asset	
		Igreja da Misericórdia de Esposende	Igreja da Misericórdia de Ponte de Lima
Water depth (m)	20	0.23	0.87
	100	0.73	1.96
	1000	1.43	2.64
Relative damage	20	0.16	0.03
	100	0.24	0.17
	1000	0.49	0.28
Risk index	n/a	0.11	0.06

Level-I Fire vulnerability assessment

$$V_f = \sum_{i=1}^{n=4} G_i \times W_i$$

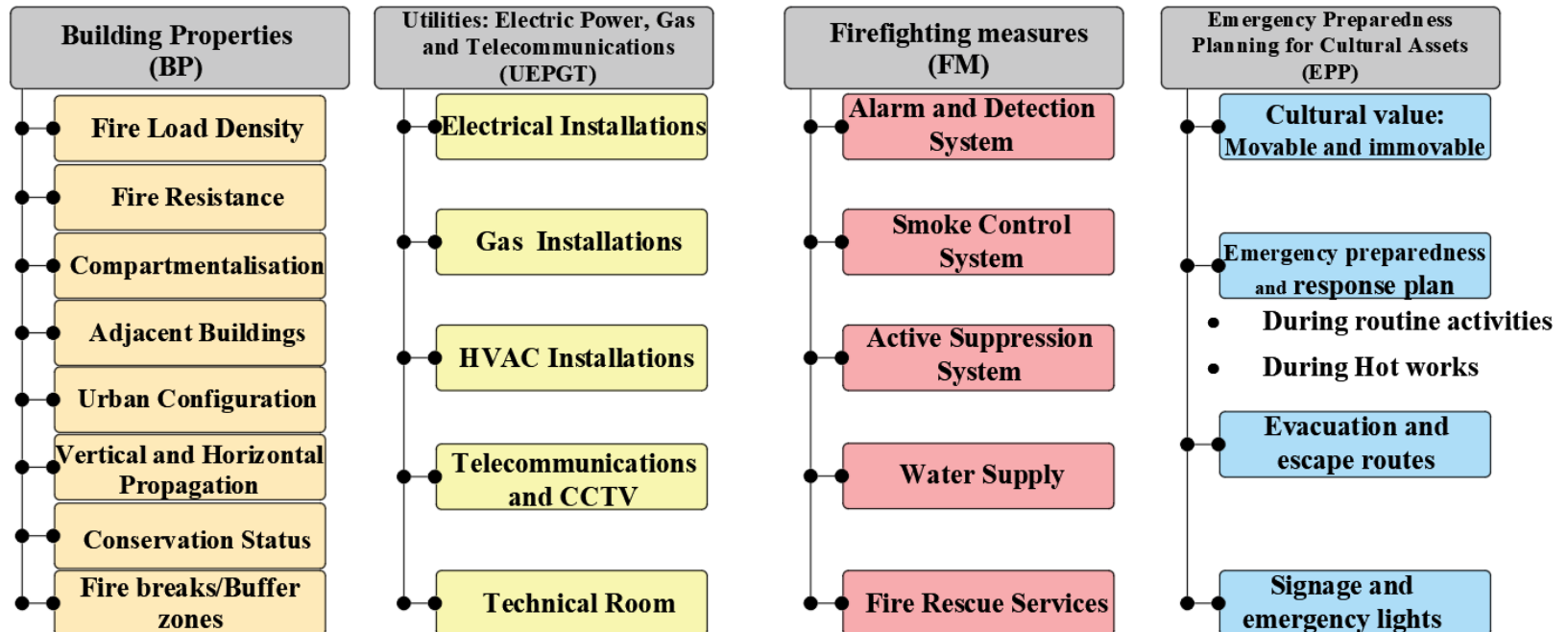
$$G_1 = BP = [Max(P_{i,i=1:7})] \times 0.35$$

$$G_2 = UEPGT = [Max(P_{i,i=8:12})] \times 0.20$$

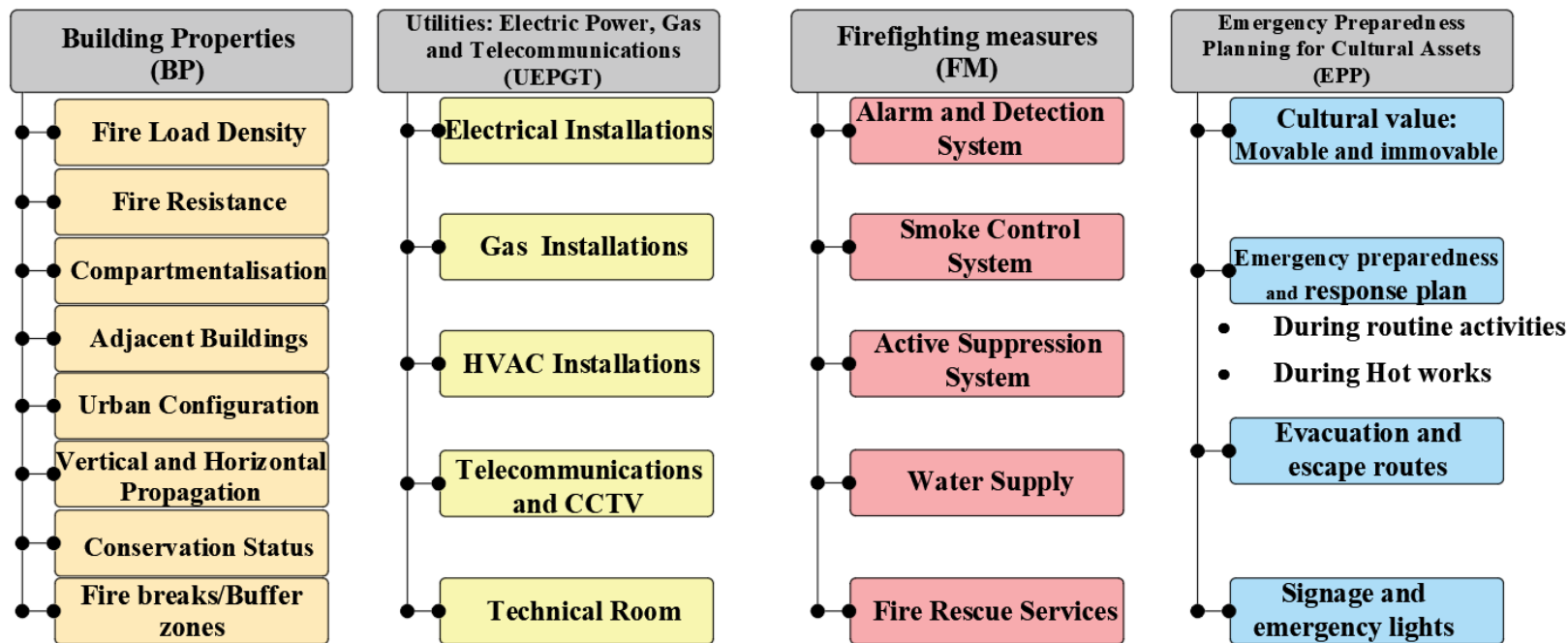
$$G_3 = FM = [Max(P_{i,i=13:17})] \times 0.30$$

$$G_4 = EPP = [Max(P_{i,i=18:21})] \times 0.15$$

Based on extensive literature review



Level-I Fire vulnerability assessment



- The classification of the indicators focusses on preserving cultural heritage value
- The classification of each indicator is performed according to 5 levels

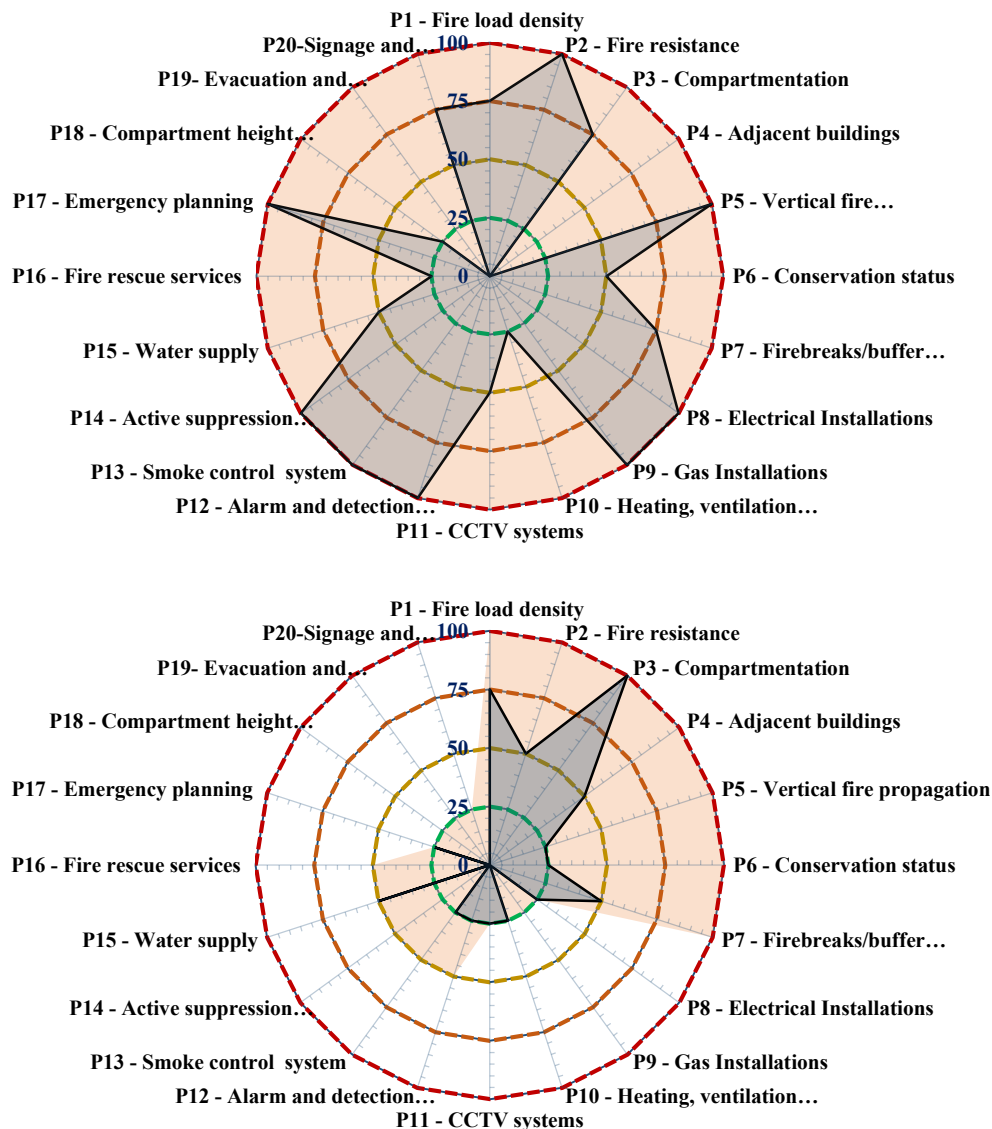
Damage Potential Class-DPC				
A	B	C	D	E
0	25	50	75	100

Level-I Fire vulnerability assessment

Indicator	Damage Potential Class				
	A	B	C	D	E
	0	25	50	75	100
P_8 - Electrical Installation	EX	G	M	BA	VB
Deficient implementation or lack of a lightning rod (increase a level)	B	C	D	E	

Type	Description
EX-Excellent	Adequate isolation of electrical components and combustible materials installed by professionals
G- Good	It refers to installations similar to EX but not installed by professionals
M – Medium	Installation with both new and older electrical components
BA - Bad	Installation with older electrical components only
VB – Very Bad	Installation similar to BA but with known electrical deficiencies

Level-I Fire vulnerability assessment

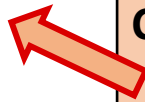
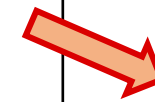
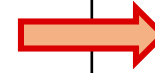


Level-I Earthquake vulnerability assessment

Different types of constructions exhibit **different behaviours under earthquakes**, cultural heritage units need to be assigned to **architectural classes** reflecting those different behaviours



Architectural class	Description
CA1	Single-storey or multi-storey masonry building
CA2	Hollow slender masonry construction
CA3	Solid slender masonry construction
CA4	Arched masonry construction



Level-I Earthquake vulnerability assessment

Damage analysis procedures were developed for each class (based on existing research and literature; forms and manuals were also developed):

- **Class CA1** - indicator-based approach involving 14 parameters
- **Class CA2** - similar to class CA1 but with 12 parameters
- **Class CA3** - mechanics-based analysis of overturning stability
- **Class CA4** - mechanics-based analysis of transversal failure mechanisms

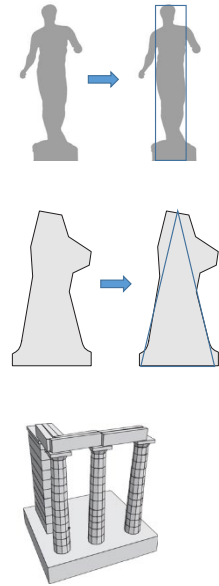
Form for class CA1

Avaliação do nível de dano esperado para um BCI da classe arquitetônica CA1				Formulário FCA1
Identificação do BCI: Localização:			Data: Avaliador:	
P	1. Classificação dos parâmetros relacionados com o BCI			
P1. Tipo e organização do sistema resistente		C	p	F
Edifício construído ou reforçado de acordo com procedimentos, recomendações e/ou normas de construção sísmo-resistente	0			
Edifício de características construtivas sísmo-resistentes razoáveis	5	0.75		
Edifício de características construtivas sísmo-resistentes insuficientes	20			
Edifício sem características construtivas sísmo-resistentes	50			
P2. Tipo de alvenaria do sistema resistente				
Alvenarias da Classe A	0			
Alvenarias da Classe B	5	1.00		
Alvenarias da Classe C	20			
Alvenarias da Classe D	50			
P3. Classe da resistência lateral				
Coefficiente de resistência γ da Classe A	0			
Coefficiente de resistência γ da Classe B	5	1.50		
Coefficiente de resistência γ da Classe C	20			
Coefficiente de resistência γ da Classe D	50			
P4. Distância máxima entre paredes				
$(L/H)_{max} \leq 15$ ou $(H/H)_{max} \leq 15$	0			
$15 < (L/H)_{max} \leq 18$ ou $15 < (H/H)_{max} \leq 20$	5	0.50		
$18 < (L/H)_{max} \leq 25$ ou $15 < (H/H)_{max} \leq 20$	20			
$(L/H)_{max} > 25$ ou $(H/H)_{max} > 20$	50			
P5. Altura do edifício				
Edifício com 1 piso	0			
Edifício com 2 ou 3 pisos	5	0.75		
Edifício com 4 ou 5 pisos	20			
Edifício com mais de 5 pisos	50			
P6. Perfil do terreno e fundações				
Condições geotécnicas e fundações da Classe A	0			
Condições geotécnicas e fundações da Classe B	5	0.75		
Condições geotécnicas e fundações da Classe C	20			
Condições geotécnicas e fundações da Classe D	50			
P7. Localização do edifício e interação				
Edifício isolado ou de banda (no meio) que não pode chocar com os adjacentes	0			
Edifício isolado ou de banda (no meio) que pode chocar com os adjacentes	5	1.50		
Edifício de gaveto que não pode chocar com os adjacentes	20			
Edifício de banda (numa extremidade) ou de gaveto que pode chocar com os adjacentes	50			
P8. Irregularidade em planta do edifício				
Valor do parâmetro $\beta_1 \geq 0.75$ ou $\beta_2 \leq 0.30$	0			
Valor do parâmetro $0.50 \leq \beta_1 < 0.75$ ou $0.30 < \beta_2 \leq 0.20$	5	0.75		
Valor do parâmetro $0.25 \leq \beta_1 < 0.50$ ou $0.20 < \beta_2 \leq 0.30$	20			
Valor do parâmetro $\beta_1 < 0.25$ ou $\beta_2 < 0.30$	50			

P9. Irregularidade em altura do edifício			
Irregularidade da Classe A	0		
Irregularidade da Classe B	5	1.50	
Irregularidade da Classe C	20		
Irregularidade da Classe D	50		
P10. Desalinhamento e área de aberturas nas fachadas			
Aberturas da Classe A	0		
Aberturas da Classe B	5	0.50	
Aberturas da Classe C	20		
Aberturas da Classe D	50		
P11. Tipo de sistema estrutural dos pavimentos			
Pavimentos da Classe A	0		
Pavimentos da Classe B	5	1.00	
Pavimentos da Classe C	20		
Pavimentos da Classe D	50		
P12. Tipo de cobertura do edifício			
Cobertura da Classe A	0		
Cobertura da Classe B	5	1.00	
Cobertura da Classe C	20		
Cobertura da Classe D	50		
P13. Estado de conservação da estrutura do edifício			
Edifício sem danos	0		
Edifício em bom estado de conservação	5	1.00	
Edifício em mau estado de conservação	20		
P14. Perigo de queda e colapsos locais			
Edifício sem elementos decorativos ou outros não-estruturais com possibilidade de queda	0		
Edifício com elementos decorativos ou outros não-estruturais de pequena dimensão com possibilidade de queda mas que se encontram bem ligados à estrutura principal	5		
Edifício com elementos decorativos ou outros não-estruturais de pequena dimensão com possibilidade de queda mas que se encontram mal ligados à estrutura principal	20	0.50	
Edifício com elementos decorativos ou outros não-estruturais de dimensão significativa com possibilidade de queda e que se encontram mal ligados à estrutura principal	50		
2. Classificação do índice de fragilidade sísmica		3. Classificação do coeficiente de fiabilidade	
$I_{FS} = \frac{\sum C_i \cdot P_i}{620}$		$F_{FS} = \frac{\sum F_i \cdot P_i}{16}$	
0.25 < I _{FS} < 1.0		0.4 < F _{FS} < 1.0	
4. Análise do coeficiente de fiabilidade			
$F_{FS} \leq 0.20$: terá de ser efetuada uma nova análise mais detalhada do BCI			
$0.20 < F_{FS} < 0.50$: recomenda-se realizar uma análise mais detalhada do BCI			
$F_{FS} \geq 0.50$: a análise do BCI é considerada válida			
5. Classe de fragilidade sísmica			
Baixa (I _{FS} < 0.25); Moderada (0.25 < I _{FS} < 0.40); Elevada (I _{FS} > 0.40)			
6. Nível de dano esperado			
Representativa da ação	Ação Sísmica Tipo 1	Nível de Dano	Ação Sísmica Tipo 2
Baixa			
Média			
Alta			

Form for class CA3

Avaliação do nível de dano esperado para um BCI da classe arquitetônica CA3				Formulário FCA3
Identificação do BCI: Localização:			Data: Avaliador:	
1. Classificação do tipo de estrutura				
Tipo I Tipo II Tipo III				
2. Classificação dos parâmetros relacionados com o BCI				
Varáveis geométricas e fatores de levantamento e derrube				
$2 \times H = \dots$ (m) $2 \times B = \dots$ (m) $h = \dots$ (m) $h/H = \dots$ (m) $\alpha = \arctan(h/H) = \dots$ (°) $\alpha = \arctan(3h/H) = \dots$ (°) $\alpha = \arctan(h/h) = \dots$ (°) $R_0 = \sqrt{h^2 + B^2} = \dots$ (m) $R_0 = \sqrt{h^2 + B^2} = \dots$ (m) $R_0 = \sqrt{h^2 + B^2} = \dots$ (m)				
Propriedades materiais				
$p_{ed} = \dots$ (kN/m ²) $p_{ed} = \dots$ (kN/m ²) $p_{ed} = \dots$ (kN/m ²) $\zeta = \min(\dots, \dots) = \dots$				
Inclinação do terreno				
$\beta = \dots$ (°) $\alpha_1 = \alpha - \beta = \dots$ (°)				
Parâmetros de frequência e de coesão				
$\lambda = \sqrt{\tan(\alpha_1)} = \dots$ $\lambda = \sqrt{\tan(\alpha_1)} = \dots$ $p = \sqrt{\frac{2 \cdot E}{1 + R_0}} = \dots$ $p = \sqrt{\frac{2 \cdot E}{1 + R_0}} = \dots$ $p = \sqrt{\frac{2 \cdot E}{1 + R_0}} = \dots$				
Efeito do solo e do tipo de fundação				
$S = \dots$				
Coefficientes de fragilidade do BCI (se a fundação for da classe A ou B)				
$r_1 = \frac{1}{(1 + S)} \dots$ (g) $r_1 = \frac{1}{(1 + S)} \dots$ (g) $r_1 = \frac{1}{(1 + S)} \dots$ (g)				
Tipo de cenário de ocorrência da ação sísmica (se a fundação for da classe A ou B)				
Ação sísmica Tipo 1: $\tau_{max, ed} = \dots$ (g) $\tau_{max, ed} = \dots$ (g) $\tau_{max, ed} = \dots$ (g)				
Ação sísmica Tipo 2: $\tau_{max, ed} = \dots$ (g) $\tau_{max, ed} = \dots$ (g) $\tau_{max, ed} = \dots$ (g)				
3. Nível de fiabilidade				
6. Nível de dano esperado (se a fundação for da classe A ou B)				
Representativa da ação				
Nível de Dano	Ação Sísmica Tipo 1	Nível de Dano	Ação Sísmica Tipo 2	Nível de Dano
Baixa				
Média				
Alta				



Level-I Earthquake vulnerability assessment

For class CA1

Parameters		Fragility Class C_i				Weight p_i	Fragility index IFS
		A	B	C	D		
P1	Type of global structural system	0	5	20	50	0.75	$IFS = \frac{\sum_{i=1}^{14} C_i \cdot p_i}{650}$ $(0 \leq IFS \leq 1.0)$
P2	Type of masonry of the walls	0	5	20	50	1.00	
P3	Lateral strength	0	5	20	50	1.50	
P4	Maximum distance between walls	0	5	20	50	0.50	
P5	Height of the construction	0	5	20	50	1.50	
P6	Soil conditions and foundations	0	5	20	50	0.75	
P7	Interaction with other constructions	0	5	20	50	1.50	
P8	In-plan configuration	0	5	20	50	0.75	
P9	Regularity in elevation	0	5	20	50	0.75	
P10	Alignment of wall openings	0	5	20	50	0.50	
P11	Type of floor structural system	0	5	20	50	1.00	
P12	Type of roof structural system	0	5	20	50	1.00	
P13	Conservation state	0	5	20	50	1.00	
P14	Hazards due to non-structural elements	0	5	20	50	0.50	

IFS is lower than 0.25, between 0.25 and 0.40, or higher than 0.40, the construction is assigned to a CFS class of *Low*, *Moderate* or *High* fragility.

CFS	Earthquake zone				
	2.1	2.2	2.3	2.4	2.5
<i>Low</i>					
<i>Moderate</i>					
<i>High</i>					

Expected level of damage		
<i>Light</i>	<i>Medium</i>	<i>High</i>

A framework for the simplified risk analysis of cultural heritage assets.

<https://www.sciencedirect.com/science/article/pii/S1296207416300875>

Loss indicator for damaged heritage assets

Establish the **baseline pre-disaster qualitative value of cultural heritage properties** in a country

	Exceptional value (20)	Considerable value (15)	Some value (10)	Limited value (5)	Unknown value (1)	No value (0)
Evidential value			X			
Historical value		X				
Aesthetic value			X			
Communal value		X				

The **baseline value of a property** is $BV = \sum_{i=1}^4 V_i$

The **cultural heritage capital CHC** at the country level is $CHC = \sum_{i=1}^{NCHP} BV_i$

NCHP is the number of properties relevant to CHC

Loss indicator for damaged heritage assets

Post-disaster damage is defined by **qualitative levels** collected for each property affected by the disaster.

	No damage (0)	Damaged and can be restored to its initial state (0.3)	Damaged and can't be restored to its initial state (0.7)	Destroyed (1)
Evidential value			X	
Historical value		X		
Aesthetic value			X	
Communal value		X		

The **qualitative post-disaster loss in value indicator LV** for a property is then

$$LV = \sum_{i=1}^4 V_i \times D_i$$

Loss indicator for damaged heritage assets

The **total relative post-disaster loss in value** TRLV of the damaged properties (NDCHP) is then

$$TRLV = \frac{\sum_{i=1}^{NDCHP} LV_i}{CHC}$$

and the indicator for the **equivalent economic loss for damaged cultural heritage properties** I_{LV} is

$$I_{LV} = \frac{TRLV \times GVA + RR}{GDP}$$

(GVA is the **gross value added for the cultural heritage sector**, RR are **post-disaster cultural heritage repair and recovery costs**, and GDP is the **gross domestic product**)

An Indicator for Post-disaster Economic Loss Valuation of Impacts on Cultural Heritage <https://www.tandfonline.com/doi/full/10.1080/15583058.2019.1643948>