

Shelter

Sustainable Historic Environments
hoListic reconstruction through
Technological Enhancement &
community-based Resilience

D2.7. Development the SHELTER cross-scale HA systemic resilience assessment methodology

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Glossary

Acronym	Full name
CAS	Complex and Adaptive System
CCA	Climate Change Adaptation
CHM	Cultural Heritage Management
CNH	Cultural and Natural Heritage
DRR	Disaster Risk Reduction
DRM	Disaster Risk Management
DSS	Decision Support System
DoA	Description of Action
EC	European Commission
HA	Historic Areas
IPCC	Intergovernmental Panel on Climate Change
OKF	Operational Knowledge Framework
OL	Open Labs
SES	Socio Ecological System
WP	Work Package

1 Executive summary

Link with SHELTER operational framework:

This report describes the activities and results from the last task from the Work Package (WP) dedicated to the methodologies for risk and resilience assessment (“WP2-Knowledge generation: Systemic HA resilience assessment and monitoring”). To wrap up the methodological framework and transfer it to the WPs that should integrate the results (mainly WP5 with the Data-Driven Platform (DDP) and WP4 with the proposal of policies and the Step-by-step guide for replication) three specific results has been achieved:

1. An update of the framework that was proposed at the beginning of the project¹ to make it more operational and user-oriented to be input to the WP development.
2. The proposition of a HA systemic resilience assessment based on indicators as input for the resilience dashboard.
3. The proposition of the workflow for the Decision Support System (DSS) to be developed in T5.4 and an initial categorization of the impact of the solutions that were proposed in T3.4 and T3.3²

Key Findings and Conclusions:

The original structure of the SHELTER framework has proved to be very useful for the articulation of the developments of the projects, but it was necessary to update it to transfer it to the end-user for resilience planning. The comparison and study of selected frameworks, coming from different fields (CCA, DDR and CHN) but focused on offering specific guidelines to local authorities allowed us to identify several conclusions for the definition of our framework:

- Governance and financial planning are key for the implementation since the engagement of the key stakeholders and citizens and the securing of enough resources to implement strategies are requirements for any successful implementation.
- A team with clear responsibilities has to be appointed for the beginning
- Assessing the risk to prioritise and plan is a crucial but challenging steps
- The recovery and building back better phase is not as defined as other phases
- Planning for resilience should be an iterative process where a robust and operative monitoring strategy is key.
- The importance of the characterisation of the system as a whole (SES approach) is frequently overlooked. In HA it should be focused on defining

¹ SHELTER deliverable “D2.1: HA Resilience structure”

² SHELTER deliverables “D3.3: Consolidation and structural stabilization in emergency phases” and “D3.4 : Portfolio to improve CH buildings and sites”

the CNH as a valuable and sensitive receptor including their specific values and vulnerabilities.

The Resilience Index has been conceived as an easy to use tool and a self-assessment methodology able to measure the capacity of HA to adapt, cope and transform to better respond to hazards. The methodology for the establishment of the qualitative indicators especially considers in its assessment the nature and the specific components and characteristics of the Historic Area and, by considering resilience in a broader sense, has been designed in order not to be hazard dependent. Considering as a basis the indicators framework previously developed in the project and the continuous evolution of the work and its validation with OLs, this list brings together all the SHELTER fundamentals approach to resilience as well as the progress achieved in the assessment of risk components together with the experience of OLs. According to this, a quantitative approach to the Resilience Index is proposed, to allow OLs to monitor those indicators which have particular relevance for their area and consider the information they are already collecting for the risk assessment calculation.

Lessons Learned & EC expectations

To characterise the risk reduction and resilience enhancement solutions selected in WP3 regarding their impact in the different hazard elements (reduction of exposure and sensitivity and enhancement of coping, adaptive and transformative capacity) has shown some limitations of the developed Portfolio of Solutions to address an impact in all hazards and risk elements. To overcome this limitation the possibility of including the catalogue of solutions created in the ARCH project in the DSS will be explored in T5.4.

2 Introduction

2.1 Aims and objectives

This task is the last task from “WP2-Knowledge generation: Systemic HA resilience assessment and monitoring” and aims to wrap up the methodological framework and transfer it to other WPs, especially:

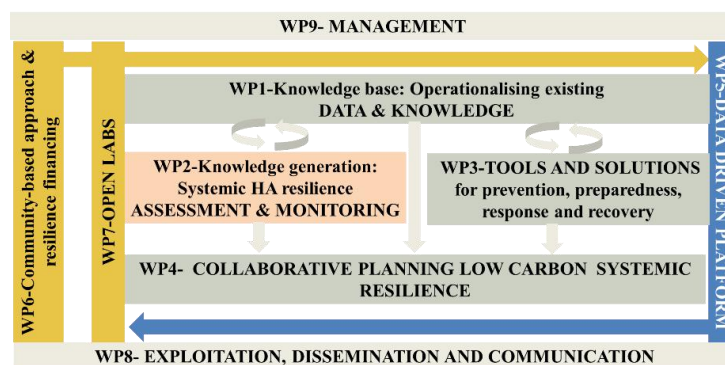
- To **WP4** (“Collaborative planning for building low carbon systemic resilience”) to integrate the methodological developments in the general framework.
- To **WP5** (“Data-Driven Platform”) to implement it in the DSS workflow.

This task has developed in this sense three specific tasks:

1. A review of the framework that was proposed at the beginning of the project³ to update it and compare it with other frameworks to ensure compatibility.
2. The proposition of a HA systemic resilience assessment based on indicators
3. The proposition of the workflow for the Decision Support System (DSS) to be developed in T5.4 and an initial categorization of the impact of the solutions that were proposed in T3.4 and T3.3⁴

2.2 Relations with other activities in the project

SHELTER project has been structured in 8 Work Packages (WP) to ensure cross-fertilization among the different steps and partners. The main objective of WP2 (Knowledge generation: Systemic HA resilience assessment and monitoring) is to produce a knowledge generation methodology to build multidimensional, cross-scale and systemic resilience assessment and monitoring workflows that will provide information in all the phases of Disaster Risk Management (DRM) (see **iError! No se encuentra el origen de la referencia.**):



³ SHELTER deliverable “D2.1: HA Resilience structure”

⁴ SHELTER deliverables “D3.3: Consolidation and structural stabilization in emergency phases” and “D3.4 : Portfolio to improve CH buildings and sites”

Figure 1: PERT chart of SHELTER

Within WP2, the work developed in Task 2.1 (Conceptual design, architecture and workflow of SHELTER framework operative knowledge), established the base of the resilience assessment and the architecture of the framework. Task 2.1 frames all the development of WP2, especially Task 2.2 where the indicators for resilience assessment and monitoring that will allow measuring the singularity of CH physical vulnerability against single and multi-risk contexts framed in a broader concept of multidimensional HA resilience has been developed. T2.3 and T2.4 characterised the receptor (HA) and the considered hazards. T2.5 developed the multi-hazard risk assessment and finally T2.7 developed the resilience assessment and prepare the ground for T4.6 and T5.4. updating the SHELTER framework and starting characterising the impact of the solutions that have to be assessed by the DSS.

Task 2.7 has a strong relation with all the WPs in SHELTER project. The main relationships are the following:

- **WP3** (Tools and solutions for prevention, preparedness, response and recovery) seeks to characterize and develop cost-effective low carbon technological solutions for prevention, preparedness, response and recovery through building back better (BBB) and integrate them in a dynamic portfolio to be used for the data-driven platform in Strategic DSS. T2.7 started with the characterisation of the impact of these solutions.
- **WP4** (Collaborative planning for building low carbon systemic resilience) aims at integrating cultural heritage into planning policies and tools, linking DRM, CCA and heritage site management, making use of the Resilience ID incremental strategy. T2.7 updates the framework proposed initially for the SHELTER Operational Knowledge Framework (OKF) that will be on the base of the developments of WP4, Specially the step-by-step guide that will be developed in T4.7.
- **WP5** (Data-Driven Platform) the resilience assessment indicators developed in this task will be implemented in the dashboard (T5.3) and the characterisation of the impact of the solutions will be implemented in the DSS (T5.4).
- In **WP7**, Open Labs, are functioning as knowledge generator and evaluation frameworks, demonstration sites, long-term thinking transition labs and learning environments. The resilience assessment developed in this task will be shared to the OLs to test it.

2.3 Report structure

The document is structured as follows:

- **Section 2** establishes the purpose of the deliverable and the links with other work packages and tasks of SHELTER project
- **Section 3** describes the update of the SHELTER Operative Framework for Resilience Planning and Measuring Resilience

- **Section 4** proposed a indicator-based HA systemic resilience assessment methodology
- **Section 5** defines the workflow of the DSS and the impact of the solutions in the defined risk elements
- **Section 6** draws the conclusions and describes the future work

3 Operative Framework for Resilience Planning and Measuring Resilience

In D2.1⁵ the structure of **SHELTER operational knowledge framework** was proposed a community- and evidence-based framework "to guide the HA in the transformation towards more resilient, circular, smart and inclusive historic environment taking advantage of the window of opportunity that the awareness, adaptation and preparations against hazards provides".

This structure was based on a matrix acting as a canvas for the project developments. The step-by-step guide will be based on this canvas to provide guidelines for replication in other HAs posteriorly. The structure was the result of:

- The intersection between the four DRM phases (prevention including CCA, preparedness, response and recovery including reconstruction).
- The tools and mechanisms that support the resilience building in HA (existing data and knowledge operationalisation, assessment and monitoring framework, tools and solutions development and collaborative planning).

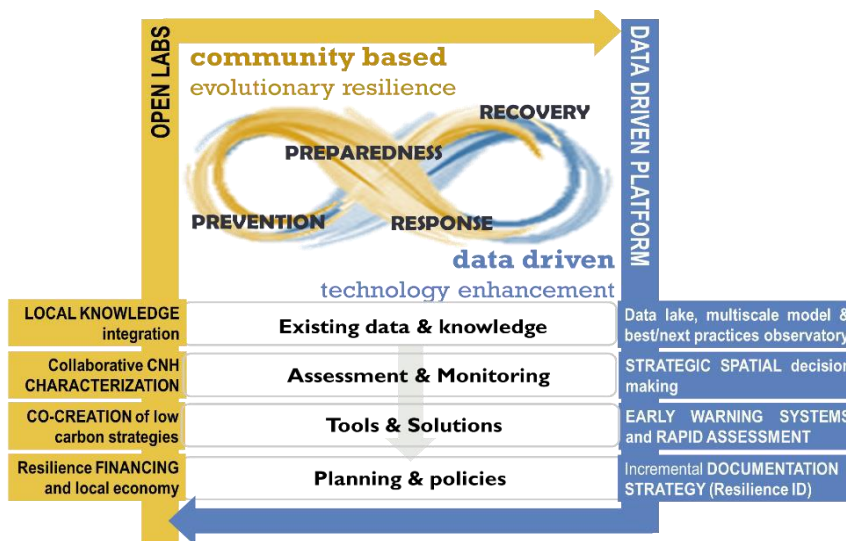


Figure 2: Structure of SHELTER operational knowledge framework

Following the data-driven and community-based approach, the framework was articulated around these two interfaces that support, shape and contextualize all co-creation processes: Open labs and Data-driven platform. The following diagram (see Figure 3) shows the initial SHELTER Operational knowledge framework:

⁵ SHELTER deliverable "D2.1: HA Resilience structure"

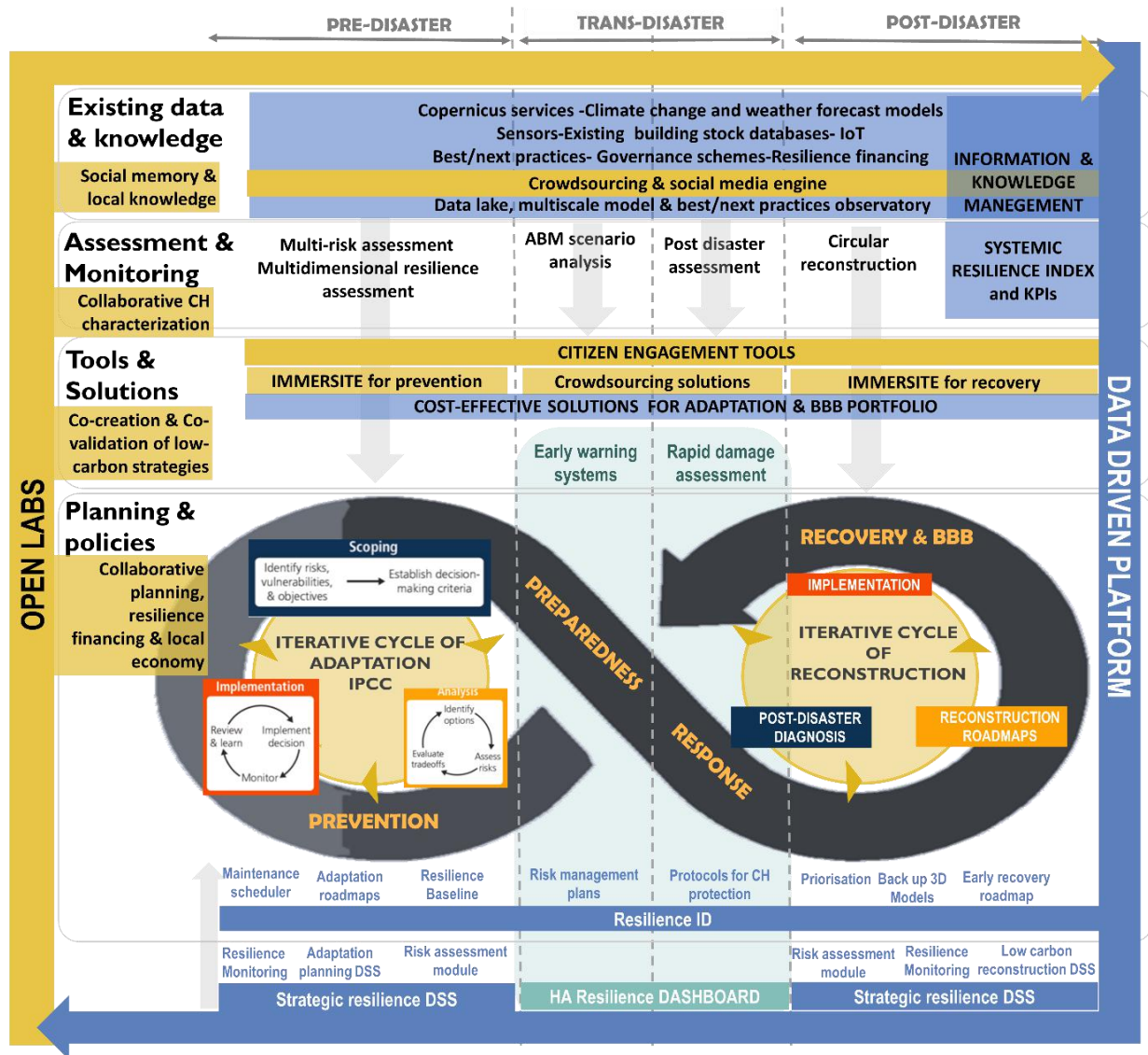


Figure 3: SHELTER Operational knowledge framework

To update this initial framework, more focused in the development of the project results, to a more operative one and in this way prepare the ground for the step-by-step guide that has to be developed in T4.6 (“Building low carbon systemic resilience through SHELTER operative knowledge framework: a step-by-step guide”), this task has compared different frameworks that have the objective to provide operative guidelines to plan the resilience, CCA and DRM, and that they are especially focused in the implementation and guidance to local authorities.

Resilience in HA within **SHELTER** project was defined in D2.1⁶ as: “Resilience of HA refers to the ability of an historic urban or territorial system-and all its social, cultural, economic, environmental dimensions across temporal and spatial scales to maintain or

⁶ SHELTER deliverable “D2.1: HA Resilience structure”

*rapidly return to desired functions in the face of a disturbance, to adapt to change, and use it for a systemic transformation to still retain essentially the same function, structure and feedbacks, and therefore identity, that is, **the capacity to adapt in order to maintain the same identity***". This definition recognises resilience as a dynamic process and HA as complex and adaptive systems (CAS). From resilience planning research it has been selected the resilience planning framework developed by Resilience Alliance [1] for its dynamic vision and approach to socio-ecological systems resilience to cope "with both known and unexpected change" including research insights from complex adaptive systems (CAS). It is a workbook for practitioners that uses "strategic questions and activities to construct a conceptual model of a social-ecological system that represents a place of interest, along with its associated resources, stakeholders, institutions, and issues".

From the Climate Change Adaptation perspective, the adaptation cycle proposed by the IPCC in their 5th Assessment report [2] and from DRM Sendai Framework priorities have been selected [3]. But to facilitate the implementation of the latter, the "Ten Essentials for Making Cities Resilient" have been included also. Since these "essentials" have been developed "to accelerate implementation of the Sendai Framework for Disaster Risk Reduction (2015-2030) at local level. The Ten Essentials map directly against the Sendai priorities of action and its indicators for monitoring actions on disaster risk reduction. They are the critical and independent steps that need to be undertaken to build and maintain resilience (...) the actions identified under each Essential should be part of the overall disaster risk reduction and resilient planning process and influence urban development planning and design". These essentials were included in the Handbook For Local Government Leaders from UNISDR "How To Make Cities More Resilient" that also included the steps to develop a process called the "Resilience Building Cycle" [4]

A valuable combined approach is the one provided by the "Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX)", that "asses the relationship between climate change and extreme weather and climate events ('climate extremes') to the implications of these events for society and sustainable development" [5]. To explore the compatibility of the results and to include the CH centric vision, it has been also included the framework produced by the ARCH project has been translated to the Standard Draft CWA 17727 currently under revision. The following table (Table 1) shows the results of this comparison:

SHELTER 2019		RESILIENCE PLANNING FRAMEWORK	IPCC ADAPTATION CYCLE	ARCH/STANDARD	SENDAI PRIORITIES	SENDAI ESSENTIALS	UNISDR steps to make cities more resilient	SREX
PREVENTION	Existing data and knowledge	1 PREPARATION PHASE Developing systems perspective Review existing plans review governance scan policy and R&D scope SES develop learning approach		1-prepare the ground formation of a cross-sectoral resilience team or office collected initial data about key information about the community and historic area relevant climate change-related and natural hazards, available data on all relevant aspects of sustainability, climate change adaptation and resilience, information about the available funding and personnel resources stakeholder mapping and analysis define objectives		Essential 1: Organize for disaster resilience Put in place an organizational structure with strong leadership and clarity of coordination and responsibilities. Establish Disaster Risk Reduction as a key consideration throughout the City Vision or Strategic Plan.	Phase1: Organizing and preparing to apply the Ten Essentials 1-Prepare institutional setting, raise awareness 2. Convene actors, formalize participatory process 3. Plan and execute the process	Integration of local knowledge with additional scientific and technical knowledge Local participation supports community-based adaptation to benefit management of disaster risk and climate extremes.
	Assessment and monitoring	2 DEFINING THE SYSTEM scales SES VALUES BIG ISSUES						Stronger efforts at the international level do not necessarily lead to substantive and rapid results at the local level (high confidence). There is room for improved integration across scales from international to local . [7.6
		3- RESILIENCE TO WHAT Drivers Shocks alternate states, thresholds, feedbacks controlling variables general resilience assessment	SCOPING identify risk, vulnerability and objectives establish decision-making criteria	2- assess risk/vulnerability select hazards perform a risk and vulnerability assessment establish a risk database and management system	Priority 1: Understanding disaster risk	Essential 2: Identify, understand and use current and future risk scenarios	Phase 2: Diagnosis and assessment of the city's risk 4. Be acquainted with the city's risks 5. Conduct a risk assessment 6. Analyze the local environment and actors 7. Prepare an assessment report:	Multi-hazard risk management approaches provide opportunities to reduce complex and compound hazards
	Tools and solutions	4 SO WHAT Assess implications for maintaining or building resilience to the system what kind of change where? exploring options for achieving change high level prioritisation	ANALYSIS identify options Assess risk evaluate trade-offs	3-identify measures 4-asses the measures		Essential 5: Safeguard natural buffers to enhance the protective functions offered by natural ecosystems Essential 6: Strengthen institutional capacity for resilience Essential 7: Understand and strengthen societal capacity for resilience		low-regrets measures are available starting points for addressing projected trends in exposure, vulnerability, and climate extremes.

SHELTER 2019		RESILIENCE PLANNING FRAMEWORK	IPCC ADAPTATION CYCLE	ARCH/STANDARD	SENDAI PRIORITIES	SENDAI ESSENTIALS	UNISDR steps to make cities more resilient	SREX
	Planning and policies	5 NOW WHAT? strategy development implementation planning stress testing prioritisation				Essential 4: Pursue resilient urban development and design. Carry out risk-informed urban planning and development based on up-to-date risk assessments with particular focus on vulnerable populations. Essential 8: Increase infrastructure resilience	Phase 3: Developing a safe and resilient city action plan 8. Define vision, objectives and main actions 9. Define programmes and projects 10. Institutionalize and sustain the disaster risk reduction plan	Effective risk management generally involves a portfolio of actions to reduce and transfer risk and to respond to events and disasters, integrated approaches are more effective when they are informed by and customized to specific local circumstances Successful strategies include a combination of hard infrastructure-based responses and soft solutions such
		6 ADAPTIVE IMPLEMENTATION test assumptions trial innovations implement triple loop learning	IMPLEMENTATION Implement decisions Monitor Review and learn	6- establish monitoring	Priority 2: Strengthening disaster risk governance to manage disaster risk Priority 3: Investing in DRR for resilience	Essential 3: Strengthen financial capacity for resilience. Prepare a financial plan by understanding and assessing the significant economic impacts of disasters. Identify and develop financial mechanisms to support resilience activities.	Phase 4: Implementing the plan 11. Implementation and resource mobilization 12. Ensure broad participation and ownership Phase 5: Monitoring and follow-up 13. Monitor, follow up and evaluate the plan 14. Disseminate and promote the plan	An iterative process of monitoring, research, evaluation, learning, and innovation Addressing knowledge gaps through enhanced observation and research
PREPAREDNESS				5-implement options & emergency response		Essential 9: Ensure effective disaster response. Create and regularly update preparedness plans, connect with early warning systems and increase emergency and management capacities		Effective risk communication builds on exchanging, sharing, and integrating knowledge about climate-related risks among all stakeholder groups.
RESPONSE				7-conduct emergency procedures 8- asses needs and impacts 9-stabilise situation	Priority 4: Enhancing disaster preparedness for effective response, and to BBB in recovery, rehabilitation and reconstruction			
RECOVERY AND BBB				10-recover & building better (revision of 1-6)		Essential 10: Expedite recovery and build back better. Establish post-disaster recovery, rehabilitation, and reconstruction strategies that are aligned with long-term planning and providing an improved city environment		

Table 1: Framework comparison

Some conclusions that can be useful for the definition of our framework could be the following:

- Governance and finance planning is key for the implementation since the engagement of the key stakeholders and citizens and the securing of enough resources to implement strategies are requirements for any successful implementation.
- A team with clear responsibilities has to be appointed for the beginning
- Assessing the risk to prioritise and plan is a crucial but challenging steps
- The recovery and building back better phase is not as defined as other phases
- Planning for resilience should be an iterative process where a robust and operative monitoring strategy is key.
- The importance of the characterisation of the system as a whole (SES approach) is frequently overlooked. In HA it should be focused on defining the CNH as a valuable and sensitive receptor including their specific values and vulnerabilities.

The following table (Table 2) shows an updated structure for the SHELTER OKF as input for the developments of WP4 and the links to the tools and results from SHELTER.

		PREVENTION/ADAPTATION	PREPAREDNESS	RESPONSE	RECOVERY BBB	LINKED SHELTER TOOLS/RESULTS
0	Preparation	RESILIENCE TEAM/OFFICE appointment and responsibilities definition				D6.3-Mapping of adaptive governance schemes
		Developing systems perspective, high-level objectives and scope SES				D2.1- HA Resilience structure D4.1-Resilience ID incremental strategy D4.5- HA systemic resilience: step by step guide
		Develop learning/monitoring strategy and community-approach				D6.4- HA Resilience co-production playbook D4.1-Resilience ID incremental strategy D3.5-Crowdsourcing solutions
1	Existing data and knowledge	Establish the information management system				D1.3-Data lake D1.4-Multiscale data model D5.3-Resilience dashboard D4.1-Resilience ID incremental strategy D5.2- IoT module
		Review existing plans and tools, scan policy and R&I for resilience, adaptation and preparation	Review existing plans and tools, scan policy and R&I for preparedness	Review existing plans and tools, scan policy and R&I for response	Review existing plans, scan policy and R&I for recovery and BBB	D1.1-Data sources and Knowledge D1.2-Building of best/next practices observatory
		collect information about the available funding and personnel resources				D6.6-Resilience business and financing landscape geography
		Detect gaps and opportunities for CH				D2.3-Anatomy of HA
		Local knowledge gathering and structuration				D6.2-ICT-community interaction rulebook D6.5-Methodology for Local Knowledge extraction
2	Characterization and assessment	Characterisation of the HA: scales, values, stakeholders map, HA as SES, CHN assets, identification of priorities				D2.3-Anatomy of HA D2.2-HA Systemic resilience assessment and monitoring framework D3.5-Crowdsourcing solutions
		Characterisation of hazards/stressors, impact chains and scenarios				D2.4-Characterisation of hazards, climate change events and impacts
		Cross-scale risk assessment: exposure, sensitivity, coping capacity, adapting capacity and transforming capacity				D2.5-Specific hazard risk assessment
		Resilience baseline				D2.7-HA systemic Resilience Index
3	Tools and solutions	identify solutions (including local solutions) for adaptation, mitigation and prevention	identify solutions (including local solutions) for preparedness (specially EWS)	identify solutions (including local solutions) for response: i.e. stabilization, rapid damage assessment, crowdsourcing	identify solutions (including local solutions) for recovery and BBB	D5.4- Strategic Decision Support System D3.6-SHELTER IMMERSITE tool D4.3-Maintenance protocols and rehabilitation D4.4- Guidelines for the integrated management D3.3- Consolidation and structural stabilization in emergency phases D3.4- Portfolio to improve CH buildings and sites resilience D2.6- ABM for scenario analysis
		identify criteria				
		identify impacts				

		strategy development				
4	Planning and policies	planning for adaptation & prevention	planning for preparedness	rapid response plans	rapid recovery plans	D4.2- Strategy for early recovery roadmap
		exploring options for change		assess needs and impacts		
		Define the action plan & roadmap				D4.5- HA systemic resilience: step by step guide
5	Implementation	funding	Rapid damage assessment		funding	D6.6- Resilience business and financing landscape geography D3.2- Rapid damage assessment technologies
		implement solutions	Needs assessment		implement solutions	
		ensure sustainability/maintenance	Execute emergency plans		ensure BBB	
6	Loop learning/monitoring	monitoring and feedback strategy			monitoring and feedback strategy	D3.1- Multi-hazard early warning systems
		revision of the whole strategy			revision of the whole strategy	D4.5- HA systemic resilience: step by step guide

Table 2: Updated structure of SHELTER OKF and linked results

4 HA systemic resilience assessment methodology

Within the SHELTER project, the resilience of the Historic Area (HA) has been defined as: “the ability of a historic urban or territorial system-and all its social, cultural, economic, environmental dimensions across temporal and spatial scales to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and use it for a systemic transformation to still retain essentially the same function, structure and feedbacks, and therefore identity, that is, the capacity to adapt in order to maintain the same identity”⁷

The different dimensions of the urban and territorial systems and specifically their application to heritage sites have been already addressed in the project approach and lead to the following definitions:

DIMENSION	SHELTER APPROACH
Historic building environment resilience	SHELTER addresses specifically historic buildings physical vulnerability as a nested concept for a more general resilience and vernacular architecture as catalyser of a heritage-led resilience where its intrinsic characteristics are capitalised (redundancy of parts, reparability and reuse of components, traditional adaptation strategies) and its singularities contemplated for conservation-friendly planning.
Cultural resilience	SHELTER will consider CH (tangible and intangible) as key driver in HA Resilience. Cultural diversity has the capacity to increase the resilience of social systems, since it is the result of centuries of slow adaptation to the hazards that affect local environments.
Social resilience	SHELTER will consider social memory as key part of HA resilience. Vulnerable groups (elderly, migrants, children, disabled) will be specifically considered and gender perspective will be transversal. Issues especially important to HA as depopulation and gentrification will be tackled in reconstruction phase).
Governance and institutional resilience	SHELTER will adopt an adaptive governance perspective and a GLOCAL approach (linking 'local' and 'global' tendencies and interpretations pragmatically). Open Labs will function to integrate all stakeholders in the decision making and knowledge generation.
Economic resilience	SHELTER will foster local economy boosting and territory activation through innovation (including insurance perspective). Economic impact of disasters will consider intangible values.
Environmental resilience	SHELTER will propose circular approaches and sustainable reconstruction.

Table 3: Dimensions and SHELTER approach

⁷ SHELTER Project (2019). Deliverable “D2.1: HA Resilience structure”

Furthermore, the SHELTER integrated framework considers risk as a function of hazard, exposure and vulnerability, where this last one comprises sensitivity, coping capacity, adaptative capacity and transformative capacity ⁸, which include the following elements:

VULNERABILITY COMPONENTS	
measuring sensitivity	<ul style="list-style-type: none"> social/demography characteristics economic characteristics infrastructure characteristics building characteristics environmental sensitivity
measuring coping capacity	<ul style="list-style-type: none"> awareness/information networks/solidarity/Community preparedness insurance/funds DRM social memory shelter capacity protection of natural resources
measuring adaptative capacity	<ul style="list-style-type: none"> human capital/education social capital/learning economic capital institutional capital/governance cultural capital/identity built capital/infrastructure natural capital
measuring transformative capacity/inherent resilience	<ul style="list-style-type: none"> Social memory Living with uncertainty/improvising Self-organisation, reflective and shared learning Resourcefulness/Efficiency/ Collaboration/inclusive/diversity/intersectoriality Innovation Robustness/Strength/appropriately connected Coupled with Local Natural Capital

Table 4: Measuring objectives of SHELTER indicators

The HA resilience assessment has been therefore built considering all the previous research finds and is conceived as a self-assessment methodology based on the concept that resilience improvement is the capacity of a system to adapt, cope and transform to better respond to hazards.

⁸ SHELTER Project (2020). Deliverable "D2.2: HA Systemic resilience assessment and monitoring framework"

The methodology, intended as a friendly and easy to use tool, brings together the indicators previously developed in the project, which were selected and prioritized by the OLs and transforms them into qualitative indicators focused on assessing the current capacities of the HA to identify strengths and weaknesses and better focus future improvement strategies. The main objective is to provide end-user with a final resilience score that can be visualised and broken down into partial scores for the different types of resilience and capacities as considered by the SHELTER project.

The resilience assessment methodology is not hazard-dependant and for this reason, indicators were in some cases merged and generalized to be applicable to a broader range of HA, with different characteristics, scales and hazards. Nevertheless, the importance of assessing natural or cultural heritage has been considered as a priority, as some indicators are specifically designed to evaluate the characteristics of these types of heritage. Mixed sites comprising both natural and cultural heritage will have to address all the indicators.

Besides the extensive literature already analysed and its relation to the indicators developed within the project, the UNESCO Culture 2030 Indicators [6] publication and the Resilience Assessment Dashboard developed under the ARCH project⁹ as well as Sendai Framework for Disaster Risk Reduction [3] were further explored to better address synergies. Particularly, the Culture 2030 indicators, a framework of thematic indicators aiming at measuring and monitoring the contribution of culture to the 2030 Agenda, and Dimension 1 "Environment and Resilience" was deeply analysed to include some indicators related to climate change and cultural and natural heritage safeguarding; The Sendai Framework was considered as relevant for the proposal of indicators related to the inclusion of traditional, indigenous and local knowledge and practices to complement scientific knowledge in disaster risk assessment as well as for the cross-sectoral approach (see Sendai Framework 24 (i)); finally, the recent development of the ARCH Resilience Assessment Dashboard, aiming at assessing the implementation of the DRM framework and inspired by Disaster Resilience Scorecard for Cities and the Disaster Resilience Scorecard for Buildings developed by UNDRR [7] [8], was taken as a basis and adapted to SHELTER objectives and compatibility among tools.

As a result, 44 qualitative indicators are proposed, being 33 of them applicable to both cultural and natural heritage, 3 specifically addressing cultural heritage and 8 specifically addressing natural heritage and are distributed according to the following dimensions:

TYPE OF RESILIENCE	TYPE OF CAPACITY			TOTAL
	ADAPTATIVE CAPACITY	COPING CAPACITY	TRANSFORMATIVE CAPACITY	
CULTURAL RESILIENCE	2	2	2	6

⁹ [ARCH | Home \(savingculturalheritage.eu\)](http://ARCH | Home (savingculturalheritage.eu))

ECONOMIC AND ENVIRONMENTAL RESILIENCE	3	10	1	14
GOVERNANCE AND INSTITUTIONAL RESILIENCE	2	6	3	11
HISTORIC BUILDING ENVIRONMENT RESILIENCE	2	2	2	6
SOCIAL RESILIENCE	4	2	1	7
TOTAL	13	21	10	

Table 5: Number of resilience indicators per type of capacity and type of resilience

Indicators are associated to a 5-degree scale, being 1 the worst scenario and 5 the best one. The Resilience index is calculated as the sum of the average of each type of resilience.

The following tables (Table 6, Table 7, Table 8, Table 9 and Table 10) detail the proposed indicators as well as the associated scale of assessment for each type of resilience and type of capacity.

Furthermore, considering the indicators that were established for the risk assessment methodology¹⁰ and that will be collected in the data model, a matching between these and the resilience index was proposed, with the aim of providing a quantitative assessment that will help the monitoring of the resilience improvement. A matching with the indicators proposed in D2.2 was also performed, in order to cover those aspects which are not part of the risk methodology and that will possibly help to quantitatively address, partially or totally, the resilience assessment indicators. This matching is shown in Table 11, Table 12, Table 13, Table 14 and Table 15.

¹⁰ SHELTER Project (2022). Deliverable "D2.5: Specific hazard risk assessment"

CULTURAL RESILIENCE

	CH	NH	QUALITATIVE INDICATOR	SCALE
ADAPTATIVE CAPACITY	Yes	Yes	Evidence of community-led processes during inventorying of heritage elements	<ol style="list-style-type: none"> 1. Heritage elements are not inventoried 2. Heritage elements are identified and inventoried but the process doesn't involve the community 3. Heritage elements are identified, inventoried and documented but the community is only informed and does not take part in the decision-making process 4. Heritage elements are identified, inventoried and documented with the participation of the communities, groups and individuals concerned but regularly update is not foreseen 5. Heritage elements are identified, inventoried, documented and regularly updated with the participation of the communities, groups and individuals concerned
	Yes	Yes	Availability of research results on local knowledge and climate change used to safeguard heritage	<ol style="list-style-type: none"> 1. No results available 2. Research results on the contribution of local knowledge to natural and cultural heritage safeguarding are highly incomplete and not updated 3. At least one scientific study on the contribution of local knowledge to natural and cultural heritage safeguarding was conducted in the last 2 years 4. At least three scientific studies on the contribution of local knowledge to natural and cultural heritage safeguarding were conducted in the last 2 years and results shared with local administration 5. Research activities on the contribution of local knowledge to natural and cultural heritage safeguarding are conducted on a regular basis and results are shared with local administration and the community
COPING CAPACITY	Yes	Yes	Availability of open access and open source risk information	<ol style="list-style-type: none"> 1. Little or no useful information is available 2. Some information is available, but data are not easily accessible 3. Information is heterogeneous and scattered 4. Information and data are available for some specific sectors 5. Information is complete and data available and shared
	Yes	Yes	Existence of effective communication and information channels/ tools coordinated with relevant actors and provided with plans and trained staff	<ol style="list-style-type: none"> 1. No communication exists 2. Communication and information channels and tools address some hazards, are not updated and available only upon request 3. Communication and information channels and tools are available but incomplete and address only some hazards 4. Communication and information channels and tools are available, address all hazards but have some omissions 5. Communication and information channels and tools are available, complete and integrated

CULTURAL RESILIENCE				
	CH	NH	QUALITATIVE INDICATOR	SCALE
TRANSFORMATIVE CAPACITY	Yes	Yes	Evidence of policies/measures and strategies taking into account traditional and local community knowledge, traditions and practices in assessing the possible impact of hazards on heritage elements	<ol style="list-style-type: none"> 1. No information on traditional and local knowledge is available 2. Some information on traditional and local knowledge is available but is not addressed nor integrated in any policy, measure or strategy 3. Information on traditional and local knowledge, construction methods, sustainable ecosystem maintenance, etc., is available, partially analysed and some efforts have been done to currently or in the next future incorporate this information in policies, measures and strategies 4. Information on traditional and local knowledge, construction methods, sustainable ecosystem maintenance, etc., is available, mostly analysed and integrated and applied in policies, measures and strategies with minor shortcomings 5. Information on traditional and local knowledge, construction methods, sustainable ecosystem maintenance, etc., is fully available, analysed, integrated and applied in policies, measures and strategies
	Yes	Yes	Evidence of programmes and progress of museums and galleries in digitizing their collections	<ol style="list-style-type: none"> 1. No digital content available 2. Some digital content is available for major museums based on individual initiatives and it mainly created for visitors and tourism purposes 3. Digital content is available and some specific content for conservation purposes available but can be accessed only upon request and varies according to economic resources available 4. Most of the museums and galleries collections have been digitized but there is still a lack in implementing a common programme with a defined objective and resources allocation 5. Almost all museums and galleries have digitized their collections, which are fully accessible, and information is shared in an integrated platform

Table 6: Cultural resilience qualitative indicators

ECONOMIC AND ENVIRONMENTAL RESILIENCE				
	CH	NH	QUALITATIVE INDICATOR	SCALE
ADAPTATIVE CAPACITY	Yes	Yes	Economic resources allocated on mitigation and adaptation measures for cultural and natural heritage	<ol style="list-style-type: none"> 1. Cultural and natural heritage don't have specific budget allocated 2. Limited allocation of national budget mainly devoted to emergency response 3. Legal norms establishing budgetary allocations to cultural and natural heritage to national and local governmental agencies 4. Progressive allocation at the national and local level for vulnerability reduction, the creation of incentives for heritage protection 5. National support for loans requested by local governmental agencies devoted to heritage adaptation and mitigation measures
	Yes	Yes	Land use policies and regulations	<ol style="list-style-type: none"> 1. No land use policies, regulations and plans in place 2. Land use policies, regulations and plans are outdated and allow for changes leading to random and unrestricted patterns 3. Land use policies, regulations and plans are outdated but prevent land use changes in conservation areas 4. Land use policies, regulations and plans are updated, aim at preserving conservation areas but are defined according to current scenario 5. Land use policies and restrictions are designed considering future scenarios and serve as major protective measure for conservation areas
	Yes	Yes	Existence of permanent solutions to reduce the exposure of heritage and ecosystems to hazards	<ol style="list-style-type: none"> 1. Little or no knowledge on available solutions at local level 2. Basic installation of solutions which are not sufficient to reduce exposure 3. Some effective solutions are installed and their number is planned to increase progressively in the future, nevertheless a maintenance plan is not in force 4. Solutions are installed and in good state of maintenance and their effectiveness is proved in average case scenarios 5. Permanent solutions exist, are sufficient to reduce exposure of the whole area including in worst scenarios and are regularly maintained
COPING CAPACITY	Yes	Yes	Heritage covered by any form of insurance	<ol style="list-style-type: none"> 1. Little or no coverage exists for heritage sites 2. The level of insurance highly depends on individuals 3. Public goods are covered by insurance but still little uptake for private assets 4. The historic area promotes insurance coverage for heritage sites through specific programmes 5. The uptake for insurance products in heritage sites is high

ECONOMIC AND ENVIRONMENTAL RESILIENCE				
	CH	NH	QUALITATIVE INDICATOR	SCALE
	Yes	Yes	Existence of social safety nets and funds	<ol style="list-style-type: none"> 1. No social safety nets or funds exist 2. Social safety nets or funds have major weakness and their availability varies according to other priorities 3. Social safety nets or funds are insufficient and don't guarantee the overall coverage 4. Social safety nets or funds exist but with minor shortcomings 5. Safety nets and funds for disasters exist and are designed in advance of potential hazards and define procedures, time plans, responsibilities, capacities and human resources
	Yes	Yes	Existence of monitoring systems and deployment of equipment to evaluate parameters or characteristics that make materials or elements more vulnerable	<ol style="list-style-type: none"> 1. No or minimum instrumentation exists 2. Basic instrumentation networks with problems of updated technology and continuous maintenance 3. Some networks with advanced technology exist in particular areas but information on how to interpret data and protocols are poorly established 4. Good and progressive instrumentation cover and some automatic warning systems working 5. Wide coverage of station and sensor networks in all parts of the territory; analysis of information and automatic early warning systems working continuously
	No	Yes	Existence of measures to secure and safeguard natural capital	<ol style="list-style-type: none"> 1. No measures implemented 2. No measures are implemented but will be in the next future 3. Some measures are implemented and additional measures are foreseen 4. Most relevant measures are implemented still their effectiveness must be proven 5. Comprehensive measures are implemented and their effectiveness and impacts have been proven
	No	Yes	Existence of structural and functional connectivity of green infrastructure	<ol style="list-style-type: none"> 1. No connectivity of green infrastructures 2. Existence of partial structural connectivity of green infrastructures 3. Existence of structural connectivity of green infrastructures 4. Existence of structural connectivity and partially functional connectivity of green infrastructures 5. Existence of structural and functional connectivity of green infrastructures
	No	Yes	Existence of policies or mechanisms to protect and maintain native species and local ecosystems	<ol style="list-style-type: none"> 1. No policies or mechanisms implemented 2. No policies or mechanisms are implemented but will be in the next future 3. Some policies or mechanisms are implemented and additional measures are

ECONOMIC AND ENVIRONMENTAL RESILIENCE				
	CH	NH	QUALITATIVE INDICATOR	SCALE
				foreseen 4. Most relevant policies or mechanisms are implemented still their effectiveness must be proven 5. Comprehensive policies or mechanisms are implemented and their effectiveness and impacts have been proven
	No	Yes	Sustainable forest management and maintenance guidelines	1. No sustainable forest management and maintenance guidelines are available 2. No sustainable forest management and maintenance guidelines are available but will be in the next future 3. Sustainable forest management and maintenance guidelines are available for public authorities but still require mayor improvements 4. Comprehensive sustainable forest management and maintenance guidelines are available for public authorities 5. Comprehensive sustainable forest management and maintenance guidelines are available for public authorities and private owners
	No	Yes	Trends in habitats restoration and regeneration	1. Trends are unknown due to the lack of information 2. Trends in habitats restoration and regeneration decreased in the last 5 years, even if degraded areas are abundant 3. Trends in habitats restoration and regeneration are stable since last 5 years but expected to increase in the future, still degraded areas are common 4. Trends in habitats restoration and regeneration increased in the last 5 years and the majority of degraded areas have been or will be cured 5. Trends in habitats restoration and regeneration increased in the last 5 years and consider future scenarios of climate change. Most of degraded areas has been cured
	No	Yes	Habitat functional composition	1. No functional habitat composition 2. Very low functional habitat composition 3. Partially functional habitat composition 4. High functional habitat composition 5. Fully functional habitat for inhabiting species
	No	Yes	Existence of policies or mechanisms aiming at maintaining livestock productivity and sustainable production to ensure environmental protection	1. No policies or mechanisms implemented 2. No policies or mechanisms are implemented but will be in the next future 3. Some policies or mechanisms are implemented and additional measures are foreseen 4. Most relevant policies or mechanisms are implemented still their

ECONOMIC AND ENVIRONMENTAL RESILIENCE				
	CH	NH	QUALITATIVE INDICATOR	SCALE
				effectiveness must be proven 5. Comprehensive policies or mechanisms are implemented and their effectiveness and impacts have been proven
TRANSFORMATIVE	No	Yes	Inclusion of climate change scenarios on habitat suitability	<ol style="list-style-type: none"> 1. Climate change analysis on habitat suitability is not performed 2. Climate change analysis on habitat suitability is not performed but is planned in the next future 3. Qualitative analysis of climate change on habitat suitability is performed 4. Semiquantitative analysis of climate change on habitat suitability is performed 5. Quantitative analysis of climate change on habitat suitability, including future scenarios is performed

Table 7: Economic and environmental resilience qualitative indicators

GOVERNANCE AND INSTITUTIONAL RESILIENCE				
	CH	NH	QUALITATIVE INDICATOR	SCALE
ADAPTATIVE CAPACITY	Yes	Yes	Existence of cultural patronage, sponsorship or public-private partnership	<ol style="list-style-type: none"> 1. There is still low level of understanding on the application of these mechanisms to cultural heritage 2. The procedural process is still complicated and appropriateness of these mechanisms in regard to project identification is still challenging 3. Some practices exist but the number of initiatives is still insufficient compared to the cultural heritage dimension 4. Cooperation between the public and private sectors is an established practice, still some regulatory improvements are needed 5. Initiatives are well-known practices and are legally supported by exemptions and tax breaks.
	Yes	Yes	Climate change and disaster risk management approaches in land use changes and planning	<ol style="list-style-type: none"> 1. Consideration of some means for identifying risk, and environmental protection in physical planning. 2. Promulgation of national legislation and some local regulations that consider some hazards as a factor in territorial organization and development planning. 3. Progressive formulation of land use regulations in various cities that take into account hazards and risks; obligatory design and construction norms based on microzonations. 4. Wide ranging formulation and updating of territorial organization plans with a preventive approach in the majority of municipalities. Use of microzonations with security ends. 5. Generalized approval and control of implementation of territorial organization plans that include risk as a major factor, and the respective urban security regulations.
COPING CAPACITY	Yes	Yes	Existence of regulatory frameworks or guidelines designed through multi-level or cross-sectorial governance structures and instruments to for climate change adaptation and risk management in heritage sites	<ol style="list-style-type: none"> 1. Inexistence of any type of regulatory framework or guidelines 2. Infrequent contacts among sectorial governance structures but no regulatory framework exist 3. Regulatory frameworks or guidelines are under development, still identification of roles and responsibilities is not clear 4. Some regulatory framework or guidelines exist, however there is some overlapping in role and responsibilities 5. There is a clear and coordinated framework among levels and governance structures defined by in force regulatory frameworks or guidelines

GOVERNANCE AND INSTITUTIONAL RESILIENCE				
	CH	NH	QUALITATIVE INDICATOR	SCALE
	Yes	Yes	Existence of hazard monitoring and forecasting systems	<ol style="list-style-type: none"> 1. Minimum and deficient instrumentation of some important hazards 2. Basic instrumentation networks with problems of updated technology and continuous maintenance 3. Some networks with advanced technology at the national level or in particular areas; improved prognostics and information protocols established for principal hazards 4. Good and progressive instrumentation cover at the national level, advanced research in the matter on the majority of hazards, and some automatic warning systems working 5. Wide coverage of station and sensor networks for all types of hazard in all parts of the territory; permanent and opportune analysis of information and automatic early warning systems working continuously at the local, regional and national levels.
	Yes	Yes	Evidence of a review of the impact of climate change and natural disaster on heritage within the last 5 year	<ol style="list-style-type: none"> 1. Impact of climate change and natural disaster on heritage are not considered 2. Major impacts of climate change and natural disaster on heritage are partially addressed with major omissions 3. Major impacts of climate change and natural disaster on heritage are addressed but gaps are present 4. Impacts of climate change and natural disaster on heritage are addressed but not updated 5. Impacts of climate change and natural disaster on heritage are fully addressed and regularly updated
	Yes	Yes	Specific policies/ plans/regulations for cultural and natural heritage recovery and reconstruction	<ol style="list-style-type: none"> 1. No specific policies/ plans/regulations exists 2. Specific policies/ plans/regulations exist but are insufficient and focused only on post disaster planning 3. Specific policies/ plans/regulations exist but are sectorial and not integrated, leaving gaps among them 4. Specific policies/ plans/regulations exist but have not been tested and have minor gaps 5. Specific policies/ plans/regulations exist, are detailed enough and have been tested successfully
	Yes	Yes	Existence of local Disaster Risk Reduction Plan(s) for heritage sites/elements	<ol style="list-style-type: none"> 1. No plan exists for heritage sites 2. A plan exists but is quite basic and of doubtful value 3. A plan exists for some sites/elements but presents gaps and is not

GOVERNANCE AND INSTITUTIONAL RESILIENCE				
	CH	NH	QUALITATIVE INDICATOR	SCALE
				<p>updated</p> <p>4. A plan exists for almost all heritage sites/elements but may need minor updates</p> <p>5. An up to date plan exists for almost all heritage sites/elements</p>
TRANSFORMATIVE CAPACITY	Yes	Yes	Existence of self-protection mechanisms or specialized units services whose purpose will be to secure respect for cultural property, artefacts or natural heritage in case of hazard	<p>1. No specialized units nor self-protection mechanisms exist</p> <p>2. No specialized units exist but self-protection mechanisms are implemented</p> <p>3. No specialized units exist but their creation is planned in the future</p> <p>4. Specialized units exist and personnel is trained to take appropriate measures</p> <p>5. Specialized units exist, personnel is trained to take appropriate measures and their duties and responsibilities are formally and legally established</p>
	Yes	Yes	Responsibilities decentralized to regional/provincial/ local/municipal authorities, which have a budget for the area	<p>1. Basic organizations at the national level arranged in commissions with limited budget, principally with an emergency response approach</p> <p>2. Legislation that establishes decentralized, interinstitutional and multisectoral organization for the integral management of risk and the formulation of a general risk management plan with budget allocation to national level</p> <p>3. Interinstitutional risk management systems active at the local level with specific budgetary allocation. Inter-ministerial work at the national level in the design of public policies for vulnerability reduction</p> <p>4. Continuous implementation of risk management projects associated with programs of adaptation to climate change and environmental and heritage protection with progressive allocation of discretionary budget</p> <p>5. Expert personnel with wide experience incorporating risk management in sustainable development planning at the local level. High technology information systems available and budgetary support.</p>
	Yes	Yes	Evidence of management plan(s)/policies/measures supporting traditional forms of land ownership and land management elaborated in the last 5 years	<p>1. No reference to traditional forms of land ownership and land management exist on management plan(s)/policies/measures</p> <p>2. Willingness to include traditional forms of land ownership and land management in management plan(s)/policies/measures but their contribution to ecosystems is unknown</p> <p>3. Some traditional forms of land ownership are mentioned in management plan(s)/policies/measures and in some cases implemented</p> <p>4. Management plan(s)/policies/measures generally enforce traditional forms of land ownership and land management</p>

GOVERNANCE AND INSTITUTIONAL RESILIENCE				
	CH	NH	QUALITATIVE INDICATOR	SCALE
				5. Management plan(s)/policies/measures, which are regularly updated, strongly support and enforce traditional forms of land ownership and land management
	Yes	Yes	Existence of institutions for safeguarding cultural heritage with powers of enforcement	1. No of institutions for safeguarding cultural heritage exist 2. Institutions for safeguarding cultural heritage are in place but lack of authority and resources 3. Institutions for safeguarding cultural heritage are in place, have authority but lack of appropriate resources 4. Institutions for safeguarding cultural heritage are in place, have authority and resources but lack of intersectoral support 5. Institutions for safeguarding cultural heritage are well established, have appropriate resources and authority

Table 8: Governance and institutional resilience qualitative indicators

HISTORIC BUILDING ENVIRONMENT RESILIENCE				
	CH	NH	QUALITATIVE INDICATOR	SCALE
ADAPTATIVE CAPACITY	Yes	Yes	Existence of specific equipment on heritage sites to reduce the exposure and vulnerability of heritage and ecosystems to the risks of climate change and other hazards	<ol style="list-style-type: none"> 1. Little or no knowledge on available resources and equipment at local level 2. Basic supply and inventory of resources for public organizations at local level 3. Centre with reserves and specialized equipment for emergencies exist. Inventory of resources in public and private organizations. 4. Well stocked Centre with communication equipment and adequate registry systems considering public and private organisations. Progressive complimentary stocking 5. Interinstitutional support networks for equipment supply. Public and private organisation as well as the majority of citizens have sufficient equipment and resources to reduce damages
	Yes	No	Trends in the number of historic buildings reinforced or retrofitted with hazard compliant techniques/materials as a percentage of all historic buildings	<ol style="list-style-type: none"> 1. Trends are unknown due to the lack of information on reinforced or retrofitted buildings 2. Information on reinforced or retrofitted buildings is available but compliancy with hazard techniques/materials is unknown 3. Trends in reinforced or retrofitted buildings with hazard compliant techniques/materials have decreased in the last 5 years, even if the building stock requires interventions 4. Trends in reinforced or retrofitted buildings with hazard compliant techniques/materials are stable since last 5 years but expected to increase in the future, as the building stock requires interventions 5. Trends in reinforced or retrofitted buildings with hazard compliant techniques/materials are increased in the last 5 years and a large portion of the building stock will be addressed
COPING CAPACITY	Yes	Yes	Redundancy and network of public spaces and functions	<ol style="list-style-type: none"> 1. Scenarios are not available to estimate foreseen disruptions 2. Significant disruptions are foreseen for average scenarios of relevant hazards 3. Some disruptions are expected in a limited timeframe for average scenarios of relevant hazards 4. Minor disruptions are expected in a limited timeframe for average or worst scenarios of relevant hazards 5. No disruptions are expected in a limited timeframe for average or worst scenarios of relevant hazards

HISTORIC BUILDING ENVIRONMENT RESILIENCE				
	CH	NH	QUALITATIVE INDICATOR	SCALE
	Yes	Yes	Accessibility of cultural facilities and natural areas to emergency services	<ol style="list-style-type: none"> 1. Evaluation of the accessibility of cultural facilities and natural areas in case of hazard occurrence has not been performed 2. Rough estimation on loss factor accessibility to cultural facilities and natural areas in case of hazard is available 3. Estimation on loss factor accessibility to cultural facilities and natural areas in case of hazard is available and some scenarios are available 4. Emergency planning in relation to accessibility of cultural facilities and natural areas is available, considering different scenarios 5. A detailed plan on accessibility of cultural facilities and natural areas is available, considering alternative routes for emergency vehicles and equipment deployment based on real time data information
TRANSFORMATIVE CAPACITY	Yes	No	Existence of conservation policies aiming at maintaining use and state of conservation of the historic area	<ol style="list-style-type: none"> 1. No policies exist even if the historic area is mainly degraded 2. Conservation policies exist but are mainly focused on elements of unique and exceptional value 3. Conservation policies exist but have not been yet implemented 4. Conservation policies exist and consider the specific problematic of the historic area and have been partially implemented 5. Conservation policies exist, fully cover the specific problematic of the historic area and are continuously implemented
	Yes	No	Existence of updated safety standards and construction codes addressing specific hazards in the area	<ol style="list-style-type: none"> 1. No real use or voluntary use of norms and codes 2. Adaptation of some requirements and specifications according to some national and local criteria and particularities but no planning for updating 3. Promulgation and updating of obligatory norms adjusted to hazard evaluations made in the country 4. Technological updating of the majority of security and construction code norms for new and existing buildings considering also climate change scenarios 5. Permanent updating of codes and security norms for new and existing buildings including heritage: establishment of local regulations for construction based on microzonations, and their strict control and implementation.

Table 9: Historic building environment resilience qualitative indicators

SOCIAL RESILIENCE				
	CH	NH	QUALITATIVE INDICATOR	SCALE
ADAPTATIVE CAPACITY	Yes	Yes	Availability of training courses for practitioners covering the use of traditional construction materials and techniques, traditional land uses and disaster risk management	<ol style="list-style-type: none"> 1. Little or no training exists 2. Existence of some training modules, but contents should be improved 3. Existence of some training courses to some specific sectors 4. Existence of regular training courses covering traditional skills, resilience and disaster 5. Existence of regular training course covering traditional skills, resilience and disaster involving local communities
	Yes	Yes	Access to health and shelter capacity	<ol style="list-style-type: none"> 1. National legislations poorly define mechanisms for activation, coordination and command of emergency phases for most relevant hazards, but doesn't consider local healthcare capacities or persons potentially in need of shelter 2. Legislation defines mechanisms for activation, coordination and command for all phases of emergency and is reviewed regularly following an all-hazard approach. Healthcare and shelter capabilities are calculated according to average case scenarios for relevant hazards 3. Legislation defines mechanisms for activation, coordination and command for all phases of emergency and clearly defines role and responsibilities of actors involved at national and local level for all hazards. Healthcare and shelter capabilities are determinate according to risk assessment analysis based on average case scenarios for all hazards 4. Available local protocols and procedures for the collection, management, analysis and dissemination of the necessary data for conducting risk assessments and performing emergency-preparedness planning, including well defined roles and responsibilities. Mechanisms for carrying out rapid health and shelter needs assessments are in place. 5. Local protocols and procedures for emergency preparedness are regularly updated and information mechanisms established at the community level and trained staff available. The number of shelter places available is higher than the person potentially in need of shelter for all hazards and healthcare capabilities calculated considering worse scenario
	Yes	Yes	Volunteers formally registered and trained in community based disaster risk reduction	<ol style="list-style-type: none"> 1. Volunteering is an uncommon practice in the community and little or no training on disaster management for this category exists. 2. Volunteering is poorly practiced by the community and training materials are not harmonized across stakeholders 3. Volunteering is quite extended in the community and there some opportunities for disaster risk reduction training 4. Volunteering is a common practice in the community and disaster risk

SOCIAL RESILIENCE				
	CH	NH	QUALITATIVE INDICATOR	SCALE
COPING CAPACITY				reduction training is available according to shared curricula and materials 5. Procedures for integrating national and international volunteers into service delivery exists and training provided regularly according to harmonized curricula and materials, including basic knowledge on intervening in heritage assets/areas
	Yes	Yes	Professionals certified/ trained in heritage recovery and preservation	<ol style="list-style-type: none"> 1. No information on certified and trained professionals dealing with heritage recovery and preservation 2. Only some categories of professionals are included in the recovery phase but certification or proven experience is not requested 3. A list of professionals dealing with heritage recovery and conservation exist but no with no information on post disaster intervention skills 4. Professionals dealing with heritage recovery and conservation have proven experience and have basic training on intervention in post disaster phase 5. Professionals dealing with heritage recovery and conservation have proven experience, are certified and need to attend specific training to intervene in the post-disaster phase
	Yes	Yes	Monitoring of changes in risk perception of the community	<ol style="list-style-type: none"> 1. No information available on risk perception 2. Studies on community risk perception have been conducted but continuous monitoring was not addressed 3. Sporadic studies on the community risk perception are available but analysis is still fragmented and no or little actions have been conducted 4. Community risk perception is well addressed through questionnaire or participatory dynamics but related actions are still partially covering this aspect 5. Prevention, mitigation and adaptation initiatives and communication activities are planned and designed according to updated and frequent analysis of the community risk perception
	Yes	Yes	Evidence of measures and initiatives, including knowledge, traditions and practices of people and communities, intended to address climate change and hazards impacts on heritage sites	<ol style="list-style-type: none"> 1. Knowledge, traditions and practices of people and communities are not considered in policies and practices for disaster risk management in heritage sites 2. Knowledge, traditions and practices of people and communities are known but are not included as complementary knowledge in the development of policies and practices for disaster risk management in heritage sites 3. Knowledge, traditions and practices of people and communities are known and documented but are only partially included in policies and practices and

SOCIAL RESILIENCE				
	CH	NH	QUALITATIVE INDICATOR	SCALE
				without a cross-sectoral approach 4. Policies and practices for disaster risk management ensure the use of traditional, indigenous and local knowledge and practices to complement scientific knowledge but without a cross-sectoral approach 5. Policies and practices for disaster risk management ensure the use of traditional, indigenous and local knowledge and practices to complement scientific knowledge with a cross-sectoral approach (Sendai Framework 24 (i))
TRANSFORMATIVE CAPACITY	Yes	Yes	Evidence of capacity-building and training programme(s), implemented in the last 5 years, to increase expertise in safeguarding and transmission of cultural heritage by/in local communities	1. No training or capacity building programme on the topic exist 2. Some training and capacity building initiatives are under development or exist as ad hoc content provision 3. Some training and capacity building initiatives exist but is specific to some heritage 4. Training and capacity building initiatives exist but still don't include all the involved community, including minority cultures 5. Training and capacity building initiatives is available for all heritage and involves all relevant stakeholders and the whole community

Table 10: Social resilience qualitative indicators

CULTURAL RESILIENCE					
	CH	NH	QUALITATIVE INDICATOR	INDICATORS INCLUDED IN D2.5	INDICATORS PROPOSED IN D2.2
ADAPTATIVE CAPACITY	Yes	Yes	Evidence of community-led processes during inventorying of heritage elements	-	241. Intangible value of cultural and natural heritage
	Yes	Yes	Availability of research results on local knowledge and climate change used to safeguard heritage	-	-
COPING CAPACITY	Yes	Yes	Availability of open access and open source risk information	84. Percentage of population with access to risk information	399. Existence of a platform for information sharing and networking using tools and routines and number of unique users
	Yes	Yes	Existence of effective communication and information channels/ tools coordinated with relevant actors and provided with plans and trained staff	-	278. Media observation for public pressure 313. Public information and community participation
TRANSFORMATIVE CAPACITY	Yes	Yes	Evidence of policies/measures and strategies taking into account traditional and local community knowledge, traditions and practices in assessing the possible impact of hazards on heritage elements	-	241. Intangible value of cultural and natural heritage
	Yes	Yes	Evidence of programmes and progress of museums and galleries in digitizing their collections	-	-

Table 11: Quantitative indicators associated to cultural resilience

ECONOMIC AND ENVIRONMENTAL RESILIENCE					
	CH	NH	QUALITATIVE INDICATOR	INDICATORS INCLUDED IN D2.5	INDICATORS PROPOSED IN D2.2
ADAPTATIVE CAPACITY	Yes	Yes	Economic resources allocated on mitigation and adaptation measures for cultural and natural heritage	329. Budget allocation and mobilization	172. Ten-year average per capita spending for mitigation projects 287. Economic Resilience Index adapted based on Disaster Deficit Index
	Yes	Yes	Land use policies and regulations	144. Yearly average imperviousness change between two reference years 180. Land take 397. Area under vegetation and wetlands	150. Average annual rate of change of the percentage urban 183. Land cover 381. Urban green space proportion
	Yes	Yes	Existence of permanent solutions to reduce the exposure of heritage and ecosystems to hazards	-	145. Dam capacity
COPING CAPACITY	Yes	Yes	Heritage covered by any form of insurance	-	124. Infrastructure and housing insurance as a percent of GDP 331. Insurance coverage and loss transfer strategies for public assets
	Yes	Yes	Existence of social safety nets and funds	-	330. Existence of social safety nets and funds
	Yes	Yes	Existence of monitoring systems and deployment of equipment to evaluate parameters or characteristics that make materials or elements more vulnerable	38. Relative water content in the top few centimetres of soil 56. Vegetation density (NDVI) 363. Soil Water Index (SWI)	59. Street noise/ acoustic pollution 411. Building walls rotations
	No	Yes	Existence of measures to secure and safeguard natural capital	148. Share of the protected lands 316. Management of river basins and environmental protection	373. Proportion of natural areas within a defined zone 401. Percentage of renewable energy 431. Total carbon sequestered and carbon sequestration rate
	No	Yes	Existence of structural and functional connectivity of green infrastructure	-	364. Structural connectivity of green infrastructure 365. Functional connectivity of green infrastructure

ECONOMIC AND ENVIRONMENTAL RESILIENCE					
	CH	NH	QUALITATIVE INDICATOR	INDICATORS INCLUDED IN D2.5	INDICATORS PROPOSED IN D2.2
	No	Yes	Existence of policies or mechanisms to protect and maintain native species and local ecosystems	366. Number of non-native species of flora introduced 367. Number of non-native faunal species introduced 368. Species diversity within defined area per Shannon Diversity Index 369. Number of species within defined area per Shannon Evenness Index 370. Number of veteran trees per unit area 372. Extent of habitat for native pollinator species 374. Number of conservation priority species	-
	No	Yes	Sustainable forest management and maintenance guidelines	371. Quantity of dead wood per unit area	-
	No	Yes	Trends in habitats restoration and regeneration	-	378. Area of habitats restored
	No	Yes	Habitat functional composition	-	379. Habitat functional composition (relative abundance of functional features)
	No	Yes	Existence of policies or mechanisms aiming at maintaining livestock productivity and sustainable production to ensure environmental protection	416. Agricultural occupation rate 417. Total number of cattle heads 418. Total number of sheep heads 419. Total number of goat heads 420. Total number of poultry heads 421. Total number of swine heads 422. Total number of equine heads	-

ECONOMIC AND ENVIRONMENTAL RESILIENCE					
	CH	NH	QUALITATIVE INDICATOR	INDICATORS INCLUDED IN D2.5	INDICATORS PROPOSED IN D2.2
TRANSFORMATIVE	No	Yes	Inclusion of climate change scenarios on habitat suitability	-	430. Habitat-suitability index under climate change scenarios

Table 12: Quantitative indicators associated to economic and environmental resilience

GOVERNANCE AND INSTITUTIONAL RESILIENCE					
	CH	NH	QUALITATIVE INDICATOR	INDICATORS INCLUDED IN D2.5	INDICATORS PROPOSED IN D2.2
ADAPTATIVE CAPACITY	Yes	Yes	Existence of cultural patronage, sponsorship or public-private partnership	-	226. Mechanisms for communities to engage with government
	Yes	Yes	Climate change and disaster risk management approaches in land use changes and planning	315. The extension to which risk is taken into account in land use and urban planning	52. Albedo 65. Construction material (public space) 358. New buildings rate
COPING CAPACITY	Yes	Yes	Existence of regulatory frameworks or guidelines designed through multi-level or cross-sectorial governance structures and instruments to for climate change adaptation and risk management in heritage sites	-	223. Coordination with other government bodies
	Yes	Yes	Existence of hazard monitoring and forecasting systems	-	248. Prediction capacity 310. Hazard monitoring and forecasting 322. Emergency response planning and implementation of warning systems
	Yes	Yes	Evidence of a review of the impact of climate change and natural disaster on heritage within the last 5 year	311. Hazard assessment and mapping 312. Vulnerability, risk assessment and mapping	-
	Yes	Yes	Specific policies/ plans/regulations for cultural and natural heritage recovery and reconstruction	326. Rehabilitation and reconstruction planning	410. Building transformation
	Yes	Yes	Existence of local Disaster Risk Reduction Plan(s) for heritage sites/elements	-	174. Percentage population covered by a mitigation plan
TRANSFORMATIVE	Yes	Yes	Existence of self-protection mechanisms or specialized units services whose purpose will be to secure respect for cultural	321. Organization and coordination of emergency operations	267. Number of buildings hosting collections with storage capacity in upper floors 324. Simulation, updating and testing of inter-institutional response capability

GOVERNANCE AND INSTITUTIONAL RESILIENCE					
	CH	NH	QUALITATIVE INDICATOR	INDICATORS INCLUDED IN D2.5	INDICATORS PROPOSED IN D2.2
			property, artefacts or natural heritage in case of hazard		
	Yes	Yes	Responsibilities decentralized to regional/provincial/local/municipal authorities, which have a budget for the area	327. Decentralized organizational units, inter-institutional and multisector coordination	328. Availability of resources for institutional strengthening
	Yes	Yes	Evidence of management plan(s)/policies/measures supporting traditional forms of land ownership and land management elaborated in the last 5 years	-	-
	Yes	Yes	Existence of institutions for safeguarding cultural heritage with powers of enforcement	-	241. Intangible value of cultural and natural heritage 242. Presence of a traditional culture

Table 13: Quantitative indicators associated to governance and institutional resilience

HISTORIC BUILDING ENVIRONMENT RESILIENCE					
	CH	NH	QUALITATIVE INDICATOR	INDICATORS INCLUDED IN D2.5	INDICATORS PROPOSED IN D2.2
ADAPTATIVE CAPACITY	Yes	Yes	Existence of specific equipment on heritage sites to reduce the exposure and vulnerability of heritage and ecosystems to the risks of climate change and other hazards	323. Supply of equipment, tools and infrastructure	74. Fire-protection installations 250. Available (collective) equipment to limit damage 266. Number of blue and green roofs 389. Percentage of existing primary infrastructures provided with back-up systems
	Yes	No	Trends in the number of historic buildings reinforced or retrofitted with hazard compliant techniques/materials as a percentage of all historic buildings	67. Insulation 263. Percentage of buildings with open ground floor or with ground floor above the maximum level of possible floods 264. Percentage of buildings with structural materials resistant to water penetration 320. Reinforcement and retrofitting of public and private assets	73. Fire-resistant sector partitions 256. Percentage of buildings with drainage system in good condition and appropriate dimension 265. Percentage of buildings with facade materials resistant to water penetration
COPING CAPACITY	Yes	Yes	Redundancy and network of public spaces and functions	-	190. Infrastructure Redundancy
	Yes	Yes	Accessibility of cultural facilities and natural areas to emergency services	105. Distance to service centres 106. Distance to fire brigades 409. Site accessibility	72. Accessible windows
TRANSFORMATIVE CAPACITY	Yes	No	Existence of conservation policies aiming at maintaining use and state of conservation of the historic area	63. State of conservation 77. Building use/function	-
	Yes	No	Existence of updated safety standards and construction codes addressing specific hazards in the area	319. Updating and enforcement of safety standards and construction codes	138. Percentage of buildings complying with hazard-resistant building codes and/or standards

Table 14: Quantitative indicators associated to historic building environment resilience

SOCIAL RESILIENCE					
	CH	NH	QUALITATIVE INDICATOR	INDICATORS INCLUDED IN D2.5	INDICATORS PROPOSED IN D2.2
ADAPTATIVE CAPACITY	Yes	Yes	Availability of training courses for practitioners covering the use of traditional construction materials and techniques, traditional land uses and disaster risk management	83. Number of participants in training courses executed by authorities, institutions, corporations or other bodies, specific for DRM	-
	Yes	Yes	Access to health and shelter capacity	-	129. Hospital beds per 10,000 persons 130. Hotels/motels per 10,000 persons
	Yes	Yes	Volunteers formally registered and trained in community based disaster risk reduction	-	170. Number of registered volunteers
	Yes	Yes	Professionals certified/ trained in heritage recovery and preservation	384. Number of professionals trained in post- disaster recovery and preservation of CH	
COPING CAPACITY	Yes	Yes	Monitoring of changes in risk perception of the community	-	188. Risk Perception
	Yes	Yes	Evidence of measures and initiatives, including knowledge, traditions and practices of people and communities, intended to address climate change and hazards impacts on heritage sites	-	245. Number of measures taken by individuals to reduce damage
TRANSFORMATIVE	Yes	Yes	Evidence of capacity-building and training programme(s), implemented in the last 5 years, to increase expertise in safeguarding and transmission of cultural heritage by/in local communities	-	-

Table 15: Quantitative indicators associated to social resilience

5 Decision making for resilience improvement

To support resilience through strategic decision-making a multi-hazard risk assessment tool is being developed based on the multiscale data model and in the methodology developed in T2.5¹¹. The tool will produce risk maps that will serve as baseline input for a strategic DSS that will link the multiscale risk assessment methodology developed and the adaptation and reconstruction solutions characterization developed in T3.4¹² through a decision-making methodology for the selection of adaptation and reconstruction solutions. As the first step for the implementation of this SHELTER DSS in T5.4, in this task, the solutions and the risk assessment methodology has been linked studying the solutions characterised in WP3¹³ regarding their impact on the risk elements defined in T2.5.

5.1 Workflow in the DSS

The DSS will support the selection of the best strategies based on the risk baseline and follow the steps that could be found in the next table (Table 16):

STEP	OBJECTIVE	PARAMETERS	
1	Import the risk baseline	imports risk assessment from the dashboard	
2	Select the target area/assets	Identify which assets have more value and are more at risk	manually
			hazard area
			by area
			semantically
3	Filter the solutions	filtering by parameters	Hazard
			DRM phase
			Action Scale
			Type of solution
			Impact on cultural value:
			Reversibility
			Impact on protected HB
4	Rank solutions	optimising by multicriteria	technical feasibility
			cost
			footprint
			impact in CH
6	Calculate the impact	visual charts	
7	Create the report		

¹¹ SHELTER Project (2022). Deliverable "D2.5: Specific hazard risk assessment"

¹² SHELTER Project (2021). Deliverable "D3.4: Adaptation and reconstruction portfolio to improve CH buildings and sites resilience"

¹³ SHELTER deliverables "D3.3: Consolidation and structural stabilization in emergency phases" and "D3.4: Portfolio to improve CH buildings and sites"

8	link with dashboard	sent the selected strategy and new maps to the dashboard	
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Table 16: Workflow of the DSS

Being SHELTER a CHN-centric project, the value of the cultural and natural heritage has to be considered in all the decision-making processes. The following table (Table 17) shows this role:

		RISK					MEASURES					
		HAZ.	EXP.	VULNERABILITY			TO REDUCE		TO ENHANCE			
				SENS.	COP.	ADAPT.	TRANS.	EXP.	SENS.	COP.	ADAPT.	TRANS.
RISK	HAZARD	RISK ASSESSMENT MODULE: CALCULATION OF RISK OF ELEMENTS					DSS: calculation of reduction of risk of selected strategies					
	EXPOSURE											
	VULNERABILITY											
	SENSITIVITY											
	COPING CAPACITY											
	ADAPTIVE CAPACITY TRANSFORMATIVE CAPACITY											
MEASURES	TO REDUCE	EXPOSURE	DSS: reduction of risk of selected strategies					PORTFOLIO OF SOLUTIONS: characterisation of the measures regarding their capacity to reduce risk/enhance resilience				
		SENSITIVITY										
	TO ENHANCE	COPING CAPACITY										
		ADAPTIVE CAPACITY TRANSFORMATIVE CAPACITY										
VALUE		SPECIFIC SENSITIVITY OF CHN	INHERENT RESILIENCE OF CHN			PORTFOLIO OF SOLUTIONS: characterisation of the measures regarding their impact in the values						
		RISK ASSESSMENT MODULE-PRIORISATION OF ELEMENTS: which elements have more value and are at more risk					DSS-PRIORISATION OF SOLUTIONS: which solutions have less impact in value and reduce the risk/enhance the resilience more					

Table 17: The role of value in the decision making

5.2 Impact of the solutions

As stated from the beginning of Shelter, cultural heritage, in all its forms and nature, has a multiscale character¹⁴: "The form has a direct implication on the dimension of the heritage considered (statue, archaeological site or landscape), while the nature on the spatial representation (industrial heritage along a river, historic centre or cultural routes)". To characterise the risk reduction and resilience enhancement solutions

¹⁴ SHELTER deliverable "D2.1: HA Resilience structure"

selected in WP3¹⁵ regarding their impact in the different hazard elements (reduction of exposure and sensitivity and enhancement of coping, adaptive and transformative capacity) the same structure of the SHELTER conceptual framework has been followed. Artefacts, buildings and archaeological sites have been grouped and named as the **object/building scale**, while neighbourhoods/districts, cities and regions have been assigned to the **urban/territorial scale**.

5.2.1 Solutions for heatwaves

5.2.1.1 At building level

Code	Name of the solution	Action Scale	Main Function	IMPACT				
				TO REDUCE		TO ENHANCE		
				EXP.	SENS.	COP.	ADAPT.	TRANS.
NBS1	CLIMBER GREEN WALL	Building	Climate adaptation					
NBS2	PLANTER GREEN WALL	Building	Climate adaptation					
NBS3	Greenwall system	Building	Climate adaptation					
NBS4	VEGETATED PERGOLA	Building	Climate adaptation					
NBS5	INTENSIVE and SEMI-INTENSIVE GREEN ROOF	Building	Water/flood management					
NBS6	EXTENSIVE GREEN ROOF	Building	Water/flood management					
NBS12	GREEN PAVEMENTS	Building	Water/flood management					
NBS16	Natural ventilation (and design for)	Building	Building stabilization					
VA1	Shading and sun screens in vernacular architecture	Building	Climate adaptation					
VA3	Building layout and courtyards in traditional urban patterns	Building	Climate adaptation					
VA4	Architectural form of vernacular buildings in hot climate zones	Building	Climate adaptation					
HW	External thermal insulation composite system (ETICS): synthetic organic insulation	Building	Envelope insulation					
HW	External thermal insulation composite system (ETICS): synthetic inorganic insulation	Building	Envelope insulation					
HW	Internal thermal insulation system: natural and mineral insulation	Building	Envelope insulation					
HW	Internal thermal insulation system: synthetic organic insulation	Building	Envelope insulation					
HW	Vacuum insulated panels (VIP). External application	Building	Envelope insulation					
HW	Vacuum insulated panels (VIP). Internal application	Building	Envelope insulation					
HW	Cavity wall insulation	Building	Envelope insulation					
HW	Internal thermal insulation system: aerogel	Building	Envelope insulation					
HW	Phase Change Materials (PCM)	Building	Envelope insulation					
HW	External thermal insulation of roofs	Building	Envelope insulation					
HW	Internal thermal insulation of roofs	Building	Envelope insulation					
HW	Insulated glazing	Building	Envelope insulation					
HW	Solar control glass	Building	Envelope insulation					

¹⁵ SHELTER deliverables “D3.3: Consolidation and structural stabilization in emergency phases” and “D3.4: Portfolio to improve CH buildings and sites”

HW	Vacuum Insulating Glass	Building	Envelope insulation					
HW	Aerogel Insulating Glass	Building	Envelope insulation					
HW	Solar protection film	Building	Envelope insulation					
HW	Passive smart glass	Building	Envelope insulation					
HW	Active smart glass: electrochromic glass	Building	Envelope insulation					
HW	Passive smart glass: Phase Change Material (PCM)	Building	Envelope insulation					
HW	Cool coverings	Building	Envelope insulation					
HW	Ventilated façade	Building	Envelope insulation					
HW	Shade elements for façades	Building	Envelope insulation					
HW	Heat pump systems: geothermal heat pumps	Building	HVAC systems					
HW	Heat pump systems: air to air	Building	HVAC systems					
HW	Air conditioning	Building	HVAC systems					
HW	Cogeneration	Building	HVAC systems					
HW	Low tech traditional practices of thermal regulation	Building	Climate adaptation					

Table 18: Link of the solutions with the risk element for heatwaves at building level (EXP.= Exposure, SENS.= Sensitivity, COP.= Coping Capacity, ADAPT.= Adaptive capacity and TRANS.= Transformative Capacity)

5.2.1.2 At district or territory level

Code	Name of the solution	Action Scale	Main Function	IMPACT				
				TO REDUCE		TO ENHANCE		
				EXP.	SENS.	COP.	ADAPT.	TRANS.
NBS7	PARKS AND GARDENS	District	Water/flood management					
NBS8	NBS STRUCTURES ASSOCIATED TO URBAN NETWORKS	District	Water/flood management					
NBS9	GREEN WATERFRONT	District	Water/flood management					
NBS15	FLOODPLAIN AND FLOODABLE PARK	District	Water/flood management					
NBS21	Green urban furniture	District	Climate adaptation					
HW	Cool Pavements	District	Urban temperature control					
HW	Shade sails	District	Urban temperature control					
OT2	Crowdsourcing Solutions	Territory	Climate adaptation					

Table 19: Link of the solutions with the risk element for heatwaves at district level (EXP.= Exposure, SENS.= Sensitivity, COP.= Coping Capacity, ADAPT.= Adaptive capacity and TRANS.= Transformative Capacity)

5.2.2 Solutions for flooding

5.2.2.1 At building level

Code	Name of the solution	Action Scale	Main Function	IMPACT				
				TO REDUCE		TO ENHANCE		
				EXP.	SENS.	COP.	ADAPT.	TRANS.
NBS5	INTENSIVE and SEMI-INTENSIVE GREEN ROOF	Building	Water/flood management					
NBS6	EXTENSIVE GREEN ROOF	Building	Water/flood management					

NBS10	STRUCTURAL SOIL	Building	Soil structure stabilization						
NBS12	GREEN PAVEMENTS	Building	Water/flood management						
NBS16	Natural ventilation (and design for)	Building	Building stabilization						
VA6	Foundation drainage methods in vernacular architecture	Building	Soil structure stabilization						
S22	Breakaway walls	Building	Building stabilization						
S23	Pile foundation reinforcement	Building	Building stabilization						
FL1	Temporary flood protection systems: Sandbags (buildings)	Building	Building protection						
FL3	Temporary flood protection systems: shields and panels (building)	Building	Building protection						
FL5	Installation of check systems and pumps (building)	Building	Building protection						
FL11	Sand or gravel basement filling	Building	Foundations stabilization						
FL12	Permanent floodwalls and gates for openings	Building	Building stabilization						
FL13	Surface protection for materials vulnerable to the washing-out effects	Building	Envelope consolidation						
FL14	Wet-floodproofing interventions	Building	Building stabilization						
FL17	Temporary flood protection systems: shields and panels (building)	Building	Building protection						
FL18	Identification of adequate storage facilities for movable heritage	Building	Water/flood management						
FL20	Floating basement	Building	Climate adaptation						
OT1	Back-up power generator	Building	Building protection						

Table 20: Link of the solutions with the risk element for flooding at building level (EXP.= Exposure, SENS.= Sensitivity, COP.= Coping Capacity, ADAPT.= Adaptive capacity and TRANS.= Transformative Capacity)

5.2.2.2 At district or territory level

Code	Name of the solution	Action Scale	Main Function	IMPACT				
				TO REDUCE		TO ENHANCE		
				EXP.	SENS.	COP.	ADAPT.	TRANS.
NBS7	PARKS AND GARDENS	District	Water/flood management					
NBS8	NBS STRUCTURES ASSOCIATED TO URBAN NETWORKS	District	Water/flood management					
NBS9	GREEN WATERFRONT	District	Water/flood management					
NBS11	VEGETATION ENGINEERING SYSTEMS FOR SLOPE EROSION CONTROL	District	Soil structure stabilization					
NBS13	REDESIGN NATURAL AND SEMI-NATURAL WATER BODIES AND HYDROGRAPHIC NETWORK TO LIMIT FLOODS	District	Water/flood management					
NBS14	GREEN AREA FOR WATER MANAGEMENT	District	Water/flood management					
NBS15	FLOODPLAIN AND FLOODABLE PARK	District	Water/flood management					
NBS19	In-channel Tree Felling	Territory	Building protection					
S25	Elevate Building on Piles	Territory	Building consolidation					
FL2	Temporary flood protection systems: Container systems (districts)	District	Building protection					

FL4	Temporary flood protection systems: Free-standing and frame barriers	District	Building protection					
FL6	Installation of check systems and pumps (district)	District	Building protection					
FL7	Early Warning System	Territory	Building protection					
FL8	Seawalls	Territory	Building protection					
FL9	Debris Basin	Territory	Building protection					
FL10	Shoreline structure	District	Building protection					
FL15	Dikes or dams	District						
FL16	Urban floodwalls and barriers	District	Water/flood management					
FL19	Rapid Damage Assessment	Territory	Climate adaptation					
FL21	IMMERSITE®	Territory	Water/flood management					
EA16	Aquadam	District	Building protection					
EA17	Underground drain system	District	Building protection					
WF18	Debris Basin	Territory	Building protection					
OT2	Crowdsourcing Solutions	Territory	Climate adaptation					

Table 21: Link of the solutions with the risk element for flooding at district level (EXP.= Exposure, SENS.= Sensitivity, COP.= Coping Capacity, ADAPT.= Adaptive capacity and TRANS.= Transformative Capacity)

5.2.3 Solutions for earthquakes

5.2.3.1 At building level

Code	Name of the solution	Action Scale	Main Function	IMPACT				
				TO REDUCE		TO ENHANCE		
				EXP.	SENS.	COP.	ADAPT.	TRANS.
VA2	Timber Laced Masonry construction	Building	Building stabilization					
VA5	Load absorbing structural connections between structural elements	Building	Building stabilization					
VA6	Foundation drainage methods in vernacular architecture	Building	Soil structure stabilization					
VA7	Lightweight timber structures	Building	Building stabilization					
VA8	Laced bearing wall construction for citadels	Building	Building stabilization					
VA9	Reinforcement of non-engineered vernacular buildings	Building	Building stabilization					
S1	Vertical Timber Props (Support System)	Building	Structure stabilization					
S2	Vertical Steel Props (Support System)	Building	Structure stabilization					
S3	Sloped Timber Props (Peg contrast system)	Building	Structure stabilization					
S4	Sloped Timber Props (Base contrast system)	Building	Envelope stabilization					
S5	Horizontal Timber Props (Unloading contrast system)	Building	Structure stabilization					
S6	Horizontal Timber props (equal contrast system)	Building	Structure stabilization					
S7	Sloped Steel Props (contrast system)	Building	Structure stabilization					
S8	Steel Props Contrast System	Building	Envelope stabilization					
S9	Timber support system for openings	Building	Structure stabilization					
S10	Steel support system for openings	Building	Structure stabilization					
S11	Timber rib for arches	Building	Structure stabilization					
S12	Steel rib for arches	Building	Structure stabilization					

S13	Timber rib for vaulted structures	Building	Structure stabilization					
S14	Steel rib for vaulted structures	Building	Structure stabilization					
S15	Steel tie rods for arches	Building	Structure consolidation					
S16	External steel tie rods for masonry without crosspieces	Building	Structure stabilization					
S17	Internal steel tie rods for masonry: steel-cased system for walls	Building	Building consolidation					
S18	Polyester hoop system for columns and pillars	Building	Structure stabilization					
S19	Polyester hoop system for building portions	Building	Structure stabilization					
EA1	Kerbs	Building	Structure consolidation					
EA2	Reinforced perforations made with steel bars	Building	Structure consolidation					
EA3	Application of composite materials strips to vaults and arches	Building	Building consolidation					
EA4	Artificial diatons	Building	Structure consolidation					
EA5	Jacketing through composite material strips	Building	Structure consolidation					
EA6	Coccioforte vaults consolidation	Building	Structure consolidation					
EA7	Steel hooping for columns, pillars and beams	Building	Structure consolidation					
EA8	CAM hooping for columns, pillars and beams	Building	Structure consolidation					
EA9	FRP hooping for columns, pillars and beams	Building	Structure consolidation					
EA10	Expansion of foundation system	Building	Foundations stabilization					

Table 22: Link of the solutions with the risk element for earthquakes at building level (EXP.= Exposure, SENS.= Sensitivity, COP.= Coping Capacity, ADAPT.= Adaptive capacity and TRANS.= Transformative Capacity)

5.2.3.2 At district or territory level

Code	Name of the solution	Action Scale	Main Function	IMPACT				
				TO REDUCE		TO ENHANCE		
				EXP.	SENS.	COP.	ADAPT.	TRANS.
EA11	EEWS: PRESTo	Territory	Building protection					
OT2	Crowdsourcing Solutions	Territory	Climate adaptation					

Table 23: Link of the solutions with the risk element for earthquakes at district level (EXP.= Exposure, SENS.= Sensitivity, COP.= Coping Capacity, ADAPT.= Adaptive capacity and TRANS.= Transformative Capacity)

5.2.4 Solutions for subsidence

5.2.4.1 At building level

Code	Name of the solution	Action Scale	Main Function	IMPACT				
				TO REDUCE		TO ENHANCE		
				EXP.	SENS.	COP.	ADAPT.	TRANS.
NBS10	STRUCTURAL SOIL	Building	Soil structure stabilization					
S1	Vertical Timber Props (Support System)	Building	Structure stabilization					
S2	Vertical Steel Props (Support System)	Building	Structure stabilization					
S9	Timber support system for openings	Building	Structure stabilization					
S10	Steel support system for openings	Building	Structure stabilization					
S11	Timber rib for arches	Building	Structure stabilization					
S12	Steel rib for arches	Building	Structure stabilization					

S13	Timber rib for vaulted structures	Building	Structure stabilization						
S14	Steel rib for vaulted structures	Building	Structure stabilization						
S20	Resin Injections	Building	Foundations consolidation						
S21	grouting	Building	Foundations consolidation						

Table 24: Link of the solutions with the risk element for subsidence at building level (EXP.= Exposure, SENS.= Sensitivity, COP.= Coping Capacity, ADAPT.= Adaptive capacity and TRANS.= Transformative Capacity)

5.2.4.2 At district or territory level

Code	Name of the solution	Action Scale	Main Function	IMPACT					
				TO REDUCE		TO ENHANCE			
				EXP.	SENS.	COP.	ADAPT.	TRANS.	
OT2	Crowdsourcing Solutions	X	Climate adaptation						

Table 25: Link of the solutions with the risk element for subsidence at district level (EXP.= Exposure, SENS.= Sensitivity, COP.= Coping Capacity, ADAPT.= Adaptive capacity and TRANS.= Transformative Capacity)

5.2.5 Solutions for wildfires

5.2.5.1 At building level

Code	Name of the solution	Action Scale	Main Function	IMPACT					
				TO REDUCE		TO ENHANCE			
				EXP.	SENS.	COP.	ADAPT.	TRANS.	
WF8	Sodium bentonite-based coating	Building	Building protection						
WF10	Fire Hydrant	Building	Building protection						
WF13	Sprinkler	Building	Building stabilization						
WF14	Early Warning System: building level	Building	Building stabilization						
WF22	Fire Curtains	Building	Building protection						

Table 26: Link of the solutions with the risk element for wildfires at building level (EXP.= Exposure, SENS.= Sensitivity, COP.= Coping Capacity, ADAPT.= Adaptive capacity and TRANS.= Transformative Capacity)

5.2.5.2 At district or territory level

Code	Name of the solution	Action Scale	Main Function	IMPACT					
				TO REDUCE		TO ENHANCE			
				EXP.	SENS.	COP.	ADAPT.	TRANS.	
NBS17	Contour-felled logs (LEBs)	Territory	Building protection						
NBS18	Straw wattles	Territory	Building protection						
NBS19	In-channel Tree Felling	Territory	Building protection						
NBS20	Firebreak	Territory	Building protection						
FL9	Debris Basin	Territory	Building protection						
FL19	Rapid Damage Assessment	Territory	Climate adaptation						
WF2	Checdam	Territory	Barriers to erosion						
WF3	Straw mulches	Territory	Building protection						
WF4	Wood mulches	Territory	Building protection						
WF5	Hydromulches	Territory	Building protection						

WF6	polyacrylamide PAM as soil binder	Territory	Building protection					
WF7	Silt Fence	Territory	Building protection					
WF9	Grade Stabilizer	Territory	Building protection					
WF11	Cleaning under high voltage lines	Territory	Building protection					
WF12	Design access paths	Territory	Building protection					
WF15	Early Warning System: territory level	Territory	Fire spread control					
WF16	Stream Bank Armoring	Territory	Building protection					
WF17	Road decommissioning	Territory	Barriers to erosion					
WF18	Debris Basin	Territory	Building protection					
WF19	Culvert Modification	Territory	Building protection					
WF20	Debris Rack and Deflectors	Territory	Building protection					
WF21	Trail Stabilization	Territory	Building protection					
WF23	Controlled weed burning	Territory	Fire spread control					
WF24	Reforestation	Territory	Reforestation					
WF25	Prohibition of stubble burning in fire risk condition	Territory	Fire spread control					
WF26	Biomass management	Territory	Fire spread control					
OT2	Crowdsourcing Solutions	Territory	Climate adaptation					
WF27	Cleaning under high voltage lines	Territory	Fire spread control					

Table 27: Link of the solutions with the risk element for wildfires at district level (EXP.= Exposure, SENS.= Sensitivity, COP.= Coping Capacity, ADAPT.= Adaptive capacity and TRANS.= Transformative Capacity)

5.2.6 Solutions for storms

5.2.6.1 At building level

Code	Name of the solution	Action Scale	Main Function	IMPACT				
				TO REDUCE		TO ENHANCE		
				EXP.	SENS.	COP.	ADAPT.	TRANS.
VA7	Lightweight timber structures	Building	Building stabilization					
S22	Breakaway walls	Building	Building stabilization					
S23	Pile foundation reinforcement	Building	Building stabilization					
S24	Load Paths	Building	Structure consolidation					
EA13	Rapid installation panels shutter	Building	Envelope stabilization					

Table 28: Link of the solutions with the risk element for storms at building level (EXP.= Exposure, SENS.= Sensitivity, COP.= Coping Capacity, ADAPT.= Adaptive capacity and TRANS.= Transformative Capacity)

5.2.6.2 At district or territory level

Code	Name of the solution	Action Scale	Main Function	IMPACT				
				TO REDUCE		TO ENHANCE		
				EXP.	SENS.	COP.	ADAPT.	TRANS.
S25	Elevate Building on Piles	Territory	Building consolidation					
FL8	Seawalls	Territory	Building protection					
FL10	Shoreline structure	District	Building protection					
FL15	Dikes or dams	District						
EA14	Storm detector	District	Building protection					

EA15	Lightning rod	District	Building protection					
EA16	Aquadam	District	Building protection					
EA17	Underground drain system	District	Building protection					
OT2	Crowdsourcing Solutions	Territory	Climate adaptation					

Table 29: Link of the solutions with the risk element for storms at district level (EXP.= Exposure, SENS.= Sensitivity, COP.= Coping Capacity, ADAPT.= Adaptive capacity and TRANS.= Transformative Capacity)

6 Conclusions and future work

The “HA systemic Resilience Index” (T2.7) apart from producing an indicator-based resilience assessment also aimed to wrap up the methodological framework and transfer it to other WPs producing an update of the framework that was proposed at the beginning of the project to make it more operative for end-users and more replicable. The proposition of the workflow for the Decision Support System (DSS) and an initial categorization of the impact of the solutions to be used by this DSS has the objective also to facilitate the transfer of the methodological developments.

The original structure of the framework proved to be very useful for the articulation of the developments of the projects, but it was necessary to update it to transfer it to the end-user for resilience planning. The comparison and study of selected frameworks, coming from different fields (CCA, DDR and CHN) but focused on offering specific guidelines to local authorities allowed us to identify several conclusions for the definition of our framework:

- Governance and financial planning is key for the implementation since the engagement of the key stakeholders and citizens and the securing of enough resources to implement strategies are requirements for any successful implementation.
- A team with clear responsibilities has to be appointed for the beginning
- Assessing the risk to prioritise and plan is a crucial but challenging steps
- The recovery and building back better phase is not as defined as other phases
- Planning for resilience should be an iterative process where a robust and operative monitoring strategy is key.
- The importance of the characterisation of the system as a whole (SES approach) is frequently overlooked. In HA it should be focused on defining the CNH as a valuable and sensitive receptor including their specific values and vulnerabilities.

The Resilience Index has been conceived as an easy to use tool and a self-assessment methodology able to measure the capacity of HA to adapt, cope and transform to better respond to hazards. The methodology for the establishment of the qualitative indicators especially considers in its assessment the nature and the specific components and characteristics of the Historic Area and, by considering resilience in a broader sense, has been designed in order not to be hazard dependent.

The Resilience Index is calculated as the sum of the different types of resilience considered by the project: cultural, economic & environmental, governance & institutional, the historic built environment and social resilience to allow end-users to easily identify strengths and weaknesses and better focus future improvement strategies.

Considering as a basis the indicators framework previously developed in the project and the continuous evolution of the work and its validation with OLs, this list brings together all the SHELTER fundamentals approach to resilience as well as the progress achieved in the assessment of risk components together with the experience of OLs. According to this, a quantitative approach to the Resilience Index is proposed, to allow OLs to monitor those indicators which have particular relevance for their area and consider the information they are already collecting for the risk assessment calculation.

To characterise the risk reduction and resilience enhancement solutions selected in WP3¹⁶ regarding their impact in the different hazard elements (reduction of exposure and sensitivity and enhancement of coping, adaptive and transformative capacity) has shown some limitations of the developed Portfolio of Solutions to address an impact in all hazards and risk elements. To overcome this limitation the possibility of including the catalogue of solutions created in the ARCH project in the DSS will be explored in T5.4.

¹⁶ SHELTER deliverables “D3.3: Consolidation and structural stabilization in emergency phases” and “D3.4: Portfolio to improve CH buildings and sites”

7 References

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