



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



### **D.2.1. HA Resilience structure**

<i>Version number</i>	1
<i>Dissemination level</i>	pu
<i>Lead partner</i>	Tecnalia
<i>Due date</i>	30.11.2019
<i>Type of deliverable</i>	report
<i>Status</i>	delivered

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*This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821282*

### Published in the framework of:

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

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### Revision and history chart:

VERSION	DATE	AUTHOR/EDITOR	COMMENT
0.1	27/09/2019	TEC	Table of content
0.2	18/11/2019	TEC, IHED, ULIEGE	Advanced draft
0.3	26/11/2019	TEC, POLITO, LINKS, ULIEGE, UPV/EHU	Reviewed version
1.0	29/11/2019	TEC	Final version

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## Glossary

Acronym	Full name
CA	Consortium Agreement
CCA	Climate Change Adaptation
CH	Cultural Heritage
CHM	Cultural Heritage Management
DoA	Description of Action
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
EC	European Commission
HA	Historic Area
RCA	Root-cause analysis
SD	Sustainable development
WP	Work Package

## 1 Executive summary

The objective of the work described in this deliverable was to establish the conceptual base for the posterior methodological and technical developments of the project. This conceptual base was achieved by defining the concept of resilience in historic areas, establishing the strategy for its assessment, designing the architecture of the operational knowledge framework that will improve it and finally assigning the role of the Open Labs as co-creators and validators of the framework. This conceptual base aims to ensure that the outputs from SHELTER will share a common understanding of the special nature of the concept of resilience in cultural heritage and historic built environments, considering the different dimensions, characteristics and scales of resilience in historic areas.

The results of this deliverable are based in a critical review of the existing literature regarding building/urban/territorial, community and disaster resilience. The length of the existing literature and its fragmentation has made necessary to start with a first review of the literature to establish the SHELTER approach to resilience, keeping always from the cultural heritage and historic areas perspective: proposing a workable definition of resilience for historic areas, gathering the existing characteristics of resilience in order to identify their link with historic environments for a heritage-led resilience, defining the dimensions of the resilience and their singularity regarding cultural heritage, defining the scales and the considered hazards and establishing the requirements for the SHELTER assessment of systemic resilience and the operative knowledge framework

Once that the dimensions, scales, and requirements were defined, a second literature review was designed. The objective was to identify the relevant papers that could contribute to the result of the project and to frame this knowledge in the structure of the project.

This deliverable has set the conceptual basis for the resilience improvement of historic areas that has to be validated and fine-tuned through the Open labs. The next logical step is the quantification of these concepts through the indicators that have going to be developed latter in the project.



## 2 Introduction

### 2.1 Aims and objectives

Extreme events and climate change affect different societal and environmental sectors and cultural heritage (CH) is one of them, being Europe outstanding in cultural richness (47,07% of sites listed in UNESCO's World Heritage List-WHL<sup>1</sup>). There are roughly 207 million buildings in Europe and statistics reveal that 14% of EU-27 building-stock dates before 1919, other 12% between 1919 and 1945, being almost 54 million buildings constructed before 1945 [1]. Even if only a reduced number of these buildings are formally protected and listed buildings (5% of the total building stock before 1945), around 30% has an historic value and form a part of Europe's typical landscape. But resilience of historic areas (HA) cannot be just limited to historic building stock, it must be addresses from a broader perspective (e.g. including the singularities of archaeological sites, cultural landscapes or intangible cultural heritage). World Heritage List has 440 cultural European sites (111 cities, 19 earthen architecture sites, 53 cultural landscapes and 15 transboundary), but they are only one small percentage of nationally listed historic areas (even smaller if we consider the ones valued by the community).

SHELTER is expected to achieve the establishment of a world-class operational knowledge framework linking the scientific community, the conservators & heritage managers international community and citizens under the overall aim of managing cultural heritage within community- and knowledge-based criteria leading to maximising resilience, reducing vulnerability and building back better and safer in historic areas with respect to climate change and other natural hazards.

In order to make operable such fluid and multifaceted concepts as resilience and cultural heritage, SHELTER will be based on a solid integrated frame definition to allow interdisciplinary research and capitalisation of existing knowledge. This deliverable aims to be the base for further SHELTER project developments by:

- Establishing the SHELTER concept and definition for resilience in HA
- Defining the base for the assessment of systemic resilience in HA
- Defining the architecture of the SHELTER operative knowledge framework

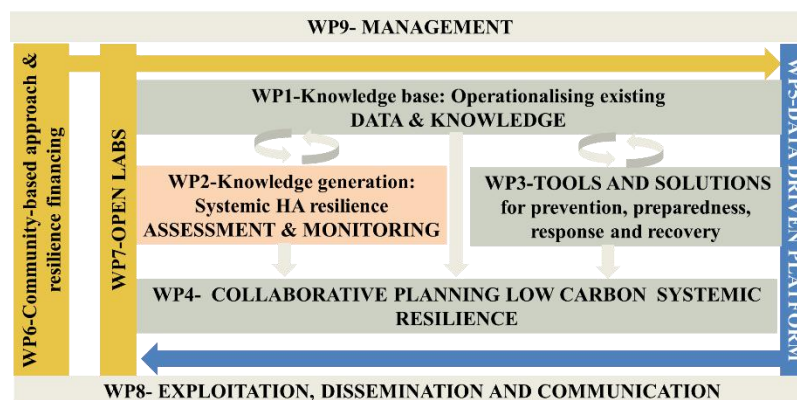
The objective is to ensure that the results from SHELTER will share a common understanding of the special nature of the concept of resilience in cultural heritage and historic built environments, considering the different dimensions, characteristics and scales of resilience in HA.

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<sup>1</sup> <https://whc.unesco.org/en/list/>

## 2.2 Relations to 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 Figure 1):



**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), establishes the base of the resilience assessment and the architecture of the framework. This task will frame all the development of WP2, especially the knowledge generation methodology to build the systemic 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. This task has a strong relation with all the WPs in SHELTER project, since it establishes the basis for the results of the project. The main relationships are the following:

- While T2.1 is generating the conceptual framework for SHELTER, **WP1** (Knowledge base: operationalising existing data and knowledge) is generating the knowledge base through operationalizing existing data, information and (local) knowledge available and usable. T2.1 will define the role of the information and knowledge management defined in T2.3 (Data lake) and T2.4 (Multiscale data model). Moreover, the literature review carried out in this task will feed T1.2 (Codification of existing knowledge).
- The definition of the architecture of the operative framework will allow the establishment of the strategy for the integration of the different project results (**WP3**-Tools and solutions for prevention, preparedness, response, recovery and recovery and WP5-Data Driven Platform) in the SHELTER operative knowledge

framework that is going to be developed in **WP4** (Collaborative planning for building low carbon systemic resilience)

- This task also defines and establishes the role of Open Labs within the SHELTER operational knowledge framework guiding the work of **WP6** (Community approach and resilience financing) and **WP7** (Open Labs)

## 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 methodology followed to build the backbone of the assessment of systemic resilience and SHELTER Operational Framework
- **Section 4** establishes the SHELTER approach and methodology
- **Section 5** describes the design of the literature review and its results
- **Section 6** establishes the backbone of the systemic resilience
- **Section 7** establishes the architecture of the operational knowledge framework
- **Section 8** establishes the workflow for developing the framework
- In **Section 9** the conclusions are drawn

## 2.4 Contribution of partners

The following table (Table 1) details the contribution of each partner:

Partner	Contribution
TEC	Responsible for the coordination of the task and deliverable. Responsible for definition of the methodology. Drafting of Section 1, 2, 3, 4, 5, 6 and 8.
UNIBO	Contributions to literature review.
UNESCO	Contributions to literature review.
POLITO	Contributions to literature review. Review of the whole document.
ULIEGE	Contributions to literature review. Drafting of Section 7.
UPV/EHU	Contributions to literature review.
IHED	Contributions to literature review. Drafting of Section 7.
LINKS	Review of the whole document.
CRCM	Contributions to literature review.
EGIS	Contributions to literature review.

**Table 1:** Contribution of partners

### 3 Methodology

Knowledge and evidence-based approaches and solutions cannot be implemented without a solid and multi-disciplinary knowledge base. The results of this deliverable are based in a critical review of the existing literature regarding building/urban/territorial, community and disaster resilience. The length of the existing literature, the fragmentation of the knowledge and the fuzziness of the resilience concept has made necessary to start with a first review of the literature to establish the SHELTER approach to resilience in order to:

- Establish the SHELTER definition of resilience for HA
- Gather the existing characteristics of resilience in order to identify their link with historic environments for a heritage-led resilience
- Define the dimensions of the resilience and their singularity regarding cultural heritage
- Define the scales and the considered hazards
- Establish the requirements for the SHELTER assessment of systemic resilience and the operative knowledge framework

Once that the dimensions, scales, and requirements were defined, a second literature review was designed. The objective was to identify the relevant papers that could contribute to the result of the project and to frame this knowledge in the structure of the project. The design and results of this second literature review are described in Section 5.

## 4 SHELTER approach and concept

Current disaster statistics and studies usually do not consider heritage as a sensitive and valuable element of the living environment, even though it is being affected by the increasing in frequency and intensity of climate-related events, such as flooding, storms and drought in addition to other destructive natural phenomena, such as earthquakes, creating a situation that poses new challenges and needs to conservators and heritage managers. Although culture is now explicitly recognised as a key dimension of DRM and the need to protect and draw upon the various benefits of heritage as an asset for resilience is more clearly highlighted with a few notable exceptions, policies to protect heritage from disaster risk remain fragmented, while efforts to learn from heritage and traditional knowledge for building resilience remain ineffective. Consequently, and even if the relation between climate change and increase in disasters frequency is acknowledged by the society and the scientific and policy-making communities, the increasing risk and impacts of climate change on cultural heritage are hardly addressed through effective DRM plans. DRM and Climate Change Adaptation (CCA) strategies share common approaches and methodologies around concepts such as resilience, vulnerability and capacity. It is necessary to build on national, European and international synergies and similarities already established while integrating inclusion of cultural heritage into the wider framework of sustainable development.

### 4.1 Defining resilience

In the last years the concept of resilience has become a buzzword partially substituting the omnipresent sustainability concept when describing optimal and desirable states for our building environment. This may be due to the challenges posed by climate change and the raising perspective of cities as complex socioeconomic systems [2]. **SHELTER project can be in the intersection between urban/territorial resilience, community resilience and disaster resilience.** The fuzziness, intersectionality and heterogeneous roots of these concepts have triggered various attempts to re-define and operationalise them [2]–[10].

There are different views of resilience as an action in response to specific risks or as a vision from systemic evolution lens and self-organization [8]. The work of Folke (2006) describes the evolution of the concept, from "*the more narrow interpretation to the broader social-ecological context*" [11] as it can be seen in the following figure Table 2:

Resilience concepts	Characteristics	Focus on	Context
Engineering resilience	Return time, efficiency	Recovery, constancy	Vicinity of a stable equilibrium
Ecological/ecosystem resilience social resilience	Buffer capacity, withstand shock, maintain function	Persistence, robustness	Multiple equilibria, stability landscapes
Social–ecological resilience	Interplay disturbance and reorganization, sustaining and developing	Adaptive capacity transformability, learning, innovation	Integrated system feedback, cross-scale dynamic interaction

**Table 2:** A sequence of resilience concepts, from the more narrow interpretation to the broader social–ecological context according to Folke (2006) [11]

Therefore, a general and specified resilience can be differentiated. **Specified resilience** is when the socio-ecological system is addressing problems arising from particular hazards affecting specific components. **Generalised resilience** is when resilience to all kinds of shocks and disturbances (including unknown ones) want to be addressed [3]. It is important to keep the focus in both perspectives to not lose resilience in parts of the systems [12]. Moreover, a hazard specific resilience, risk and vulnerability assessments can use direct quantitative and spatial approaches for prioritization and identification of specific “hot spots” making it especially beneficial for the protection of historical built environment (conservation-friendly resilience).

General resilience is a much fuzzier concept, dependent of the vulnerability of the system but also its adaptive, learning and self-organization capabilities that could be difficult to assess quantitatively and make it actionable. But it is also a **transdisciplinary bridge** [2] that can function as a central unifying concept for the fields of DRM, CCA, cultural heritage Management and Sustainable Development (SD). It is also transversal to human and environment, and allows focusing on relevant interactions, thus, bridge disciplinary approaches through a transdisciplinary perspective. It can be suitable for a heritage-led resilience enhancement assessment because of its focus on the transformation processes (how societies cope with uncertainty, adapt to new situations and transform to new environmental, social, economic conditions to make the new system more sustainable while retaining their identity). To address both of the concepts is important, since practitioners tend to focus only in specified resilience narrowing options for dealing with new hazards and shocks [2].

The operationalisation of the concept of resilience, that is how we can close the gap between the theory and the practice is one of the main objectives of some of the most notable effort in the resilience literature of the last years. As Manyena et al. (2019) described [7] “*how do we operationalize resilience in policy and practice? The epistemological assumptions that underlie, as well as shape, and sometimes constrain, the conceptualisation, purpose and content of resilience, are slowly giving way to assumptions that more accurately reflect how resilience is operationalised in various contexts*”

Resilience has been define also as “capacity” given that the majority of the definitions of resilience associate it with the “capacity” of a community exposed to a destabilising event *“to do something’ positive before, during and after the destabilising event in order to reduce its impact”* [7]

Inspired in these works, Resilience in historic areas in the within **SHELTER** project can be defined 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 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”***

In this definition, resilience is dynamic and recognises:

- The multidimensionality of HA that includes cultural, environmental, economic, social, governance together with the physical resilience of the historic build environment.
- The HA as complex and adaptative systems [13].
- The heritage-led resilience that exploits the inherent resilience characteristics of HA (self-learning capacities, circular economy approaches, intrinsic sustainability, multi-stakeholder integration, redundancy, resourcefulness and flexibility).
- The conservation-friendly resilience that to ensure the balance between cultural identity preservation and adaptation to new requirements while taking into account the higher vulnerability of materials and structures, accessibility difficulties, density of the urban fabric, material and cultural values compatibility requirements and traditional lifestyles).
- The cross-scale resilience that acknowledges the different temporal and spatial scales.

This definition will be validated and updated if necessary, in the Open Labs in the second cycle of workshops (between M10-M12) <sup>2</sup>.

## 4.2 Characteristics of resilience in HA

Cultural heritage and resilience concepts, both have broadened considerably in the last decades. Since the Venice Charter of 1964, the management of cultural heritage has included environmental, economic and social factors, which stand away from the past conservation of objects and sites as end in themselves. According to this new paradigm of cultural heritage preservation, the protected heritage is not only defined in a multidimensional way, but also as continuous in the territory (from the artefact/object

<sup>2</sup> Del 9.2 Open Labs Management Plan due by month 6



to the trans-regional cultural landscapes) and shaped by the perception of its local community. Similarly, as we have seen previously, the concept of resilience has evolved from an engineering perspective, where the objective is to return to the initial hypothetical status, to a much broader, humanistic and comprehensive one where the objective is the adaptation and transformation of socio-ecological systems to a more sustainable status. Within this new paradigm, resilience building of CH environments and HA is not linear but a dynamic and iterative process influenced by forces across spatial and temporal scales where a sustainable management of change is required and the ordinary dynamics of HA has to be combined with exceptional changes due to extreme events. The resilience thinking paradigm requires also a change from mechanistic views to most organic vision of HA as complex adaptive systems, process dependent, multidimensional, multiagent, multi-scalar and with self-organizing capabilities.

Resilience phenomenon in HA is still not effectively approached or even theoretically supported [14]. Historic environments are singular from vulnerability and resilience perspective. They have inherent resilience characteristics that have been tested along centuries that **can trigger a cultural and natural heritage-led resilience enhancement**, but also specific characteristics that makes them more vulnerable against hazards and disruptions that **makes mandatory a conservation friendly resilience**. The following table summarises some of the resilience characteristics gathered from the literature and its implications for the heritage-led resilience in HA (see Table 3):

Characteristics of the notion of resilience	Literature	HERITAGE-LED RESILIENCE
Robustness Strength	[11] [15] [16] [17] [18]	The survival of the HA until modern times shows the capacity of these environments to recover from past disasters. The social memory and local knowledge result of this history has to be gathered and operationalise.
Flexibility Adaptability Adaptive Capacity Learning capacity Autonomy Room for autonomous change Reflexivity	[11] [15] [16] [18] [17] [19] [20] [21] [22] [18]	HA are results of evolution processes to adapt to the requirements of each epoch. The strategies to improve the resilience must include and respect the result of these processes (local techniques, selection of materials and construction cultures) but they also need to learn from the flexibility and adaptability of changing conditions that create these results.
Living with uncertainty Social memory	[23] [24] [25]	Generalised resilience requires to learn to live with uncertainty (“expecting the unexpected”) and to build a memory of past events in order to build the capability to learn from crisis and disasters. Long-enduring urban environments as HA have developed adaptations to deal with these disturbances, using social memory as key part of the system resilience.
Self-organisation	[24] [23] [26]	The HA have been during a significant part of their story an example of urban self-organisation. Similarly, to nature’s cycles involving renewal



		and reorganization the resilience of a system is closely related to this capacity for self-organization.
Diversity Variety Inclusive Fair governance Collaboration Social capital	[17] [27] [20] [21] [23] [18]	In ecological systems, diversity provides the conditions for new opportunities in the renewal cycle so the diversity of stakeholder's partnership and arrangement already created around the heritage conservation in HA can be used to bring diversity of views and considerations in to the discussion expanding the role of information, education, and dialogue.
Cross-scale dynamic	[11] [25]	Response to challenges as climate change and disasters require of building cross-scale management capabilities, similar to the ones necessary for urban conservation.
Resourceful Efficiency	[17] [19] [18] [20] [21]	HA has shown effective ways to construct and design functional urban environments with local and durable materials. New resilient strategies should manage the changing process to keep this identity, considering issues such as maintenance, life-cycle, durability and compatibility of the materials, local construction techniques...taking into account the singularity of CH physical vulnerability framed in a broader concept of multidimensional HA resilience
Intersectorality Integrated	[19] [18]	Urban conservation policies and strategies always have required from integrated visions in order to include all the needed competences. The improvement of resilience in HA is going to need to continue with this tradition and include new department and sectors in the decision making.
Innovation Combining different kinds of knowledge for learning Interdependence	[27] [23] [17]	Cultural heritage field has always needed the bringing of different kinds of knowledge together. The focus on the complementarity of these knowledge can help to increase the capacity to learn. Climate change and urban conservation can be used as an example to illustrate the potential contributions of local and traditional knowledge.

**Table 3:** Summary of characteristics describing the notion of resilience and their implications for SHELTER

### 4.3 Multidimensional resilience

Resilience is a multi-faceted aspect, so an ideal resilience assessment framework should address all different dimensions of an urban system [8].

DIMENSIONS OF HA RESILIENCE	
<b>Historic building environment resilience</b>	How the historic building environment addresses disruption, affordable comfort, structural security through traditional techniques, vernacular architecture and built/unbuilt environment relationships and its relevance as container and management unit for other CH scales (as movable CH)
<b>Cultural resilience</b>	How HA addresses social inclusion and supports social and technical innovation through cultural identity, local knowledge, intangible CH and openness to exploring novel pathways.
<b>Social resilience</b>	How individual's physical and psychological well-being are addressed within the HA and strong and healthy personal relationships, connection to culture and nature and learning and sharing new skills are enabled.
<b>Governance and institutional resilience</b>	How links and partnerships are created and managed with support networks and across sectors (including public sector/government, research and business)

<b>Economic resilience</b>	How the creation of a different sort of local economy can positively stewards the local environment and resources to enhance biodiversity, cut carbon dependence and creates meaningful locally based livelihoods.
<b>Environmental resilience</b>	

**Table 4:** Dimensions of HA resilience

Parson et al. (2016) [23] identified the following dimension: social character, economic capital, infrastructure and planning, emergency services, community capital, information and engagement, governance, policy and leadership, and social and community engagement. The following table shows the detailed link that the authors made of these themes with the resilience and how they are related SHELTER dimensions:

Theme definition		Description of theme	Relationship to resilience	SHELTER DIMENSION						
				HBR	CR	SR	GIR	ECR	ENR	
<b>Social character</b>	The social characteristics of the community.	Represents the social and demographic factors that influence the ability to prepare for and recover from a natural hazard event.	Gender, age, disability, health, household size and structure, language, literacy, education and employment influence abilities to build disaster resilience [28] [29]							
			Cooperation and trust are essential to building disaster resilience and arise partly through social mechanisms including social capital [24], [30]							
<b>Social and community engagement</b>	The capacity within communities to learn, adapt and transform.	Represents the social enablers within communities for engagement, learning, adaptation and transformation.	Behavioral change has a social and cultural context [31] [32]							
			Social networks assist community recovery following disaster [33]							
<b>Community capital</b>	The cohesion and connectedness of the community.	Represents the features of a community that facilitate coordination and cooperation for mutual benefit.	Bonding, bridging and linking social capital can enhance solutions to collective action problems that arise following natural disasters [34]							
			Access to economic capital may be a barrier to resilience [35]							
<b>Economic capital</b>	The economic characteristics of the community	Represents the economic factors that influence the ability to prepare for and recover from a natural hazard event.	Losses from natural hazards may increase with greater wealth, but increased potential for loss can also be a motivation for mitigation.							
			Economic capital often supports healthy social capital [29]							
<b>Infrastructure and planning</b>	The presence of legislation, plans, structures or codes to protect infrastructure.	Represents preparation for natural hazard events using strategies of mitigation or planning or risk management.	Considered siting and planning of infrastructure is an important element of hazard mitigation. Multiple levels of government are involved in the planning process [36] [37]							
			Planners can be agents of change in building disaster resilience [38]							
<b>Emergency services</b>	The presence of emergency services and disaster response plans.	Represents the potential to respond to a natural hazard event.	Emergency response capabilities and systems support resilience through the PPRR (prevention, preparedness, response and recovery) cycle [39]							

<b>Information and engagement</b>	Availability and accessibility of natural hazard information and community engagement to encourage risk awareness.	Represents the relationship between communities and information, the uptake of information about risks and the knowledge required for preparation and self-reliance.	Emergency management community engagement comprises different approaches including information, participation, consultation, collaboration and empowerment.						
			Community engagement is a vehicle of public participation in decision making about natural hazards [40]						
<b>Governance, policy and leadership</b>	The capacity within government agencies to learn, adapt and transform.	Represents the flexibility within organizations to adaptively learn, review and adjust policies and procedures, or to transform organizational practices.	Effective response to natural hazard events can be facilitated by long term design efforts in public leadership [41] [42]						
			Transformative adaptation requires altering fundamental value systems, regulatory or bureaucratic regimes associated with natural hazard management [43]						
			Collaborative learning facilitates innovation and opportunity for feedback and iterative management [44] [21]						

**Table 5** Themes of resilience and their relationships natural hazard resilience according to [23] HBR= Historic building environment resilience; CR= Cultural resilience; SR=Social resilience; GIR=Governance and institutional resilience; ER=Economic resilience; ENR= Environmental resilience)

SHELTER has a CH centred vision, aiming to be cost-effective in the development of specific approaches only when the singularity of HA makes it mandatory and reuse and adapt concepts already more developed in other fields whenever it is possible. The following table shows the dimensions of HA resilience, the SHELTER approach and the singularity in HA of the dimension (see Table 6):

DIMENSION	SHELTER APPROACH	SINGULARITY
<b>Historic building environment resilience</b>	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.	<b>Very High</b>
<b>Cultural resilience</b>	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.	<b>Very High</b>
<b>Social resilience</b>	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	<b>High</b>

	to HA as depopulation and gentrification will be tackled in reconstruction phase).	
<b>Governance and institutional resilience</b>	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.	<b>High</b>
<b>Economic resilience</b>	SHELTER will foster local economy boosting and territory activation through innovation (including insurance perspective). Economic impact of disasters will consider intangible values.	<b>Medium</b>
<b>Environmental resilience</b>	SHELTER will propose circular approaches and sustainable reconstruction.	<b>Medium</b>

**Table 6:** Dimensions and SHELTER approach

#### 4.4 Multiscale resilience

Cultural heritage, in all its forms and nature, has a multiscale character. 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 structure the SHELTER conceptual framework, 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**. This categorization allows for analysing the degree of certainty regarding the hazards at different spatial scales, as methods used to assess resilience in these two spheres varies.

Methods, methodologies and tools used to assess cultural heritage resilience depend on both the type of hazard as well as on type of heritage considered. If the study or research is addressing a specific object or building or is considering a territory with several elements, the type of analysis and the results representation will vary accordingly. When addressing an object or a building, leaving aside the size it may have, resilience is assessed on the specificities or characteristics of this particular heritage and thus are much more detailed in terms of, among others, materials and/or structural characteristics, decay mechanisms, microclimate analysis and associated cultural values. Research methods often comprise scanning, sampling, monitoring and simulation. On the other hand, when addressing a large area comprising several type of heritage elements, research methods are based on typologies creation and extrapolation of available information. Research approach are therefore more oriented to elements inventory, clustering, use of remote sensing technologies and indicators development.

When addressing the severity of the hazard, methodologies used at both scales do not vary considerably, as hazards usually have impact on larger areas and not on a specific object or building. Hazards impacts may be predictive, considering a probabilistic approach of events occurrence or future scenarios or can be based on the analysis of past events to derive the possible damages based on past experiences. Both methodologies can apply to the object/building scale and the urban/territorial scale.

When a specific hazard or multiple hazards are addressed two approaches to determine cultural heritage resilience predominate: i) both the object/building scale and the urban/territorial level are case studies driven. Even the methodology can be extrapolated to other locations, methodologies arise or have been validated in a specific location; ii) resilience is evaluated in a concrete and specific typology of heritage as the response to an impact highly depends on the behaviour of a material or constructive type, independently of the location.

#### 4.5 Multi-risk resilience

Risks to HA are dependent on the nature, specific characteristics, inherent vulnerability and geographical environment of the site. Because of climate change, catastrophic events are increasing in frequency and intensity, leading to increase in CH losses. Conservation has traditionally been dealing with deterioration mechanisms related to materials and works of art but has rarely applied to analyse and predict emergency and sudden damages interventions.

In the NatCatSERVICE database, 2.250 natural loss events in Europe have been registered since 1990 (see Table 7), being the storm and floods the most recurrent ones (46,90% and 31,80%) and the events with more overall losses (having the floods a bigger loss per event ratio and the storms a much higher percentage of insured losses). Losses are not limited to property and infrastructure; since 1990, around 150.000 lives have been lost due to natural disasters: 94,60 % of these have been caused by climatological events, predominantly heat waves [45]. Moreover, loss estimates are lower bound as many impacts, such as loss of human lives, cultural heritage, and ecosystem services, are difficult to value and monetize, and thus they are poorly reflected [46]. Specifically, there are no reliable available data that would determine the share of CH losses, not only due to a lack of data collecting but also due to a lack of methodology for assessing damage in monetary terms considering CH values [14].

Type of event	Percentage distribution for relevant natural events in Europe and associated losses (1990 – 2017)								SHELTER Case study	Regional representativeness
	No. events	%	Overall losses (\$)	%	Insured losses (\$)	%	Fatalities	%		
<b>Geophysical</b> <i>Earthquakes</i>	97	4,30	57,39	11,50	3,36	2,10	1.023	0,70	Ravenna Seferihizar	Mainly Southern countries
<b>Meteorological</b> <i>Storms</i>	1.055	46,90	170,66	34,20	99,04	61,90	2.924	2,00	Dordrecht	Atlantic and boreal areas
<b>Hydrological</b> <i>Floods</i>	715	31,80	174,15	34,90	45,60	28,50	3.947	2,70	Dordrecht Sava river Basin	Central-Eastern Europe
<b>Climatological</b> <i>Heat wave, Wildfire, Subsidence</i>	383	17,00	37,43	7,50	12,00	7,50	138.289	94,6	Ravenna Seferihizar Baixa	Mediterranean areas
<b>TOTAL</b>	2.250		499,00		160,00		146.183			

**Table 7:** Events in Europe and associated losses (1990-2017) (Data source: NatCatSERVICE database)

According to the IPCC global warming will result in increases in frequency and intensity of weather extremes[47]. The German Association of Insurers (GDV) modelled future insured losses caused by climate change, especially storms and floods, on a basis of the current property insurance portfolio in Germany. The results showed that, for example, it is expected that the losses caused by convective storms in the summer will increase by 25% on average over the next 30 years, and for the period 2041–2070 they are expected to increase by 61%. Flood events causing losses of €750 million, which are currently expected every 50 years, will become about 20-year events within the next 30 years [48].

SHELTER will generate knowledge regarding the hazards with more impact in CH through five case studies that cover earthquakes, storms, floods, heat waves, wildfire and subsidence. 3 of the cases are multi-hazard situations and 2 are transboundary. The following table shows how catastrophic events may impact on cultural heritage assets, structures and artefacts:

Type of event	Impact related to cultural heritage
<b>EARTHQUAKES</b>	<b>Climate change effects:</b> not related
<b>Physical</b>	One of the natural disasters with most devastating impact in terms of loss of lives and damage to structures. Frequently, followed by other disasters such as fire, floods, landslides or tsunamis. The case of L'Aquila, Abruzzo (2009, Italy) showed that only 23% of cultural heritage buildings were adequate for earthquakes.
<b>Social</b>	Loss of human lives and abandonment of HA
<b>Environmental</b>	Soil erosion, loss of biodiversity, and, higher risk of landslides
<b>Economic<sup>3</sup></b>	Decrease in tourism and related activities and economic losses for CH managers and insurance companies.

<sup>3</sup>Any one of these risks has a huge economic impact in the area, but in this table only the impact directly related with CH is addressed.



<b>STORMS</b>		<b>Climate change effects:</b> Increase in the number of extreme storm events
<b>Physical</b>	Material decay (fungal growth, degradation of material, biogenic patinas and deterioration of movable heritage). Intense wind-driven rain can alter the distribution of damage on facades. Penetrative moisture into porous CH materials. Static and dynamic loading of historic or archaeological structures.	
<b>Social</b>	Loss of identity and common values; progressive abandonment HA due to new comfort parameters. Significant adverse effects on human health, increasing mortality and health risks	
<b>Environmental</b>	Adverse effects on vulnerable ecosystems. Decrease on the landscape quality and biodiversity loss.	
<b>Economic</b>	Economic losses for heritage managers and/or insurance companies.	
<b>FLOODS</b>		<b>Climate change effects:</b> Coastal, fluvial and pluvial floods due to global temperature rise (increase of precipitation volume and number of extreme events)
<b>Physical</b>	Damage and failures due to: 1) static and dynamic loads (water pressure, water flow, uplift forces), 2) impacts from floating objects, 3) wetting of building materials, 4) effects of soluble salts, chemical pollutants and biological infection, 5) temperature and humidity fluctuations and hygrothermal cycles increase material decay (cracking, detachment, fungal growth, biogenic patinas...).	
<b>Social</b>	Disruption of communities, loss of rituals and breakdown of social interactions.	
<b>Environmental</b>	Soil erosion, loss of biodiversity and higher risk of landslides. Deterioration of water quality.	
<b>Economic</b>	Decrease in tourism and economic losses due to damages in infrastructure and buildings.	
<b>HEAT WAVES</b>		<b>Climate change effects:</b> Heatwaves & higher than average temperatures: Prolonged periods of abnormally hot weather and presence of tropical nights (minimum temperature at night of 20 °C) because of the global warming effect
<b>Physical</b>	Material decay due to temperature and humidity fluctuations, hygrothermal cycles and increasing biological colonisation. Deterioration of facades due to thermal stress. Changes in 'fitness for purpose' of some structures (alterations to the historic fabric due to the introduction of engineering solutions)	
<b>Social</b>	Progressive abandonment of HA due to temperature increase; impact on health and wellbeing (specially in vulnerable population)	
<b>Environmental</b>	Energy demand increase for air conditioning.	
<b>Economic</b>	Impact in local economy due to depopulation, lowered labour productivity and changing	
<b>WILDFIRE</b>		<b>Climate change effects:</b> Increase in global temperatures, heat waves and related to water scarcity/droughts
<b>Physical</b>	In European countries, fire is the common catastrophe that threatens built heritage in urban areas and fire prone cultural landscapes. Damage due to water-based suppression system.	
<b>Social</b>	Depopulation. Increase health and mortality risks due to health hazards from air pollution.	
<b>Environmental</b>	Forest fires are a central part in shaping forest ecosystems but can be particularly devastating especially when threaten residential areas. Air pollution	
<b>Economic</b>	Economic losses for heritage managers and/or insurance companies. Indirect economic losses can also occur through job losses and lower incomes, especially in areas that rely on offering tourist products that are based on natural and cultural beauty	
<b>SUBSIDENCE</b>		<b>Climate change effects:</b> triggered by various extreme weather events.
<b>Physical</b>	Damage in residential, commercial, and public buildings, spaces and assets and public	
<b>Social</b>	Fatalities and population displacement	
<b>Environmental</b>	Removal of vegetation and soil and the deposition of this material on different ecosystems	
<b>Economic</b>	Damage to economic assets and transport infrastructure and have negative effect on the economy both directly and indirectly (from job losses and restricted ability to access work).	

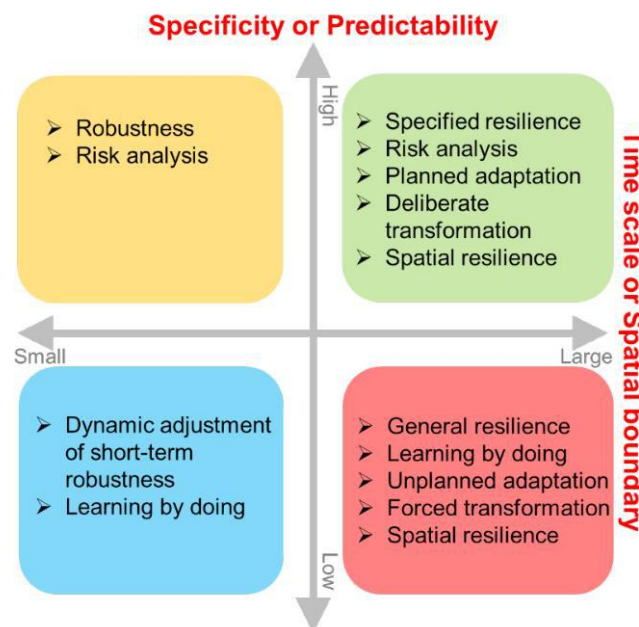
**Table 8:** Impact on CH of events

## 4.6 Requirements for systemic resilience assessment

According to the first literature review, the requirements of the resilience assessment within SHELTER should link the two concepts and:

- Link generalised resilience with specialised resilience
- Cross-scalarly, being applicable from artefact/building scale to urban or transregional HA
- Consider the multidimensionality of resilience (physical, social, economic, institutional and cultural)
- Allow semi-automatic assessment, prioritisation, decision-making, auto evaluation and monitoring serving for compass in the different long-term decision points but also for short term monitoring strategies (including project results). Allow the assessment the singularity of CH physical vulnerability framed in a broader concept of multidimensional HA resilience
- Acknowledge resilience, vulnerability and adaptive capacity as nested concepts, linking them across the spatial, temporal and uncertainty scales

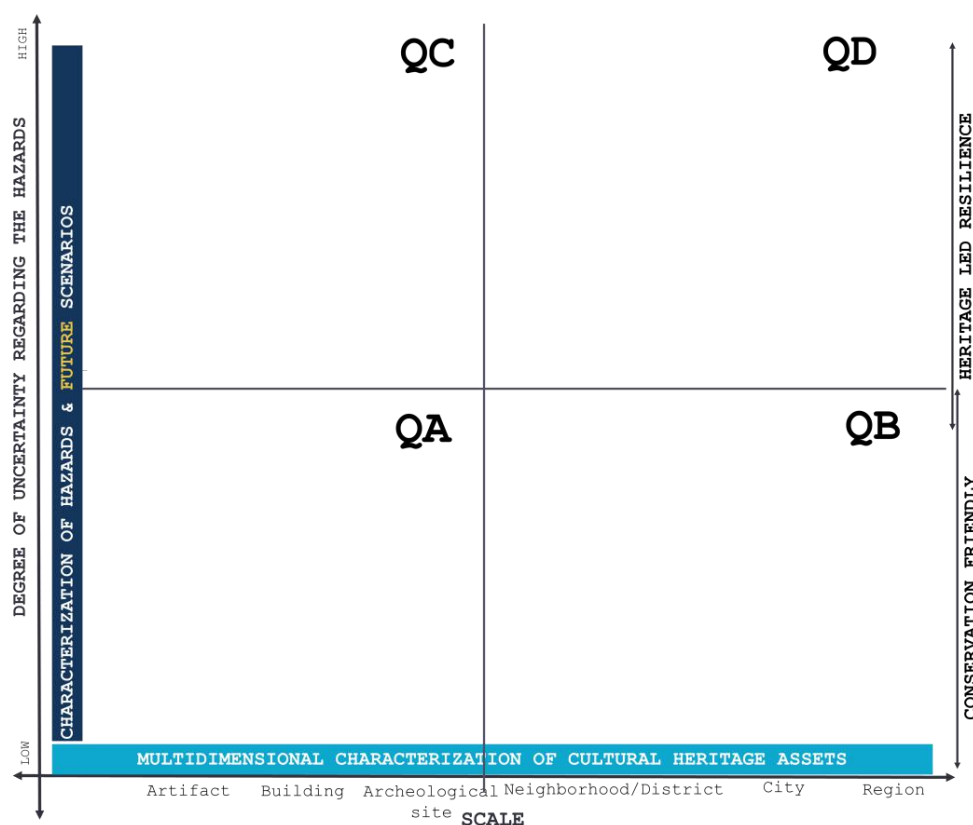
The work of Yu et al. [49] aiming align different schools of thought on resilience establishes a promising approach where different resilience concepts are mapped and integrated regarding their “specificity of predictability” and “time scale or spatial boundary” as it can be seen in the following figure (Figure 2):



**Figure 2:** Relevance of the resilience-related concepts discussed along four analytical dimensions (time scale, spatial boundary, specificity of key variables, and predictability). [49]



Using as inspiration this structure, SHELTER structures the resilience conceptual framework in four quadrants depending of the degree of certainty regarding the hazards and the scale as it can be seen in the following figure (see Figure 3):



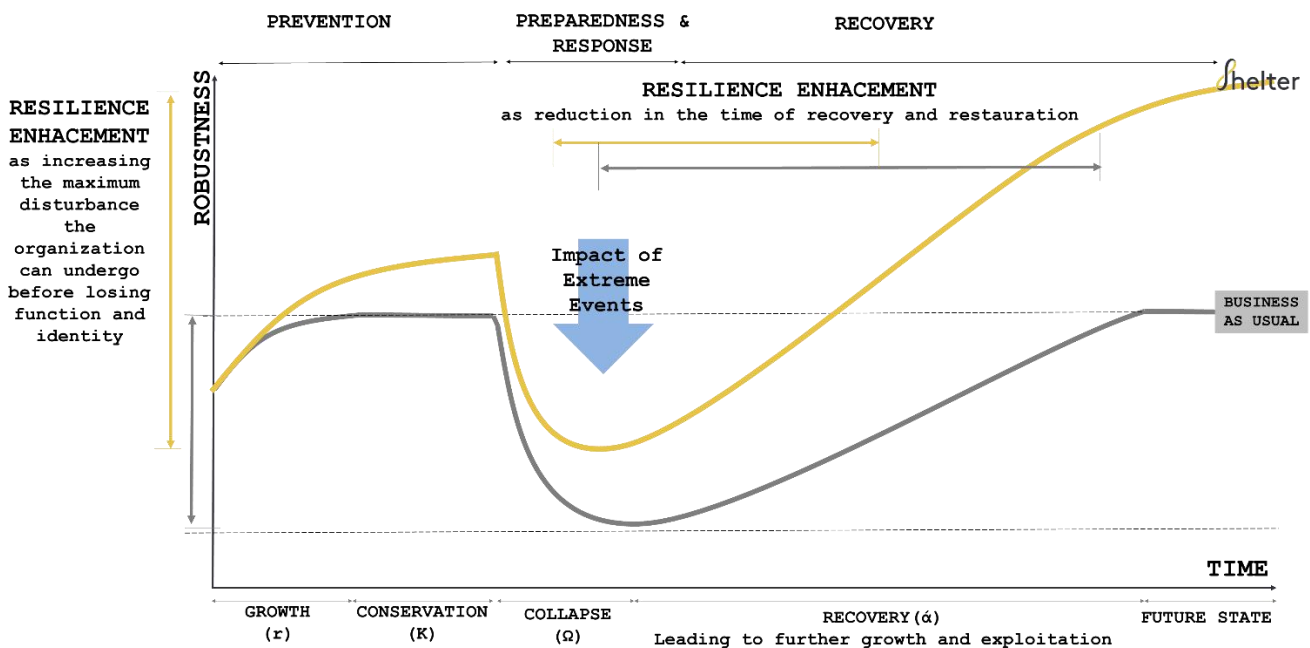
**Figure 3:** Structure for SHELTER resilience assessment and knowledge structuring

The Y axis represent the hazards and the degree of certainty that we have about them and splits the framework between the generalised (top half) and specified resilience (bottom half). The X axis represent the geographical scales of the HA.

#### 4.7 Requirements for SHELTER operative framework for resilience enhancement and building back better

Resilience enhancement means anticipating the adverse effects of climate change and other natural hazards and taking appropriate action to prevent or minimise the damage they can cause and taking advantage of opportunities that may arise. The impact of resilience enhancement measures and actions can be calculated in terms of the **adaptive cycle** [11], [50], [51] which focuses on the dynamics of systems that do not have an equilibrium condition but repeatedly pass through four characteristic phases: growth and exploitation; conservation; collapse or release; and renewal and reorganisation.

These shifts between phases are result of either the sequences of gradual changes or rapid shocks. Thus, resilience can be expressed in terms of a system's robustness and rapidity. As seen in the following diagram (see Figure 4: Enhancement of resilience as improvement of HA's robustness and rapidity (adapted from [10])), a system's robustness is determined according to its strength to carry and absorb uncertain disturbances, whilst its rapidity refers to the flexibility to rearrange itself into a new stable state after a disturbance occurs.



**Figure 4:** Enhancement of resilience as improvement of HA's robustness and rapidity (adapted from [10])

The operative knowledge framework SHELTER should **enhance the resilience** and reduce the vulnerability of HA to climate change and other natural hazards, both increasing the robustness of the system and reducing the time of recovery and restauration. The operative knowledge framework should improve the capacity of the HA to cope with hazards and climate change related events:

- By the identification and integration of multiple data sources (satellite, sensors, crowdsourcing, predictive models, statistic models...) and existing knowledge (including local social memory regarding past events, best and next practices and results from linked research initiatives)
- By systemic resilience assessment that will address direct and indirect impacts of events in CH assets (i.e., from physical damage and degradation of sites to socio-cultural, environmental and socio-economic dimensions) and consider, on both levels, sensitiveness, adaptive capacity as well as exposure to a specific or to a combination of multiple hazards.

- By spatially explicit strategic decision-making tools that facilitate the design of adaptation roadmaps that will include conservation-friendly multifunctional solutions as the implementation of NBS and local solutions to boost local economy to increase economic and social resilience
- By community-based approaches that facilitate the effective applicability of the strategies by conservators & heritage managers and authorities and increase the adaptive capacity
- By providing tested tools and technologies for resilience and reconstruction, a validated data driven platform capable of managing the methodological and analytical process to produce actionable planning and governance schemes
- By developing methods to evaluate the real loss and damage costs assigning economic value to CH assets outside of the market mechanisms using Agent Based Modelling Techniques and involving insurance perspective.

The operative knowledge framework should **reduce the time** a HA needs to recover from a disruption:

- By integrating early warning systems, early damage assessment and crowdsourcing tools
- By a documentation strategy that will make accessible protocols and pre-planned early recovery roadmaps in trans-disaster and post-disaster phases (since adequate easily accessible pre-planned response and recovery planning increases the speed of recovery and the effectiveness of response)
- By identifying and implementing suitable and effective adaptive solutions
- By supporting stakeholders in being prepared for the challenges of climate change and natural hazards: collecting and exchanging best practices, lesson learnt and next practices in the field of CH, increasing awareness and understanding of response options and interdependencies in a peer learning environment. Moreover, it should explicitly address vulnerable groups that would have more difficulties (e.g. elderly people, immigrants, children) in post-disaster phases by targeted procedures and awareness campaign through citizens engagement tools, that will allow to include women's knowledge and perspective in the analysis and evaluation of needs and potential solutions.
- By the codification of social memory (local experience to dealing with past) and local knowledge that will make actionable the lesson learnt in past events

## 5 Design of the literature review and results

### 5.1 Methodology

Once that the requirements for the assessment of resilience and the operative framework were defined, a second literature review was designed and carried out. Scopus data base were searched to find papers with the following queries in the abstract, title and keywords:

- (TITLE-ABS-KEY("urban resilience"))
- (TITLE-ABS-KEY("territorial resilience"))
- (TITLE-ABS-KEY("historic areas" AND "vulnerability"))
- (TITLE-ABS-KEY("historic buildings" AND "vulnerability"))

Then results were restricted to English language, relevant fields, conference or papers and with a defined author. The following table summarised the number of papers identified:

Date	Query	Number of papers in the first results	Number of papers in the restricted results
30/07/2019	"URBAN RESILIENCE"	682	495
	"TERRITORIAL RESILIENCE"	36	20
	"CULTURAL HERITAGE" AND "RESILIENCE"	176	99
	"HISTORIC AREAS" AND "VULNERABILITY"	8	8
	"HISTORIC BUILDINGS" AND "VULNERABILITY"	140	122

**Table 9:** Number of papers identified by query

A first screen was done in order to identify the relevant papers. The abstracts were classified as following:

- 0= the paper does not seem to be relevant to SHELTER
- 1=the paper could be interesting, but it is necessary to read more
- 2=The paper refers clearly to one or more assessment quadrants<sup>4</sup> or /and the paper refers clearly to one or more dimensions of HA resilience (economic, social, physical, institutional and cultural)
- 3=the paper is focused in historic areas (in the queries that are not cultural heritage specific) and/or the paper describes indicator systems and/or the paper describes methods/concepts to link different quadrants

<sup>4</sup> See Section 4.6

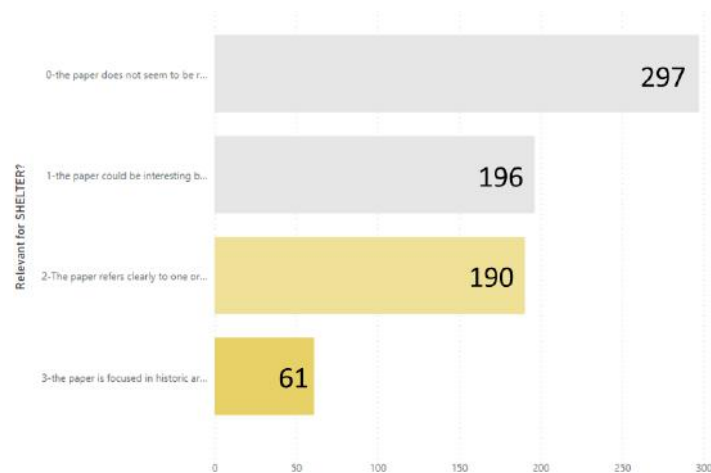
In a second screening the papers with relevancy (2 or 3) were categorised as following in order to see the magnitude of aspect of resilience:

- Is the paper focused on historic areas?
- Dimension
  - Historic building resilience
  - Cultural resilience
  - Social resilience
  - Governance and institutional resilience
  - Economic resilience
  - Environmental resilience
  - Multidimensional
- Hazards:
  - Earthquakes
  - Storms
  - Floods
  - Heat waves
  - Wildfire
  - Subsidence
  - Climate-related
  - Other hazards
  - Non-specific hazard
- Assessment quadrants
  - QA- specific hazards and object/building scale
  - QB- specific hazards and urban/territorial scale
  - QC- non-specific hazards and object/building scale
  - QD- non-specific hazards and urban/territorial scale
- Has the paper addressed any set of indicators?
- Is it a review paper?
- Keywords

Finally, the papers with high relevance were analysed in detail in order to extract and structure the knowledge useful for the project.

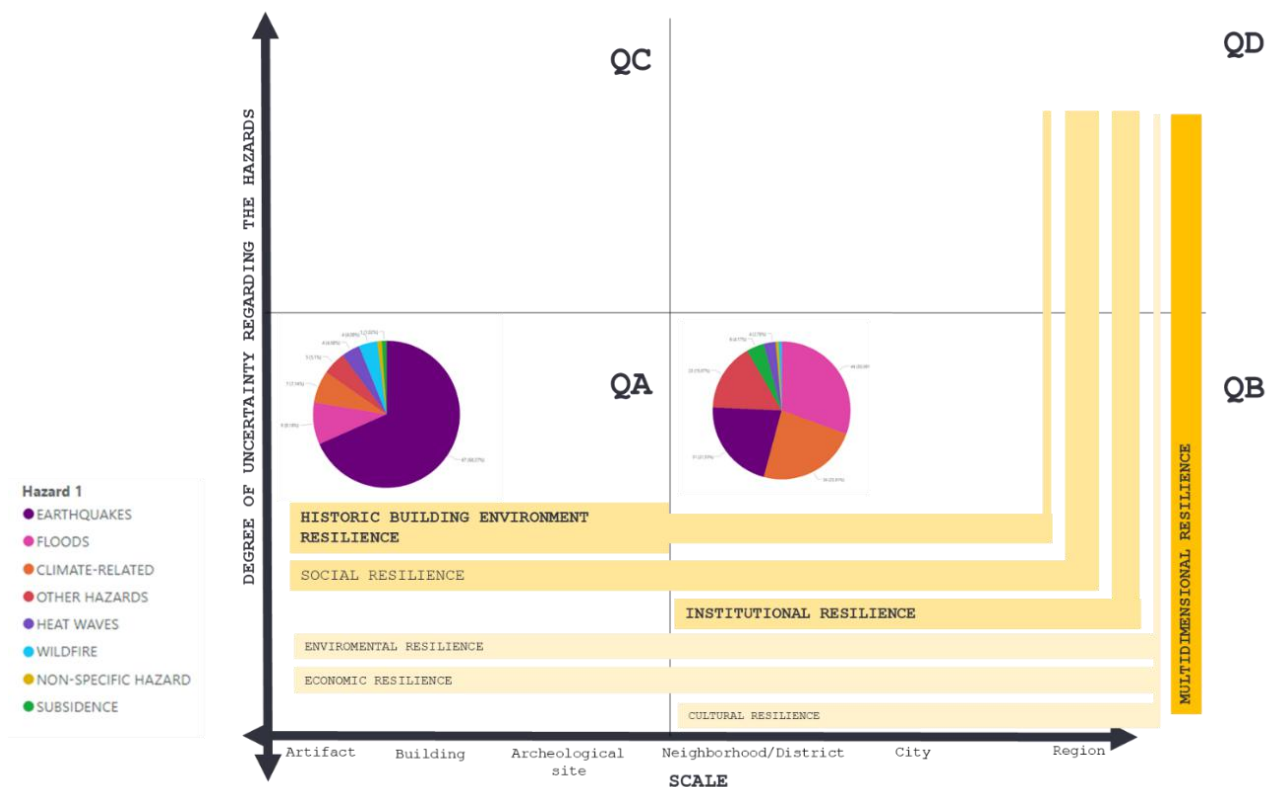
## 5.2 Results

In a first scanning 744 were reviewed, and 61 were found relevant for SHELTER (see Figure 5):



**Figure 5:** Number of papers for degree of relevance

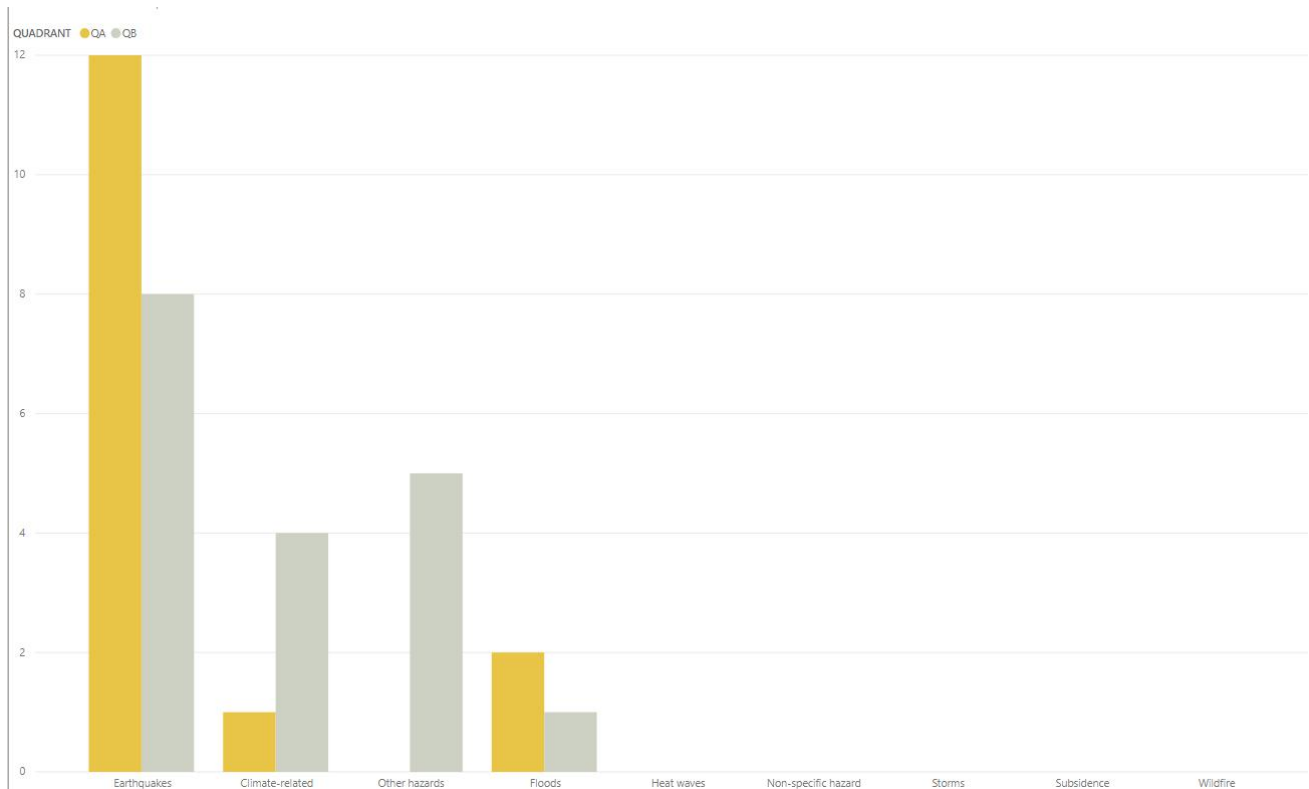
The results of the categorisation of the papers with 2 and 3 relevance can be seen in the following figure (see Figure 6):



**Figure 6:** Results of the categorisation of relevant papers.

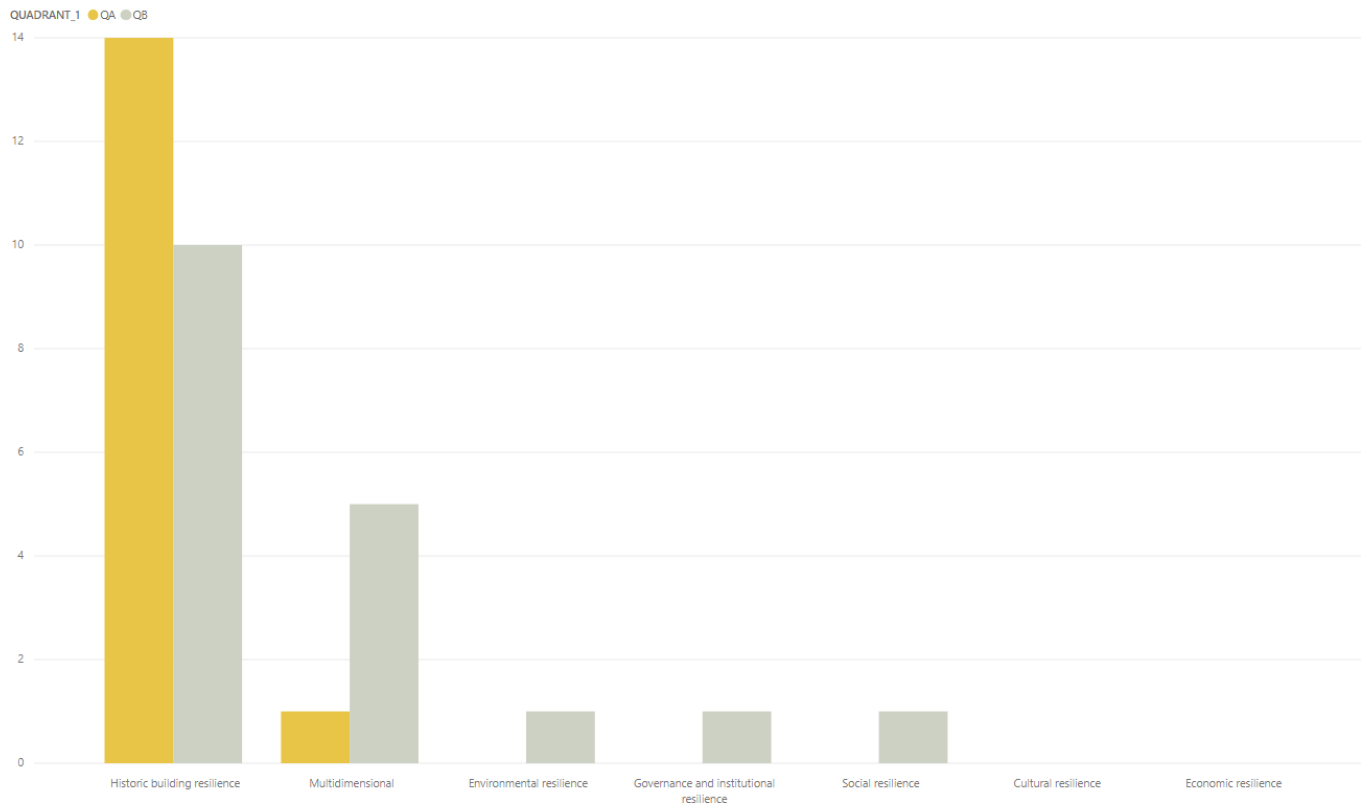
The following figure (see Figure 7) represents the number of papers, with level 3 of relevancy, per hazard regarding specialized resilience (QA and QB quadrants). Most of the papers on the object/building scale address earthquakes, a couple of them floods

and only one climate related hazards. On the urban and territorial scale, the majority of papers address earthquakes, other hazards such as storms, tsunamis and wind, climate related hazards and only one paper floods.



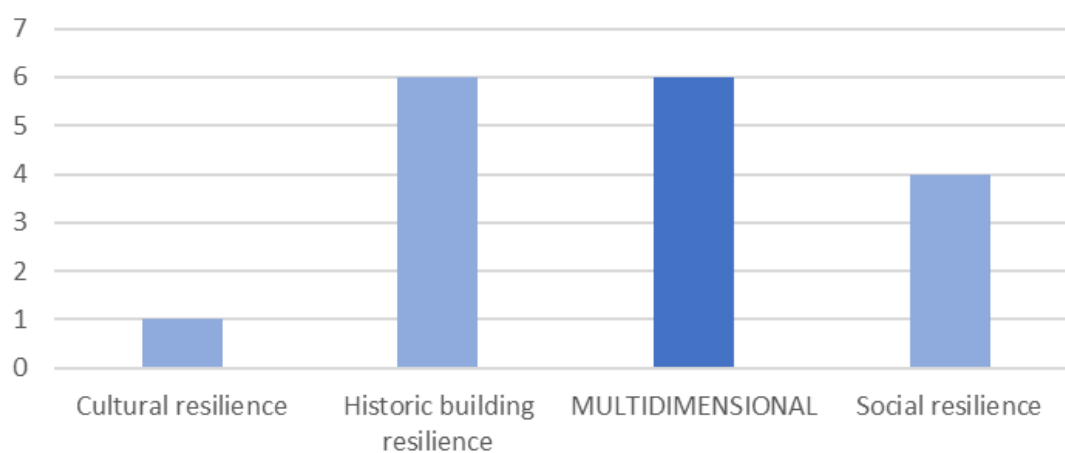
**Figure 7:** Hazards representation in QA and QB

Almost all papers addressing the object/building scales are related to the historic building resilience and only one papers touches the cultural resilience. On the urban/territorial scales, papers related to specific hazards are mainly related with the historic building resilience or are multidimensional (considering the historic building resilience together with the economic dimension and/or the social resilience and/or cultural resilience). Some of the papers are related with other dimensions, such as social resilience, environmental resilience and governance (see Figure 8).



**Figure 8:** Dimension representation in QA and QB

Regarding generalised resilience there is a significant number of examples addressing it as it is planned to do in SHLETE, i.e. from the multidimensional perspective, as it can be seen in Figure 9:



**Figure 9:** Dimension representation in QD



## 6 Assessment of systemic resilience for historic areas

Resilience thinking represents a dynamic view of the future where risk, uncertainty and surprises are the norm and are used to build a more sustainable system and a system-wide transformation.

### 6.1 Improvement of specialised resilience

#### 6.1.1 Object and building scale

The detailed literature review of the papers related to the QA quadrant, considered as very relevant for SHELTER project, consisted on analysing 15 scientific papers. Most of the papers in this quadrant are associated with earthquakes, but also flooding and climate change are tackled. The analysis is presented according to the main dimension they are referring at:

##### 6.1.1.1 *Historic building environment resilience*

According to the literature review, this dimension is the most relevant for the quadrant, both for the number of papers associated as well as for the contents addressed by the sole paper which is multidimension.

Papers agree in the need of addressing **vulnerability** assessment of historic structures to hazards. Methodologies are developed for assessing vulnerability through structural criteria (also cultural) [52], [53] and also in regard of the exposure to hazards [53]. The need of the optimum interventions for preventive measures against seismic vulnerability is also discussed [54].

Most of the researchers focus on theoretical analyse (simulations) of the hazards-related damages into the built environment. This is mainly studied in exempt historic fabric buildings and particularly in earthquake related damages. The urban scale is not deeply studied, and the historic areas' analyses are mostly referred to as an aggregation of buildings. Nor is the territorial scale.

There are several studies that use numerical approaches to obtain a **quantitative seismic risk assessment**. They generally follow the same approach: they calculate the hazard response (via simulations) and therefore foresee (or understand) the causes of partial or total collapse of buildings [55]–[59]. Hazard response has also been analysed in correlation to national building codes [60]. Modelling tools and strategies are analysed [61] and failure mechanisms and damage patterns' evaluation methods are presented [62].

**Monitoring systems** and procedures are studied [63], [58] before and after hazard assessment monitoring technologies addressed [64], and, monitoring tools' improvements studied [63].

Hazard response of the buildings is usually referred to the structure geometrics (mainly), the materials, the ground type, and particular attention is put in the adjacent buildings and structures.

Aiming improving resilience, **reinforcing and retrofitting solutions** are considered. Studies are made for the calculation of capacity and, thus, provide compressive strength solutions of structures for reliability assessment [65], [66].

HISTORIC BUILDING ENVIRONMENT RESILIENCE				
<ul style="list-style-type: none"> <li>Addressing vulnerability assessment of historic structures to hazards and assessing vulnerability also in regard of the exposure to hazards.</li> <li>Theoretical analyse (simulations) of the hazards-related damages into the built environment.</li> <li>Also, numerical studies to obtain a quantitative seismic risk assessment. Calculation of the hazard response (via simulations) and therefore foresee the causes of partial or total collapse of buildings.</li> <li>Building modelling tools and strategies and modelling systems and procedures are studied. Monitoring systems and procedures are studied before and after hazard assessment.</li> <li>Hazard response of the buildings is usually referred to the structure geometrics (mainly), the materials, the ground type, and particular attention is put in the adjacent buildings and structures.</li> <li>Aiming improving resilience, reinforcing solutions are considered</li> </ul> <p><b>Hazard response of the buildings is usually referred to the structure geometrics (mainly), the materials, the ground type, and particular attention is put in the adjacent buildings and structures.</b></p> <p><b>Aiming improving resilience, reinforcing solutions are considered</b></p>				
VERY RELEVANT				
HAZARDS	REF	ASSOCIATED METHODOLOGIES	FACTORS	INPUTS FOR SHELTER
EARTHQUAKES	[52]	The Vulnerability Index Methodology, for assessing the seismic vulnerability. Four criteria to assess vulnerability: Structural seismic vulnerability is the most relevant part of the knowledge process, but when coming to Historic Buildings new parameters need to be addresses: architectural-artistic value, urbanistic value and social-economic value.	-	Four assessing indicators methodology for addressing vulnerability (one mechanical/structural, three cultural)
EARTHQUAKES	[55]	Seismic response in masonry aggregates through non-linear dynamic analyses performed on detailed 3D FE numerical simulations.	High vulnerability of perimeter walls, opening decreases strength of walls, and walls of the tall units without lateral supports are the most damaged. Structural response of a single unit is affected by the interactions with the adjacent parts.	The seismic performance of the aggregates can be evaluated in terms of damage distribution, energy density dissipated by tensile damage and maximum normalized displacements.
EARTHQUAKES	[56]	Numerical simulations of the global behaviour and local instability to analyse the causes of collapse	Masonry building structure: Configuration, materials, masonry arrangement, ground type, wall-to-wall and wall-to-roof connections, and others. Earthquake's seismic direction The use of incorrect retrofitting techniques	With simple and effective preventive interventions, it would be possible to highly reduce the seismic vulnerability

EARTHQUAKES	[66]	Calculation of the shear strength capacity of the masonry wall with which is determined the degree of insurance against earthquake and the seismic risk class of the structure	It evaluates the influence of strengthening solutions	Demonstrated that the main failure criterion of the unreinforced masonry walls is diagonal cracking due to main tensile stresses.
EARTHQUAKES	[57]	Mathematical analysis	Specific set of indicators used to assess the structural vulnerability: a dynamic characterization of the historic building to identify the structural damage and assess the seismic performance	Direct correlation exists between dynamic characterization, damage identification and seismic vulnerability assessment
EARTHQUAKES	[59]	Innovative and expeditious methodologies to evaluate all the main structural features of the monumental buildings. It critically compares the results obtained for the three levels of evaluation there defined: LV1 (analysis at territorial level), LV2 (local analysis) and LV3 (global analysis).	Effects of the presence of adjacent constructions at the lower level. Facades' overturning highlighted a potentially critical local configuration. Effects of the neighbouring buildings at the lower level.	Only a clear understanding of the structural behaviour based on a comparative approach can assure the definition of reliable strengthening interventions, thus reducing the extent of the remedial measures.
EARTHQUAKES	[63]	Hypothesis of simplified dynamic monitoring procedures through the reduction/optimization of the accelerometric sensors used for three case studies, which differ in structural typology such as Churches, Towers and Palaces.	The structural complexity, the variability of materials, as well as the damage and the deterioration that the structure has sustained throughout its existence.	Hypothesis of simplified dynamic monitoring procedures
EARTHQUAKES	[62]	Numerical method approach evaluating damage pattern obtained by non-linear dynamic analysis and the energy dissipated by each macro-element during earthquakes.	-	The method can define a scale of vulnerability depending on the failure modes and the DED (Dissipated Energy Density) values for each macro-element.
EARTHQUAKES	[65]	Methodology for assessing the reliability level of masonry structures under seismic loads is the estimation of structural resistance in order to obtain a limit state function of structural reliability	The stochastic characteristics of construction materials play a key role in the determination of a probabilistic model of structural resistance.	Should lead to more realistic values to obtain more accurate levels of reliability without requiring degradation of the historic buildings
EARTHQUAKES	[61]	Two modelling strategies were applied—failure mechanisms analysis by means of macro element methodology (MEM) and non-linear response analysis by means of structural element modelling.	The most critical failure mechanisms were due to out-of-plane loading.	The accuracy in predicting failure modes by MEM ranged between 50 and 80 % of the stock of building in rural area.

EARTHQUAKES	[54]	Integrated methodology which establishes a wider, multi-disciplinary framework of preventive measures against seismic vulnerability, including essential steps complementary to the execution of interventions.	-	It discusses the optimum interventions for vertical and horizontal elements and building connections as well as advanced instrumented dissipative devices.
EARTHQUAKES	[60]	Seismic analysis of masonry voussoir arches, according to the Italian building code, that proposes a new verification approach based on an algorithm devoted to this topic.	Rigid overturning of structural portions	It is possible to individualize the kinematism and its related collapse load factor.
FLOODS	[64]	Two phases methodology: "pre-flooding" stage, aims to gain a preliminary dataset of the site, "post-flooding" stage aims to monitor (TLS scanner and Photogrametry) and damage evaluation.	All water-related problems: Precipitation, high groundwater level, Surface runoff water and complete submergence. AND the assess of the magnitude of the damages: Probability or extent of the damage happening, the degree of loss, the fraction of the area susceptible to threat, the sensitivity to change.	A methodology to document and track damages by flooding. A proposition for a remote sensing combination integrated in GIS system into a multi-layer monitoring system.
FLOODS	[14]	Studies the nature of the vulnerability of historic structures, and places it in the context of risk assessment, accounting for the vulnerable object and the subsequent exposure of that object to flood hazards	Age of the building, Listed status, Storeys, Construction (type) and condition	Determining the applicability of these indicators to fragility analysis, and the determination of the relative vulnerability
CLIMATE-RELATED	[58]	Environmental monitoring system for hygrothermal conditions of historic buildings. Determination of risk of mould germination and micro-cracking risk from monitored T& RH.	Correlation between wind-driven rain measurements and semi empirical relationships.	The current prediction of more intense more frequent rain and increase in temperatures, can only create more adverse environmental conditions than presently monitored.

**Table 10:** Analysis of papers addressing the object/building scale and historic building environment

**6.1.1.2 Cultural resilience**

Of the analysis performed, only one paper partially addresses the cultural resilience dimension, being the research multidimensional and considering mainly the built resilience.

In this sense, methodologies are being developed for assessing vulnerability through cultural criteria that need to be addresses: architectural-artistic value, urbanistic value and social-economic value [52].

CULTURAL RESILIENCE				
<ul style="list-style-type: none"> <li>Assessing vulnerability through cultural criteria that need to be addressed: architectural-artistic value, urbanistic value and social-economic value.</li> </ul>				
SLIGHTLY RELEVANT				
HAZARDS	REF	ASSOCIATED METHODOLOGIES	FACTORS	INPUTS FOR SHELTER
EARTHQUAKES	[52]	When coming to Historical Buildings new parameters need to be addresses: architectural-artistic value, urbanistic value and social-economic value.	Assessing vulnerability depends on the cultural value, to be calibrated and correlated	Could be applied on sites with cultural value as it can provide important prioritization criteria for the local authorities

**Table 11:** Analysis of papers addressing the object/building scale and cultural resilience

### 6.1.2 Urban and territorial scale

The detailed literature review of the papers related to the QB quadrant, considered as very relevant for the SHELTER project, consisted in extrapolating information from 18 scientific papers. In this quadrant, most papers are associated to earthquakes [67]–[74], climate related hazards [75]–[78], other hazards such as landslides, wind and tsunami [79]–[83] and only one is directly associated to floods [84].

The analysis is presented according to the main dimension they are referring at:

#### 6.1.2.1 *Historic building environment resilience*

According to the literature review, this dimension is the most relevant for the quadrant, both for the number of papers associated [67], [68], [70], [71], [73], [74], [76], [77], [79], [80] as well as for the contents addressed by papers which are multidimensional [69], [72], [75], [81], [84]. Many research efforts have been done in studying the built environment in relation to Disaster Risk Reduction (DRR) by correlating, in a qualitative and quantitative way, the urban element and the structural component.

Assessment of time-variable hazards processes has to be addressed at different spatial scales, in order to provide sufficient information on the condition of the whole observed area and estimate the potential impacts on the physical environment [74], [76].

Hazards assessment generally follows similar approach, but spatial scales are assessed in a different way: from the local or micro scale, comprising buildings or critical infrastructures, which aims at a better understanding of the impacts of a placed based hazard [67], [69]–[73], with the objective of improving local managers in the whole decision-making process to larger scales including cities, countries or transnational regions, such as the meso or macro scale, which aim at harmonising information and calculate indirect effects to improve assessments and estimate catastrophic events consequences [74], [75], [79], [84].

Studies on the territorial level usually assess the geological and morphological characteristics of a territory and its behaviour in relation to different risk scenarios [67], [68], [75], [79], [84]. Other elements, such as land use, might be included to assess the impact of the hazard in different areas [84]. This type of analysis usually includes specific tools, analysis of historic events, remote sensing imagery and GIS processing [74], [75], [84].

Hazards assessment on the urban scale are usually performed considering two components: the ground layer, meaning the geological and geomorphological characteristics and the surface layer, considering the constructed or natural elements.

The urban scale is often presented and intended as an aggregation of buildings. This is especially due to the availability of information which is often abundant at the building level as well as for the type of assessment, which consider the number of elements affected as well as the type of possible damages. Although the land use composition can



vary considerably, historic areas in urban environments are predominantly characterised by residential and commercial uses, typologies which are addressed in almost all papers and monuments, which are specifically addressed in some of the papers [67], [69], [70]. In order to address the whole urban scale, typologies or categories based on constructive similarities are often defined. This enable to extrapolate information and estimates to the whole building stock [67], [69], [71], [73], [76], [77].

Nevertheless, urban morphology is taken into account in the assessment of some specific hazards, such as earthquakes and strong winds, as it considerably affects the severity of the impacts [72], [80]. For example, in the case of earthquakes, failure mechanisms can be amplified in case of buildings which are attached together.

Almost all the papers analysed and the methodologies proposed are located driven and are the results of a specific context analysis [67], [68], [71]–[75], [79], [84].

Specific hazards and urban/territorial scale are therefore mainly related to the degree of exposure and the sensitivity of the elements. The management of historical, present and future data, considering the changing nature of urban settlement, is a core issue which leads from one side to the inclusion of new technologies for rapid information acquisition and, from the other side to the need of continuously update the necessary information in order to build consistent knowledge.

HISTORIC BUILDING ENVIRONMENT RESILIENCE				
<ul style="list-style-type: none"> <li>Built environment, in relation to Disaster Risk Reduction, is analysed by correlating the urban element and the structural component.</li> <li>Assessment of time-variable hazards processes has to be addressed at different spatial scales</li> <li>Hazards assessment generally follows similar approach, but spatial scales are assessed in a different way: Studies on the territorial level usually assess the geological and morphological characteristics of a territory and its behaviour in relation to different risk scenarios; Hazards assessment on the urban scale are usually performed considering two components: the ground layer, meaning the geological and geomorphological characteristics and the surface layer, considering the constructed or natural elements</li> <li>The urban scale is often presented and intended as an aggregation of buildings</li> <li>Specific hazards and urban/territorial scale are mainly related to the degree of exposure and the sensitivity of the elements.</li> </ul>				
VERY RELEVANT				
HAZARDS	REF	ASSOCIATED METHODOLOGIES	FACTORS	INPUTS FOR SHELTER
EARTHQUAKES	[67]	Matrix approach: data the built environment and those of systematic interpretation of the built fabric can be joined, with the objective of defining a priority of actions.	Age of the built heritage, constructional characteristics, relative vulnerability. Amplifying factors are considered according to the use	Strategies for the integration of urban resilience into territorial management
EARTHQUAKES	[68]	Microzonation of the city centre through an experimental technique (horizontal over vertical ratio, or H/V, method) using ambient noise measurements and a 1D numerical methodology from geotechnical data	Soil amplification factor used to obtain the seismic design acceleration	Obtain realistic damage estimations for emergency planning at local scale
EARTHQUAKES	[69]	Evaluate the seismic hazard using two different approaches: i) deterministic approach; ii) spectral values using both deterministic and probabilistic methods. The VIM (vulnerability index method) allows identifying differences among buildings with the same structural typology or monuments classification	Building typology (according to structure) and Monuments classification (according to use)	Definition of buildings vulnerability indices for prevention planning at local scale
EARTHQUAKES	[70]	Macro seismic approach and clustering of structures into vulnerability classes. These are based on a damage probability matrix, which takes into account observations on buildings stricken by past earthquakes	Class type is made by gathering into groups the structures that are similar with reference to the use, architecture and possible seismic behaviour.	First assessment based on expected damage for a large population of buildings for prevention planning at regional or national level
EARTHQUAKES	[71]	Vulnerability analysis of buildings is based on the prediction of failure mechanisms. Stratigraphical method was adopted to subdivide complex buildings. Materials sampling was performed and representative of the whole	The interpretation of failure or damage mechanisms in the case of large aggregates of buildings, attached together, is particularly complex.	Support the local designers in the choice of the most suitable repair and intervention projects in the recovery phase

EARTHQUAKES	[72]	Non detailed assessment group was conducted using the mean values obtained from the detailed analysis, assuming the masonry building characteristics homogeneous in the area.	Structural system, irregularities and interactions, floor slabs and roofs, conservation status and other elements	Reduction of seismic vulnerability through the implementation of seismic building codes suitable both for new and existing structures in prevention phase
EARTHQUAKES	[73]	Seismic risk is obtained by the combination of the seismic hazard and the vulnerability and exposure of the constructed facilities, including the site effects related to the soil conditions. Structural inventory identified the most dominant type of structures. Due to absence of data from past earthquake, vulnerability curves from analytical models adapted to the structural and material characteristics were obtained.	Identification of the structural characteristics to build a typological class	Definition of buildings vulnerability for prevention planning at local scale
EARTHQUAKES	[74]	Methodology to monitor and characterize environmental and building vulnerability in the context of a seismic/hydrogeological hazard prone areas. The proposed approach is based on the combined use of Interferometric Synthetic Aperture Radar (SAR) and ground-based Real Aperture Radar (RAR) sensors.	Analysis of the deformation phenomena due to seismic/hydrogeological hazards	Supports seismic vulnerability mitigation activities in pre- and post-earthquake intervention plans, at different spatial and temporal scales.
FLOODS	[84]	Calculate the rate of loss of different land covers due to sea-level rise. Several scenarios of sea level rise over the next century were assumed and analysed to define regional and urban scale impacts.	Number of buildings located in flood prone areas	Mapping risk areas on a large scale
CLIMATE-RELATED	[75]	Preliminary analysis phase focused on the collection of data and information. The analysis supports the diagnosis phase for the assessment of inherent vulnerabilities and qualities of historic towns, in order to carry on the final phase for the definition of potential enhancement and improvement strategies.	<u>Vulnerabilities:</u> Morpho-typological arrangement and mechanical characteristics of the soil; Management systems of rainwater; Planimetric layout and distribution of underground and surface waters; Physical-mechanical characteristics of “tuff” stone as building materials. <u>Qualities:</u> Management systems of rainwater; State of conservation of hypogea	The historic-geographic, urban-architectural, functional and normative analysis, and the diagnosis at the environmental, socio-cultural and socio-economic levels, pave the way for the identification preventive strategies
CLIMATE-RELATED	[76]	Establishment of a set of indicators to assess vulnerability for historic areas. These were designed according to different typologies: quantitative and qualitative indicators, simple or compound indicators and indirect or “proxy” indicators build on available information	Exposure, sensitivity and adaptive capacity	Prioritization of most vulnerable buildings or areas as preliminary assessment in the preventive decision-making
CLIMATE-RELATED	[77]	Set of indicators developed for each hazard and impact. The main criterion for the methodology was to define indicators based on existing and available information	Socio-economic factors, energy efficiency and built environment	Prioritization of most vulnerable buildings or areas as preliminary assessment in the preventive decision-making

OTHER HAZARDS (landslides)	[79]	Analyse natural/human factors accountable for the abandonment of settlements and conservation state of deserted places. The procedure uses of geological, geomorphological, historical, and remote-sensing investigations and effectiveness of free-of-charge remote-sensing images to analyse the vegetation growth.	Repeated mass movements were not considered by inhabitants and institutions as a "warning", but the areas heavily affected by landslide occurrences were, in some cases, rebuilt and the urban expansion continued	Inclusion of risks in urban planning in preventive and recovery phases
OTHER HAZARDS (wind)	[80]	Experimentally and numerically investigate historic buildings degradation due to wind exposure. Air velocity field and viscous stresses have been investigated by means Computational Fluid Dynamics (CFD) techniques. A 3D site model has been realized and the air velocity investigated in the wind tunnel	Velocity field, Reynolds stresses and wall viscous stresses	The analysis of the environmental context for historic buildings preservation and for the whole project of restoration
OTHER HAZARDS (tsunami)	[81]	Demarcation of potential Tsunami risk areas	Height of the wave, thematic maps of buildings, roads, hydrology and land use	Mapping risk areas on a local scale

**Table 12:** Analysis of papers addressing the urban/territorial scale and historic building environment resilience

**6.1.2.2 Cultural resilience**

Of the analysis performed, only one paper addresses the cultural resilience dimension, being the research multidimensional and considering almost all aspects of resilience [75].

Cultural resilience is reflected in the morphology, typology, construction technology and the spatial and functional configuration of the historic city, resulting from a continuous evolution process. The paper presents an analysis and diagnosis of the case study of the "Sassi" of Matera, assessing the main vulnerabilities and qualities with reference to the environmental, socio-cultural and socio-economic dimensions. The cultural dimension is very much related to the social dimension, as the preservation of the community cultural identity is mainly related to the fruition of open spaces and the state of conservation of open space and buildings, which are the reflection of the development over time of tangible and intangible values, as traditional skills, knowledge and vernacular constructive methods.

CULTURAL RESILIENCE				
<ul style="list-style-type: none"> <li>Creation of a community sense of identity and belonging based on the development over time of intangible and tangible values, such as traditional skills and knowledge and vernacular construction practice.</li> <li>Cultural resilience is reflected in the morphology, typology, construction technology and the spatial and functional configuration of the historic city, resulting from a continuous evolution process.</li> </ul>				
SLIGHTLY RELEVANT				
HAZARDS	REF	ASSOCIATED METHODOLOGIES	FACTORS	INPUTS FOR SHELTER
CLIMATE-RELATED	[75]	Preliminary analysis phase focused on the collection of data and information. The analysis supports the diagnosis phase for the assessment of inherent vulnerabilities and qualities of historic towns, in order to carry on the final phase for the definition of potential enhancement and improvement strategies.	<u>Vulnerabilities</u> : State of conservation of comparts; Use of urban chambers. <u>Qualities</u> : Local construction tradition	The historic-geographic, urban-architectural, functional and normative analysis, and the diagnosis at the environmental, socio-cultural and socio-economic levels, pave the way for the identification preventive strategies

**Table 13:** Analysis of papers addressing the urban/territorial scale and cultural resilience

### 6.1.2.3 *Social resilience*

Social resilience has been addressed by 4 papers analysed through different perspectives. On the one hand, it can barely be associated to physical safety, considering the number of people that can possibly be affected by a catastrophic event [69]. This is the case of the paper related to earthquakes, which calculates the occupancy rate of each building and consequently the impact that the event will have on the population. This approach is strictly related to the building environment dimension, as severity of the damages is simulated according to the constructive typology but can support awareness rising in local authorities and citizens in a preventive phase and first responders in the emergency phase.

On the other hand, social resilience is associated to well-being in a broader context as well as cohesion and people's capacity and involvement in decision-making. It is demonstrated that hazards can be mitigated and overcome by social cohesion, as the concept of "neighbourhood", basic unit of the society, guarantee mutual protection, assistance, sustenance and capacity to react to negative effects [75]. Social resilience is often associated to the built environment, as state of conservation, abandonment of buildings and accessibility are parameters which have a direct effect on safety, living conditions, comfort and fruition [75]. Furthermore, there is also a direct relation with the economic dimension, as refurbishment, commercial activities and tourism may lead to both positive or negative effects on the society [82].

Even if tourism should need a specific assessment methodology, one of the papers present how to mobilize and train communities in eco-touristic approach suitable for areas which experience repeated hazards [81]. This approach leads to better prepared communities and foster the implementation of activities compatible with the hazardous characteristics of the territory, while respecting the natural and cultural values.

SOCIAL RESILIENCE				
<ul style="list-style-type: none"> <li>Physical safety and impact of the hazard on the population</li> <li>Involvement of communities in tourism activities based on cultural and natural values promotion through trainings and awareness campaigns</li> <li>Relation among social well-being, cohesion and involvement in decision-making and hazards mitigation</li> </ul>				
RELEVANT				
HAZARDS	REF	ASSOCIATED METHODOLOGIES	FACTORS	INPUTS FOR SHELTER
EARTHQUAKES	[69]	Occupancy rate of each building. Severity of the hazard scenario and density of population and of the built area.	Population living in historic buildings	Damage assessment and emergency management
CLIMATE-RELATED	[75]	Preliminary analysis phase focused on the collection of data and information. The analysis supports the diagnosis phase for the assessment of inherent vulnerabilities and qualities of historic towns, in order to carry on the final phase for the definition of potential enhancement and improvement strategies.	<u>Vulnerabilities</u> : Liveability of indoor space; connection with the modern city; Accessibility. <u>Qualities</u> : Social value of places; Bioclimatic behaviour	The historic-geographic, urban-architectural, functional and normative analysis, and the diagnosis at the environmental, socio-cultural and socio-economic levels, pave the way for the identification preventive strategies
OTHER HAZARDS (gentrification)	[82]	Review of the rehabilitation programme aiming at promoting social restoration as well as urban resilience, including building rehabilitation		Participative conservation through the inclusion of local and international experts
OTHER HAZARDS (tsunami)	[81]	An eco-touristic approach is adopted to maintain the sustainability of the sites. People mobilization and training programs were conducted for the communities. Identify Tsunami evacuation sites using GIS techniques	Height of the wave, thematic maps of buildings, roads, hydrology and land use	Identification of evacuation site for emergency management and sustainable planning in recovery phase

**Table 14:** Analysis of papers addressing the urban/territorial scale and social resilience



**6.1.2.4 Governance and institutional resilience**

Of the papers analysed only one addresses the governance and institutional resilience dimension [78]. The research paper introduces an integrated framework and a platform, a Cloud infrastructure where the data will be collected and processed, providing tools and services both at macro level to give a global view of the entire value chain and at specific level to promote the improvement of specific processes for protection and prevention. Among the objective of the project presented, it aims at defining a collaboration and knowledge-sharing framework for the community of stakeholders engaged in the protection of CH from climate change and natural hazards. To this aim, different information data sources are integrated, processed, managed and make available to all cultural heritage users involved in the monitoring and decision-making processes.

GOVERNANCE AND INSTITUTIONAL RESILIENCE				
<ul style="list-style-type: none"> <li>Integration, process, management and availability of different information data sources to all cultural heritage users involved in the monitoring and decision-making processes.</li> </ul>				
SLIGHTLY RELEVANT				
HAZARDS	REF	ASSOCIATED METHODOLOGIES	FACTORS	INPUTS FOR SHELTER
CLIMATE-RELATED	[78]	Systematic and integrated methodology for risk assessment and management in response to adverse effects of natural hazards and climate change-related events.	The STORM risk assessment procedure has been developed based on the current risk assessment standards and guidelines	Allow any category of a CH users to always monitor a site's condition

**Table 15:** Analysis of papers addressing the urban/territorial scale and governance and institutional resilience

**6.1.2.5      *Economic resilience***

The economic resilience dimension has been addressed by 4 papers. The assessment of this dimension depends on the type of hazard considered. For earthquakes economic parameters are related to loss estimations [69], [72], considering damages scenarios in the building stock as well as repair, restoration or replacement costs associated; for floods an economic value of affected commercial, industrial or tertiary activities is given, considering also, a part of structural damages, jobs [84]; for climate-related hazards, again the case study of the “Sassi of Matera” considers the positive effect of tourism in terms of incomes for retrofitting, reuse and management of the historic site and development perspectives versus the uncontrolled development of the tertiary sector [75].

ECONOMIC RESILIENCE				
<ul style="list-style-type: none"> <li>Loss estimations, considering damages scenarios and repair, restoration or replacement costs associated</li> <li>Economic activities and jobs affected by hazards</li> <li>Economic incomes derived from tourism and investments in new business</li> </ul>				
RELEVANT				
HAZARDS	REF	ASSOCIATED METHODOLOGIES	FACTORS	INPUTS FOR SHELTER
EARTHQUAKES	[69]	Economical losses are estimated as the present restoration cost of the damaged buildings	The classification into macro elements and collapse mechanisms has allowed the definition of methods to assess damage and to quickly acquire useful information for handling emergencies	Damage assessment and emergency management for local planning
EARTHQUAKES	[72]	The mean damage grade can be interpreted either economically or by means of an economic damage index representing the ratio between repair and replacement costs	Estimation obtained for different damage scenarios. Damage estimation models are dependent on the physical damage grades	Seismic risk mitigation through planning, strengthening campaigns and action plan
FLOODS	[84]	Estimation of economic losses of land if no action for protection or remedial measures are taken.	Land cover, urban land use, employment and jobs	Better assessment of regional planning and preventive actions
CLIMATE-RELATED	[75]	Preliminary analysis phase focused on the collection of data and information. The analysis supports the diagnosis phase for the assessment of inherent vulnerabilities and qualities of historic towns, in order to carry on the final phase for the definition of potential enhancement and improvement strategies.	<u>Vulnerabilities</u> : Development of tertiary sector. <u>Qualities</u> : Touristic development	The historic-geographic, urban-architectural, functional and normative analysis, and the diagnosis at the environmental, socio-cultural and socio-economic levels, pave the way for the identification preventive strategies

**Table 16:** Analysis of papers addressing the urban/territorial scale and governance and economic resilience

**6.1.2.6 Environmental resilience**

Only one paper of the 18 analysed is oriented towards the environmental resilience [83]. The research presented addresses a geo-hydrological mapping developed through the use of different techniques, such as field survey and remote sensing with the objective of identifying heritage elements located in slope instability prone areas. This dimension can be considered as part of the information necessary to address the building environment dimension, as it gives information on the ground layer described above. Knowledge on type of soil or geological information is therefore the basis to assess the different response of the materials to weathering, erosion, seismic shocks or man-made excavations.

ENVIRONMENTAL RESILIENCE				
<ul style="list-style-type: none"> <li>This geological-geomorphological setting where heritage is located can be particularly prone to hazards</li> </ul>				
SLIGHTLY RELEVANT				
HAZARDS	REF	ASSOCIATED METHODOLOGIES	FACTORS	INPUTS FOR SHELTER
OTHER HAZARDS (geo-hydrological hazards)	[83]	A geo-hydrological mapping was carried out by combining geological and geomorphological field surveys with remote sensing data, with GPS surveys and pre-existing topographic data	Location and geological and geomorphological conditions	Geomorphological characterization and hydrological analysis for risk area identification in preventive planning

**Table 17:** Analysis of papers addressing the urban/territorial scale and governance and environmental resilience

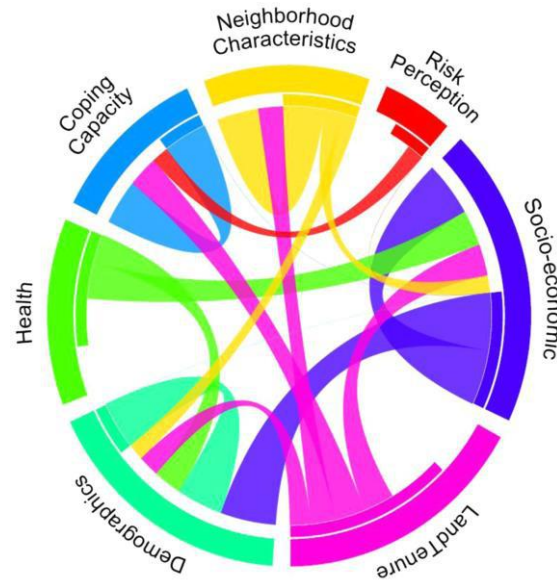
## 6.2 Improvement of generalised resilience

The generalised resilience deals with the improvement of non-hazard specific resilience. In the following sections the existing literature is critically reviewed regarding the generalised resilience when it addresses a specific dimension, but also when the aim is more holistic.

### 6.2.1 Dimensional Generalised Resilience

Existing literature addresses quite evenly the identified dimensions in this quadrant. The literature established the inherent qualities of traditional or vernacular building environments. As they are result of evolution processes to adapt to local conditions by local materials and construction cultures they can be considered to be more resilient and climate responsive [85] [86] [87]. One of the examples from literature to assess this dimension is the work of Ray and Shaw (2017) [86] that evaluates the historic built form with respect to climate responsive and socially interactive spaces in a small settlement in West Bengal, to understand the implications of changing built form on urban resilience and review the perception of the local residents towards changing built form. Ariestadi et al. (2017) [88] used typology-morphology analysis through architectural and spatial qualitative description on buildings and environment in order to reveal socio-culture and historical background behind the physical appearances of the spaces, buildings, and environments [12].

The work of Rufat et al. (2015) addressed the social dimension analysing the drivers of social vulnerability in 67 case studies of flood disasters proposing theoretical indicators of social vulnerability (see Figure 10) [89]. The concern of the authors regarding the use of indicators for measuring social vulnerability ("*indicators may mislead decision-making if practical considerations of cost, data availability, and measurability are prioritized over validity*") can be extrapolate to all the dimensions. The Adaptive Capacity Wheel proposes a method to assess the inherent characteristics of institutions to enable the adaptive capacity of society [20].



**Figure 10:** Connectivity within and among social vulnerability drivers [89]

Economic resilience is a major way to reduce losses from disasters, but it is necessary to precisely define and measure it and make the distinction between pre-disaster phase (static economic resilience where an efficient allocation of existing resources is necessary) and post-disaster phase (dynamic economic resilience where the urgency is to speed the recovery through repair and reconstruction) [90]. Disaster governance is an emerging concept related to environmental governance with implications in state-civil society relationships, economic organization, and societal transitions [91]. Various measures can be employed to assess disaster governance; more research is needed in this nascent field of study on factors that contribute to effective governance and on other topics, such as the extent to which governance approaches contribute to long-term sustainability.

## 6.2.2 Multidimensional Generalised Resilience

As it can be seen from the literature review, generalised resilience is more commonly addressed from a multidimensional perspective. Literature is focused in offering new tools, frameworks and assessment methods to operationalise the resilience and include it in urban planning processes.

### 6.2.2.1 Frameworks for resilience

The recent literature has reviewed existing resilience frameworks trying to operationalise resilience [3] [24] [92] being quite critical regarding the numerous attempts of creating new frameworks “as they tend to be vague, piecemeal, and, in some cases theoretically

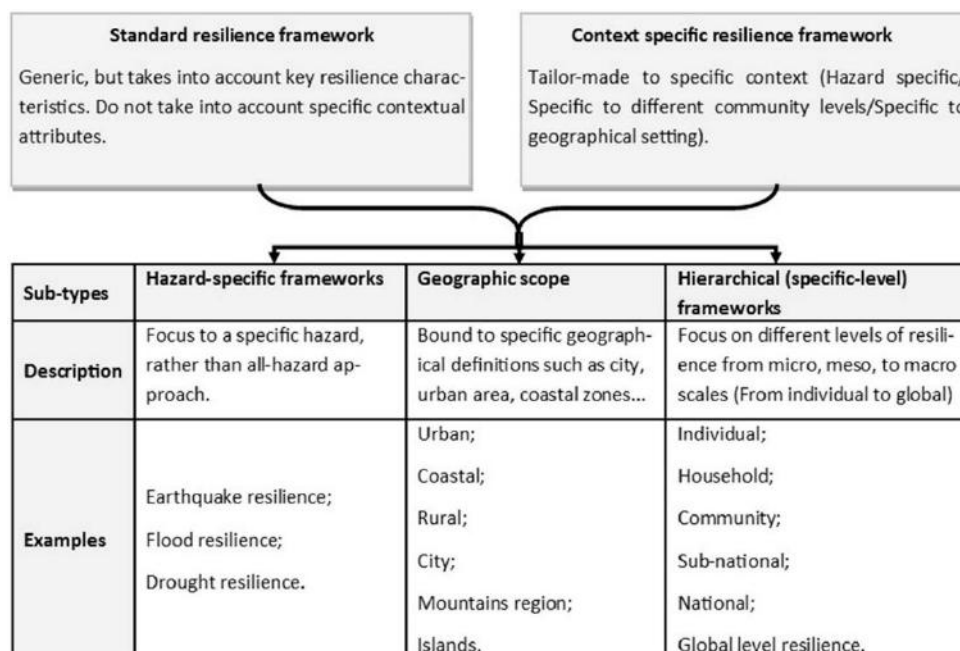


weak” [6]. The work done by Cerè et al. [3] established that existing resilience framework research is quite fragmented and facing several shortcomings:

- Only a few studies deal with the resilience assessment of an urban system as a whole, considering the relationships and inter- actions between multiple urban components;
- There is a lack of studies of the system recovery phase;
- Given the available metrics, time-dependency of the system resilience is often neglected;
- As a measure for system performance, only one figure-of-merit is usually used;
- In existing quantitative approaches to the resilience assessment of urban systems the social aspect is frequently considered in a very simplified or limited way, which means that some important issues may be neglected;
- Open space and its potential are usually ignored in the case of studies about the quantitative assessment of the seismic resilience of urban

Resilience frameworks have been classified in different ways:

- The work of Saja et al. [3] categorised the existent resilience frameworks found in disaster management literature primarily as standard or context-specific frameworks and then as hazard-specific, geographic scope and hierarchical frameworks as it can be seen in the following figure (see Figure 11):



**Figure 11:** Types of resilience framework development approaches [4]

- Another classification effort divides the theoretical frameworks in models that depict resilience as a set of net- worked capacities or based on social, economic, and community capitals [29].
- Asadzadeh et al. (2017) clasified the approaches in *static* or *result-oriented*, referring to models that view the term resilience as *bouncing back* to the same condition before an adverse event and *Dynamic* or *process-oriented*, when an adaptive resilience is adopted to respond to, recover from, and adapt to new conditions [93].

Some of the frameworks identified in the literature and useful for the project are the following:

- Frameworks that enlarge the concept of resilience with concepts as “ecosystem health”, since it includes concepts as “vigour” and “organisation” [94] valuable for resilience assessment.

Level of resilience	<div style="display: flex; align-items: center;"> <span style="margin-right: 10px;">←</span> <span style="margin-right: 10px;">Low</span> <span style="margin-left: 10px;">High</span> <span style="margin-left: 10px;">→</span> </div>		
Resilience approach	Coping	Incremental adaptation	Transformational adaptation
Definition	Coping with the consequences of disasters and change	Incrementally improving existing conventional measures	Transforming the way to address climate impacts in a broader and systemic way
Contributing actions	Actions aiming at restoring current way/quality of life after disaster (disaster risk management) and/or reducing disaster risk  Rebuilding after each disaster and reactive management of change while focusing on current conditions	The extension of familiar actions that are normally taken to reduce losses or enhance benefits from climate variability and extreme events  Doing more of the same to deal with current climate variability and extremes to keep the present system in operation	Questioning the effectiveness of existing measures Foreseen and planned management of change Addressing the root causes of vulnerability by using behaviour and technology Single initiatives or a series of rapid incremental changes in a particular direction to support transformation
Approach to “change”	Change is seen as high risk, builds on past experience to manage risk  <i>High risk of maladaptation</i>	Change is seen as risk, uses known methods and increases their efficiency  <i>Medium risk of maladaptation</i>	Change is seen as opportunity, explores alternative and innovative solutions  <i>Low risk of Maladaptation</i>
Time horizon	Dealing with the immediate impacts of extreme events once they appear or when stresses become obvious (short-term)	Building on existing adaptation measures and knowledge gained by incrementally improving efficiency in short to medium-term.	Taking an integrative, innovative, and long-term view
Scale	Sectoral and local (little connection to larger scales)	Sectoral and local orientation (modest connection to larger scales)	System-wide or multi-system perspective
Examples	<ul style="list-style-type: none"> <li>• Approving development in high-risk, flood-prone areas without any consideration of risks (Chadenas, Creach, &amp; Mercier, 2014)</li> <li>• Emergency management and soft short-term measures such as awareness raising campaigns (EEA, 2016)</li> <li>• Infrastructure upgrade to existing standards or in the exact same location (Matyas &amp; Pelling, 2015)</li> <li>• Existing planning instruments (zoning, setbacks, or building codes without a consideration of risks) (EEA, 2016)</li> <li>• Consideration of current levels of risk in planning (EEA, 2016)</li> </ul>	<ul style="list-style-type: none"> <li>• Inclusion of existing/short to medium-term risk levels to planning instruments (zoning, setbacks, building codes) (EEA, 2016)</li> <li>• Increasing capacity of mitigation infrastructure (e.g. raising sea walls from previous levels, or sewage capacity, dykes) (EEA, 2016; Matyas &amp; Pelling, 2015)</li> <li>• Consideration of lower levels of risk (e.g. 1.5-2 °C warming) (EEA, 2016)</li> </ul>	<ul style="list-style-type: none"> <li>• Incorporating uncertainty into decision-making (EEA, 2016)</li> <li>• Paradigm shift in infrastructure planning: promoting resilience attributes such as redundancy, decentralisation, diversity, etc. (Matyas &amp; Pelling, 2015), Integrated infrastructural measures (integrated seawalls with land use change) (Kates, Travis, &amp; Wilbanks, 2012)</li> <li>• Ecosystem-Based Adaptation (Wamsler, 2015)</li> <li>• Anticipatory learning (Tschakert &amp; Dietrich, 2010)</li> <li>• Sharing resilience knowledge between communities (Chang et al., 2015)</li> <li>• Preparedness for higher levels of change (e.g. 4-6 °C)</li> </ul>

**Figure 12:** Levels of resilience based [95]

- Frameworks with an incremental approach that focus on reactive response to the impacts of climate-related disasters in the short to medium-term, identifying three levels of resilience: coping, incremental adaptation and transformational

adaptation [95]. This kind of frameworks can be useful to design the adaptation roadmaps as they provide a way to do it step by step (see Figure 12).

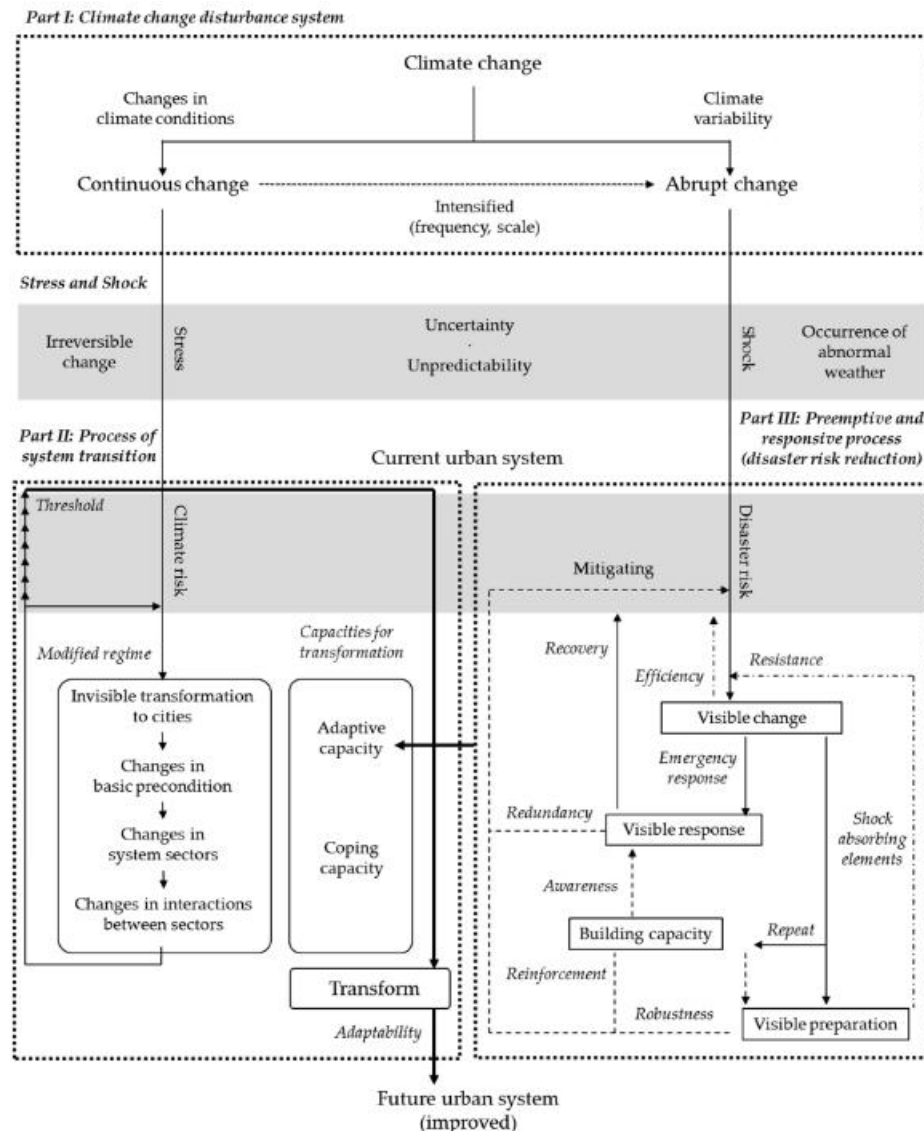
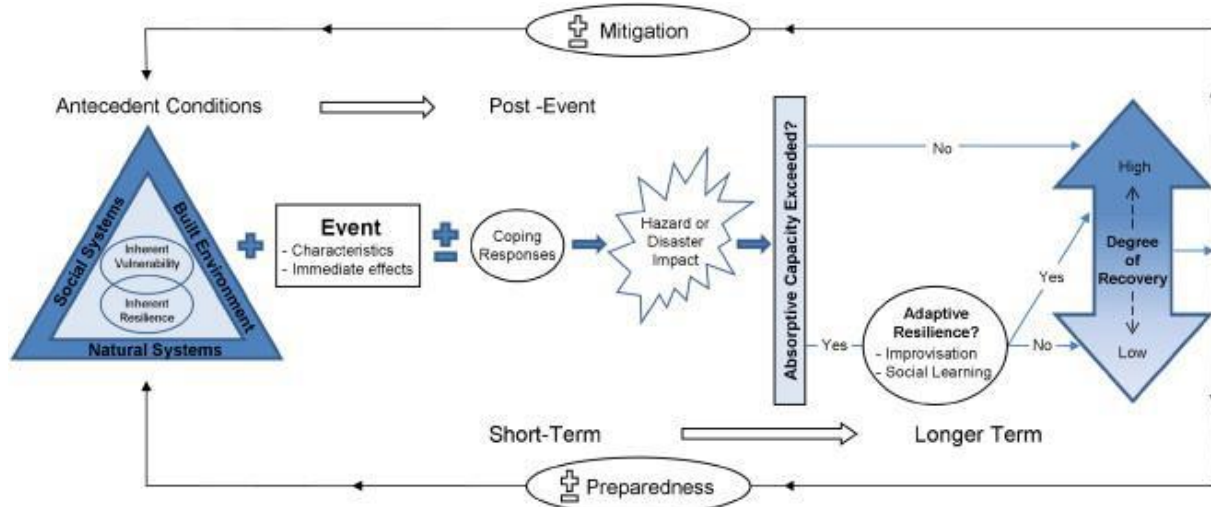


Figure 2. Conceptual framework for urban climate resilience.

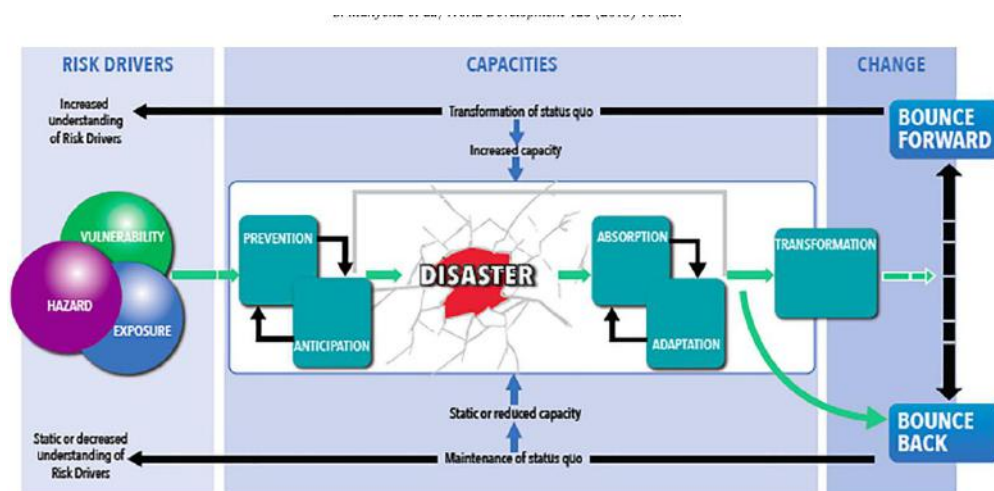
Figure 13 Conceptual framework for urban climate resilience[5]

- Frameworks for urban climate resilience [5], since they include specifically the disturbance coming from climate change (see Figure 13).
- Frameworks designed to improve comparative assessments of disaster resilience at the local or community level and with similar approaches to SHELTER understanding resilience as a dynamic process [96] (see Figure 14)



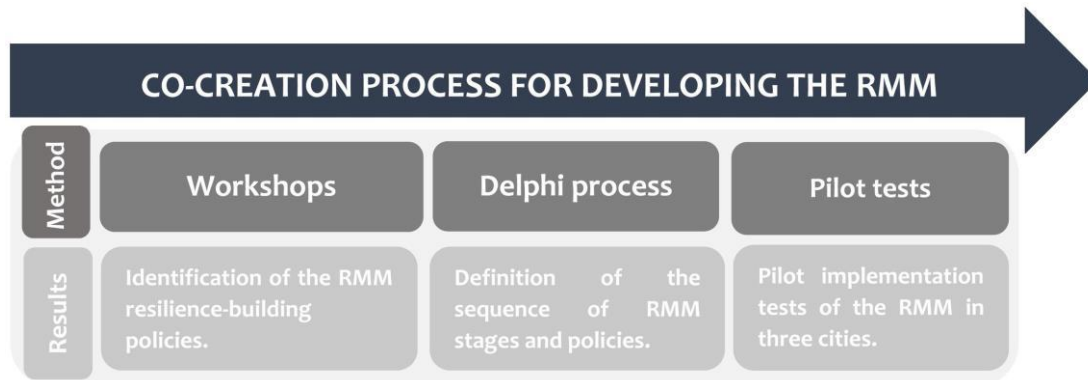
**Table 18** Schematic representation of the disaster resilience of place (DROP) model.[96]

- Frameworks that propose the concept of capacity, as one of the principal bridges between the resilience theory and practice as the Disaster Resilience Integrated Framework for Transformation (DRIFT) [7] (see Figure 14)



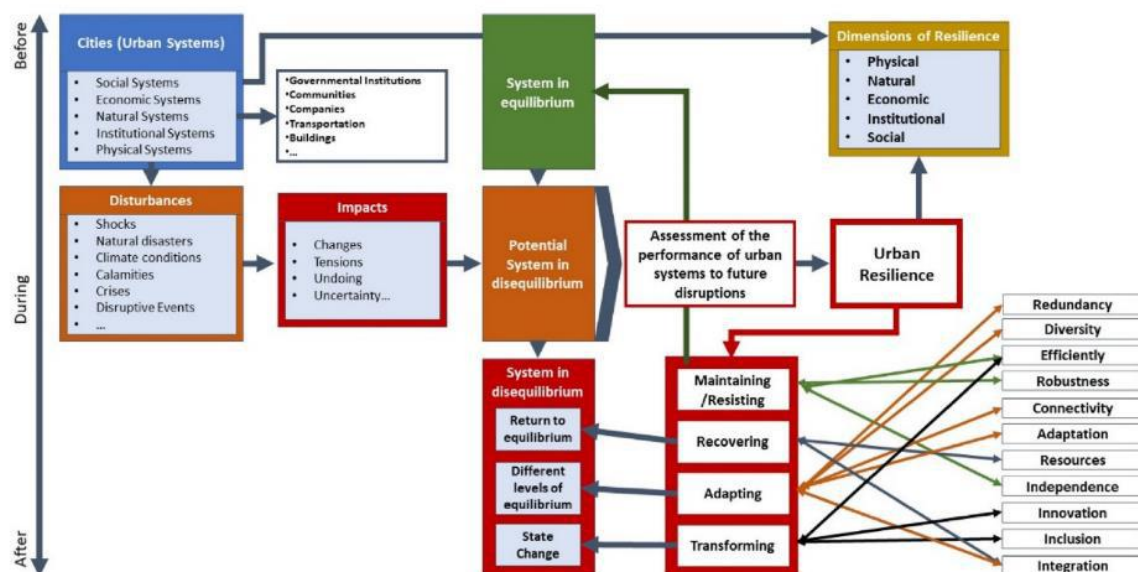
**Figure 14:** Disaster Resilience Framework for Transformation (DRIFT)[7]

- Frameworks that present paths for operationalizing resilience as resilience maturity model (RMM) [97] (see Figure 15)



**Figure 15:** The resilience maturity model (RMM) presents a path for operationalizing resilience.

- Multidimensional urban resilience frameworks similar to SHELTER, like the one proposed by Ribero and Pena (2019) that take into accounts five dimensions (natural, economic, social, physical and institutional), together with four basic pillars (resisting, re- covering, adapting and transforming), and integrating eleven characteristics (redundancy, robustness, connectivity, independence, efficiency, resources, diversity, adaptation, innovation, inclusion and integration) [98] (see Figure 16)



**Figure 16:** Framing of base characteristics in urban resilience framework [98]

- Place-based models analysing the drivers and processes of disaster resilience that are especially critical for the development of management plans to enhance



resilience of communities as the Resilience Performance Scorecard [92] (see Figure 17)



**Figure 17:** Resilience Performance Scorecard [92]

- Framework conceived to allow cities to understand, analyse, and assess their own resilience as The City Resilience Framework developed for the 100 Resilient Cities Programme [18].



**Figure 18:** The City Resilience Framework as developed by ARUP [99]

### 6.2.2.2 Measuring resilience

The critical review of selected 36 tools for assessing community resilience made by Sharifi in 2016 [100] is very revealing regarding the dimensions that has been considering in the literature so far and how the cultural heritage and HA have been neglected. Six criteria were used for evaluating the performance of these resilience assessment tools: addressing multiple dimensions of resilience, accounting for cross-scale relationships, capturing temporal dynamism, addressing uncertainties, employing participatory approaches, and developing action plans. In the following figures (see Figure 19) it can be seen the list of criteria evaluated and proportion of tools including each criterion. Local knowledge and culture have been evaluated as:

- Past experience with disaster recovery, learning from the past (considered in less than the 50% of the papers)
- Cultural and historical preservation, indigenous knowledge and traditions (considered in less than the 50% of the papers)
- Considering and respecting local culture and specificities in the process (considered in less than the 25% of the papers)

Sub-Dimension	Criteria	N	Sub-dimension	criteria	N		
Environmental (environment and resources)	Ecosystem monitoring and protection	56	Economic	Insurance (domestic and non-domestic) and social welfare	58		
	Using local knowledge and native species	11		Financial instruments (Contingency funds, operating funds, capital funds etc.)	53		
	Erosion protection	19		Stability of prices and incomes, property value	17		
	Protection of wetlands and watersheds	25		Inward investment	19		
	Availability and accessibility of resources (air, energy, water, food, soil, etc.)	19		Investment in green jobs and green economy (self-sufficiency, urban farming, etc.)	17		
	Reduction of environmental impacts (various types of pollution)	11		Connections with regional economy	8		
	Quality of resources	56		Business cooperation (inter and intra)	8		
	Biodiversity and wildlife conservation	25		Diverse economic structure and livelihood strategies	64		
	Resource management (production, consumption, conservation, recycling, etc.)	28		Openness to micro enterprises and micro-finance services, entrepreneurialism	31		
	Population composition	39		Public-private partnership	28		
	Language abilities	17		Private investment	8		
	Car ownership, mobility	17		Locally owned businesses and employers	17		
	Land and home ownership	25		Balance of local labor market supply and demand	8		
	Diverse skills (to pool skills at the time of disaster)	17		Robustness & redundancy	72		
	Social (Community bonds, social support, and social institutions)	Degree of connectedness across community groups		39	Robustness and Fortification (of critical infrastructure, vital assets, ecosystems, etc.)	61	
Volunteerism and civic engagement in Social networks		89	Spatial distribution of critical infrastructure (measure against cascading effects)	8			
Collective memories, knowledge, and experience		22	Location of critical infrastructure and facilities	17			
Trust, norms of reciprocity		44	Consolidation of critical utilities and collaboration between utility providers	11			
Shared assets		11	Multi-functionality of spaces and facilities	11			
Strong international civic organizations		17	Shelter and relief facilities and services	72			
Place attachment and sense of community and pride		33	Regular monitoring, maintenance, and upgrade of critical infrastructure	39			
Existence of conflict resolution mechanisms		6	Retrofit, renewal, and refurbishment of the built environment	22			
Empowerment and engagement of vulnerable groups, social safety-net mechanisms		25	Promotion of efficient infrastructure	17			
Safety and wellbeing		Crime prevention and reduction	25	ICT	Diverse and reliable information and communication technology (ICT) networks	58	
		Security services such as police	6	Emergency communication infrastructure (before, during, after disaster)	44		
		Physical and psychological health	64	Transport	Capacity, safety, reliability, integratedness (connectivity), and efficiency of transportation	64	
		Preventive health measures	36				
		Responsive health measures	47				
		Gender norms and equality	33		Inclusive and multi-modal transport networks and facilities	39	
	Social (Local culture)	Ethnic equality and involvement of minorities and population with special needs	22	Land use & urban design	Accessibility of basic needs and services over time (food, water, shelter, energy, health, education)	61	
		Diverse workforce in culturally diverse places	6		Site selection and avoiding risk and habitat areas (floodplain, flood prone; exposed coastal zone)	50	
		Decency, affordability, and fair access to basic needs, infrastructure and services	72		Urban form (compact, dispersed, etc., SVF, aspect ratio)	11	
		Past experience with disaster recovery, learning from the past	28		Mixed-use development	3	
		Cultural and historical preservation; indigenous knowledge and traditions	31		Street connectivity	8	
		Considering and respecting local culture and specificities in the process	11		Density of development	14	
		Positive social, cultural, and behavioral norms	17		Public spaces and communal facilities (for recreation, physical activity, etc.)	25	
		Economic (structure and security)	Employment rate and opportunities		64	Green and blue infrastructure	19
			Income (equality, multiple sources, ...), poverty		50	Amount (percent) of impervious surfaces	6
Age structure of working population			11		Aesthetics, visual qualities	8	
Qualifications of working age population			11		Landscape-based passive cooling	14	
Individuals with high and multiple skills; literacy (education)			42		Passive lighting	3	
Job density (housing-work proximity; extent of out commuting)			17		Passive heating	3	
Individual and community savings			28		Passive cooling	3	
Collective ownership of community resources			6				
Business mitigation, response and redevelopment plan	11						
Codes	≥ 0 <25%		≥ 25% <50%	≥ 50% <75%	≥ 75% ≤100%		

Sub-dimension	Criteria	%
Leadership and participation	Strong Leadership	44
	Stability of leadership and political stability	3
	Shared, updated, and integrated planning vision (long term)	36
	Transparency, accountability, corruption etc.	36
	Multi-stakeholder planning and decision making	64
	Decentralized responsibilities & resources	6
Management of resources	Efficient management of resources (funds, staff, etc.)	19
	Skilled personnel and emergency practitioners	39
	Population with emergency response and recovery skills (first aid, etc.)	14
	Redundant capacity in terms of personnel	8
Contingency, emergency, and recovery planning	Integration of risk reduction and resilience into development plans and policies	28
	Existence of climate change and environmental policy and plans	8
	Understanding risk patterns and trends	14
	Continuous and updated risk assessment; scenario making for different kind of infrastructure and services (costs, losses, etc.)	42
	Emergency planning and existence of emergency operation center that integrates different agencies and organizations	25
	Availability and update of contingency plans (e.g. post-storm traffic management)	61
	Availability of mitigation plan	53
	Early warning, evacuation plan, and access to evacuation information	61
	Inclusion of transient population (tourists, etc.) in emergency planning	3
	Inclusion of disaster resilience and lessons learned in the recovery plan	14
	Speed of recovery and restoration	19
	Ongoing process of revising and monitoring plans and assessments	39
	Standardized, updated, and integrated databases for action planning, monitoring and evaluation purposes	19
	Cross-sector collaboration (alignment of aims) and partnership among organizations	39
Collaboration	MOUs and MOAs with neighboring communities and agencies within the broader region	39
	Knowledge and information transfer and best practice sharing (inter and intra city)	28
R&D	Innovation and technology update	36
	Research (funds, facilities) on risks and academy-society collaborations	25
Regulations/enforcement	Availability and enforcement of legislations (policing, crime, building code, environmental law, business law, etc.)	64
Education and training	Management of informal settlements	11
	Behavioral issues and demand management	3
	Education (from elementary or secondary school), training, and communication	75
	Drills and exercises	22
	Education and training for all linguistic groups; and all groups generally	8
	Capacity building and enhancing awareness; dissemination of statistical data and assessment results	44
	Incentives for encouraging mitigation and adaptation (including self-mobilization, self-organization, etc.)	19

**Figure 19:** List of criteria evaluated and proportion of tools including each criterion [100]

According to the work of Asadzadeh et al. [5] the measurement focus of the different resilience frameworks is deeply related with their concept of resilience:

- Engineering resilience: measuring recovery and stability of communities by focusing on return time and efficiency of characteristics
- Ecological resilience: capturing persistence level of communities through focusing on buffering capacity, withstanding shocks, and maintaining functions
- Socio-ecological resilience: measuring adaptive capacity, as well as learning, and transformability (which enable communities to respond successfully to, recover from, and adapt to new conditions [26].

The approach of SHELTER of measurement of resilience through indicators is becoming increasingly common maybe due to the inherent difficulty of its quantification [93]. If an assessment of resilience from the holistic perspective is desired, the used resilience indicators should be able to capture the change in resilience at different scales and should be cross-scale [75]. There are various efforts to offer systematic methods to address the suitability of those indicators. Parson et al. for example developed a top-down assessment conceptual framework using coping and adaptive capacities (Australian



Natural Disaster Resilience Index- ANDRI). They selected well-developed assessment approaches and identify generalized criteria for indicator selection to assess the resilience [101]. The work that is summarised in the following table (see Table 19) it could be very useful for indicator selection in Task 2.2:

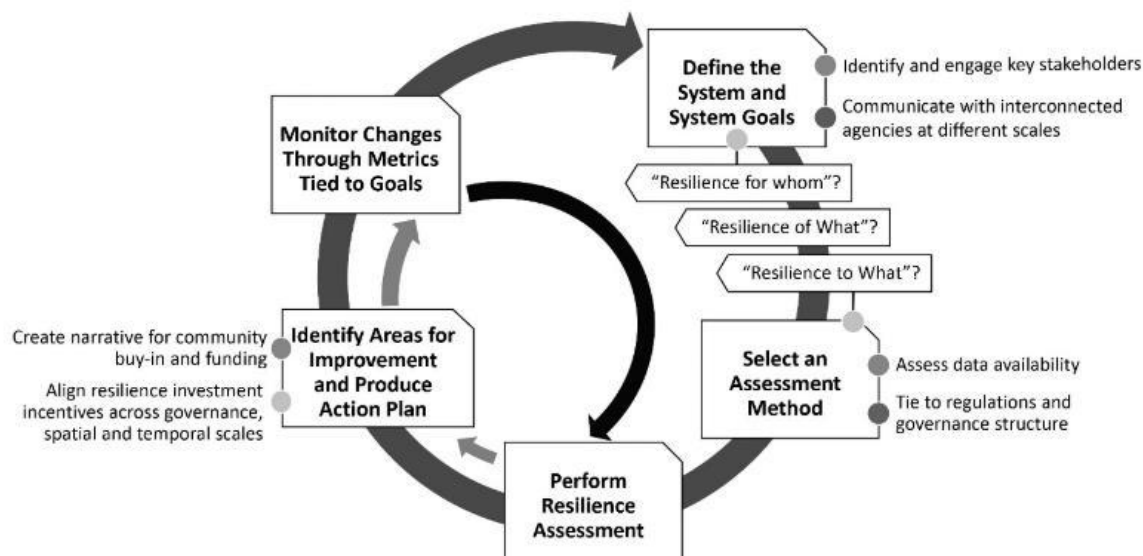
Criteria for indicator selection	Requirements
The indicator reflects a justifiable element of natural hazard resilience	•The relationship between the indicator and natural hazard resilience has been verified in the academic/professional literature
The indicator can track change and variability in natural hazard resilience	•Change in the indicator can be determined and associated with change in resilience spatially and temporally
The indicator is relevant to the scale(s) of assessment	•The indicator aligns with the scale at which the assessment is undertaken. There may be a requirement for an indicator to remain valid across scales (e.g. local to national).
The indicator is measurable and readily interpretable	•The indicator is specific and precisely defined. •The indicator is quantifiable and spatially referenced •The indicator is easy to define, understand and communicate
The measurement method for the indicator is robust	•Measurement is reliable (and verifiable) and representative of reality •Measurement occurs regularly enough for the purpose •Measurement is methodologically sound
The indicator is achievable – data are available, accessible and cost effective	•Data are available at the required scales across most of the study area •Data are readily available from secondary sources •Data can be accessed within the cost and resource framework

**Table 19** Generalized criteria for indicator selection [101]

### 6.2.2.3 Participation in resilience building

Improvement of HA resilience is deeply context-specific, not only because historic environments have very specific local materials, construction techniques and legislative frameworks, but also because resilience depends strongly on local aspirations, therefore participatory approaches for the conceptualization of resilience are required [8]. Only by involving all the required stakeholders and interest groups is it possible to balance all the diverse interests and requirements[19]. One of the key questions when operationalising resilience is “Who has the right to decide which trade-offs are acceptable?” [102]. As the work of Sharifi et al. states co-design methods can be employed for conceptualizing resilience and answer to this question. The authors used the Structured Interview Matrix to facilitate discussions among a diverse group of researchers and practitioners attending the International Workshop on Tools and Indicators for Assessing Urban Resilience [8]. This work could be very useful in SHELTER when working in the Open Labs (see section 7). The authors describe a participatory event that brought together a group of scholars and practitioners to identify key themes, highlight research gaps, and identify a list of priority questions that should be further

addressed in future work. The result was the definition of critical consideration for decision making in resilience (see Figure 20)



**Figure 20:** Critical consideration for effective resilience assessment and decision making [8]

#### 6.2.2.4 Operationalising resilience: integrating in urban planning

Generalised resilience has to deal with future uncertainties and errors in predictions being this one of the biggest challenges of urban planning processed [8]. There is a need to change from the classical “predict-and-prevent” paradigm since it does not capture all the complexities of the urban environments [103], from a “fail-safe” approach to a “safe-to-fail” one. Iterative processes and collaborative scenario building across different time horizons are suggested by literature as effective tools to address urban complexities and uncertainties [8]. “Safe-to-fail” HA would require planning and design processes that introduce the resilience characteristics previously identified in Section 4.2.

P. Lu and D. Stead (2013) based in their work in Rotterdam identified six characteristics of urban resilience addressed by urban planning in order to operationalise it:

- **Attention to the current situation** “indicates the ability to understand and maintain the existing conditions of the environment. It addresses physical facilities and the monitoring and evaluation of policy”
- **Attention to trends and future threats** “concerns the ability of prediction on the basis of current information, for instance, scientific scenarios, models of future impacts, and the probability of risks in policy-making. This characteristic relates to issues of trust and learning”

- **Ability to learn from previous experience:** *"Urban resilience also draws on experiences from the past and requires the capacity to utilise the necessary knowledge to deal with similar conditions in the future"*
- **Ability to set goals:** *"The ability to set goals indicates the willingness (and power) to respond to issues of change such as climate change and flood risk management. Visioning exercises involving multi-sectoral collaboration may be used to formulate goals"*
- **Ability to initiate actions:** *"The ability to initiate actions is related to the authority of policy-making, including formal and informal forms of power. These involve different kinds of resources (e.g., experts, knowledge producers, projects) which allow actions to occur"*
- **Ability to involve the public:** *"The ability to involve the public addresses the degree of public participation in policy decisions, both in terms of informing the public and responding to concerns from the public"*

Based in these characteristics, the same authors proposed an assessable framework of resilience in planning decision-making as it can be seen in the following table (see Table 1)

Planning related stage	Overarching question	Resilience characteristics addressed by planning system	Measures/indicators: (the capacity to)
The assessment stage	How well can and does city assess its vulnerabilities to disturbances and its capacity to respond to threats?	1. Attention to current situation	A1: Monitor current conditions
		2. Attention to trends and future threats	A2: Predict regional trends and patterns
			A3: Identify and assess the probability of risks and disturbances
		3. Ability to learn from previous experience	A4: Learn from past lessons
		4. Ability to set goals	A5: Set up 'priorities' based on risk assessments and probabilities
		5. Ability to initiate actions	A6: Invest in and develop scientific scenarios for risk assessments
			A7: Collaborate decision-making between different levels of governance
The readiness stage	How well can and does city ready itself to respond to the assessments and potential disturbances?	6. Ability to involve public responses	A8: Communicate findings (concepts, skills, actions) in planning policy
		1. Attention to current situation	R1: Evaluate and maintain the conditions of flood-protective facilities
		2. Attention to trends and future threats	R2: Forecast
		3. Ability to learn from past failures	R3: Learn from past lessons (artificial reasons which cause floods)
		4. Ability to set goals	R4: Propose new standards
		5. Ability to initiate actions	R5: Authorise and mandate infrastructural actions
			R6: Coordinate readiness actions
			R7: Innovate and propose economic-benefit actions

		6. Ability to involve public responses	R9: Raise public awareness and preparation education
--	--	--	--

**Table 20:** An assessable framework of resilience in planning decision-making [10]

Complementary to this, the work of Pica [104] aims to point out how policies, legislation, organizational arrangements and local initiatives (e.g., involving municipalities) targeted at addressing the severity of disasters could be implemented under the influence of the Sendai Framework. The gaps and possible solutions are described as follows:

- Training and action oriented to education (cultural heritage protection and meaning, and so on), moreover those regarding communities' involvement, are starting to be undertaken, but are still scarce, and a distance between community-based organizations and policies led by regional and national governments is evident. These organizations (associations, universities, schools, etc.) should be more connected to local authorities through agreements or contracts.
- First aid networks and policies oriented to cultural heritage protection from man-made and natural disasters have recently been created, but must be strengthened and connected with new partnerships, together with finding new private funds. Protocols and peer-to-peer urbanism platforms should also be created, in order to use ICT technologies, early-warning systems, and remote sensing for monitoring, risk assessment and traditional housing recovery.
- Solutions must be found to the lack of funding and national frameworks oriented to owner-driven policies of reconstruction, e.g., crowdfunding platforms and social participation activities to territorial management and urban regeneration. Risk impact assessments and risk sensitive investments must be strengthened. Studies on these topics at a university level have not been encouraged enough and they should be disseminated across countries. The challenge is to ensure the inclusion of analysis based on hazard and vulnerability assessments in all development investments.
- Effective master plans at international, national and regional levels should be developed, based on local communities' participation and an owner-driven approach to reconstruction, in order to protect the traditional environment while interchanging and reviving local know-how and best practices.

THEME	REF		INPUTS FOR SHELTER
FRAMEWORKS FOR RESILIENCE	[94]	Frameworks based on “ecosystem health” (considering “vigour”, “organisation” and “resilience”)	Inputs for resilience assessment in WP2 (especially in T2.2)
	[69]	Frameworks with an incremental approach that focus on reactive response to the impacts of climate-related disasters in the short to medium-term, identifying three levels of resilience: coping, incremental adaptation and transformational adaptation	Inputs for developing the operational knowledge framework (WP4)
	[4]	Frameworks for urban climate resilience	Include climate change in the framework (WP2 and WP4)
	[70]	Frameworks for disaster resilience of place (DROP) model	Resilience as a dynamic process for developing the operational knowledge framework (WP4)
	[6]	Disaster Resilience Integrated Framework for Transformation (DRIFT)	Concept of capacity, as one of the principal bridges between the resilience theory and practice (WP4)
	[97]	The resilience maturity model (RMM)	Path for operationalizing resilience through workshop and pilot test (Open Labs in WP7)
	[98]	Multidimensional urban resilience frameworks	Urban resilience framework based on four basic pillars (resisting, re- covering, adapting and transforming), divided in five dimensions (natural, economic, social, physical and institutional) and integrating eleven characteristics (redundancy, robustness, connectivity, independence, efficiency, resources, diversity, adaptation, in- novation, inclusion and integration) (WP2 and WP4)
	[92]	Resilience Performance Scorecard	Drivers and processes of disaster resilience critical for the development of management plans to enhance resilience of communities (WP4)
	[18]	The City Resilience Framework	Frameworks for self-evaluation of resilience (WP2 and WP4)

MEASURING RESILIENCE	[73]	Critical review of selected 36 tools for assessing community resilience	Identification of tools that take into account cultural heritage and local knowledge (WP2)
	[101]	Generalized criteria for indicator selection to assess the resilience	Selection of final indicators in T2.2
	[93]	Quality metrics related to indicator appropriateness	Selection of final indicators in T2.2
PARTICIPATION IN RESILIENCE	[8]	Structured Interview Matrix	Critical considerations for decision making in resilience in Open Labs (Wp/)
INTEGRATING RESILIENCE IN URBAN PLANNING	[10]	Assessable framework of resilience in planning decision-making	Characteristics of urban resilience addressed by urban planning and indicators for (WP2 and WP4)
	[104]	Implementation of the Sendai Framework	Gaps and possible solutions for the implementation of Sendai Framework (WP4)

**Table 21:** Summary of the literature review regarding generalised resilience and their inputs for SHELTER

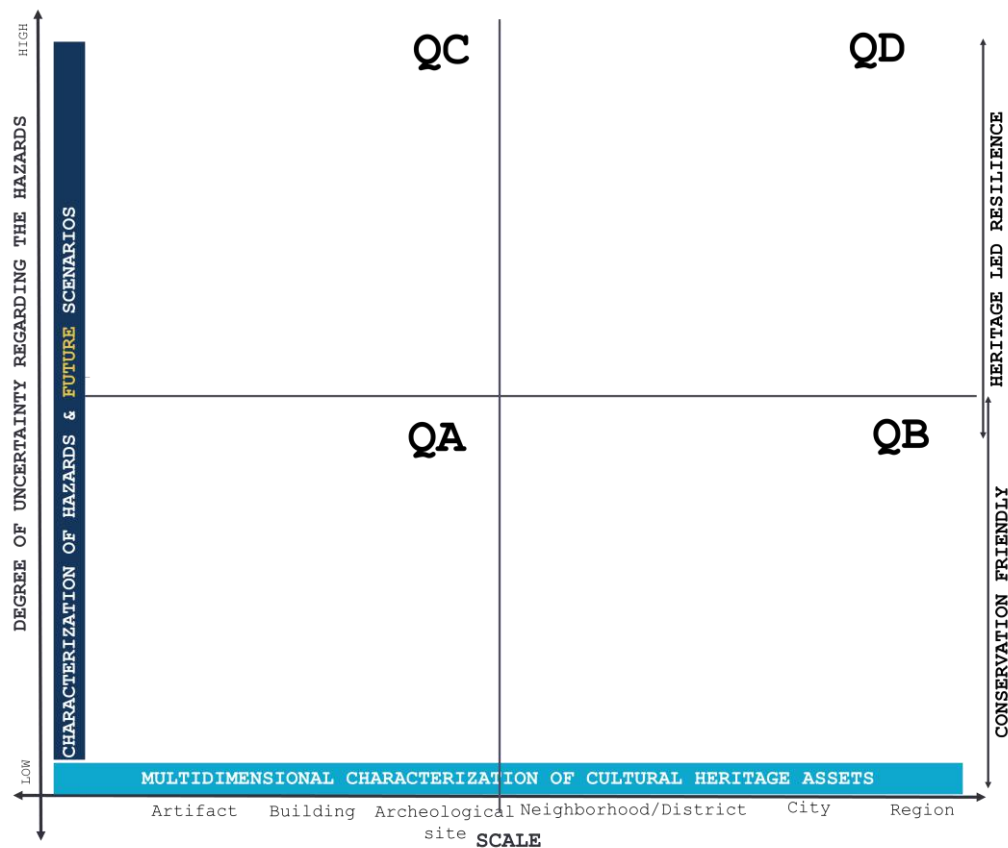
### 6.3 SHELTER strategy for systemic resilience assessment

Resilience concept can be considered as a transdisciplinary bridge that can function as a central unifying concept for the fields of DRM, CCA, CHM and SD. It is suitable for a heritage-led resilience enhancement assessment because of its focus on the transformation processes (how societies cope with uncertainty, adapt to new situations and transform to new environmental, social, economic conditions to make the new system more sustainable while retaining their identity).

SHELTER will develop a comprehensive knowledge generation methodology linking the generalised and specified resilience, that will fulfil the requirements identified in Section 4.6 :

- i) Acknowledge resilience, vulnerability and adaptive capacity as nested concepts, linking them across the spatial, temporal and uncertainty scales
- ii) Allow measuring the singularity of CH physical vulnerability framed in a broader concept of multidimensional HA resilience
- iii) Consider the multidimensionality of resilience (physical, social, economic, institutional and cultural)
- iv) Combine hazard-specific resilience with generalised resilience
- v) Will allow semi-automatic assessment, prioritisation, decision-making, auto evaluation and monitoring serving for compass in the different long-term decision points but also for short term monitoring strategies (including project results)
- vi) Be applicable from artefact/building scale to urban or transregional HA including archaeological sites.

As base for the integrated assessment strategy, SHELTER will use the frame already described in Section 4.6 (see Figure 21):



**Figure 21:** Frame for assessment strategy in SHELTER

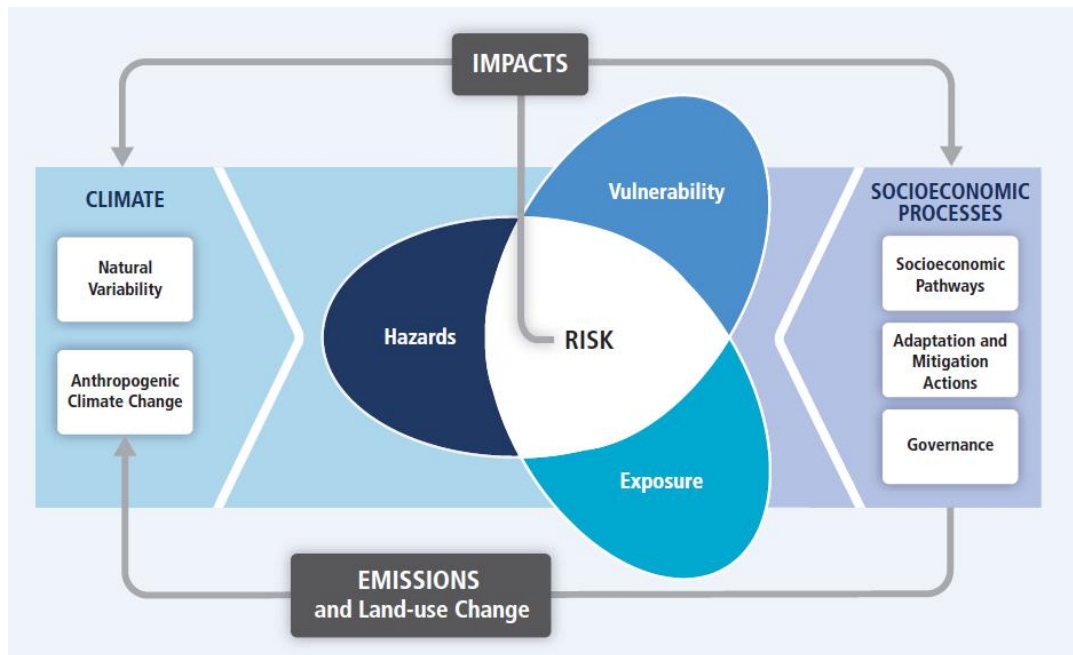
This frame allows to integrate different scales and the different degrees of certainty regarding the hazards. As a result, we will have four assessment quadrants that have been used to structure the knowledge gathered from literature review:

- QA- specific hazards and object/building scale
- QB- specific hazards and urban/territorial scale
- QC- non-specific hazards and object/building scale
- QD- non-specific hazards and urban/territorial scale

The literature shows that the QC quadrant is marginal, and SHELTER will not considerate it.

In **quadrant QA**, the hazard specific risk and vulnerability assessments can use direct quantitative and spatial approaches for prioritization and identification of specific “hot spots” making it especially beneficial for the protection of historical build environmental (conservation-friendly resilience). IPCC considers risk as a function of exposure, vulnerability and hazards [47] as it can be seen in the following figure (see Figure 22):

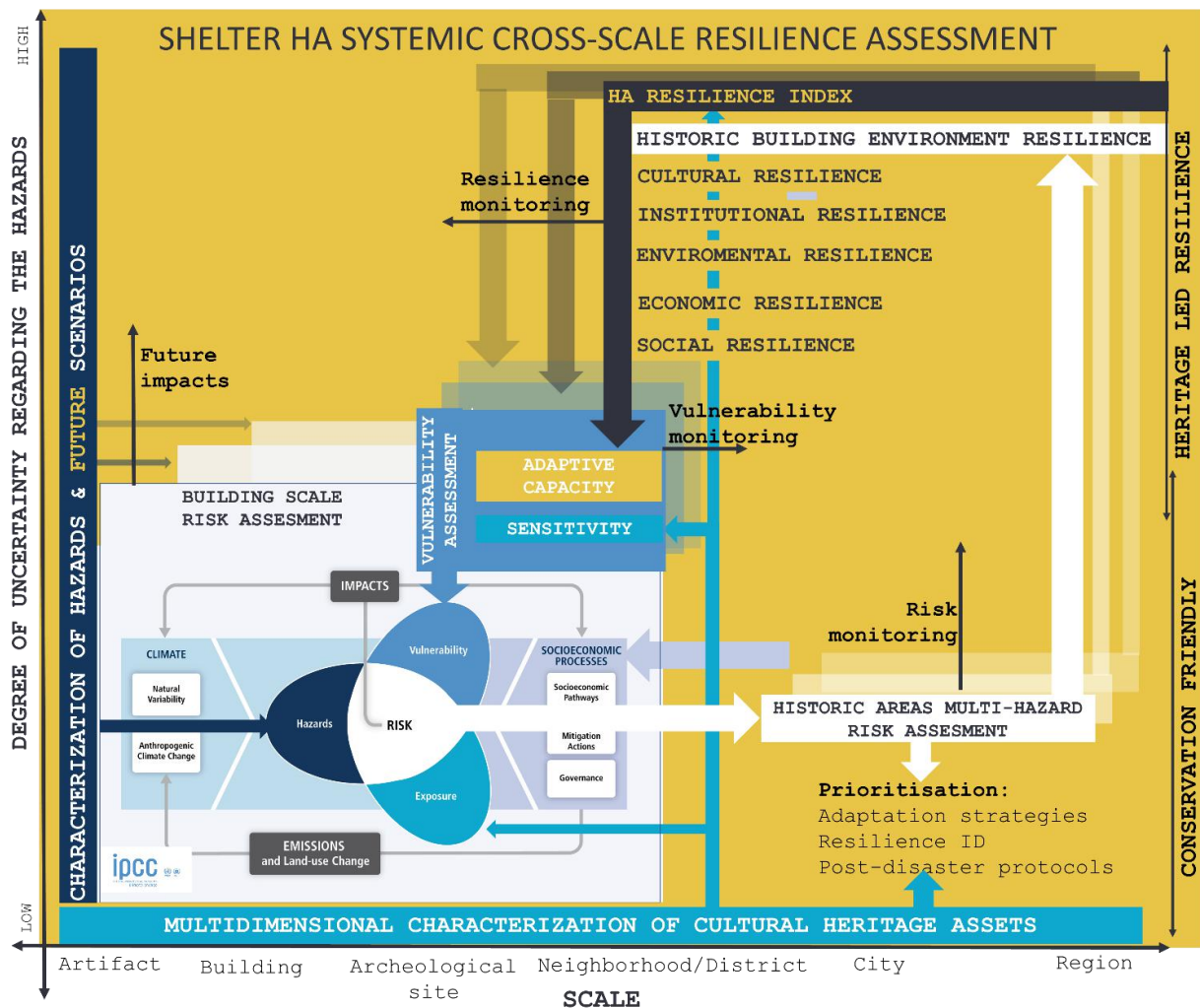




**Figure 22** Illustration of the core concepts of the WGII AR5 [79]

The urban/territorial scale, **quadrant QB**, is key to offer integrated adaptation, documentation and prioritisation strategies for HA, as well as post-disaster protocols. Section 6.1.2 has describe different methods to link with QA and QB quadrants, i.e. how to interconnect the scales, in order to keep the balance between the required information and provided results.

The **quadrant QD** is where the generalised strategy is addressed in its full multidimensional nature. The resilience measurement framework will be indicator-based and will contribute to quantify the performance of the system as a whole regarding its preparedness and the ability to absorb disturbances, to efficiently respond, and adapt to new conditions. SHELTER methodology will be based on a set of indicators that will quantify the links between multiple dimensions of HA resilience, the connections between different spatial scales and the changes across temporal scales. The system will be developed and implemented in collaboration with stakeholders to lead to development of action plans for enhancing resilience. The result will be a HA Resilience Index and KPIs for resilience monitoring, co-monitoring of the project results (in Open Labs) and benchmarking tool. The following figure describes the whole strategy (see Figure 23):



**Figure 23:** SHELTER resilience assessment strategy

In this structure the time scale is represented in the Z axis and considers the future impacts and resilience and risk monitoring.

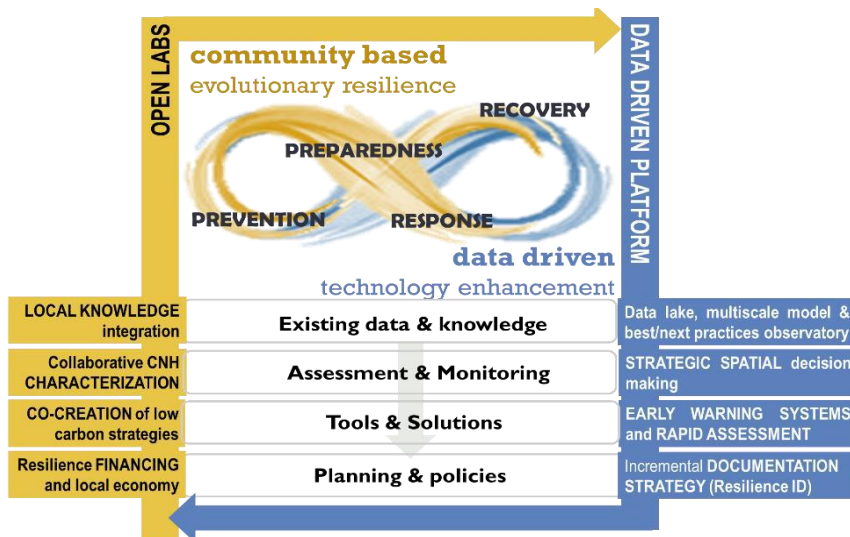
## 7 Architecture of SHELTER operational knowledge framework

Due to the complex, diverse, and context-dependent nature of resilience and reconstruction in HA there is not a single way to address them. **SHELTER operational knowledge framework** should provide a community- and evidence-based framework to local authorities, urban planners, conservation practitioners, first responders, cultural heritage owners and managers 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.

### 7.1 Structure of the SHELTER operational framework

SHELTER operational knowledge framework will be based on a matrix acting as a canvas for the project developments first and as guideline for replication in other cities posteriorly. Therefore, the operational knowledge framework is 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).



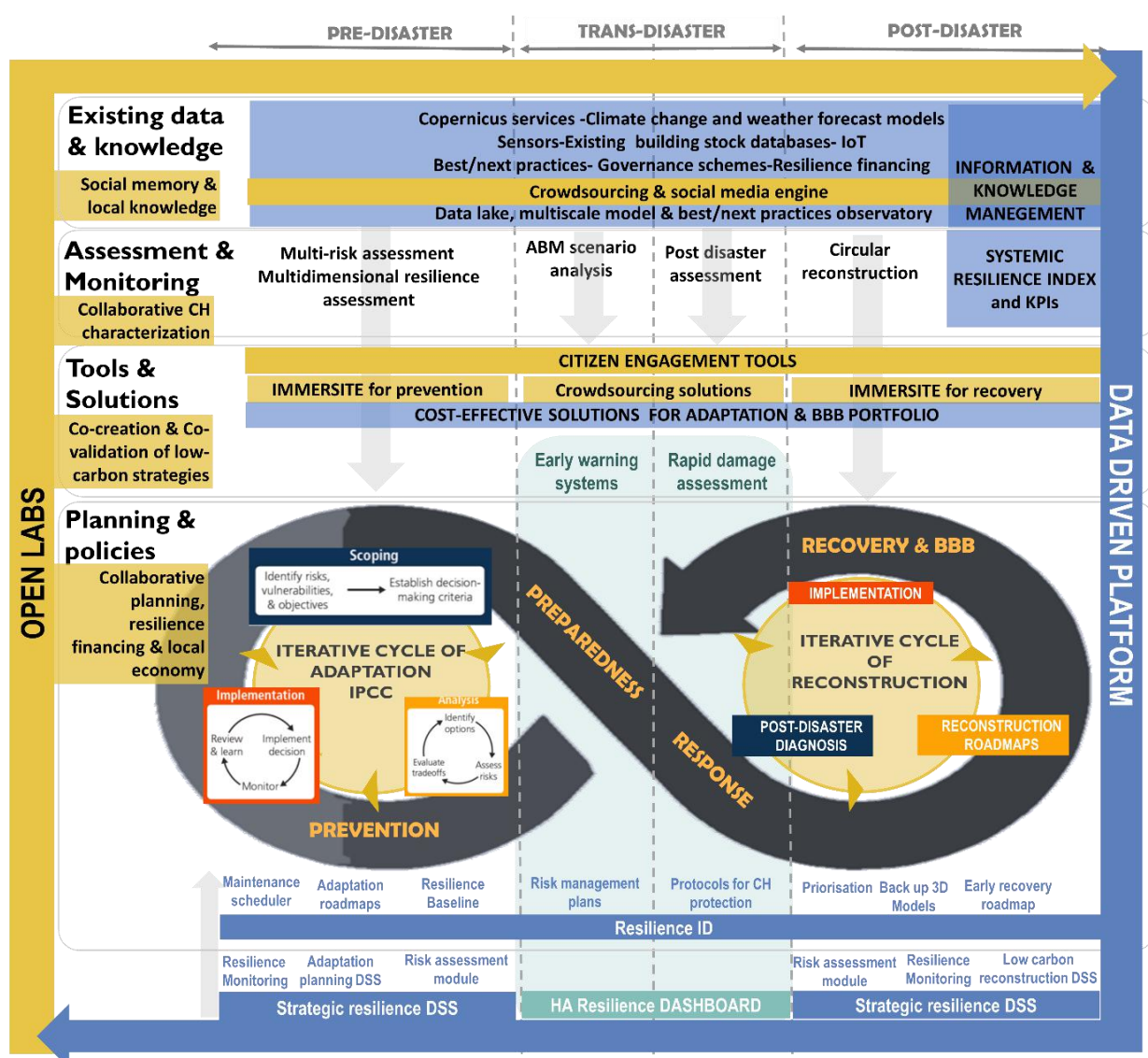
**Figure 24:** Structure of SHELTER operational knowledge framework

The framework will be articulated around two interfaces that will support, shape and contextualize all the process evolving together adapting to each HA:

- The tailored and inclusive resilience Open Labs implementing the community-based approach and,
- The modular and scalable data driven platform for knowledge management.

Both, they will drive adaptation strategies and DRM in all the phases, by providing objective and consistent information for evidence-based decision-making combined with local knowledge and co-creation strategies.

The following diagram (see Figure 25) shows the whole SHELTER Operational knowledge framework and the next sections describe each of its components:



**Figure 25:** SHELTER Operational knowledge framework

### 7.1.1 Information and knowledge management

Through diverse methods as a data lake for heterogeneous data (satellite imagery, sensor data, geo-environmental and social big data, existing building and disaster databases and crowdsourcing), a multiscale data model to structure all information from case studies and a “Best/next Practices Observatory” that will link the portfolio of sustainable and cost-effective solutions for adaptation and reconstruction, governance schemes, co-creation processes blueprints and resilience financing and business models. These three methods will feed the methodology and tools during the **4 phases (prevention, preparedness, response and recovery)** of DRM. They will also structure all the results generated (e.g. Resilience ID in multiscale data model) using open information as participatory mechanisms to encourage the collaboration between the public and private sector.

### 7.1.2 Strategic decision support system (DSS)

Proactive strategic and spatially explicit decision-making tools to support the planning. In **prevention phase** it will support the implementation on the iterative cycle of adaptation proposed by IPCC [105]. This cycle structures the process in scoping (identify risk, vulnerability and objectives and establish decision making criteria), analysis (identifying options, assessing risks and evaluating trade-off) and implementation (implementation of decision, monitoring and review & learn).

In **recovery phase**, it will facilitate the reconstruction by structuring the post-disaster diagnosis, the planning of reconstruction roadmaps and their implementation. The DSS will combine:

- i) A multi-risk assessment module for diagnosis and prioritisation (identifying “hot spots”) based on the multiscale data model and the data lake
- ii) A DSS for planning adaptation and building back better that will combine the information from the multi-risk module and the solutions portfolio
- iii) HA Resilience Index monitoring.

### 7.1.3 Crowdsourcing solutions

Citizen engagement tools for **preparedness and response phases:**

- i) Intelligent conversational tool (chatbot) able to deliver as well as retrieve multimedia geolocated contents from people smartphones, targeting citizens living in the surrounding of HA



- ii) Social media data engine able to fetch in real time social media data related to HA and automatically classify the content using advanced text analytics, image processing and deep learning algorithms.

In **prevention and recovery**, SHELTER INMMERSITE will support the local knowledge extraction and awareness raising with 3D immersion technologies and consultancy methodologies. The theoretical and practical framework for Local Knowledge Extraction (provided in SHELTER D6.5<sup>5</sup>) identifies a series of methodologies, activities and tools that will be implemented in Open Labs for gathering Local Knowledge in historic areas.

#### 7.1.4 HA Resilience Dashboard

CH specific dynamic management tools for **preparedness and response phases** that will connect multi-hazard early warning systems and rapid damage assessment technologies, with smart dashboard for social data filtering and visualization. Its objective is to effectively respond to disaster impacts on heritage assets, by a proper resources management, facing additional challenges that might amplify disaster's impact (i.e. theft, improper handling or consolidation of cultural heritage, etc.). This is done through fast data provision, to minimize the time required for the identification of affected CH, evaluation of their status and prioritization of the interventions.

#### 7.1.5 Resilience ID

Multiscale incremental documentation strategy that will store in the multiscale data model the results of the whole process to make it easily accessible when required. Each CH assets (such as historic building, intangible CH, archaeological sites, artefacts, public spaces, cultural landscapes) will eventually include:

- i) For **prevention phase**: their specific adaptation plan, their role in the general HA adaptation roadmap and a maintenance and adaptation scheduler (to program all the planned maintenance and adaptation tasks)
- ii) For **preparedness phase**: risk management plan
- iii) For **response phase**: specific protocols for CH
- iv) For **recovery phase**: back up 3D models with different level of details to preserve digital memory and support short- and long-term reconstruction strategies. The strategy will start from the prioritise elements (either for their community value or for the result of the risk assessment) and generating a roadmap for the dynamic completion of all the HA.

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<sup>5</sup> D 6.5: Methodology for Local Knowledge extraction due by month 6 This deliverable will provide a guidance dedicated to local experts willing to rapidly gather local knowledge about the history, perceived risks and resilience of a place.

## 7.2 Definition of the workflow for developing the framework

### 7.2.1 SHELTER GLOCAL strategy

The SHELTER Project adopts a GLOCAL research strategy. The term 'GLOCAL' refers to a research strategy that incorporates both a bottom up strategy as well as top down approach (see Figure 26). This allows for the SHELTER project to draw on different knowledge sources ensuring that any project outcomes are coproduced the relevant end users. The 'GLOCAL' research strategy will explore and map the GLOCAL user requirements. In an attempt to coproduce solutions which consolidates knowledge from both top down and bottom up strategies representing global and local sources of knowledge.



**Figure 26:** The GLOCAL Research Strategy utilised within the SHELTER project drawing from both local and global knowledge sources.

In the first instance, the GLOCAL strategy attempts to identify the key stakeholders which are associated with CCA and DRM in order to help steer the Open Labs. To identify these key stakeholders, three case studies are identified that represent a range of natural disasters across different spatial scales. These case studies are as follows:

- i) The 2009 Earthquake in the historic medieval city of L'Aquila earthquake in Italy
- ii) The 2017 Iberian Wildfires which started in Galicia Spain which affected both northern Portugal and North western Spain. (case study directly links to the Open Labs in WP7)

- iii) The 2002 European floods which affected a number of European countries including Prague, Austria, Czech Republic and Hungary.

For each case a detailed ex-post analysis (based on a collaborative root-cause analysis (RCA) approach) will be used exploring how the different events transpired, the types of risks, failures and key stakeholders involved within each unique context. Finally, where possible the ICT and social network services used within each disaster will be identified and its role in exchanging information at the local level explored as the disaster evolved. Finally, the findings will be unpacked in greater detail through a survey of contemporary literature. This will provide the SHELTER Project with a detailed account of the common key stakeholders which are involved in DRM & CCA. It will also highlight how the mix stakeholders differs depending on type of disaster and spatial scales. Finally, it will provide an overview of the role of social network services and how they aided in communication and the dissemination amongst local communities as the disaster developed.

The GLOCAL strategy heavily relies on the involvement of end users and community-based approaches. As a result, it utilizes a bottom up requirement analysis in the form of a survey that will explore end user requirements as regard with CCA, DRM and CHM. The stakeholders will be provided with an introductory narrative to provide context to the project and then asked to rank several potential user requirements. The results will be compared to the outcomes of the RCA. By doing so the key areas for development of the SHELTER framework will be identified based on the input of the end-users. Local stakeholders and technical partners will jointly develop these use cases, which will be based on the current state of the art of technologies that are used to support DRM and CHMN.

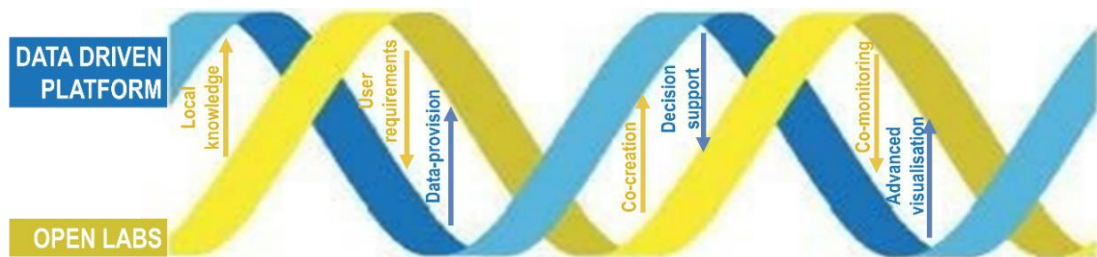
Finally, these results will be combined with the identification of the main user requirements as expressed by international experts in the field. In order to achieve this a multi stakeholders exercise will be organized through a two-day international focus group taking place in Venice, Italy. This workshop with the interactive involvement of UNESCO brings together international organizations, national governments, local governments, cultural heritage site managers, technical experts and carefully selected international advisors. The aim of the workshop is to identify the main top-down user requirements, taking stock of existing frameworks dealing with multi-hazards contexts for DRM in cultural heritage. These top-down end-users requirements typically address conceptual frameworks, legislation and financial/human resources required to address risks in a holistic perspective. The exercise will produce a first set of requirements encompassing the entire DRM cycle from early warning to post-disaster scenario, by using a full set of internationally recognized resources and tools. Overall, this task will



inform the SHELTER framework with essential top down guidance from international organizations charged with the co-ordination and delivery of DRM and CCA strategies.

In summary, an effective GLOCAL strategy will be adopted in SHELTER as a result of co-ordination and continued development of the project. These requirements will be regularly reviewed and formulated in a collaborative way all along the projects. They typically involve both local and international experts. The proposed approach will be designed as an open, collaborative method. It will thereby constitute a ready-to-use instrument for those local communities wishing to involve in a collaborative management of natural risks affecting cultural heritage. The root-cause methodology and the end-user surveys will be designed to be transferable to other places and directly useable by local authorities.

### 7.2.2 Open Labs role in SHELTER



**Figure 27:** Co-evolution of data driven platform and Open Labs

The SHELTER Open Labs represent the stakeholder-centred approach that is at the heart of the project rationale and will help shape the bottom-up side of the SHELTER GLOCAL strategy. Five Open Labs have been established across Europe, each of them revolving around a local, relevant issue concerning the resilience of cultural heritage. The three Open Labs in Ravenna (Italy), Sefeherizar (Turkey) and Dordrecht (Netherlands) have an urban character and address one or more specific historic buildings and structures. The two Open Labs in the Sava River Basin and Baixa Limia-Serra focus on larger, even cross-border, areas.

All five Open Labs (OLs), SHELTER works with a wide range of local stakeholders as co-validators and resilience co-generators. From local government to creative starts-ups, citizens, vulnerable groups and heritage managers: in each of the OLs stakeholders that represent the value chain for resilience in historic areas are engaged. Either closely in the core stakeholder group or more demand-driven as an extended stakeholder.

The diversity in knowledge, perspectives and interests gathered in the engaged stakeholder groups will enable the OLs to function as evaluation frameworks and demonstration sites for solutions and products developed in the SHELTER project. With

their local expertise they will also function as knowledge generators and learning environments, to feed the development of these solutions and products in the first place. And when the resilience solutions are getting implemented, they will be studied and function as transition labs as well.

Initially the Open Labs will mainly function as knowledge generators; disclosing the requirements of local users as well as their (local) knowledge and social memory. In the Open Labs the stakeholders will be co-designing the blueprints of the solutions and products that SHELTER will develop, as well as the design, implementation and maintenance of the overarching data-driven resilience platform. In a later stage the role of the Open Labs will transition towards demonstration sites and evaluation frameworks where project results can be validated and monitored and different cost-effective solutions will be shaped, tested and piloted. Finally, to facilitate the implementation on local level the Open Labs will function as transition labs and characterise the local business landscapes, support territory activation and resilience financing (external) in a comprehensive and thorough way.

By sharing experiences, lessons learned and good practices the diverse stakeholders in each Open Lab can learn from each other. SHELTER will formalize that process with dedicated meetings and additional training and education on disaster risk reduction. This way the Open Labs will also function as a learning environment for stakeholders from all levels (local government, civil society, communities and volunteers, as well as the private sector). Learning and capacity development will also be stimulated between the five Open Labs, facilitated by the SHELTER peer learning network. Strategically planned connections between Open Labs, based on the differences and similarities between the objectives, participants, contexts and methods in each of them, will ensure a continuous exchange of knowledge and best/next practices across Europe.

### **7.2.3 Definition of the workflow**

The detailed description of the workflow that includes open labs in the definition of the framework can be found in D9.2 (Open Labs Management Plan due by month 6).

## 8 Conclusions and next steps

SHELTER is aimed to achieve the establishment of a world-class operational knowledge framework linking the scientific community, the conservators and heritage managers international community and citizens under the overall aim of improving resilience in historic area. The objective of the work described in this deliverable was to establish the conceptual base for the posterior methodological and technical developments of the project:

- defining the concept of resilience in historic areas
- establishing the strategy for its assessment
- designing the architecture of the operational knowledge framework that will improve it
- assigning the role of the Open Labs as co-creators and validators of the framework

Similarly to other buzzwords, the literature has clearly stated the ambiguity, fuzziness and overuse of the resilience as concept. Consequently, a lot of efforts can be found lately that has been dedicated to its redefinition and operationalisation, not always helping to clarify the debate. Therefore, one of the objectives of this deliverable is to ensure that the results from SHELTER will share a common understanding of the special nature of the concept of resilience in cultural heritage and historic built environments, considering the different dimensions, characteristics and scales of resilience in historic areas.

The length of the existing literature and its fragmentation has made necessary to start with a first review of the literature to establish the SHELTER approach to resilience, keeping always from the cultural heritage and historic areas perspective: proposing a workable definition of resilience for historic areas, gathering the existing characteristics of resilience in order to identify their link with historic environments for a heritage-led resilience, defining the dimensions of the resilience and their singularity regarding cultural heritage, defining also the scales and the considered hazards and establishing the requirements for the SHELTER assessment of systemic resilience and the operative knowledge framework.

This step has allowed to design the frame to structure the existing knowledge gathered by a second systematized literature review. A general and specified resilience has been differentiated, together with a building and urban/territorial scale. This structure had defined different quadrants with their own approaches, methodologies and tools. The interconnection between these quadrants will allow the multiscale and integrated assessment (and posterior improvement) of the resilience in historic areas.

This deliverable has set the conceptual basis for the resilience improvement of historic areas that has to be validated and fine-tuned through the Open labs. The next logical step is the quantification of these concepts through the indicators that have going to be developed in Task 2.2 (Systemic resilience assessment and monitoring framework for HA: structure of indicators, definition of KPIs and resilience co-monitoring strategy).

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