ARCH

ARCH D6.4

Resilience pathway handbook

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Author(s)	Saioa Zorita (Tecnalia)
Co-Author(s)	Laura Bano, Rose Ortolani (SOGESCA); Nieves Peña (Tecnalia)
Contributor(s)	Maria von Mach (ICLEI); Efrén Feliu (Tecnalia)
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Reviewed by (if applicable)	Uta Mense (Hamburg), Vasileios Latinos, Katherine Peinhardt (ICLEI)

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Contact

wp6@savingculturalheritage.eu

www.savingculturalheritage.eu

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Version	Date	Released by	Comments
1.0	2022-07-29	SZ	Final version release (Deliverable)
2.0	2023-03-06	SZ	Better inclusion of heritage perspective: • Subsection 1.1.5 the gap of heritage focus or led pathways has been extended • Section 2. Further incorporation of heritage, culture and part perspective in to the resilience pathway methodology • Subsection 4.1 the heritage value preservation has been highlighted…

Executive Summary

This deliverable has been prepared for the European Commission-funded project ARCH: *Advancing Resilience of historic areas against Climate-related and other Hazards*. It is the key output of task 6.4.3 *Developing the Resilience Pathway Handbook*; however, it incorporates outputs from other tasks that support the development of the content of the Handbook: task 6.4.1 *Step-by step methodology for the Resilience Pathway design* (Chapter 1 & 2 of this handbook); task 6.4.2 *Developing a Resilience Pathway visualisation tool* (Chapter 3 & *Annex B: RPVT User's guide*); and task 3.4.4 *Co-create Resilience Options and Pathways* (Chapter 4). The aims of the task 6.4 are: (1) to advance on the Resilience Pathway concept, which integrates climate change adaptation and disaster risk management; and (2) to provide tools, namely the Resilience Pathway Handbook and the Resilience Pathway Visualization Tool (RPVT) to support the development of Resilience Pathways in the context of historic areas. The handbook is an educational guide, targeted at stakeholders concerned with historic areas, to support end users in the definition of Resilience Pathways for historic areas.

Chapter 1 of this handbook aims not only to clarify the concepts of Adaptation Pathways, but to provide background on the origin of Adaptation Pathways, as well as their purpose and added value in the context of adaptation planning. It also explains the need to further develop Resilience Pathways from a practical point of view and describes the main similarities and differences between adaptation and Resilience Pathways.

Chapter 2 aims to guide groups of stakeholders working together towards enhanced resilience in historic areas as to the development of Resilience Pathways, which include Adaptation Pathways. The chapter describes the methodology step by step, indicating the objectives of each and providing some hints on available resources.

The ARCH project has developed a web-based tool, the Resilience Pathway Visualization Tool (RPVT), to help with the graphical design of Resilience Pathways in the context of cultural heritage. Thus, Chapter 3 briefly presents the tool and indicates in which steps of the methodology and how the RPVT can support the development of Resilience Pathways outlined in previous chapters. A user guide to the RPVT can be found in the Annex B and can be used to understand the full content of the RPVT and help navigate through the tool.

Chapter 4 presents the ARCH co-creation and testing activities, with a detailed description on how the methodology has been applied to ARCH Foundation City Valencia. Beyond this particular pilot city example, practical considerations, reflections, and conclusions on the Resilience Pathway approach have been contributed by the other ARCH city partners, namely Bratislava, Hamburg and Camerino – and are also summarized in Chapter 4.

Updates in version 2.0 from March 2023

This second version of the Resilience Pathway Handbook was produced after the final review of the project in November 2022 upon request of the reviewers and it further describes the critical role of heritage and culture in the pathway approach (subsection 1.1.5) and adds explanations and examples to better incorporate the heritage perspective in the different steps of the approach (1.1, 1.2, 1.4, 2.2, 3.1, 3.3…). Finally, it highlights in chapter 4 how heritage values are considered in setting the objectives.

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Table of abbreviations

Acronym	Explanation
AF	**Administrative Functional urban area**
BS	British Standard
BMZ	Bundesministerium Für Wirtschaftliche Zusammenarbeit (German Federal Ministry for Economic Development Cooperation)
BCA	Benefit Cost Analysis
BCR	Benefit Cost Ratio
CCA	Climate Change Adaptation
CCI	Canadian Conservation Institute
CEA	Cost effectiveness analysis
DAFNE	Donors and Foundations Networks in Europe
DAP	Dynamic Adaptive Policymaking
DRM	Disaster Risk Management
DTS	Draft Technical Specification
EBRD	European Bank for Reconstruction and Development
ECB	European Central Bank
ECN	EU Crowdfunding Network
EEA	European Environment Agency
EIB	European Investment Bank
GPS	Global Positioning System
HA	Historic Areas
ICCROM	International Centre for the Study of the Preservation and Restoration of Cultural Property
IPCC	The Intergovernmental Panel on Climate Change
ISO	International Standardisation Organization
IVAVIA	Impact and Vulnerability Analysis of Vital Infrastructures and Built-Up Areas
MC(D)A	Multi-Criteria (Decision) Analysis
NbS	Nature Based Solutions
NGO	Non-Governmental Organizations
PET	Physiological Equivalent Temperature
PPP	Public Private Partnerships
RAM	Risk Assessment Module
RMI	Resilience Measure Inventory

RSQ	Risk Systemicity Questionnaire
RPVT	Resilience Pathway Visualization Tool
SECAP	Sustainable Energy and Climate Action Plan
SSDSS	Shelter Strategic Decision Support System
SWOT	Strength Weakness Opportunities Threats
TRL	Technology Readiness Level
UNESCO	United Nations Educational, Scientific and Cultural Organization

1. Introduction

This deliverable has been prepared for the European Commission-funded research project ARCH: Advancing Resilience of Historic Areas Against Climate-related and other Hazards. ARCH aims to enhance the resilience of areas of historic and cultural value to climate change-related and other hazards. In order to achieve this goal, a range of models, methods and tools such as the Resilience Measure Inventory (RMI), Resilience Pathway Visualization Tool (RPVT) and the Resilience Pathway Handbook (this deliverable) have been developed to support decision-making at appropriate stages of the resilience management cycle.

As a result of Task 6.1, which refers to the Inventory of Preparation, Safeguarding, Conservation & Management, and Response & Recovery Measures, the Resilience Measures Inventory (RMI) was developed, and lists 261 measures. Furthermore, Task 6.2 Assessment of Long-term Implementation Measures deepens the characterisation of these measures at the case study level, mainly via a desk study on their economic, socio-institutional and environmental performance[1]. The information gathered from the above-mentioned sources has been analysed, mined and compiled corresponding to the objectives that ARCH addresses. This information served as input for the RPVT.

On the other hand, the pathway approach is a novel methodology to assist planning. Thus, the Resilience Pathway Handbook aims to:

- Introduce the concept of adaptation and pathways and its context
- Address the advances towards Resilience Pathway methodology
- Communicate in an educational way the steps and considerations needed to build Resilience Pathways, with a special focus on historic areas
- Help with the use of the RPVT
- Describe the co-creation activities carried out as part of the ARCH project.

This deliverable D6.4, originally entitled “Resilience Pathway Visualisation Tool” in the DoA, has been renamed the “Resilience Pathway Handbook”. The reason for this change is to clarify the guiding role that the deliverable plays in providing context and guidance for using the RPVT, as well as demonstrating the purpose of the tool, which is to help create graphical displays for Resilience Pathways.

1.1. **About this Handbook**

1.1.1. What are Resilience Pathways?

A Resilience Pathway is a decision-making strategy closely related to urban planning, that addresses both slow-onset climate change and natural disaster risk management and displays

[1] Economic performance, understood as efficiency, refers to whether the benefits of making the change exceed the cost of implementing the resilience measures. Socio-institutional performance, understood as acceptability, expresses what level of acceptance have the measures to be implanted to reduce a risk. Environmental performance, understood as effectiveness, expresses whether or not resilience measures reduce the impact of natural hazards such as climate change.

a sequence of potential resilience-boosting measures that can be implemented progressively as conditions evolve. Why do we need to advance towards Resilience Pathways?

The pathway approach promotes flexible management: Not all decisions must be made immediately, rather they are deployed progressively as needed based on latest knowledge. In regard to resilience, a pathway approach has the following strengths:

- It encourages a holistic approach, by considering a mix of resilience measures both from adaptation to climate change and disaster risk management perspectives. This helps to have a better understanding and coordination among stakeholders to address risks.
- It accounts for uncertainty about the future and promotes flexible responses to a given problem. It allows planning for vulnerability and risk reduction while providing flexibility on the implementation of measures to better consider forthcoming knowledge and changing contexts. This will help to avoid an inappropriate use of resources by acting too early or too late.
- It encourages co-creation and, thus, the integration of various views and interests, which may be at times conflicting interests.
- It assists with the sequencing of measures, including identification of priorities through benchmarking to increase resilience.
- It can be translated into visual aids, similar to 'route maps' that support communication with stakeholders (see *Chapter 3: Resilience Pathway Visualisation Tool*).

Resilience Pathways can be built either based on scientific evidence or models or on stakeholder non-scientific knowledge as presented in Figure 1. These two approaches can be complementary.

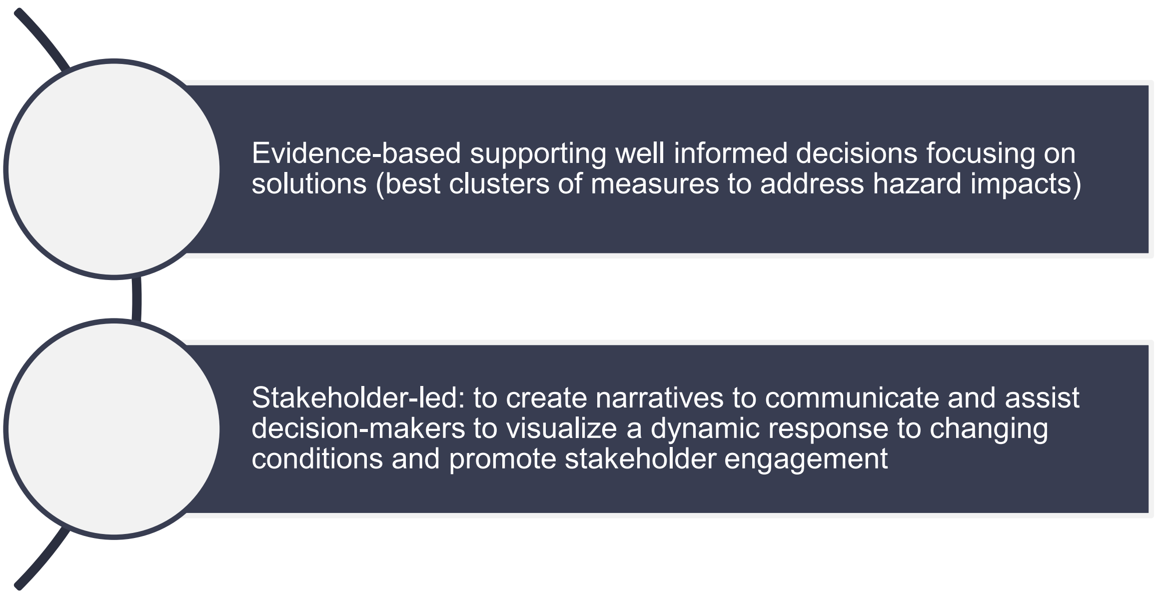

Figure 1. Working approaches for Resilience Pathways which determine their use

1.1.2. The use of Resilience Pathways in the context of Heritage

Cultural heritage is recognised as both a universal value and a factor of economic growth, as it often is a key driver for sustainable and resilient economic, social, and environmental development. Because cultural heritage places hold special value for communities, their protection is central to resilience. For this reason, the Resilience Pathway Handbook pays special attention to historic areas, though it can be used in a broader sense.

1.1.3. Who is this handbook for?

This handbook is an educational tool, targeted to city and regional stakeholders, to support cities, regions and their historic areas in the definition of pathways towards successful resilience building[2]. Therefore, the handbook provides guidelines and advice to local and regional administrations and their relevant stakeholders in order to help their historic areas and, thus, cities or regions become more resilient and sustainable.

Audiences also include stakeholders concerned with adaptation to climate change, resilience[3] or sustainability and historic areas, to support end-users in the definition of Resilience Pathways for historic or urban areas. These stakeholders can be either decision makers or technicians working at local or regional administrations as well as practitioners and consultants supporting historic areas and municipalities.

1.2. **Gender statement**

This deliverable has been developed taking into consideration the guidance on gender in research provided in the Project Handbook (D1.2), as well as State-of-the-Art (SotA) report number 5 of deliverable D7.1 “Mainstreaming gender in building cultural heritage resilience”.

Following these guidelines, the work carried out within this deliverable has been built under the established gender perspective, which aims toward gender mainstreaming in the work carried out as follows:

• Working towards gender balance when considering the researchers who carried out the development of the Resilience Pathway Handbook and RPVT in the framework of the task 6.4 and the reviewers.

• Providing equal opportunity to all members of the consortium and external participants when involved in the meetings and workshops carried out in the framework of the task 6.4. for the development of the RPVT.

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[2] To prepare historic areas against potential damages, to safeguard the historic areas (with technical, social and governance approaches) once evidence of potential damages emerges, to plan and carry out conservation and management works taking into account future climate projections into account, to tackle proper response & recovery strategies, once the damages have occurred.

[3]“The sustained ability of a historic area as a social-ecological system (including its social, cultural, political, economic, natural and environmental dimensions) to cope with hazardous events by responding and adapting in socially just ways that maintain the historic area’s functions and heritage significance (including identity, integrity and, authenticity)”

1.3. **Relation to other deliverables**

This deliverable, *D6.4 Resilience pathway handbook* and the RPVT builds on previous work described in deliverables *D6.2 Assessment of long-term implementation options*, and *D6.1 Inventory of resilience measures.* This deliverable also summarizes the main outputs of D*6.3 Inventory and Characterisation of funding measures* in terms of principal considerations for a successful funding search. The RPVT content is based on the resilience measures identified in D6.1, and the performance information gathered in the RPVT is fed by D6.2. Worth noting is that performance of all measures may not be available for all types of assessments (environmental, economic, or socio-institutional) or all types of metrics. The RPVT aims at supporting the Resilience Pathway Handbook with the visual representation of pathway roadmaps and by providing evidence-based information on resilience measures which may be used for pathway development and, thus, planning and decision making.

1.4. **Structure of this handbook**

Following this introduction, the report is divided into 4 Chapters as seen in Figure 2, plus the Glossary (Annex A) and the RPVT User's guide (Annex B).

Chapter 1 Resilience pathways: How did it come about?	**This chapter offers information:** • An overview of the origin, concept and purpose of adaptation pathways • Describing the conceptual difference between adaptation and resilience
Chapter 2 Step-by-step methodology to develop a resilience pathway	**This chapter provides:** • A replicable methodology to develop resilience pathways in an educational way • Concrete examples of tools that can support the different steps of the methodology • Practical considerations for the application of resilience pathways in historic areas
Chapter 3 Resilience Pathway Visualization Tool in the context of the Handbook	**This chapter offers:** • An overview of the Resilience Pathway Visualization Tool • A guide on how it can assist on the development of some of the given steps from Chapter 2, with special attention to historic areas • A summary of the content of the tool
Chapter 4 ARCH Co-creating and testing activities	**This chapter provides:** • The description of the co-creation activities in relation to adaptation carried out within ARCH Project in Valencia case study • Lessons learned and practical considerations of the implementation of the pathway approach in Bratislava, Camerino, Hamburg and Valencia case studies

Figure 2. Structure and content of the handbook chapters

Chapter 1. Resilience Pathways: How did they come about?

1.1. Adaptation Pathways

Climate change is increasing the frequency and intensity of climate-related hazards. Their effects will have huge economic, environmental and social impacts on European cities, for which we have to be prepared. However, the uncertainty associated with climate change makes it difficult to plan -- especially for the needed adaptation actions to protect our urban and historic areas.

Furthermore, urban and historic areas are embedded in complex systems (socio-ecological systems) that require great efforts to be modelled, analysed, understood, managed and governed (1–3). These systems, which may vary depending upon culture, economy, environment etc., involve a multitude of strongly intertwined components (4).

The quest for better cities and historic areas, in the context of climate change, has led to the search for better planning and decision-making solutions. Nowadays improved planning strategies (Figure 3) considering future scenarios have been put into place, such as:

- ”Predict and act”, when it is believed that the future can be predicted with good accuracy
- Static Robust Policymaking, when clear paths towards few future scenarios are projected

But, are these strategies adequate when planning urban adaptation to climate change? Probably not, due in large part to the fact that climate change introduces a significant amount of uncertainty, and the nature of cities is complex. Additional uncertainties arise when one also considers cascading effects. Despite this, decision-makers have to act with cost-effective and flexible approaches that allow sustainable policy implementation over time, while considering political uncertainty alongside other environmental, societal and economic changes.

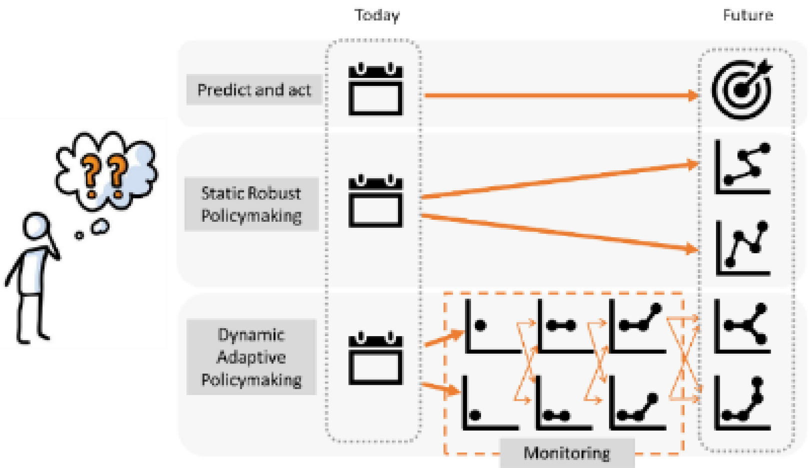


Figure 3. Approaches that policy makers apply regarding uncertainty of future scenarios. Source: Adapted from (5)

In the light of climate uncertainty and the (urban) system complexity, Flexible Adaptation Pathways, as part of Dynamic Adaptive Policymaking[4] (DAP), have emerged as decision-focussed approach to support climate change adaptation planning. Adaptation pathways ensure the consideration of a wide range of adaptation measures while considering various future alternatives. Depending on the evolution of the problem, the alternative is reinforced with another set measures, modify or even delayed. In other words, in Adaptation Pathways, measures and actions are planned well ahead to prepare for envisioned climate change impacts, while their deployment is initiated once certain conditions occur.

1.1.1. The context of Adaptation Pathways

Academia started to use the term 'deep uncertainty' in the early 2000s to respond to the need to address and name many different, yet plausible, future alternatives under climate change(6). This term was often associated with complex systems (7) and decision-making frameworks related to climate change (8). Soon, academics realized the need to assist decision makers with new approaches and tools to support planning when many plausible futures are possible. Consequently, DAP was developed. These approaches are based on assumption planning and explore a wide range of future scenarios, as seen in Figure 3. These approaches are based on the implementation of an initial plan, despite the fact that uncertainties are not yet solved, with the plan being deployed over time as new knowledge is obtained *e.g.* through monitoring of the evolution of conditions.

Yet, the concept of Dynamic or Flexible Adaptation Pathways was devised to address the challenges of climate change uncertainty around 2010 and firstly applied to coastal adaptation as a result of sea level rise scenarios (9). This approach considers the timing of actions explicitly and it develops an overview of alternative routes into the future. Since more than 200 studies on Adaptation Pathways have been published.

1.1.2. What is an Adaptation Pathway?

Adaptation pathways assist local governments and communities[5] in making decisions about adaptation to climate change in an ongoing, flexible and dynamic way. Their development and implementation, as is the case with adaptation, is an iterative process. Flexible Adaptation Pathways allow for monitoring and evaluating the outcomes of specific adaptation measures and adjusting the roadmap as appropriate. This flexibility allows stakeholders to assess and identify the most effective ways to minimise the impacts observed for a given context or expected for the future impacts of climate change. They also allow for a change of course if "maladaptations", *i.e.*, unintended negative consequences of adaptation, occur.

There are different definitions of Adaptation Pathways depending on which component is considered by the authors to be more relevant, as presented in Table 1.

Table 1. Definition of Adaptation Pathways

[4] Dynamic Adaptive Policymaking lie under the assumption that future cannot be predicted

[5] A group of people with an arrangement of responsibilities, activities, relationships and with common interests e.g. climate change. A community can also be a body of persons of common and especially professional interests

Source	Definition
CoastAdapt (10)	An Adaptation Pathway is a decision-making strategy that is made up of a sequence of manageable steps or decision-points over time
IPCC (11)	A series of adaptation choices involving trade-offs between short-term and long-term goals and values. These are processes of deliberation to identify solutions that are meaningful to people in the context of their daily lives and to avoid potential maladaptation
BS 8631:2021 (12)	Sequences of potential actions that can be implemented as conditions evolve in response to climate change risks and opportunities
Barnett et al. (2014) (13)	A sequence of linked strategies that are triggered by a change in environmental conditions, and in which initial decisions can have low regrets and preserve options for future generations
Werners et al. (2021) (14)	Sequences of actions, which can be implemented progressively, depending on future dynamics (on how the future unfolds and the development of knowledge)

In practice, Adaptation Pathways may combine evidence-based information (e.g., modelling, observations) with expert opinion to suit the Adaptation Pathway approach to the local context. As the complexities of dealing with multiple future possibilities and local contexts, as well as aims and commitments towards adaptation cannot be modelled, the Adaptation Pathway approach does not provide a single, optimal plan. Rather, it provides policymakers support in considering a wide range of actions, identifying opportunities and prioritizing them over time.

1.1.3. What are Adaptation Pathways suitable for?

Adaptation pathways may have goals with different levels of hierarchical importance towards a system adaptation or transformation as described in the British Standard BS 8631:2021 *Adaptation to climate change. Using Adaptation Pathways for decision making. Guide* (12). This may depend on how Adaptation Pathways are understood, as well as on the available resources (*e.g.* climate knowledge and its impacts, technical, economic) and socio-political commitment (Table 2) which will determine its final scope. Thus, Adaptation Pathways can be used to:

- Achieve short, medium, or long-term adaptation goals
- Facilitate adaptation planning by considering a broad range of adaptation measures and actions
- Promote awareness, learning, collaboration, and capacity building

Table 2. A summary of the goals of the Adaptation Pathway, needed resources and expected adaptation outcomes

Vision of the Adaptation Pathway	What for	Political commitment[a]	Resources[b]	Knowledge	Adaptation outcomes[c]
A sequence of measures	Develop a flexible medium long-term action plan	High	€€€	🗎🗎🗎	👍👍👍👍👍

to achieve a well-defined adaptation objective	Guidance documents that provide a methodology on how adaptation measures can be deployed over time and help incorporate them in future action plans	Medium	€€	🗎🗎🗎	👍👍👍👍
A roadmap of measures with various alternatives to promote a change towards a strategic aim	Support the consideration of a wide range of adaptation measures and the order in which they could be deployed (Quantitative analysis)	Low-Medium	€€	🗎🗎🗎	👍👍👍
	Support the consideration of a wide range of adaptation measures and the order in which they could be deployed (Qualitative analysis)	Low	€	🗎🗎	👍👍
A tool to support adaptation to climate change while considering uncertainty	Awareness raising (*e.g.* adaptation measures) to achieve adaptation goals	Low	€	🗎🗎	👍👍
	To engage and build a collective vision on adaptation	Low-Medium	€€	🗎🗎	👍

[a]The required political commitment; [b]economic and technical needs; [c]How holistic the approach is; [d]Public and private stakeholders needed to achieve the adaptation goals

1.1.4. Which advantages do Adaptation Pathways have in the context of Adaptation Planning?

Adaptation Pathways provide several benefits compared to traditional planning instruments. The three fundamental ones are:

- They can reflect different (planning) future scenarios that promote flexibility in terms of the deployment of adaptation to climate change.
- They are based on the performance of the solutions; thus, planning is supported by evidence[6].
- They are an approach that encourage consideration of a wide range of actions and the sequence in which they could be implemented to address a challenge or risk.

[6] Stakeholder-led pathways are also an option to build narratives to communicate and assist decision-makers to visualize a dynamic response to changing conditions and promote stakeholder engagement

- They reduce uncertainty in adaptation planning as the triggers for decision points are scaled against events, and not time. The deployment of measures is initiated once certain climate-related occurrences have been observed to get worse.
- They buy time to plan and reduces the pressure of making decisions now. As previously mentioned, the Adaptation Pathway is deployed over time when monitoring of conditions identifies triggering conditions, at which further decisions or measures deployment will need to be undertaken.

1.1.5. Gaps in Adaptation Pathways: Heritage

Based on literature, there is a notable lack of attention given to heritage and cultural-led approaches in the design of pathways. Despite the benefits of cultural-led approaches based on local knowledge, many planners tend to overlook them in favour of scientific knowledge-based approaches to reduce climate risks. At the time of writing this Handbook, it appears that Adaptation Pathways have only been applied once (15) for the climate adaptation for Aboriginal and cultural heritage. This work focused on the management of heritage, and it was the result of a stakeholder-led approach using a risk matrix as in Figure 13. This highlights both:

(1) that this topic is not common knowledge, for example, among heritage managers Thus, there is a need to further explore and communicate the pathway approach with heritage-related stakeholders and
(2) that there appears to be a preference for more standardised and universal strategies that can be easily implemented across different contexts, rather than context-specific solutions that draw on the knowledge and experiences of local communities. As a result, the potential contributions of heritage and culture to climate change adaptation, community resilience and sustainable development goals are often not fully recognized or utilized in the pathway design.

1.1.6. Gaps in Adaptation Pathways: Disaster Risk Management

Adaptation pathways, as previously mentioned, have been conceptualized to address the challenges of climate change adaptation. This is often related to slow-onset hazards like glacier melt, sea level rise, or the spread of invasive species. Thus, flexible Adaptation Pathways address long-term, gradual and progressive risks. However, as a result of climate change, the frequency and intensity of weather extremes is also intensifying. Disaster risk management has traditionally addressed these sudden extreme weather events and their related impacts, as well as geophysical extremes (earthquakes, volcanic eruptions etc.). Thus, there is a gap in the application of the pathway concept, as disaster risk management and adaptation are also naturally intertwined from a climate change perspective. Similarly, it has not been designed to address, for example, the resilience of historic areas to geophysical hazards. To bridge this gap, the ARCH Project has advanced the conceptualization of Resilience Pathways.

1.2. **Resilience Pathways**

What are the conceptual differences between an Adaptation and Resilience pathways?

While Adaptation Pathways deal only with slow-onset risks, Resilience Pathways integrate them and allow stakeholders to address and plan for sudden hazard extremes -- that is, disasters. Resilience pathways are aligned with the ARCH Resilience Management Framework (Figure 4,(16)), which integrates both the management cycle of climate change adaptation (17) planning and the disaster risk management cycle (18). The normal operating phase within the ARCH Resilience Management Framework encompasses both the planning of slow-onset risks as well as the prevention, preparedness and protection activities that would take place during possible future disasters. Meanwhile, the emergency operating phase (*i.e.* the during and post-disaster recovery activities) is triggered once a disaster occurs. Thus, Resilience Pathways approach mirrors the cycle by addressing the identification, assessment, prioritization, and sequencing of resilience measures during normal and emergency operating phases of the ARCH Resilience Management Framework.

Therefore, the authors of this report adopt the following definition for Resilience Pathways:

A **Resilience Pathway** is a decision-making strategy, closely related to planning, that addresses both slow-onset climate change and natural disaster management, and sequences potential measures that can be implemented progressively as conditions evolve (depending on how conditions change over time, as well as how knowledge develops further).

The main differences between adaptation and Resilience Pathways are presented in Table 3, while methodologically specific differences are covered in *Chapter 2. Step-by-step methodology to develop a Resilience Pathway.*

Table 3. Differences between adaptation and resilience approach

Pathway approach	Addressed hazard	Examples of hazards	Addressed disaster risk management phase	Considered solutions
Adaptation	Slow-onset	Slow sea level rise, average monthly or annual temperature increase	Pre-disaster*	From the adaptation to climate change perspective: -Measures to prepare areas against potential damages (Preparedness) -Measures for conservation & management, taking future climate projections into account (Prevention)

<table>
<tr><th>Pathway approach</th><th>Addressed hazard</th><th>Examples of hazards</th><th>Addressed disaster risk management phase</th><th>Considered solutions</th></tr>
<tr><td rowspan="2"></td><td></td><td></td><td></td><td>-Measures to safeguard the sites once evidence of potential damages emerges (Protection)</td></tr>
<tr><td>Sudden weather extremes</td><td>Pluvial and fluvial foods</td><td>Pre-disaster*</td><td>-Measures to prepare areas against potential damages (Preparedness)</td></tr>
<tr><td rowspan="3">Resilience</td><td>Slow-onset</td><td>Slow sea level rise, average monthly or annual temperature increase</td><td>Pre-disaster*</td><td>From the adaptation and prevention of a disaster perspective:
-Measures to prepare areas against potential damages (Preparedness)
-Measures for conservation & management, taking future climate projections into account (Prevention)
-Measures to safeguard the sites once evidence of potential damages emerges (Protection)</td></tr>
<tr><td>Sudden weather extremes</td><td>Pluvial and fluvial foods, explosive cyclogenesis</td><td rowspan="2">Pre-during-post disaster
Pre-during-post disaster</td><td rowspan="2">-Pre-disaster measures &
-Emergency response measures
-Restoration, recovery and building back better measures</td></tr>
<tr><td>Sudden geophysical extremes</td><td>Earthquakes, volcanic eruptions, tsunamis</td></tr>
</table>

Figure 4. ARCH Resilience management framework

Chapter 2. Step-by-step methodology to develop a Resilience Pathway

Both adaptation and Resilience Pathways are aligned or embedded in the climate change adaptation cycle (17, 19) and the ARCH resilience management framework (20)(Figure 4). Once the target system's vulnerabilities, risks and impacts have been evaluated, Resilience Pathways address mainly the identification, assessment and selection of the resilience measures using a specific methodology. This allows to prepare an action plan to adapt, safeguard and mitigate impacts from climate change and/or other natural hazards.

What are the **unique features of pathways** in the identification and selection of resilience measures?

- They are problem-solving roadmaps. They not only work towards the identification and selection of resilience measures, but also towards the sequencing of these measures
- They reflect on clusters of resilience measures at the same time: Aggregation of the resilience measures which are often called 'Resilience Pathway alternatives'
- They consider the performance of the resilience measures. Though not all pathway approaches may be data driven, their effectiveness is normally assessed by means of environmental or economic performance (*e.g.*, modelling or literature based) but can also be addressed by stakeholder vision co-development or/and experts' judgment.

ARCH Resilience Pathway methodology, and proposed resources, responds mainly to the following purposes (Figure 6), which are considered data-driven approaches:
- To achieve short, medium, or long-term adaptation/resilience goals
- To facilitate resilience planning by considering a broad range of resilience measures and actions

However, when there is a gap in knowledge the methodology may be adapted (*e.g.* without explicitly considering thresholds (step 1.3) or effectiveness (step 3.2) of each pathway alternative) to promote awareness, learning, collaboration, and capacity building among various local stakeholders and/or create resilience narratives. This may be also very relevant as a starting point especially in those systems where resilience management is at a preparatory phase, the management of the system is complex due to the involvement of numerous stakeholders with various responsibilities, lack of data to perform an evidence-based pathway and/or a capacity building of the stakeholders' work is sought.

The proposed methodological sequence is composed of four main steps (Figure 5), which are not necessarily linear, may be iterative and can be adjusted according to the strategic objectives, local needs, and resources of each municipality. As seen in the image, the three first steps are composed of three sub-steps, each. The British Standard BS 8631:2021 (12), on the other hand, divides the process in 9 similar steps.

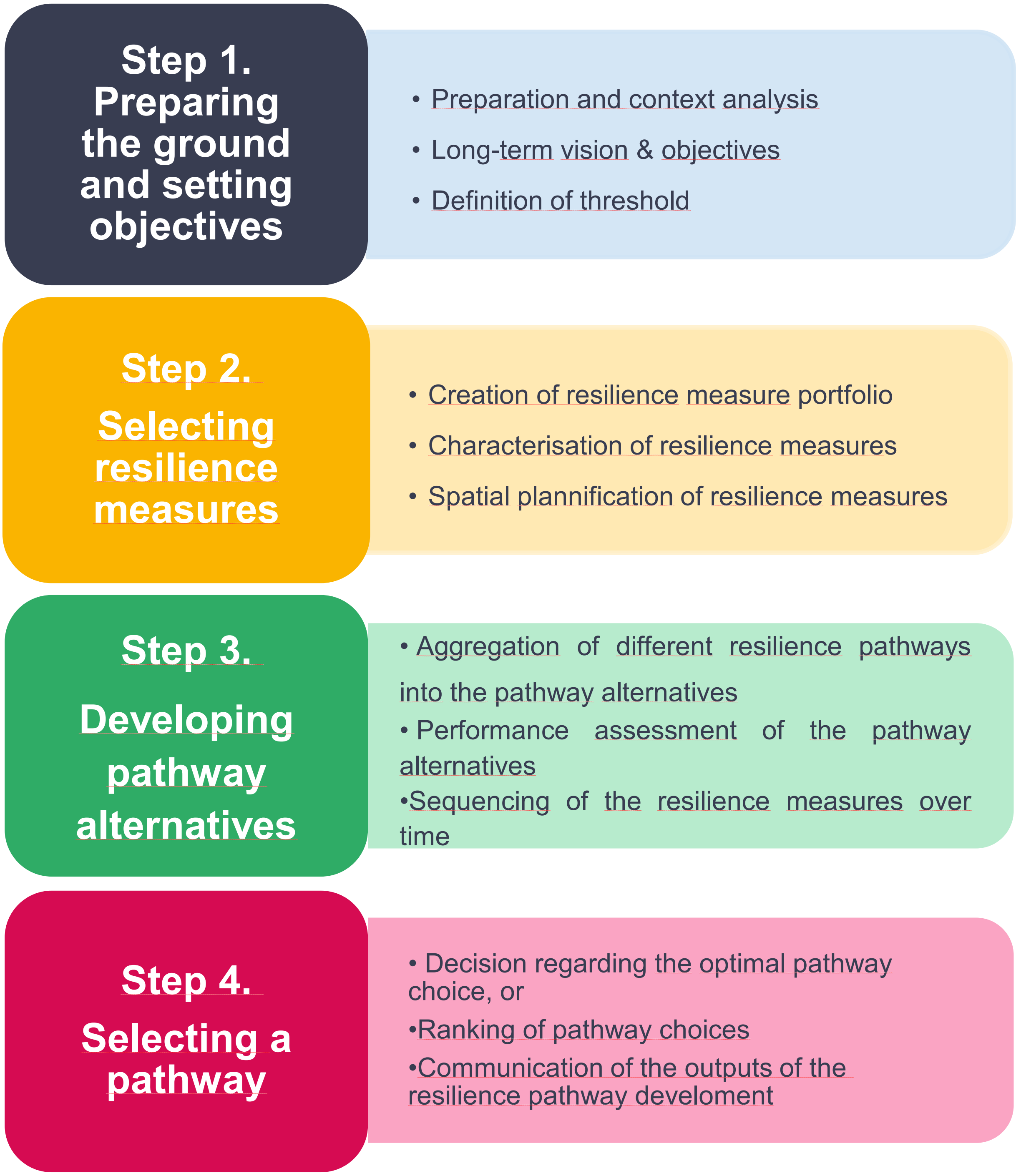


Figure 5. Methodological sequence of the Resilience Pathway approach

This chapter provides step-by-step guidance on how to develop a Resilience Pathway, explains key concepts that may be new to the reader, as well as practical consideration and tools to assist local government and communities on their development.

Step 1: Preparing the ground and setting objectives

This step is vital to ensure the successful development and implementation of a Resilience Pathway. It aims at organizing and coordinating a working group and finding the best ways to use its knowledge and the local/regional government's resources, all while reaching consensus on an integrated vision for resilience. This step is transversal and benefits from a multidisciplinary view in preparing for adaptation to climate change or other natural hazards.

Step 1.1 Setting the purpose of the Resilience Pathway approach

Objectives

- Clarify the purpose of the adaptation or resilience pathway, i.e to answer *What do we want to use the pathway for?*
- To align resources to the scope of the pathway
- To identify the best decision making framework to the scope of the pathway

Before starting to prepare the framework and structure needed to develop a Resilience Pathway, the actors and stakeholders driving the initiative must determine the purpose of the pathway approach. This will determine, among other things, the number of resources (financial, human, technical) needed, and the time needed to develop the pathway (see also Table 5). Figure 6 presents some examples of the possible purposes of the pathway, which will also determine its final impact on preparing, safeguarding and managing historic areas. The stakeholder engagement and political commitment may also determine the scope of the Resilience Pathway.

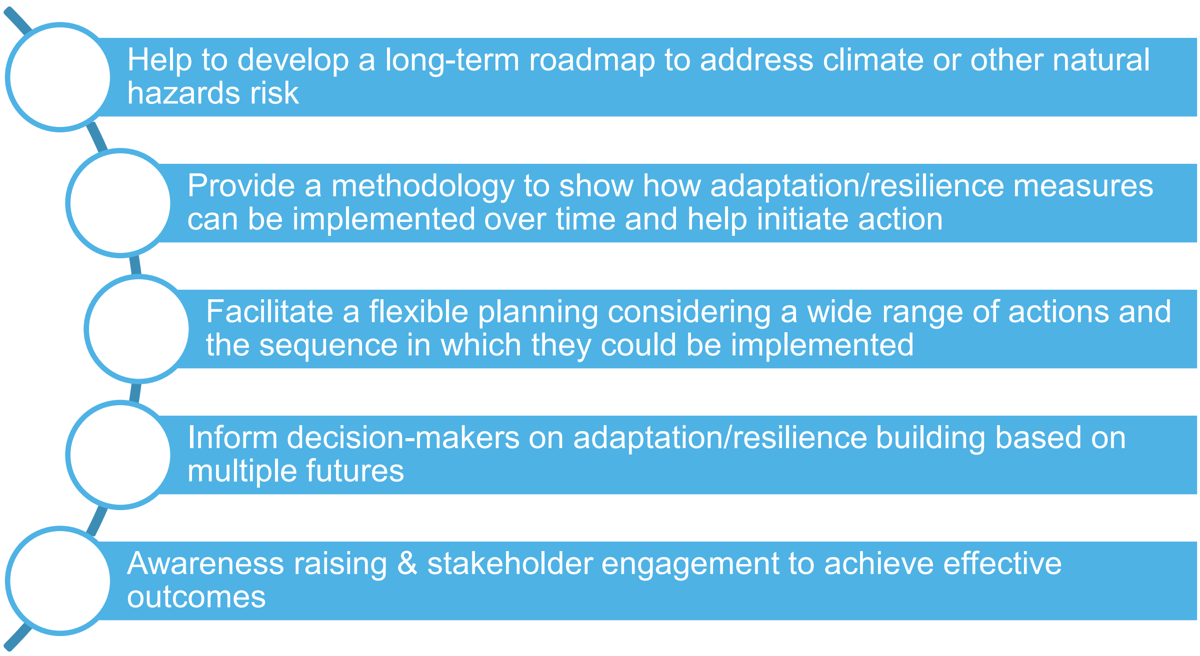


Figure 6. A non-exhaustive list of potential Resilience Pathway purposes in the context of the historic area or municipality based on the BS 8631:2021 (12)

A second relevant question to address is whether the pathway should follow an adaptation or resilience approach. In *Chapter 1. Resilience Pathways: How did it come about?* The main differences between an Adaptation and Resilience Pathways were described from a theoretical point of view, which are also represented in Figure 7. In summary, Resilience Pathways address both adaptation to climate change and disaster risk management of extreme events or disasters. Adaptation pathways only address long-term gradual adaptation to climate change and prepare for, but do not manage, impacts from weather events such as flooding.

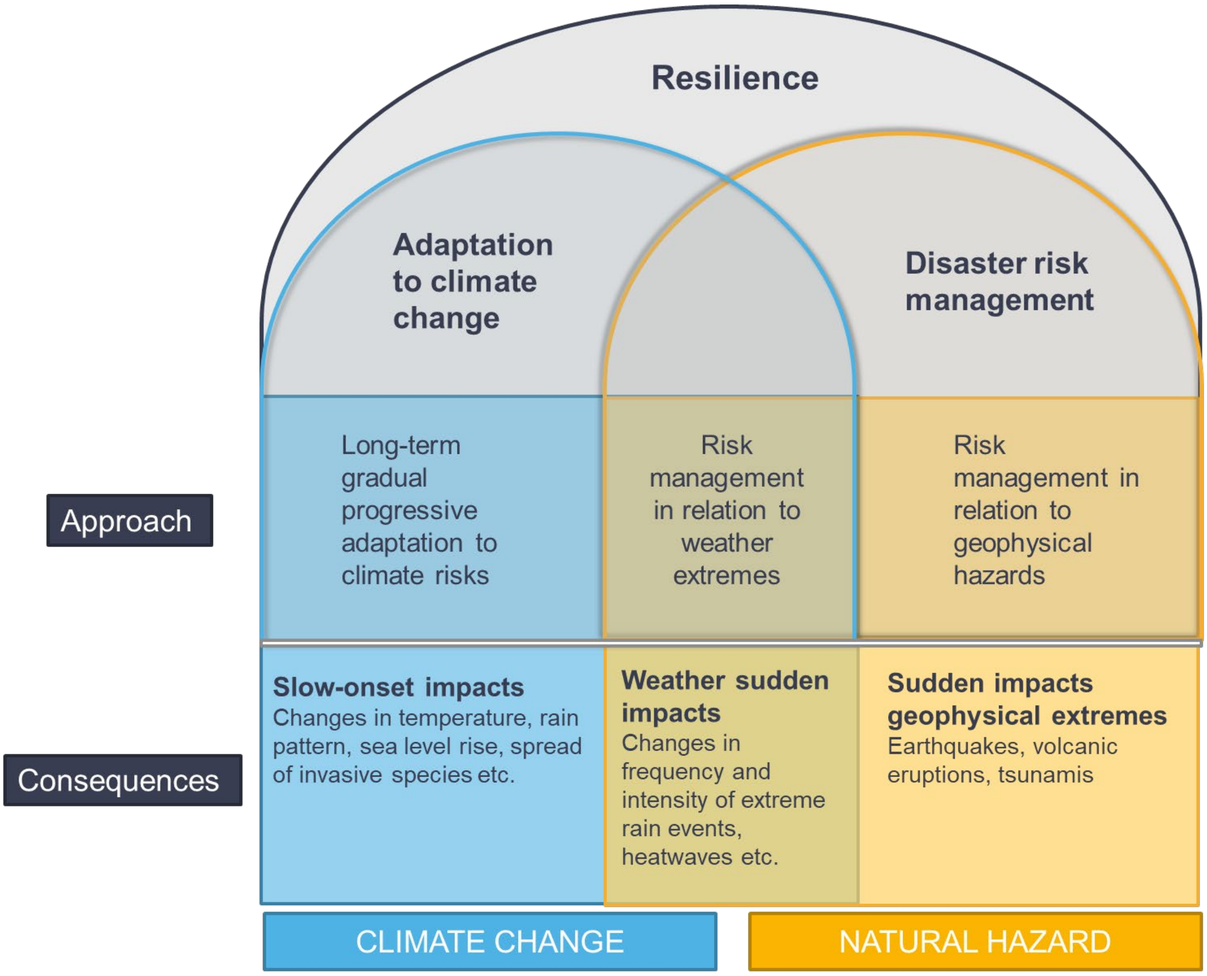


Figure 7. Intersection between disaster risk management and adaptation to climate change. Adapted from (21).

However, there are other practical considerations when deciding for the final approach (summarized in Table 4), which may determine the pathway methodology selected. This might include the type of heritage assets in question, capacity to engage with stakeholders or whether the full cycle of Disaster Risk Management (DRM) needs to be considered.

Table 4. Characteristics of the different pathway approaches and methodology. *See Figure 8 on the "tip box" for clarification

Pathway methodology	Data/ knowledge	Heritage type	Characteristic	Adaptation	Resilience
Evidence based / performance oriented	High dependence on scientific knowledge	Tangible	Nature of measures*	Structural	Structural, Social, Institutional
			DRM phase covered	Pre-disaster	Pre, during and post-disaster
			Performance indicator	Environmental and economic	Economic
Stakeholder-led based on non-scientific knowledge	High dependence on stakeholder participation and knowledge	Tangible & intangible	Nature of measures*	Structural, Social, Institutional	Structural, Social, Institutional
			DRM phase covered	Pre-disaster	Pre, during and post-disaster
			Performance indicator	Multistakeholder knowledge	Multistakeholder knowledge

TIP!

What is a structural, social and institutional adaptation or resilience measure?

Structural

- This category gathers measures with clear outputs and outcomes and that are well defined in scope, space and time
- They include structural and engineering solutions (e.g. coastal protection, building reinforcement), the application of technologies (e.g. sensors for structural stability, early warning system), the use of ecosystem-based solutions (e.g. ecological restoration, shade trees) and the delivery of services (e.g. enhanced emergency medical services)

Social

- This category aims at improving informational strategies (e.g. vulnerability map, definition of emergency storage facilities for movable heritage), favouring behavioural measures (e.g. changing cropping practices, household preparation and evacuation planning) and providing educational services (e.g. awareness raising, sharing local and traditional knowledge)
- It especially focuses on reducing social vulnerability and increasing the knowledge of elements like cultural heritage, in order to facilitate its safeguarding, management and protection against hazards

Institutional

- This category targets institutional measures that foster adaptation/resilience
- They include economic actions (e.g. financial incentives for adaptation, catastrophe bonds), laws and regulations (e.g. regulation for effective citizens' evacuation, zoning and statutory planning regulations for historic areas) and government policies and programs (e.g. integrated coastal zone management, integrated strategic planning for urban heritage conservation management)

Figure 8. Categorisation of adaptation/resilience measures based on their nature

Step 1.2 Preparing the ground

Objectives	
Objectives	• Ensure a high level of support within different fields (adaptation, heritage, civil protection, planning, funding etc.) • Minimise the risk of inadequate coordination • Clarify roles and responsibilities (internally and externally) • Minimise the risk that the involved people do not understand the importance of considering and planning both climate change adaptation and disaster risk management at the same time • Securing funding or minimising the risk of running out of funding in the without it in the implementation, with the consequences that this entails.

While there is no one exclusive way of approaching these pathways, there are some logical tasks to set the context of the historic area/municipality in terms of climate change and natural disasters. This preparatory step has a transversal nature and, while framed as an initial phase, should be integrated throughout the different steps of the pathway approach.

The proposed working sequence:

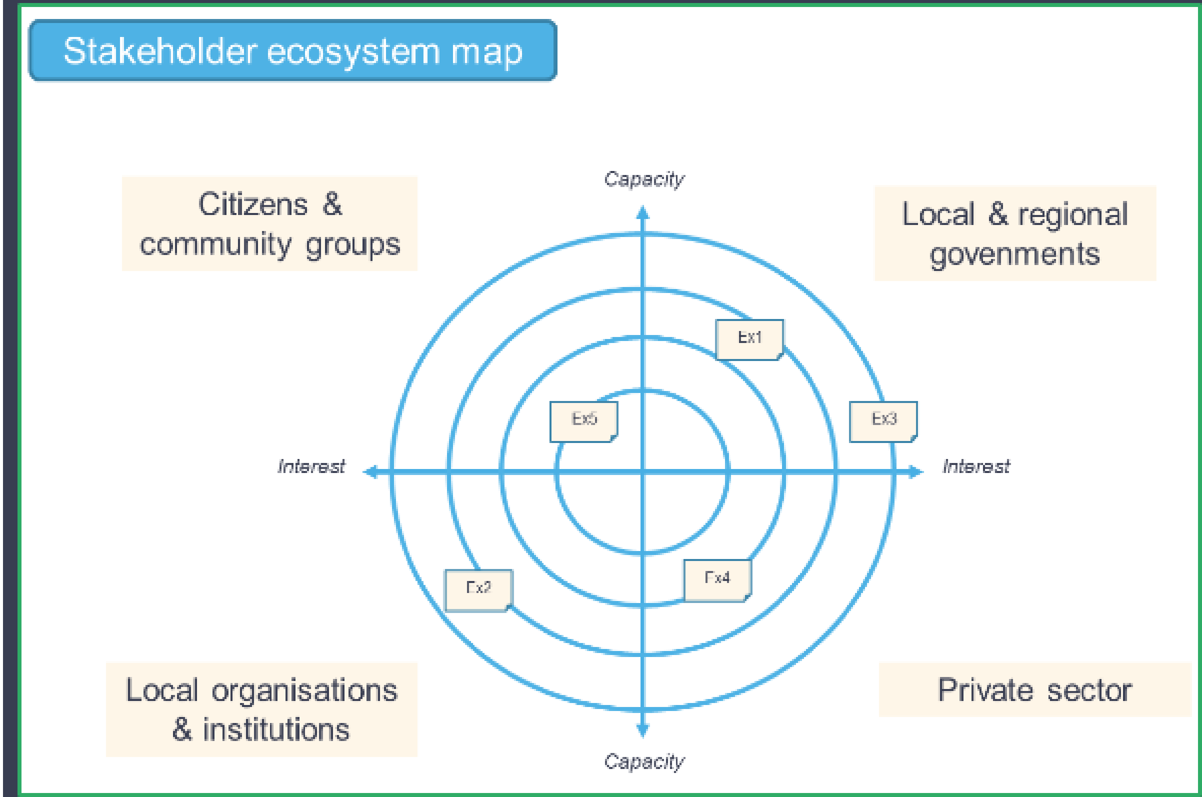
- Setup of the internal working team responsible for the resilience process in all its phases. This team should be responsible for coordinating and leading the pathway development, securing funding, clarifying roles and responsibilities, conducting stakeholder engagement, and setting a continuous communication process.

TIP!
A multidisciplinary working team is especially important when addressing historic areas as stakeholders working on climate change or civil protection traditionally do not have technical/social knowledge on heritage or its management. Similarly, heritage managers or conservation officers can lack certain knowledge on how climate change or other natural hazards will affect the historic areas or what type of work can be done to preserve the historic sites in light of climate impacts.

- Development of a map of stakeholders and institutions linked to climate change adaptation, disaster risk reduction and heritage. This map can be revised during the pathway development [See TOOLBOX 1]. For this purpose, it may be useful to have gathered information that gives relevant context to the status quo of the municipality's actions in this area: For example, data about observed impacts on heritage sites that may be associated to climate change, previous initiatives, etc.

TOOLBOX 1

There are different methodologies and tools to identify stakeholders. The stakeholder ecosystem map allows to identify stakeholders based on their typology and on their interest and capacity (technical, economic, political…). Relevant stakeholders may be among others: decision makers on district, municipal, or national level related to historic areas, resilience or adaptation to climate change, **disaster** risk managers, heritage managers (including managers of museums and collections), public administrators, sustainability and resilience officers, critical infrastructure managers, service providers, emergency service providers, civil society associations (including the cultural and creative sector), non-governmental organisations, academic and research institutions.



- Involvement of stakeholders (public, private, associations, etc.) which could contribute or have interest in making the historic area more resilient. The involvement of stakeholders often depends on the governance culture, resources of the local government, and on the political commitment of authorities. However, involving stakeholders with local, traditional knowledge and those from the cultural and creative sector is particularly important when designing resilience pathways with a focus on heritage. These stakeholders possess a wealth of knowledge about local heritage, cultural practices, and traditional ecological knowledge that can inform the design of pathways that are context-specific, grounded in local cultural values and foster community resilience. Additionally, their involvement can help ensure that heritage is not only preserved but also leveraged for the social, economic, and environmental wellbeing of local communities. Table 5 shows the type of decision-making framework in terms of stakeholder engagement with their advantages and disadvantages.

Table 5. Decision making framework based on the involved stakeholders

Centralized	City Council (Tactical expertise- the Resilience Pathway initiative is led by an individual)	Reactivity from other stakeholders, poor, not validated	Fast and cheap process
Hierarchical	City Council (Operational competences- the Resilience Pathway initiative is launched by various municipal stakeholders)	Reactivity from other stakeholders, poor, not validated	Fast and cheap process
Hierarchical with scientific knowledge	City Council (Operational competences), Expert Support	Reactivity from other stakeholders, not validated and poor form the citizens point of view	Fast process
Hierarchical with limited participation	City Council (Operational competences), Expert Support, Organizations (NGOs and local)	No representation of the citizenship	Relatively fast process
Participatory	City Council (Operational competences), Expert Support, Private Sector, Organizations (NGOs and local)	Resources invested (time and budget)	Higher level of heritage protection
Co-Design	City Council (Operational competences), Expert Support, Private Sector, Organizations (NGOs and local), Citizens	Resources invested (time and budget)	Community sense of belonging better considered from the citizens. 360-degree vision

- Funding and resources. Definition of the human and economic resources to develop the Resilience Pathway and the financing mechanism to ensure appropriate economic resources are sought for the implementation of the resilience measures (further information can be found in Step 1.6 Financing the flexible Resilience Pathway)

- Internal and external communication and citizen participation. Enabling and use (or, where appropriate, creation) of communication mechanisms and spaces for citizen participation. Using the cultural and creative sector can be a powerful way to communicate complex ideas and engage diverse audiences, by using arts, music, storytelling, and other cultural expressions to convey messages and foster meaningful dialogue.

Step 1.3 Context analysis

Objectives	• Make appropriate and optimal use of existing information • Access suitable methodologies and select those that are most appropriate for our municipality /historic area • Improve knowledge about possible impacts and effects of climate change & other natural hazards in the municipality, both negative and positive if any • Assess vulnerability and potential risks • Define those impacts that transcend the territorial or jurisdictional scope of our municipality competence of our municipality • Enable sufficient coordination between agents and institutions

Apart from stablishing a resilience team structure it is also important to identify the resilience needs of the historic area in question. In other words, stakeholders might ask of themselves:

- *We are aware of geophysical hazards in our area, and that climate change is a reality, but how does it affect this particular historic area?*
- *Which areas and activities will be most affected, and which are most vulnerable?*
- *What is our collective (or individual) capacity to react?*
- *What are the places, traditions, events, etc., that hold inherent significance for local communities, beyond those officially listed as heritage assets?*

In the process of resilience building, proposing effective measures depends on the availability and awareness of information regarding the current situation of the historic area, and of local realities when it comes to climate impacts and other hazards. It is important to quantify climate trends and their impacts, the factors that determine vulnerability to climate change or geophysical hazards, as well as the potential risks the historic area or municipality faces.

The main elements to be addressed during this step:

Compilation of available information on the defined historic area/municipality.

Often municipalities, regions and their stakeholders possess a valuable, but scattered knowledge on the local context, as well as the status of a given historic area. The integration of the knowledge from different stakeholders allows a broader picture not only of the observed changes in climatology and its impacts (*e.g.*, changes in the beginning of flowering, new pests), but of the needs and challenges that the historic area faces. Furthermore, the compilation of information in a historic area should take into account not only the historic value but also the values ascribed to the elements by the local community. This can provide a comprehensive understanding of the cultural significance of the area and serve as a basis for designing pathways that are sensitive to local needs and aspirations. ARCH D3.3 *City baseline report* and the Irish Climate Change Sectoral Adaptation report provide examples of risk profiling in heritage sites and historic areas, which can aid in identifying and characterising observed changes associated with natural hazards and climate change.

Compilation of available information on climate change, geophysical hazards and/or extreme events, including historical events.

This task aims at answering questions regarding the magnitude of projected climate impacts and changes, the ability to predict such changes, and the ability to anticipate hazards. To gain clarity in these areas, first the (climatic) variables and scenarios need to be decided upon (e.g. using business-as-usual climate projections), as well as the timeline for action.

Preliminary identification of potential future local impacts of climate change /geophysical hazards.

The existence of a climate hazard does not necessarily imply that a municipality (or its historic areas) will suffer its effects or impacts, as this varies widely depending on its context (specific historic areas, sectors of activity, infrastructure, population, ecosystems, etc.). To this end, the exposure of an area must be determined, in order to know which hazards are of the highest concern.

Exposure refers to the presence of people, livelihoods, species or ecosystems, environmental services, resources, infrastructure, or economic assets, social or cultural assets, in locations that could be adversely affected or impacted by an event or adversely affected or impacted by a climate event or trend. In order to determine what is exposed to particular hazards and to what degree or order of magnitude an impact may occur, it is often necessary to undertake local studies called impact modelling.

This involves carrying out studies of various kinds to gain a more accurate understanding of the potential extent of impacts arising from changes in climate variables or patterns, or other geophysical hazards. Examples of impact modelling include flooding studies, mapping of the heat island effect, epidemiology studies of certain diseases, seismic damage models, ecological niche displacement analysis, etc.

Due to the diversity of biophysical and socio-economic situations, the impacts of climate change for similar hazards vary from region to region, affecting different sectors, actors, and decision-makers in very different ways. This strengthens the case for carrying out these local studies. In addition, effects in one geographical area or sector may have consequences in other sectors or areas, resulting in so-called cascading effects or highlighting other interdependencies. Identifying and prioritising these direct and indirect impacts of climate change, as well as existing interdependencies, is key to define resilience measures appropriate for a given municipality or historic area.

Vulnerability and risk assessment of the historic area, municipality and/or relevant sectors.

One of the key concepts and steps in climate change adaptation and resilience building is the vulnerability analysis (22), which refers to the propensity or predisposition of a system to be affected by a hazard. Vulnerability can be assessed generally using indicators or by expert judgment, preferably through a predefined rating scale. Normally, socio-economic, or environmental indicators available in the municipality are used, such as population data, level of education, family income, age and types of buildings, classification of economic activities, unemployment rates, green space per area or inhabitant, access to services, etc. The selected indicators will be available at a certain level of disaggregation of the data. This will condition what our basic unit of analysis will be (buildings, census tract, neighbourhood, district, urban planning areas, etc.).

In any case, it is important to link with the previous step (exposure) and therefore to overlay the exposure to climate hazards with the vulnerability assessment. To carry out such an exercise, it is advisable to identify relevant impact chains[7] for our system. The formulation of an impact chain consists of pairing a climate hazard with a receptor, usually a subsystem or element of the municipality. For example, we may define that heat waves can affect health, or that floods can affect infrastructure or economic activity. In case there are multiple impact chains of interest, there are different methodologies, as shown in *e.g.* ARCH HUB to prioritise them. For each impact chain, we select the appropriate indicators that can be used to develop a risk assessment [TOOLBOX 2]. This involves selecting key data and information from previous stages regarding hazards, exposure and vulnerability.

TIP!
The IVAVIA methodology guides a risk-based vulnerability assessment, helping to map, analyse and communicate the impact of climate trends and weather events on key elements of a community's physical, social and economic fabric. IVAVIA provides guidance on how to prepare, gather, and structure data for a risk-based vulnerability assessment, to quantify and combine vulnerability indicators, to assess risk and to present outcomes.

As for vulnerability assessments, there are different qualitative and quantitative approaches to risk analysis, which can be combined. Irrespective of the approach or methodology adopted (quantitative and/or qualitative), it is important to consider the uncertainty[8] associated with the quality of the data or the methods (23) used and how to communicate it (24). The risk estimation often implies the comparison and prioritisation of the results of the risk analysis. These results can often be ranked according to a nominal scale (high, medium, medium, low) or ordinal scale (*e.g* a scale of 1 to 5). Once the risks have been analysed and their importance has been prioritised, the next step is to assess the need for action, including where and when it is needed. This assessment is likely to depend on how the risk is linked to other priorities of the municipality, the legal and jurisdictional framework, or the resources available for resilience-building actions.

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[7]Impact chains can be used to identify and describe relevant cause-effect relationships as a basis for further risk and impact analysis

[8] A state of incomplete knowledge that can result from a lack of information or disagreement about what is known or even knowable. It can have many types of origins, from imprecise data to ambiguous concepts or terminology, or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures or by qualitative statements (e.g., reflecting the judgement of a group of experts).

TOOLBOX 2

1. The **Risk Assessment Module (RAM)**, developed by the European Research Project Shelter, is an online tool (Figure 9) that calculates the risk score of the heritage asset using indicators related to the applicable hazard. It targets city technical practitioners and researchers.

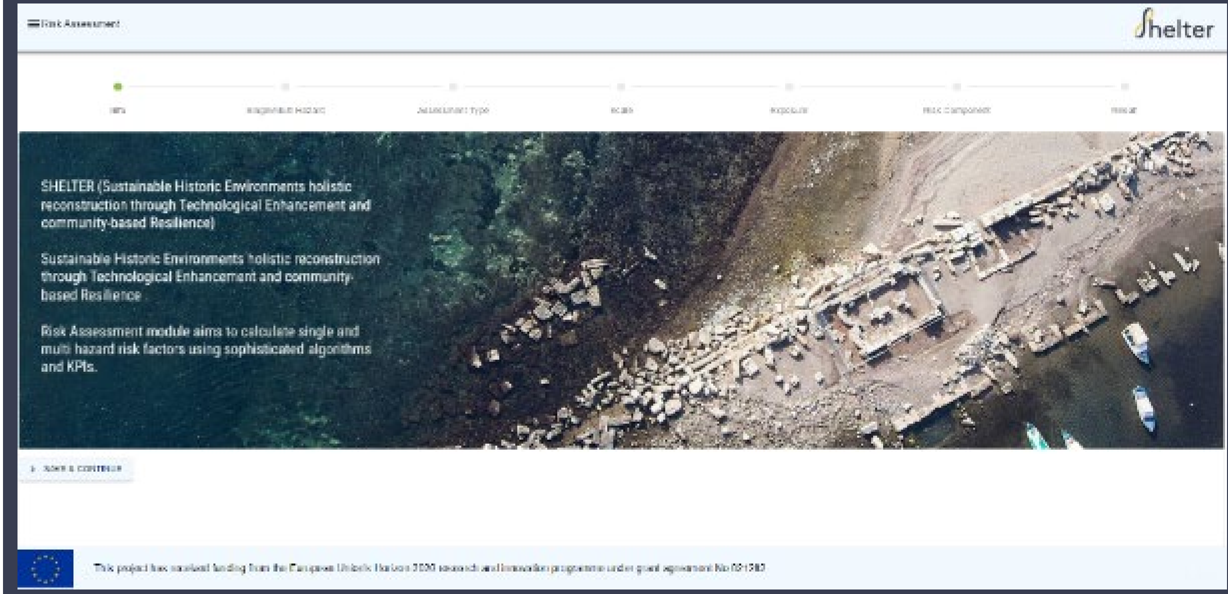


Figure 9. Shelter Risk Assessment Module. Source: https://shelter.ekodenge.com/

2. **The Risk Systemicity Questionnaire (RSQ)**, developed in a web and excel format by the European research project Smart Mature Resilience, can be used to identify and prioritise risk scenarios, where interdependencies between risks are shown to lead to networks of risks, including so-called "vicious cycles," and to review and prioritize mitigation and adaptation actions for various scenarios of risk interdependencies (Figure 10).

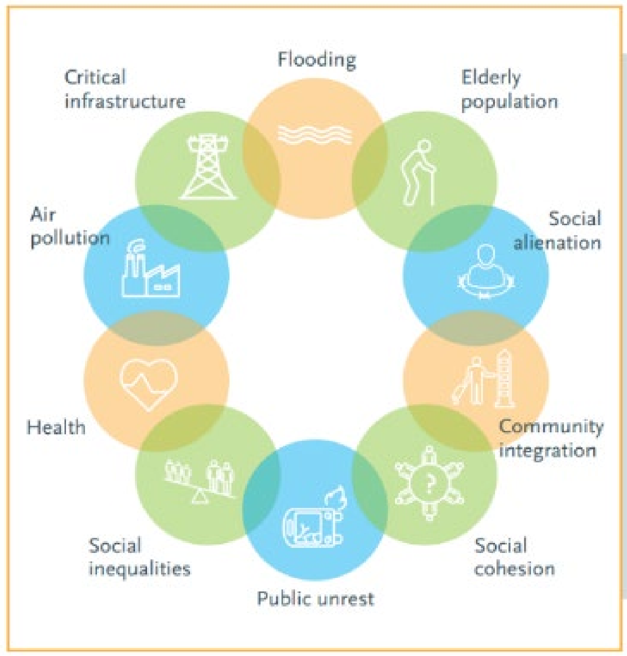


Figure 10. Topics that the RSQ includes which fall under three broad themes: social dynamics, climate change, and critical infrastructure. Source: https://smr-project.eu/tools/risk-systemicity-questionnaire/

3. **Shelter Strategic Decision Support System (SSDSS)** is a web-based application that implements and links the multiscale iterative vulnerability and resilience assessment methodology.

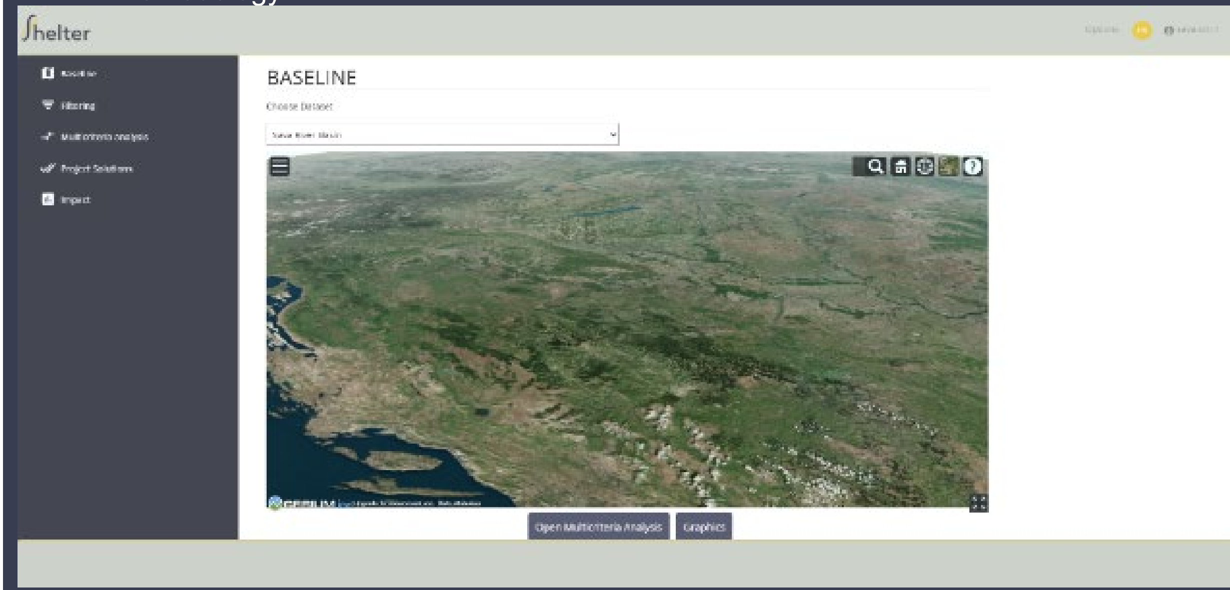


Figure 11. Shelter Strategic Decision Support System[9]

TIP!
Climate data processing, geophysical scenarios, impacts, vulnerability, and risk assessment often require expert assistance.
However, when that is not possible due to lack of resources or lack of data, screening methods (Figure 12) or conventional risk matrices (Figure 13) can be used, informed by local knowledge.

[9] https://shelter-project.com/about/. To be released by November 2022

Risk assessment template

Fill in your project details	Organisation				
	Project				
	Date				
Scope your assessment	What is the objective of this risk screening?				
	What is your planning horizon or time frame of this risk screening?			Briefly document the reason for selecting this time frame	
	Which climate change scenario/s will you include in this risk screening (i.e. high RCP8.5, medium RCP4.5, low RCP2.6 scenario)			Briefly document the reason for selecting your scenario/s	
Screen potential coastal climate risks in your coastal zone					
	Potential hazards in the coastal zone	Have these occurred in the past in your area of interest?	Do you have any existing risk management strategy in place to tackle this hazard?	Do you have any residual (existing) risk from this hazard? (i.e. if you have a record of past occurrence of a hazard, and you do not have in place an adequate risk management strategy to address it, then you have a residual risk)	What is the likely future direction of the hazard? (based on your selected time frame and climate change scenario)
Coastal hazards around open coast beaches and estuaries	Storm related beach erosion in your area (short-term erosion)	☐ Yes ☐ No ☐ Not Relevant	☐ Yes ☐ No ☐ Not Relevant	☐ Yes ☐ No ☐ Not Relevant	☐ Decrease ☐ Increase ☐ No change
	Long-term shoreline recession around open coast beaches	☐ Yes ☐ No ☐ Not Relevant	☐ Yes ☐ No ☐ Not Relevant	☐ Yes ☐ No ☐ Not Relevant	☐ Decrease ☐ Increase ☐ No change

Figure 12. Extract of the screening template on risk identification. Source: CoastAdapt Australia. https://coastadapt.com.au/tools/decision-support-templates-create-risk-register

RISK RATING KEY	LOW 0-ACCEPTABLE --------------------------- OK TO PROCEED	MEDIUM 1- GENERALLY MANAGEBLE --------------------------- TAKE MITIGATION EFFORTS	HIGH 2-UNACCEPTABLE --------------------------- SEEK SUPPORT	EXTREME 3-INTOLERABLE --------------------------- PLACE EVENT ON HOLD
	SEVERITY			
	ACCEPTABLE LITTLE TO NO EFFECT	TOLERABLE EFFECTS ARE FELT, BUT NOT CRITICAL	UNDESIRABLE SERIOUS IMPACTS	INTOLERABLE COULD RESULT IN A DISASTER
LIKELIHOOD				
IMPROBABLE RISK IS UNLIKELY TO OCCUR	LOW -1-	MEDIUM -4-	MEDIUM -6-	HIGH -10-
POSSIBLE RISK WILL LIKELY OCCUR	LOW -2-	MEDIUM -5-	HIGH -8-	EXTREME -11-
PROBABLE RISK WILL OCCUR	MEDIUM -3-	HIGH -7-	HIGH -9-	EXTREME -12-

Figure 13. A conventional risk matrix. Source: Adapted from (17)

HERITAGE TIP!

ICCROM (International Centre for the Study of the Preservation and Restoration of Cultural Property) and the Canadian Conservation Institute (CCI) published a Guide to Risk Management of Cultural heritage in 2016, which provides a specific list of common risks that heritage faces, based on real lived experiences (Figure 14). However, the guide is focused on achieving effective protection from risks, some of which are climate change related.

	Rare events	Common events	Cumulative processes
Physical forces			
Criminals			
Fire			Generally not applicable
Water			
Pests			
Pollutants			
Light and UV	Generally not applicable		
Incorrect T			
Incorret RH			

Figure 14. Identification template for the specific risks that affect heritage asset in its own context

Step 1.4 Define resilience threshold or objectives

Objectives	• Define the objectives of the resilience or adaptation pathway based on the context analysis • Help to identify 'acceptable' losses based on thresholds and thus identify when new resilience measures should be deployed to avoid non-acceptable losses • Make sure that the scope of the resilience or adaptation pathway is adjusted to the available resources

´Threshold[10] analysis is an approach to prioritize where and when action will be needed by understanding the points at which a system is deemed to be no longer effective (economically, socially, technologically or environmentally) as a result of changes in the average or extreme climatic conditions´ (25). Figure 15 presents a graphical representation of a threshold analysis and concept. The threshold analysis responds to the classical top-down approach, "What if climate changes according to scenario x?". However, threshold values are not always feasible or easy to determine for all type of hazards. In those cases, the Resilience Pathway approach can also focus on the ability to cope with climate change or other local hazards. This makes the method less dependent on climate scenarios and focuses more on resilience. In these cases, it is desirable to set specific objectives for resilience. Resilience objectives may be clear after analysing the context and resilience needs derived from vulnerability, impact and/or risk assessment. However, in cases where the targeted system or historic area is complex, there is high uncertainty on the gathered information, or there remain big gaps in knowledge, practical tools to trigger and support socio-institutional co-creation are available [TOOLBOX 3].

In any case, regardless of the approach, objectives or thresholds should be documented including how they were determined and the reason behind the assumptions made, if any.

[10] A climate threshold is a critical limit where a climate system responds drastically when exposed to an external forcing, resulting in the system changing into a different stable state

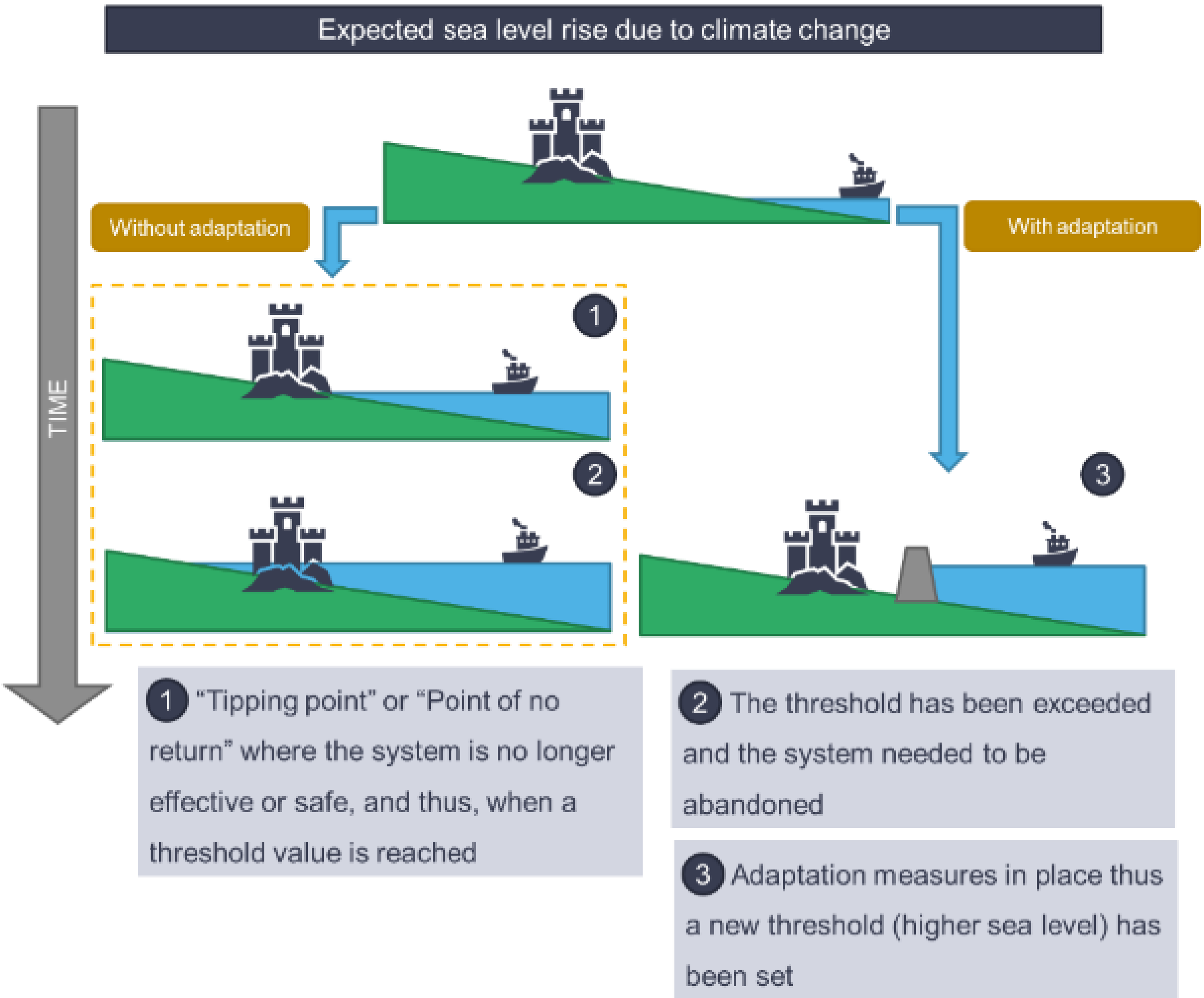


Figure 15. Tipping point and threshold concept graphical representation for sea level rise

TIP!

What is an adaptation tipping point? The point at which a series of small changes become significant enough that their impacts render a system no longer effective. An adaptation tipping point determines a point in time when the threshold is reached (see Figure 15 for an example of a tipping point) and new adaptation or pre-disaster measures are needed to safeguard a system.

What is a resilience tipping point? The point at which a significant incident or disaster modifies the system resulting to be no longer effective (the crisis stage in a process, when a significant change takes place). A resilience tipping point determines a point where the disaster occurs and during- and post-disaster measures (Emergency operating phase, see Figure 4) need to be deployed.

TOOLBOX 3a

- Theory of change aims at deeply understanding how change actually occurs

The Theory of change process was conceptualized as the mini-steps that allow a system to achieve long-term goals while setting assumptions and connections between the activities that need to be in place and the outcomes that occur at each step. It is especially focused on identifying the pre-conditions needed to achieve the long-term goals, that is, understanding what the activities do (outputs) and how these lead to the desired goals (outcomes). Then it works back from these to identify all the conditions that must be in place for the goals to occur. Source: The Center for Theory of Change (26)

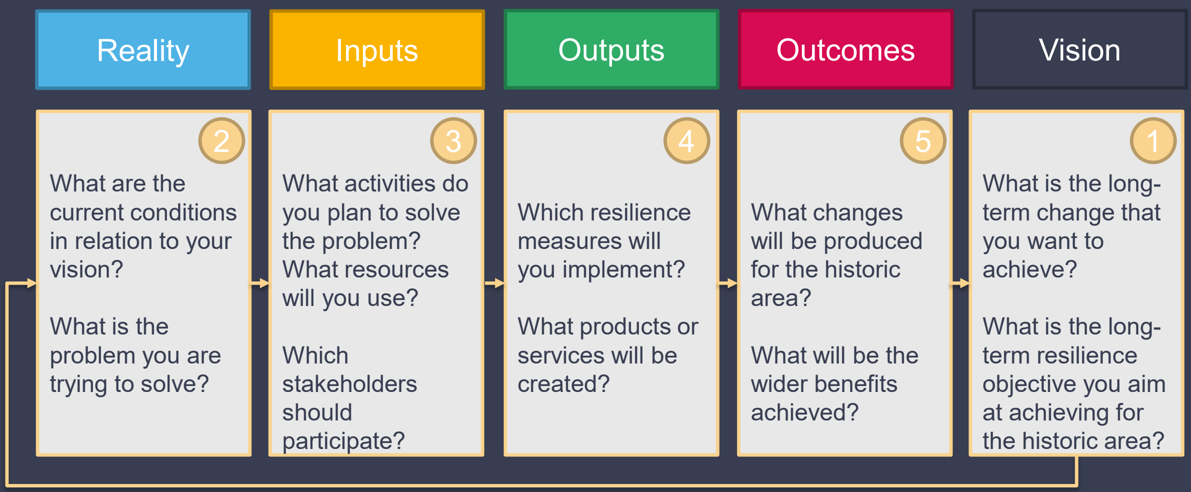


Figure 16. Schematic steps involved in the theory of change methodology

As shown in Figure 16, the Theory of Change begins by determining the desired long-term changes in, for example, the historic area in relation to the resilience objectives (vision). Then, the identification of the existing conditions and envisioned or actual climate/geophysical problems is carried out. This is followed by the determination of necessary inputs and outputs to achieve short-term as well as intermediate outcomes, which themselves lead to the desired long-term impact (vision). Furthermore, assumptions are identified and linked to a specific pathway risk to attempt to manage these by identifying what conditions must hold true for change to occur. An example of its application to heritage can be found in the Climate Heritage Network Action Plan where Theory of Change has been applied to define its goals.

TOOLBOX 3b

- **Setting SMART objectives (26)**

Five criteria (Specific, Measurable, Achievable, Relevant and Time-bound (i.e. 'S.M.A.R.T') have traditionally been used to ensure quality objectives or determine the criteria for monitoring and evaluating the results of an implemented policy. In the Resilience Pathway approach, the ***time-bound*** criterion would be replaced by ***scenario-bound*** to account for the uncertainty related to climate change (*e.g* greenhouse gasses emission scenarios, climate model uncertainty etc.)

What are SMART objectives?	
Specific	Objectives should be precise and concrete enough not to be open to varying interpretations by different people.
Measurable	Objectives should define a desired future state in measurable terms, to allow verification of their achievement. Such objectives are either quantified or based on a combination of description and scoring scales.
Achievable	Policy aims should be set at a level which is ambitious but at the same time realistically achievable.
Relevant	The objectives should be directly linked to the problem and its root causes.
Time-bound (Scenario-bound)	Objectives should be related to a scenario of change (or scenario of resilience measure implementation) to allow an evaluation of the pathway's achievement to reduce the risk per scenario.

Step 1.5 Alignment of the Resilience Pathway with long-term vision of the system

Objectives	• Make sure that the resilience objectives are aligned with the municipalities or historic area's long term-vision • Understand that the flexible resilience pathway will be the planning toot to deployed the resilience objectives, similarly to conventional sectorial or transversal strategic plan • Revise the involved stakeholders to ensure that the resilience pathway will not encounter implementation risks

This step aims to ensure that the objectives set for the Resilience Pathway are not in conflict with other municipal policies. Figure 17 shows the different planning levels to be revised within this step. It may also help to identify synergies with existing plans and promote the cooperation with the leading stakeholders, if they are not already part of the working team dedicated to the Resilience Pathway development. It is important to document the deadlines, specific objectives, and the specific plan's timeframe to align the outputs of the Resilience Pathway with ongoing projects. It is also vital at this stage to revise the stakeholder ecosystem map. This will also promote more efficient and sustainable funding and management of the different plans or projects targeting the same or similar objectives within different sectors.

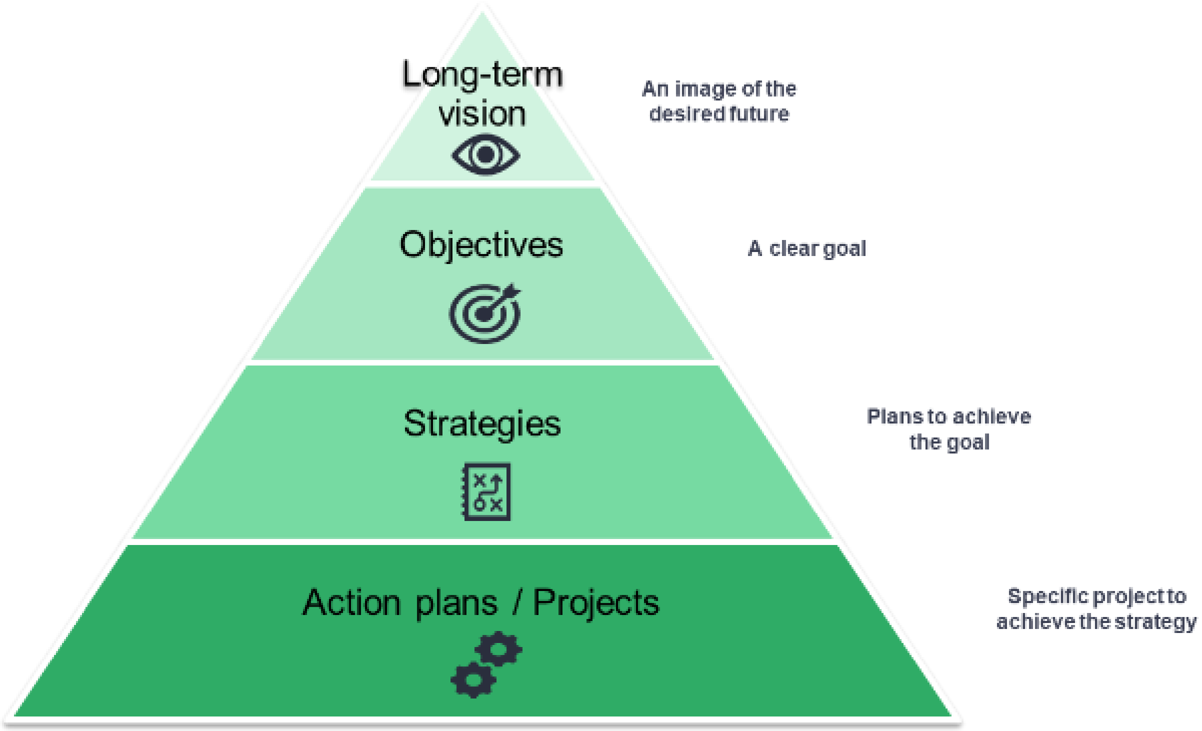


Figure 17. Framework for planning and decision-making based on the set long-term vision

Step 1.6 Financing the flexible Resilience Pathway

Objectives	• Make sure that the financing of the potential resilience measures is considered from the beginning to secure funding or minimising the risk of running out of funding at implementation, with the consequences that this entails. • Understand available funding opportunities and select the most appropriate one for each resilience measure typology and our municipality /historic area

Despite challenges to funding and financing in sustainable urban development (as reported by local authorities) (27), local action on climate change adaptation, disaster risk reduction or resilience building in general is an opportunity. Not only because it anticipates potential problems or opportunities, but because it can position municipalities to access new sources of funding, programmes and initiatives that are being carried out in Europe (LIFE+, Horizon 2020, Interreg, among others).

It is therefore essential to consider from the outset what sources of funding are available and to understand what characteristics apply to each funding programme. In order to do this, it is important to have a methodology to help identify the best funding programme for each type of resilience measure.

TIP!
The ARCH Methodology followed three main steps to identify and select the most appropriate funding opportunities.

The **(1) screening, (2) categorisation** and **(3) applicability** of funding measures is a crucial part of the pathway development for improving the resilience of historic areas to climate change-related and other hazards as it supports decision-making at appropriate stages of the management of resilience measures.

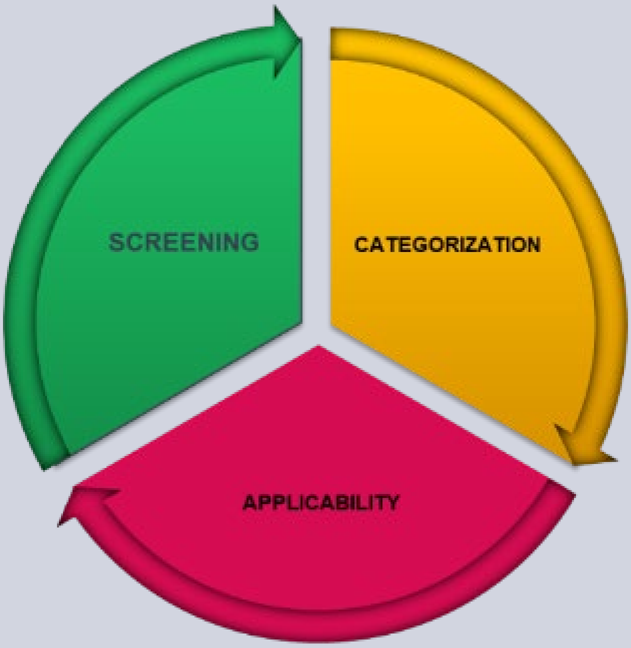


Figure 18. The methodology adopted to analyse the financing of the resilience measures in the case of ARCH pilot cities.

The initial **screening** of the funding measures is conducted to analyse all the possible funding opportunities for the identified resilience measures and narrow down the choice to a given number of possible funding sources.

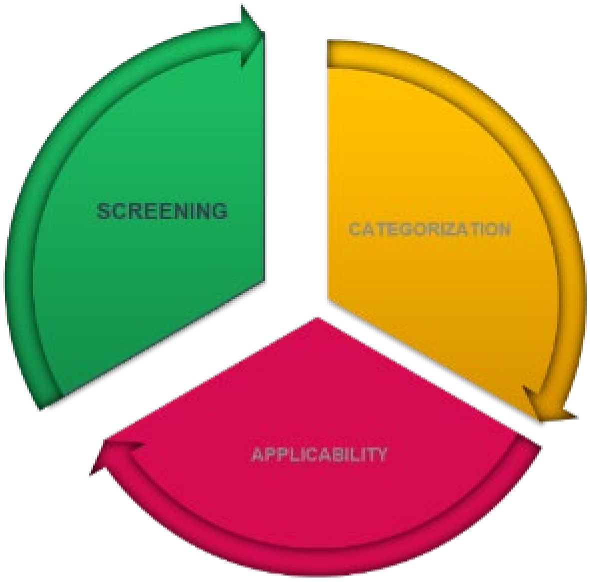
The **categorization** of funding measures is performed by performing a "Strengths, Weaknesses, Opportunities and Threat" (SWOT) analysis of the identified funding measures for selected resilience options and analysing the city's structure based on a set of indicators: social, technical, economical, institutional and organizational.

Finally, the **applicability** of the identified funding measures to the cities structure is represented with a "crossing" SWOT table that matches the SWOT analysis of the funding measures with the city's structure leading to a final result score table of the most suitable funding measures.

ARCH Example

Once the resilience measures are identified, an initial "**screening**" of possible funding measures should be performed (See Figure 18). These range from EU funds to non-traditional financing sources like crowdfunding and funding through Public-Private Partnerships (PPP). Various solutions apply and can contribute to funding resilience measures in historic areas. These should be selected paying special attention to the intersections across the fields of cultural heritage conservation, disaster risk management and adaptation to climate change.

The screening activity can be conducted by way of literature review, including research of grey and scientific literature and EU and international projects' websites. Other sources like articles and scientific publications should be consulted.



Moreover, possible funding sources to consider are bank foundations, private foundations, donors and foundations networks (*e.g.* for Europe DAFNE, ENEL Foundation, Fondazione TIM, BOCELLI Foundation, Rockefeller Foundation, Fashion sector etc.), EU institutions (ECB, EIB, EBRD, EEA), International Organisations (UNESCO, Global Heritage Fund, ICCROM, World Bank) and other sources like the EU Crowdfunding Network, and IKOSOM platform for civic Crowdfunding.

To narrow down the search for the most suitable financing solutions for the selected resilience measures, the following steps (Figure 19) for the identification of possible funding opportunities should be followed when, for example, the EU funds are investigated.

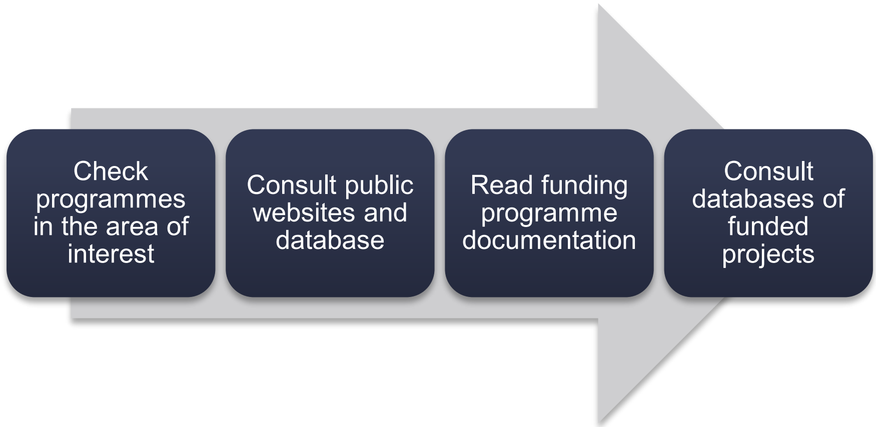


Figure 19. Four step methodology for the identification of possible funding opportunities

The first step is to **check EU Programmes in the area of interest**. In order to be financed, the identified resilience measure must meet the selection criteria and investment priorities of the regional programme. At the EU or regional/local level, strategic priorities are normally identified, and for the financing of the selected resilience measure, these must be aligned with the financing programme's priorities.

The second step is to **consult public websites and databases** for available funding instruments. Examples of EU funds database are:

- ✓ https://ec.europa.eu/info/overview-funding-programmes_en
- ✓ https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/home
- ✓ https://www.funds-navigator.eu/en

- ✓ https://euro-access.eu
- ✓ www.welcomeurope.com/programs
- ✓ www.eucalls.net

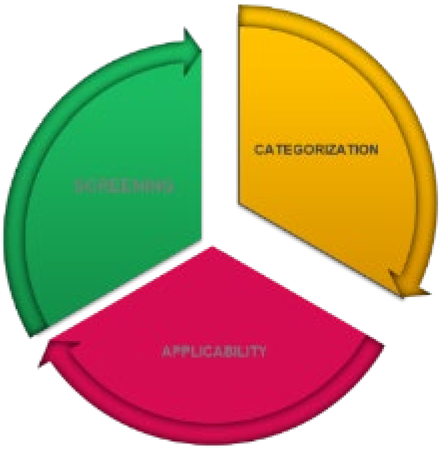
The third step is **reading funding program documentation**. This is essential to understand the strategy behind the funding instrument. The EU, for example, sets annual or even long-term goals in so-called "work programs" that are to be achieved within a certain period. Through calls for tenders, the EU then looks for service providers who can help to translate these EU work program goals from theory into practice through the implementation of very specific projects. The programmes funded under the Multiannual Financial Framework (MFF) are grouped into various headings or expenditure categories of the EU budget, each one dedicated to a specific policy area. For resilience measures, for example, these could fall into the policy area “cohesion, resilience and values” or “natural resources and environment”. Once the policy area is identified, the “programme guide” should be carefully analysed together with all the call documents, financial guidelines and other available documentation.

A fourth step is **consulting the database of funded projects** to check whether the resilience measure to be financed has been already financed or could be connected with previously financed projects.

The scheme below (Figure 20) illustrates a summary of the guiding criteria that could be applied to select the most suitable funds, once a preliminary analysis of the resilience measures and the structure of the city has been performed.

Figure 20. Guiding criteria for the funding selection

Once the screening of the available funding measures has been conducted, in order to narrow down the choice of the most suitable financing measures for the selected resilience measure to be implemented in a given context (city), the following steps of **categorization** should be followed:



- ✓ SWOT[11] analysis for identified funding measures
- ✓ Analysis of the city structure based on a set of indicators: social, technical, economic, institutional and organizational

The parameters to carry out the SWOT analysis can be the following:

1. Programme budget
2. Project budget
3. Frequency
4. Partnership
5. Project TRL (technology readiness level)
6. Complexity of project preparation
7. Success rate
8. Necessity of co-financing
9. Project innovation rate
10. Project social acceptability
11. Combination with other financial instruments
12. “Brain or bricks” focus
13. Support rate of public or private entities
14. Project reporting complexity
15. Intellectual property issues
16. Need for fundraising web platforms
17. Territorial availability
18. Project duration
19. Communication campaign requirements
20. Private stakeholder involvement

For example, the SWOT analysis of the **Horizon Europe** programme is reported in Figure 21.

[11] Strengths: These are things that enable securing the necessary funding; Weaknesses: These are things that hinder the application to resources or increase the effort needed to be eligible; Opportunities: These are things which could benefit the entity applying, but do not currently; treats: These are things which could discourage the application to that specific funding.

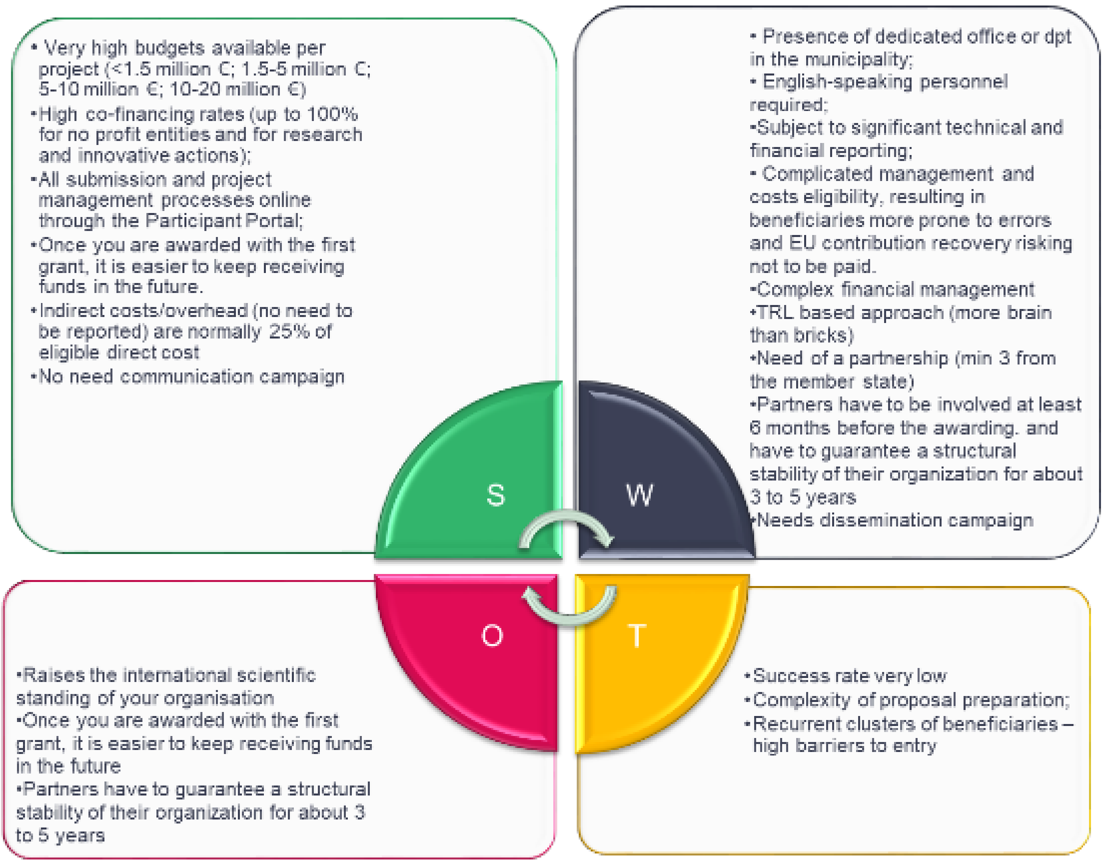


Figure 21. SWOT analysis of the Horizon Europe programme

An analysis of the local (or regional) government structure should be carried out in order to assess the applicability of the selected financing measures, keeping in mind the characteristics of the funding measures and financing mechanisms. This helps to assess the capacity of the local or regional government to access the funds based on technological, economic, institutional, and organisational criteria. Figure 22 presents the indicators used to analyse the ARCH pilot cities' structures.

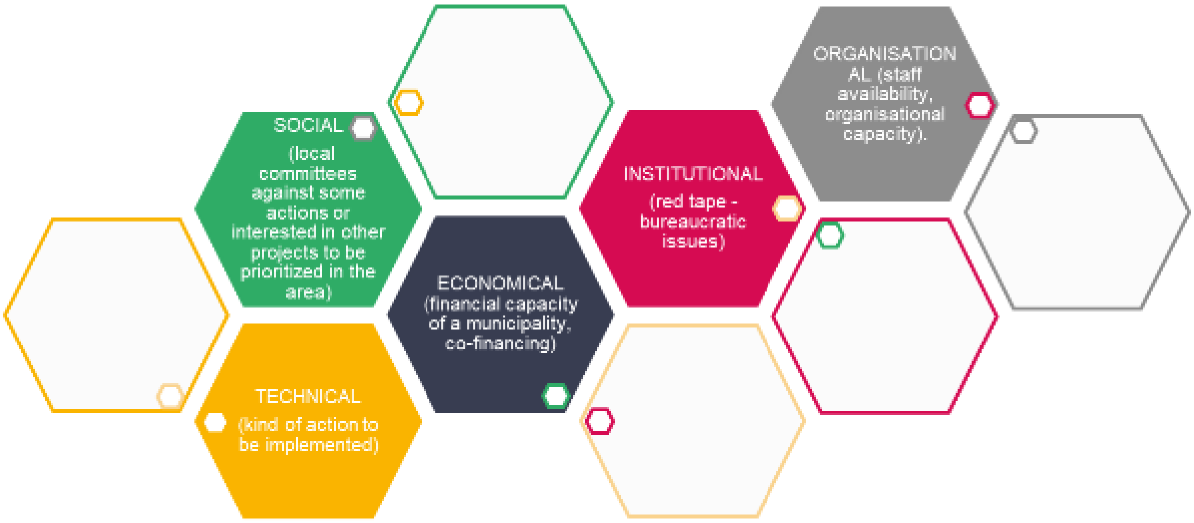


Figure 22. Indicators used to analyse the ARCH pilot cities structures

The **applicability** of opportunities is assessed by the stakeholder, supported by the administrative/technical staff of a local government based on technological, economic, social, institutional, and organisational criteria. These criteria should be employed to evaluate the benefits of funding measures in terms of effectiveness, value creation and minimised risk.

The result of the analysed funding measures as applied to the specific case of each city will be described and illustrated with a "crossing" SWOT analysis that will take into account the SWOT analysis of the funding measure (see above).

The applicability will therefore derive from both the SWOT analysis of the funding measure and the characteristics of the cities, as well as the specific type of resilience measure analysed.

The crossing SWOT can appear quite similar to the SWOT analysis performed for the funds in the categorization phase when resilience measures chosen are not executive detailed projects with identified costs and the information about the city's structures collected are not so crucial to take the priority on the characteristics of the fund itself. However, the SWOT analysis crossing tables are essential to create the final score tables related to each city case.

The SWOT below (Table 6) represents the crossing SWOT analysis of the Horizon Europe programme for financing infrastructure structural monitoring of stability in ARCH pilot city Camerino, *i.e.* technologies to provide information on the performance and condition of the infrastructure such as Global Positioning System (GPS) systems through sensors.

Table 6. SWOT analysis of the Horizon Europe Programme for financing infrastructure structural monitoring of stability

STRENGTHS	WEAKNESSES	OPPORTUNITIES	THREATS
• High co-financing rates (up to 100% for no profit entities and for research and innovative actions) • All submission and project management processes online through the Participant Portal • Indirect costs/overhead (no need to be reported) are normally 25% of eligible direct cost • No need of communication campaign to apply	• Lack of EU project dedicated office in the municipality • Limited number of English-speaking personnel • Project implementation subject to significant technical and financial reporting • Complicated management and costs eligibility, resulting in beneficiaries more prone to errors and EU contribution recovery risking not to be paid • Complex financial management • TRL based approach (more brain than bricks), chosen resilience action not so adapt • Partners have to be involved at least 6 months before the awarding and have to guarantee a structural stability of their organization for about 3 to 5 years • Needs dissemination campaign during the project	• Raises the international scientific standing of your organisation • Once the partnership is awarded with the first grant, it is easier to keep receiving funds in the future • Opportunity to exploit an existing partnership • Opportunity to involve external consultants paid by the project	• Success rate very low • Complexity of proposal preparation; • Very high budgets available per project (<1.5 million EUR; 1.5-5 million EUR; 5-10 million EUR; 10-20 million EUR) hence large structured project needed

As seen in Table 7, the results of the analysis are valued with a score from 1 to 5 (1= lowest applicability, 5= highest applicability) and represented by a traffic light in which the green light represents the solution with which it seems to be possible to proceed smoothly, the yellow light represents a solution to adopt with a more cautious approach and the red light means that, for the specific case, it is worth re-evaluating whether the fund can be effectively applied or not.

Table 7. The results of the analysis performed for Camerino case study

CAMERINO	LIFE Climate Change	Interreg	Private Public Partnership	NRRP	Invest EU Fund	Match Funding	Horizon Europe
Building Back Better				5	2	4	
Monitoring System	3			5			3
Awareness raising	2	3	4				

As illustrated above, the EU programmes are focused on clear individual themes and specialist sectors. Therefore, once the project idea is established, there is normally one main funding instrument per thematic sector to investigate. However, there is also the possibility to present cross-sectoral projects with potential synergy effects.

It is important to bear in mind that, as a general rule, it is not allowed to apply for two different funding sources for one project at the same time. However, different types of funding can be grouped, for example, private and public funds.

For financing the selected resilience measures for local authorities, the best solution could most likely be that of combining funding sources. For example, a crowd funding campaign, therefore private funds, could be anticipated by a publicly funded awareness raising campaign financed through EU grants.

Step 2: Selecting resilience measures

The possible responses and solutions associated with the impacts and effects of climate change or geophysical hazards may be familiar, even obvious, if these effects are related to an aggravation of problems already experienced by or familiar to a given place (floods, heat waves, thermal oscillation etc.). If, on the other hand, the potential impacts are new (infectious vectors, new pests, change in species productivity, etc.), they may be less obvious, and more effort will be needed to identify responses. In this phase, alternatives and possibilities for responding to the risks, challenges or opportunities must be identified, from which the best suitable measures can be selected depending on the socio-institutional context and the nature of the hazards that affect the historic or territorial context.

A wide range of resilience measures are available to reduce the negative impacts of climate change and other hazards. However, when it comes to heritage, due to its authenticity and heritage significance, the measures applicable to the specific area may be significantly reduced. This is especially true for structural measures (see Figure 8 for the definition) that may have a visual, physical and/or spatial impact and which may not be reversible. For example, in a historic area that has been designated as a sacred site by a local community, the community's perception of the heritage may determine whether certain measures, such as flood walls, are deemed appropriate or not. This may be related on how historic areas and their associated values are receptive to change based on their different qualities.

Step 2.1 Identification of resilience measures

Objectives	• Build a portfolio of resilience measures that are relevant and appropriate to the specific challenges or opportunities of the historic area and its specific characteristics • Optimise the use of existing resilience assets • Learn from good practices and "maladaptation" examples if available

A first step in this process is to identify the sources of information which may be relevant. The information to build a preliminary portfolio of resilience measures may come from catalogues of adaptation, risk reduction or resilience measures, good practices and reference cases in other historic areas or municipalities.

A few catalogues dedicated to general adaptation to climate change are available and to resilience of heritage [See HERITAGE TOOLBOX 1]:

- RESIN Adaptation Option Library[12] includes over 100 adaptation measures mainly for urban environments and addressing climate risks including heat; pluvial, fluvial and coastal floods; and drought

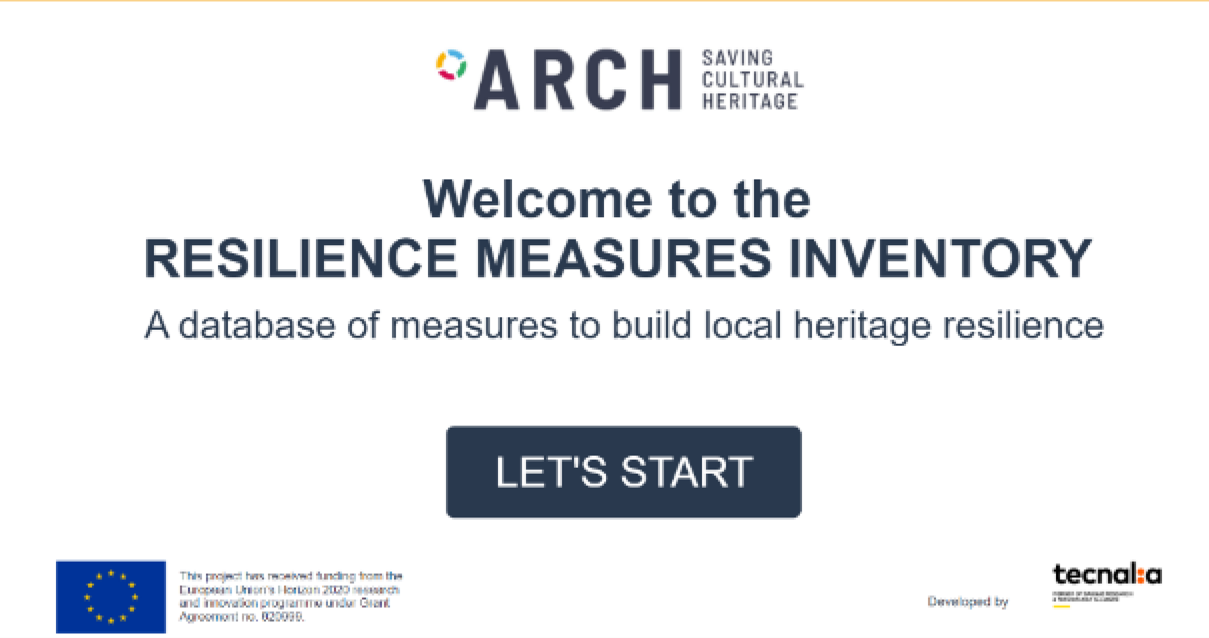
[12] https://resin-aol.tecnalia.com/apps/adaptation/v4/#!/app/summary

- Climateapp[13] provides urban designers, engineers or others insight in feasible measures for a project with a specific climate adaptation goal
- Urban Green-Blue Grids[14] for resilient cities is focused on Nature-based Solutions (NbS) and provides not only general information about each NbS typology but examples of projects.

HERITAGE TOOLBOX 1:

The ARCH Resilience Measures Inventory and SHELTER Solution Portfolio provide databases focused on building local heritage resilience.

The ARCH Resilience Measures Inventory is designed to help identify measures along the disaster risk management and adaptation process to improve the resilience of historic areas. The inventory is divided in two sections: urban built heritage and agricultural heritage. It also provides addition information on general co-benefits and negative effects provided by the measures and the impact they could have on heritage.



The SHELTER Portfolio of solutions for emergency phases includes existing solutions/strategies gathered for their suitability for Climate Change Adaptation (CCA), preparedness, response and reconstruction, taking into account all the considered hazards (earthquakes, storms, floods, heat waves, wildfire and subsidence). The Portfolio includes a Benefit-Cost Analysis and a simplified Life Cycle Assessment. The solutions/strategies are defined according to various indicators. The portfolio presents solutions and strategies to be implemented to tackle climate hazards. It is integrated in the Decision Support System of the SHELTER project.

[13] https://www.climateapp.nl/
[14] https://www.urbangreenbluegrids.com/measures/

Adaptive solution	**Temporary flood protection systems: Sandbags (buildings)**			**Prioritization Index**	0.87	Shelter	
DRM phase	☑ Emergency	☐ Prevention	☑ Preparedness	☐ Response	☐ Recovery & BBB		
Hazard	☐ **Heat waves**	☑ **Flooding**	☐ **Earthquakes**	☐ **Subsidence**	☐ **Wildfires**	☐ **Storm**	
Action Scale	Building	**Function (1)**	Building protection	**Function (2)**			
Type of AS	Soft	Architectural and engineering solutions		**Technical requirement**	Low		
Impact on cultural value:	No			**Reversibility**	Yes		
Impact on protected CH	No						
Building:	☐						
Façade	☐ Material	☐ Components	☐ Carpentry	☐ Colour/finishing			
Roof:	☐ Material	☐ Volumetry	☐ Components				
Structure:	☐ Material	☐ Structural system					
Public zone:	☐ Pavement/ material	☐ Natural species	☐ Path/ Gradient	☐ Parc / natural environment			

Implementation time	Short time	**Pictures**
Cost	Low	
Effectivity	Temporal solution	
Maintenance	Low	
Recyclable	Yes	
Reusable	Part	

Description

The use of sandbags is a simple, but effective way to prevent or reduce flood water damage. Properly filled and placed sandbags can act as a barrier to divert moving water around, instead of through buildings. Traditionally, sandbags have been used to block doorways, drains and other openings into properties. They can keep water out for short periods which can be improved by using them in conjunction with plastic sheeting.

Material

Burlap or woven polypropylene filled with sand or soil. Usually completed with plastic tarps or lones.

Other aspects:

Positive aspects:	**Negative aspects:**
Effective protection against minor flooding. They can filter out some muddy sediments found in flood waters. They are cheap and easy to obtain. No electricity or energy is needed. Adaptable and modulable. Usually traditional way to protect against floods.	Limited protection against major flooding. They take time to fill and laying them can be time consuming. They can be difficult to handle. Sacking material is biodegradable and will perish if left in place for a long time. When they come into contact with floodwater they tend to retain contaminants and bags can often only be used once. Flexible in small scale, but not easily adaptable for buildings covering a great area.

References

Environment Agency, Temporary and Demountable Flood Protection Guide, 2011.
Historic England, Flooding and Historic Buildings, 2015.
State Historical Society of Iowa, 1952.

HERITAGE TIP!

V. Rebollo and V. Latinos. (2020) Good practices in building cultural heritage resilience. Deliverable 7.2. EU ARCH Project GA no. 820999. This report is meant to serve as an inventory of good practices in building cultural heritage resilience. It contains an overview and classification of 40 cultural heritage resilience initiatives, providing information on their location, biogeographical region and lead(s). 32 of them are featured as snapshots and eight of them as case studies (containing in-depth information on aspects such as main outcomes, factors of success and lessons learned). Additionally, and reflecting upon the term "replicability", the report proposes a set of criteria to evaluate their transferability potential to other urban contexts.

Good practices in building cultural heritage resilience

3.2.6 CASE STUDY 2:

Patios de la Axerquía: Regenerating historical courtyards through social innovation

Type: Managerial -Governance model
Main hazard(s): Extreme temperatures, drought, desertification

Location: Cordoba, Spain
Biogeographical region: Mediterranean
Lead: PAX- Patios de la Axerquia

Background:

With a growing tourism industry and very little industrial activity, Cordoba (a city of some ca. 300.000 inhabitants) is now transforming itself and gradually becoming gentrified. The city is rich in architectural and intangible cultural heritage, and agriculture is very relevant for the economy. The unemployment rate in Cordoba is amongst the highest in Spain (at 28.5%).

Case description:

The historic district of Cordoba is suffering de-population as long-term residents abandon their courtyard houses seeking a more comfortable life away from mass tourism. In April 2018, PAX (Patios de la Axerquia) Association was established by local groups to regenerate the historic centre by restoring the abandoned courtyard houses (casa-patio) of the Axerquia (neighbourhood) together with resident groups constituted in housing cooperatives. An innovative operation of governance has been applied by the group fostering a change to the conventional urban development model based on speculation to one of rehabilitation of neglected areas, avoiding tourist-focused gentrification and allowing the people of Cordoba to reclaim their city's historic environment and its intangible heritage. PAX is a local experiment that is expected in the near future to evolve into a larger scale 'start-up' of urban governance facing gentrification processes.

PAX provides a new style of governance in relation to urban regeneration, incorporating social innovation in a heritage city by acquiring vacant houses and cooperatively using them; implementing multi-level co-management between the city administration and the local residents, and among the residents themselves. The project is pursuing urban regeneration of a specific vulnerable area by greening the city, recovering the architectural and intangible heritage value of the courtyard houses and forming a social and solidarity-based economy; therefore, the model bridges multiple concepts.

For more information on PAX, visit:
http://patiosaxerquia.org

Contact info:
Gaia Redaelli
gaia@patiosaxerquia.eu

Relevant sources:
www.built-heritage.net/gaia-redaelli-issue9

Courtyard Housed of Axerquia

El Pais article on Pax in the Mediterranean frame

Interview with Gaia Redaelli, co-founder and president of PAX

When considering the resilience measures for addressing the impacts and risks identified in *Step 1: Preparing the ground and setting objectives,* it can be the case that a long list of potential measures is identified. In this case, it may be relevant to classify (Figure 23) them to have an overview of the identified measures and ensure no gaps exist, or if they do exist, to be aware of them. During this step not only can future resilience measures be identified but also past and current measures that could be further deployed. At the end of this sub-step a portfolio of resilience measures should be in place per impact or impact chain.

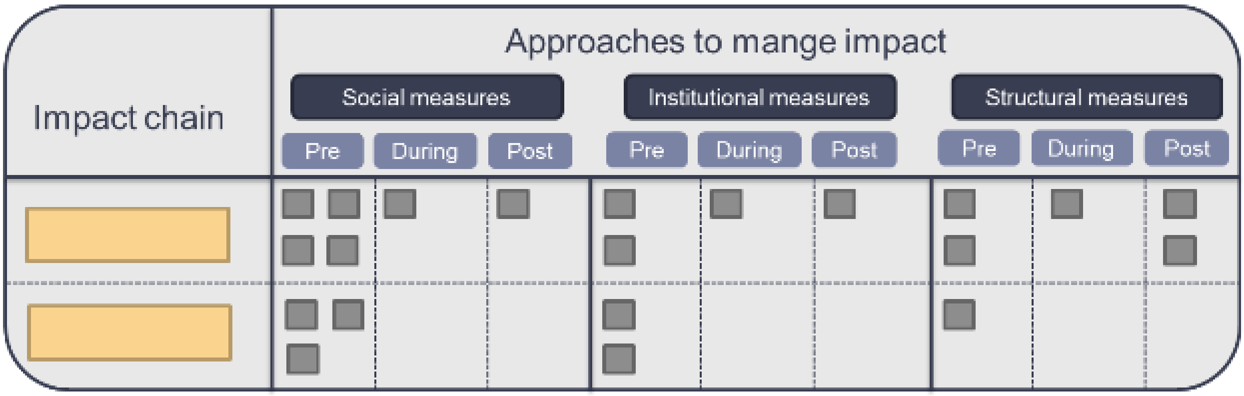


Figure 23. Example of resilience measure's classifications

Step 2.2 Selection and characterisation of resilience measures

Objectives	• Establish the feasibility information or criteria for the selection of measures appropriate to our historic area or municipal reality • Set the most suitable criteria for the characterisation and prioritisation of the resilience measures • Characterise the resilience measures • Identify appropriate methods for the prioritisation of resilience measures.

Step 2.1 aims at screening and building a portfolio of possible resilience measures, that is, to gather all resilience measures that can help prepare for, mitigate, and manage the impacts and risks of the previously prioritised hazards. Step 2.2 aims at characterising the measures based on relevant information for the stakeholders. This characterisation aims to help with the selection of resilience measures suitable for the historic area or municipality (Figure 24). This can be done sequentially in various steps or in one step depending on the number of identified resilience measures in step 2.1.

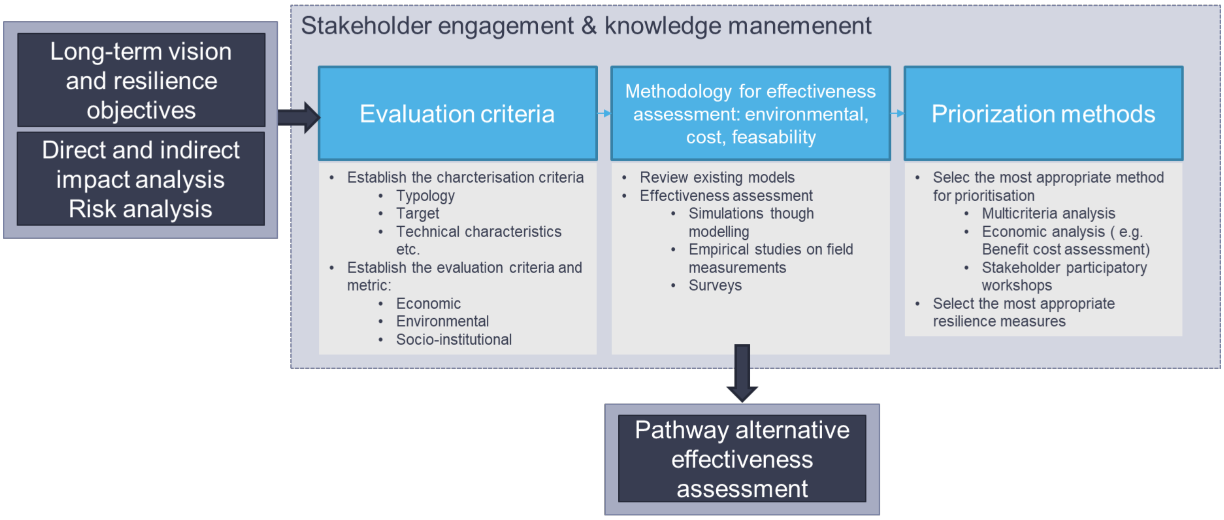


Figure 24. Framework for assessing and selecting resilience measures. The long-term vision and impact and risk analysis may determine the evaluation criteria, while the methodology for effectiveness assessment will influence the pathway effectiveness assessment

In the Resilience Pathway approach, it is important to select the characterisation criteria considering the following matters:

- Whether it will be a stakeholder-led (participatory) or a data-driven pathway approach (Figure 25)
  - Stakeholder-led assessments are often based on qualitative analysis of various criteria based on expert knowledge and experience. This may imply the consensus of a variety of stakeholders, for example on the socio-institutional acceptability of resilience measures. In this case, good knowledge of the local context and resilience themes (*e.g.*, heritage, disaster risk management, climate change etc.) is essential. These stakeholders are especially useful to build on resilience narratives based on the description of potential climate change or other hazard impacts and possible responses if/when conditions worsen. This approach encourages understanding of the bigger picture and interconnections between adaptation to climate change, disaster risk management and heritage. It is also based on awareness-raising and stakeholder dialogue, which builds cohesion.
  - Data-driven assessments often require a quantitative or semi-quantitative approach based on indicators. These indicators are often related to economic performance or environmental impact, such as benefit cost ratio and flooding height reduction, respectively. This information may be derived from modelling, literature information from laboratory or site-specific testing, statistical data, etc. It allows for the direct addressing of hazard impacts based on evidence.

- The availability of data to assess and prioritised the resilience measures. Often quantitative data may not be available for all the identified resilience measures, in this case qualitative assessment may be sought.
- The robustness of the data. This may determine the importance of the criteria in the selection and prioritisation of the criteria.

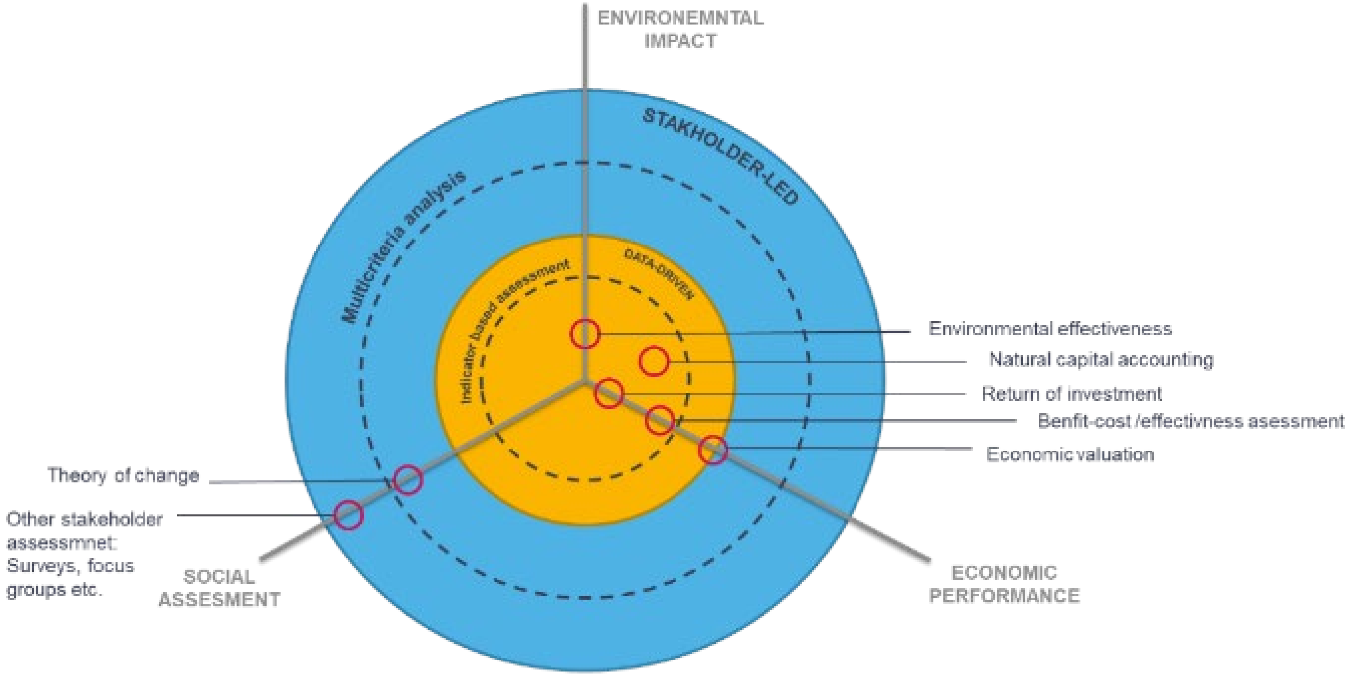


Figure 25. Performance assessment framework and options. Modified from: Veerkamp, C. et al. (2021) (28)

Table 8. Example of characterisation criteria. Economic performance, environmental effectiveness criteria are included together with criteria that describe the nature of the measures (what they are for and general characteristics). BCR: Benefit Cost Ratio

Measure name	Disaster Risk Management phase	Nature of measure	Target	Effectiveness as Expected Annual Loss reduction (%)	Cost	BCR
Awareness raising	Pre-during-post	Social	Community and stakeholders	-	Low	High
Building strengthening	Pre-post	Structural	Building & structures	High	High	Medium-High
Protocols and guidelines	Pre-during-post	Institutional	Community and stakeholders	-	Medium	Medium

Early warning system	Pre-during	Structural (social)	Community and stakeholders	-	Medium	Medium
Public and private economic instrument	Pre-post	Institutional	Community and stakeholders	-	Medium -High	Medium
Risk mapping	Pre	Social	Community and stakeholders	-	Low	Medium
Emergency stabilization	During	Structural	Building & structures	High	High	Low

As previously mentioned, the resilience measures' characterisation may be performed in one stage (see example in Table 8 or (29)) or subsequent stages. The number of resilience measures to be assessed, the type of criteria, the complexity of acquiring the information, and the pathway assessment approach (stakeholder-led or data-driven) may determine the final procedure. For example, when all measures gathered in the portfolio may not be viable for implementation and their environmental performance assessment may be difficult to obtain for all, a preliminary feasibility assessment may be done as a starting point (see Table 9 for an example). Then, the environmental effectiveness or economic performance can be assessed or searched for in literature for the shortlist of resilience measures. The feasibility criteria may vary across local contexts, but may include:

- Heritage criteria such as the physical, visual, spatial impact that the measure may have on heritage or how the measures may affect the authenticity and heritage significance
    - Will the resilience measure's implementation entail a significant change in the heritage significance and function?
    - What changes in the historic area are possible without its identity to be threatened?
- Legal criteria such requirements from e.g., the Cultural Heritage Protection Act
    - Does the national/regional/local heritage legal framework hinder the implementation of specific resilience measure?
- Technical criteria such as ease of implementation or technical knowledge requirements
    - Can the resilience measure be implemented at local administrative/government level without further support? If support is needed, would be very difficult to get this support or acquire this knowledge in the future? Can the resilience measures be implemented while maintaining the heritage values without further support?
    - Would the necessary skills and competencies to manage and maintain the resilience measure's function be available for this measure? If not, would be very difficult to get support or get these skills in the future?
- Environmental criteria such as environmental trade-off
    - Does the resilience measure's implementation result in environmental damage?

- Social criteria such as community acceptability, social equity and inclusiveness or social trade-offs
  - Does the implementation of the resilience measure undermine other social policy objectives?
  - Would the local community accept this resilience measure?
- Institutional criteria such as institutional acceptability, mainstreaming potential and other enabling conditions
  - Would local stakeholders accept this resilience measure?
  - Is there a specific limiting factor on the implementation or upscaling of this type of resilience measure?
  - Could the resilience measure be integrated with existing local government planning and policy development?
- Economic criteria such as economic constraints
  - Is there a lack of financial resources and economic structure to support this type of resilience measure? Can this constraint be overcome?
  - Does the municipal or management entity have potential access to funding to cover the cost? (See *Step 1.6 Financing the flexible Resilience Pathway*)

TIP!

Table 9. Example of a possible feasibility assessment and prioritisation methodology

Feasibility assessment							
Resilience measures	Feasibility criteria					Result	Priority actions
	Heritage	Technical	Environmental	Social	Economic		
A	Low (1)	Medium (2)	High (3)	High (3)	Low (1)	10	3
B	Low (1)	Low (1)	High (3)	Medium (2)	Medium (2)	9	4
C	Low (1)	High (3)	Medium (2)	High (3)	High (3)	12	2
D	Low (1)	Low (1)	High (3)	Low (1)	Medium (2)	8	5
E	Medium (2)	Low (1)	Low (1)	Medium (2)	High (3)	9	4
F	High (3)	High (3)	Low (1)	High (3)	High (3)	13	1

Feasibility screening can be seen as a first characterisation step which can help on the pre-selection of most suitable resilience measure or to narrow down the number of resilience measures. The next step would be to perform a deeper assessment or characterisation of the new portfolio of measures based on their **environmental or economic performance** and any other relevant criteria such as barriers, co-benefits or “maladaptation” potential (*i.e.*, may entail associated or undesirable side effects). Feasibility and impact characterisation performed subsequently may facilitate the process of resilience measure selection and their ranking, if needed.

TIP!

Resilience pathways, in contrast to Adaptation Pathways, consider not only structural measures to directly address the hazard impact based on evidence (data-driven pathway), but also social and institutional ones (Table 4). Socio-institutional measures are also important to decrease the impact of extreme events, however most socio-institutional resilience measures do not have a direct effect on the reduction of natural hazards' impact. Thus, Resilience Pathways should be assessed using an economic performance metric such as the benefit-cost ratio (BCR).

TIP!

Threshold analysis (Step 1.4 Define resilience threshold or objectives) may only be performed when working with environmental performance.

TIP!

It is worth noting that many performance metrics depend on multiple local factors. This should be kept in mind when extracting performance data from literature. The range of effectiveness (the difference between the maximum and minimum values) will allow for a better understanding of how context-dependent the performance of the specific resilience measure may be.

Prioritisation of measures is undertaken with the aim of selecting the most efficient and adequate options to face challenges and enhance the resilience of the historic area/ municipality. The most commonly used methods are:

- Monetary Analysis: The methodologies under the monetary analysis are based on assigning monetary values to inputs and outputs, and thus facilitating the comparison of a resilience measure or a group of them working towards an objective. Cost effectiveness analysis (CEA) and cost benefit analysis (CBA) are among the most used methodologies.
- Multi-criteria (Decision) Analysis is a method which has the advantage of considering not only monetary based criteria, but *e.g.,* environmental, social, cultural criteria in the evaluation. It allows stakeholders to organise information and to contribute to supporting decision-making processes (often with a high degree of uncertainty) based on the transdisciplinary understanding of the problem.

TIP!

Multi-criteria analysis (MCA) manual for making government policy provides guidance for government officials and other practitioners on how to undertake and make the best use of multicriteria analysis for the appraisal of options for policy and other decisions (30). Typical eight step process in MCA are summarized below:

1. Establish the decision context

How can the MCDA fit into Climate Change Adaptation? How can the overall problem assessment be broken down? What do we want to know?

1.1. Establish aims of the MCDA, and identify decision makers and other key players

1.2. Select technical and economic resources for conducting the MCDA

1.3. Consider the context of the appraisal

2. Identify the options to be appraised

Identify alternative policies, programmes, plans, projects or designed solutions. Are there any options? How many options should be compared in a MCDA? Which options should be compared with each other?

3. Identify objectives and criteria

Can criteria be identified and formulated? Is there enough data for the evaluation?

3.1.1. Identify criteria for assessing the consequences of each option

3.1.2. Organise the criteria by clustering them under high level or lower-level objectives in a hierarchy

4. "Scoring". Assess the expected performance of each option against the criteria. Then assess the value associated with the consequences of each option for each criterion

4.1. Describe the consequence of the options

4.2. Score the options on the criteria

4.3. Check the consistency of the scores on each criterion

5. "Weighting". Assign weights for each criterion to reflect their relative importance to the decision.

Identification of priorities at all the levels of the hierarchy structure, i.e. what is the assessment focus? Which hierarchy elements are more or less important than others?

6. Combine the weights and scores for each option to derive an overall value

6.1. Calculate overall weighted scores at each level in the hierarchy

6.2. Calculate overall weighted scores

7. Examine the results

This is an iterative process, and if the user is not satisfied after the results the evaluation and repetition of the previous steps is recommended

8. Sensitivity analysis

8.1. Conduct a sensitivity analysis: Do other preferences or weights affect the overall ordering of the option?

8.2. Look at the advantages/disadvantages of selected options, and compare pairs of options

8.3. Create possible new options that might be better than those originally considered

8.4. Repeat the above steps until a “requisite” model is obtained

Step 2.3 Spatial planning

Objectives	• Facilitate the effectiveness assessment of pathway alternatives • Identify feasible places to deploy each type of resilience measure • Assist spatial planning of structural measures to achieve resilience objectives and minimize risks

Resilience measures’ impact may depend on their spatial deployment and their effectiveness may vary, for example, on the total implemented area, the existing landscape or structures of a given area. For example, depending on where infiltration techniques are implemented at the city/neighbourhood scale[15], the pluvial flooded areas may decrease or not. To provide another example, at the building level, depending on the vulnerability of buildings towards earthquakes, the deployment of measures may vary. This spatial planning of measures is mainly relevant for structural measures and modelling exercises (Figure 26) to assess the environmental performance of pathway alternatives (Step 3).

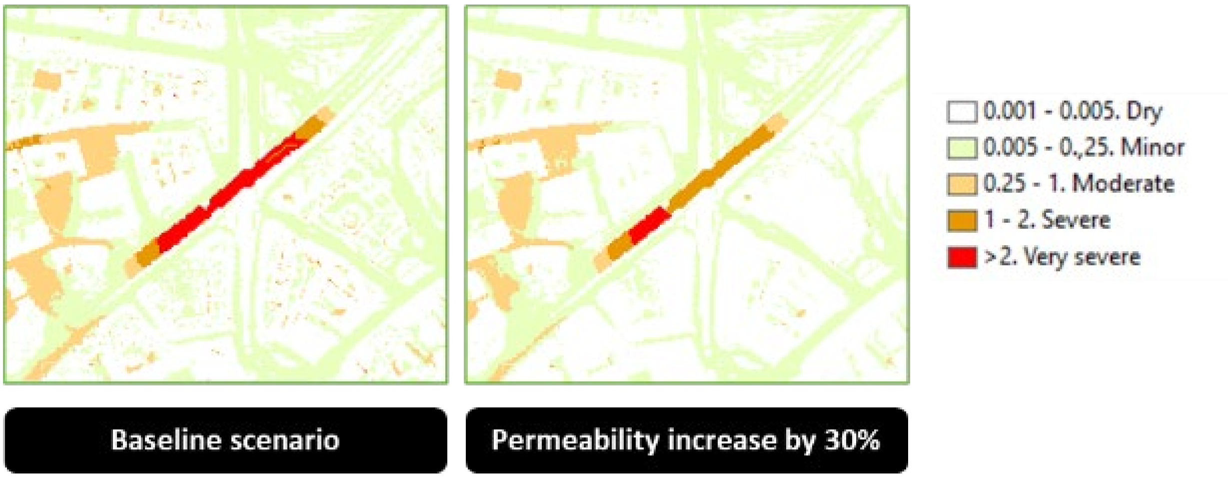


Figure 26. Modelling outputs without and with resilience measures

At this stage the focus is on where the identified measures can be implemented to minimize impacts, and thus, increase resilience. This step requires the involvement of *e.g.* planning experts to reflect what resilience measures are feasible to deploy at the local level and to identify feasible locations for the implementation of measures. In order words, the idea is to

[15] Infiltration components are used to capture surface water runoff and allow it to infiltrate (soak) and filter through to the subsoil layer. Infiltration components can be incorporated into a range of sustainable drainage systems

create an “opportunity map”. This can be done, for example, by cross-linking land use typology with resilience measures as seen in Table 10 .

Table 10. Example of prioritisation of resilience measures to address pluvial flooding per land- use typology and heritage significance of the area for Bratislava case study

Measure	Public spaces		Sidewalks		Buildings		Green areas	
	Historic	Other areas	Historic	Other areas	Historic	Other areas	Historic	Other areas
Grass	2	2					2	2
Permeable pavement	1	1	1	1			1	1
Water Plaza	4	5						
Trees	3						3	3
Parks/ gardens	5	3						
Infiltration trenches		4	2	2			4	4
Rainwater harvesting					1	1		
Green roofs						2		

Step 3: Developing pathway alternatives

This step aims at analysing and benchmarking the environmental effectiveness or economic efficiency of different groups of resilience measures or pathway alternatives. This step requires a stakeholder dialogue to set the criteria to (i) re-organise the resilience measures in groups, (ii) define the most suitable pathway alternative (Step 4: Selection of best pathway alternative) and (iii) sequence the order of the deployment of resilience measures. To minimise resource use, often the selection of best pathway alternatives is performed prior to the visual representation of the pathway. The visual representation of a pathway alternative may vary, but often is created via the sequencing of the resilience measures, like a road map.

Step 3.1 Resilience pathway alternative development

Objectives	• Encourage the consideration of a wide range of measures to help achieve a long-term vision in term of resilience • Clustering resilience measures based on relevant criteria or considerations

What is a Resilience Pathway alternative?

A pathway alternative is a cluster of resilience measures, similar to a resilience or adaptation strategy. This cluster is usually built based on a criterion or on stakeholder preferences. Criteria may vary depending on local needs and preferences. Criteria may be related to the type of mechanism of action, nature of the measure, barriers, costs, heritage significance alteration, heritage identity preservation level etc.

Figure 27 presents an example to clarify this concept. In the figure, no criterion has been applied for pathway alternative 1 considering all measures that may have hypothetically been selected in Step 2. In pathway alternative 2 just one typology of resilience measure is considered, based on the aim to address pluvial flooding, while the pathway alternative 3 is the result of the stakeholders’ preferences.

Figure 27. Example of resilience measure clustering based on different criteria

What is the advantage of considering a cluster of resilience measures in the resilience building process?

It can help to tackle a challenge in a more holistic way by assessing the impact of all potential measures simultaneously. This is especially important if the effectiveness assessment of the pathway alternatives (step 3.2) is performed by modelling or an ad-hoc economic performance analysis.

Pathway alternatives allow for better assessments of the impact of a possible resilience strategy and benchmark the performance of different clusters of measures (pathway alternatives) at the same time. When considering an environmental performance assessment in order to address the challenges indicated in Step 1, the pathway alternative will allow to determine if our objectives or thresholds are achieved. In other words, pathway alternatives will allow, in a flexible way, to determine how much pathway deployment is needed to reach to the set objectives over time (in relation to steps 3.2 and 3.3).

Step 3.2 Assessment of effectiveness

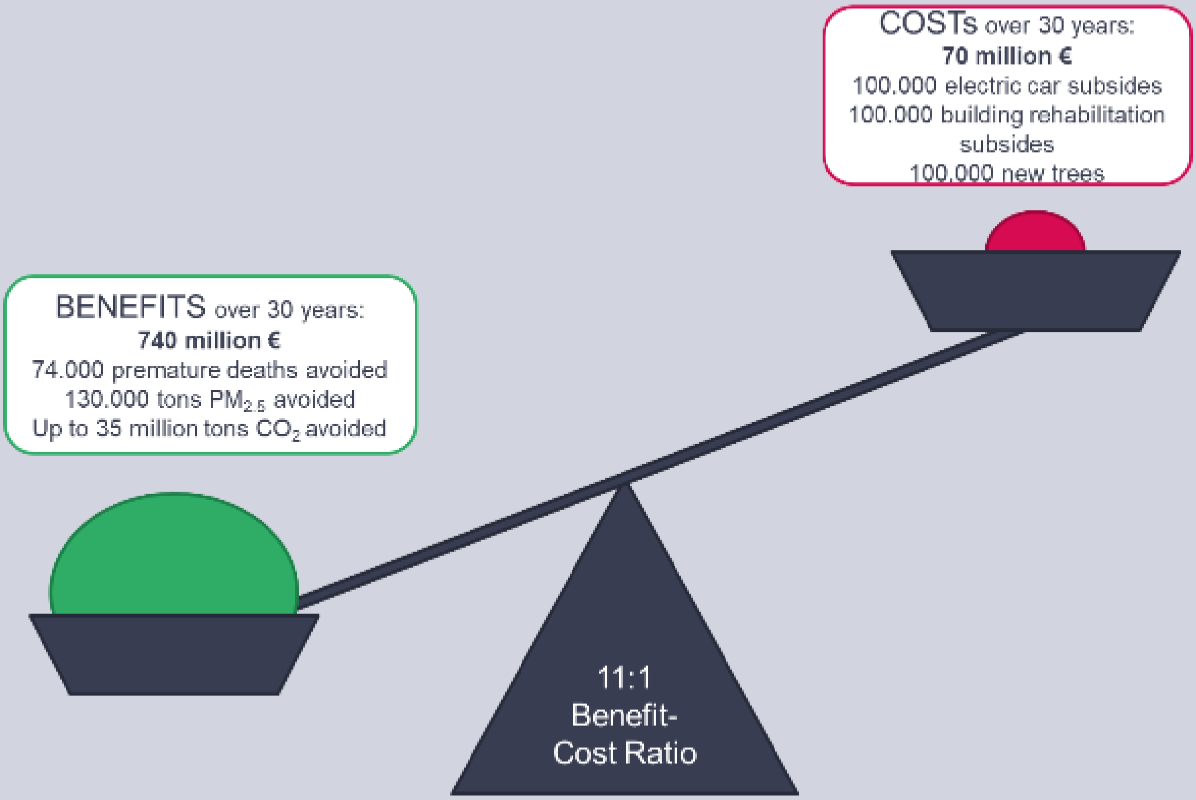
Objectives	• Assess the performance (e.g. effectiveness or efficiency) of each pathway alternative • Reveal which pathway alternatives can reach the established thresholds or objectives • Provide information that will support the sequencing of actions by providing e.g. the effectiveness or efficiency of each resilience measure

In performance-oriented or data-driven pathways to address climate change and other natural hazards, there are two different approaches to assess the performance of resilience measures:

- Quantitative:
    - Environmental performance: Simulations via modelling, as the ones shown in Figure 26) allow for the consideration of the local context and spatialization of resilience measures. Modelling accounts for drivers that may increase or decrease the impact of the hazard. Effectiveness can be presented in a dynamic way and at different scales. It assists with the identification of "hot-spots", or areas where problems may arise.
    - Economic performance: Scenario-based cost benefit analysis, or other similar methodologies, help inform the assessment of the robustness and economic desirability of the pathway alternatives, by seeing them as investment choices. It accounts for the local context, thus being more accurate than the semi-quantitative approach. It also may allow, in the design step of the flexible Resilience Pathway, to better identify which investments are necessary as starting points and keep options open to increase protection in the future, while maintaining economic efficiency.

TIP!

The Australian National Climate Change Adaptation Research Facility published an information manual **(31)** which provides guidance on a Cost-Benefit assessment to help decision makers to assess the costs and benefits of adaptation interventions and Adaptation Pathways. It advises on how to navigate the difficult landscape of deciding when, why and how to assess the costs and benefits of adaptation.



HERITAGE TIP!

Benefit-Cost analysis may help:

- Decide which heritage places to protect and conserve first (when physical interventions have spatially been decided. See Step 2.3) based on their risk to hazard, their heritage values and community benefits. This will for example help the allocation of scarce budget.
- Decide on which pathway alternative's benefit is likely to be the greatest in comparison to the costs involved to increase the resilience of the historic area.

- Semi-quantitative: Through the use of scientific data, the overall theoretical pathway effectiveness or efficiency can be calculated as the sum of an individual measure's performance (see Figure 28 as an example). Despite being less accurate than the quantitative approach in determining each pathway alternative's impact, it allows for benchmarking of the pathway alternatives and helps by presenting the pathway alternative with the highest performance. This approach may not be able to determine whether measures are relevant to lower the risk in specific vulnerable areas but will allow ranking of the different pathways based on their effectiveness in reducing the impacts of a climatic or other natural hazard. This was seen by Mendizabal *et al*. (2018) (29) by assessing various Adaptation Pathways' effectiveness towards pluvial flooding.

This approach requires fewer resources and technical knowledge than the quantitative assessment.

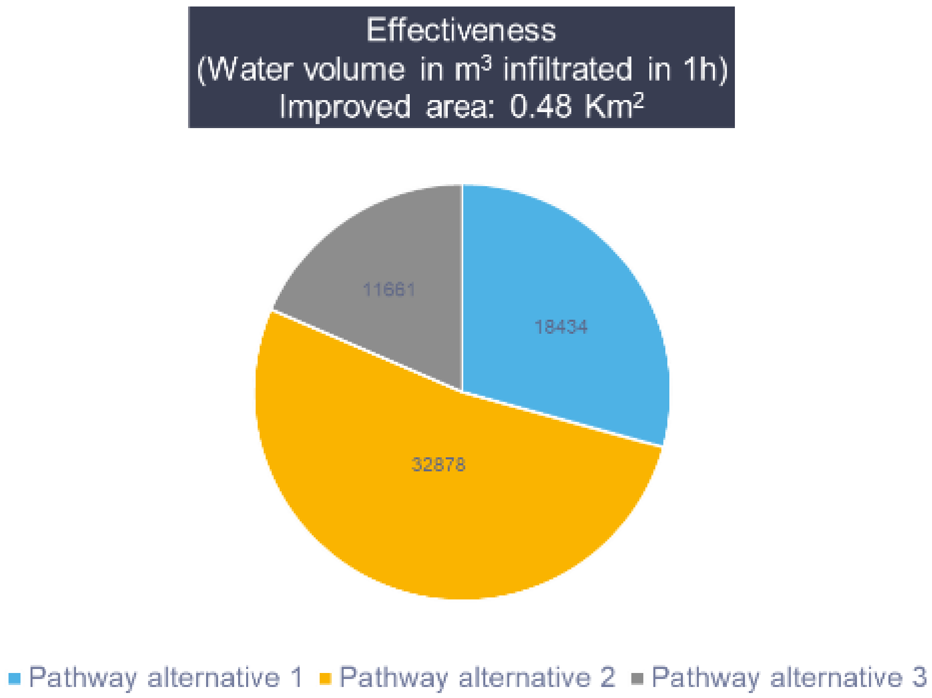


Figure 28. Example of result achieved by semi-quantitative performance analysis of pathways alternatives considered in Figure 30 for pluvial flooding

As shown in Table 4, Resilience Pathways, in contrast to Adaptation Pathways, need to be assessed using an economic performance metric such as the Benefit-Cost ratio to allow the consideration of socio-institutional measures. These measures are vital to be included in the full disaster risk management cycle. Adaptation pathways may be complemented with socio-institutional measures in a parallel qualitative pathway, which would be outside the environmental effectiveness assessment.

Step 3.3 Sequencing over time

Objectives	• Create a roadmap of resilience by assembling sequences of resilience measures to address the identified risks • Reflect under which conditions the measures loose effectiveness and new measures are needed • Select what measures have highest priority for implementation considering risks and spatial planning if necessary (where to implement)

Once the effectiveness of the resilience measures and pathway alternatives have been assessed, there is a need to draw a roadmap representing the possibilities of the measure's deployment. Generally, this roadmap is represented by a sequence of the resilience measures. It is important to consider the previously gathered information (the current situation, future expected risks, defined threshold/objectives, etc.) and other relevant criteria that may support decision-making, such as urgency of action, when establishing the order of deployment. The sequencing can be done for all pathway alternatives or just for the pathway alternative most suitable for the historic area's context (see Step 4: Selection of best pathway alternative).

The order by which the measures should be implemented over time can be decided by:

- direct stakeholder judgment
- a co-creation process
- multi-criteria analysis (see guide on page 64)
- feasibility analysis (*e.g.*, Table 9)

Which criteria may be relevant to help on the sequencing?

There are several criteria that may determine the order in which the resilience measures may be deployed to achieve the desired goals, as shown in Figure 29. The relevance of the criteria will depend, among other factors, on the local socio-institutional context including: the participating stakeholders in the resilience-building process; relevant hazards; historic area characteristics and how resilience will be built.

Figure 29. Example of criteria that may be used to prioritise the roadmap development

What are the key elements when drawing an Adaptation Pathway?

There is not only one way to design Adaptation Pathways. As previously mentioned, they are represented as a sequence of actions. They can range in complexity, and can be drawn as a linear sequence (Figure 31) or have a decision tree structure (Figure 30).

Furthermore, there are few elements that should be considered, and which makes the pathway approach unique:

1. Performance and appraisal of the pathway alternatives

Dynamic adaptive policymaking tools, in which Resilience Pathways are included, were conceptualized to address uncertainty in decision making, while incorporating evidence-based information. Though an appraisal of the pathway alternative's effectiveness is done in *Step 3.2 Assessment of effectiveness*, the graphical displays associated with the sequencing are also informative, with regards to how the order of the adaptation measures contributes to meeting the set objectives.

In Figure 30 an example of a quantitative graphical display is shown. The upper horizontal axis can represent the environmental or economic indicator to assess the effectiveness/efficiency of the resilience measures (larger size of the bar indicates higher level of effectiveness) as well as the cumulative performance, while the lower horizontal axis represents time.

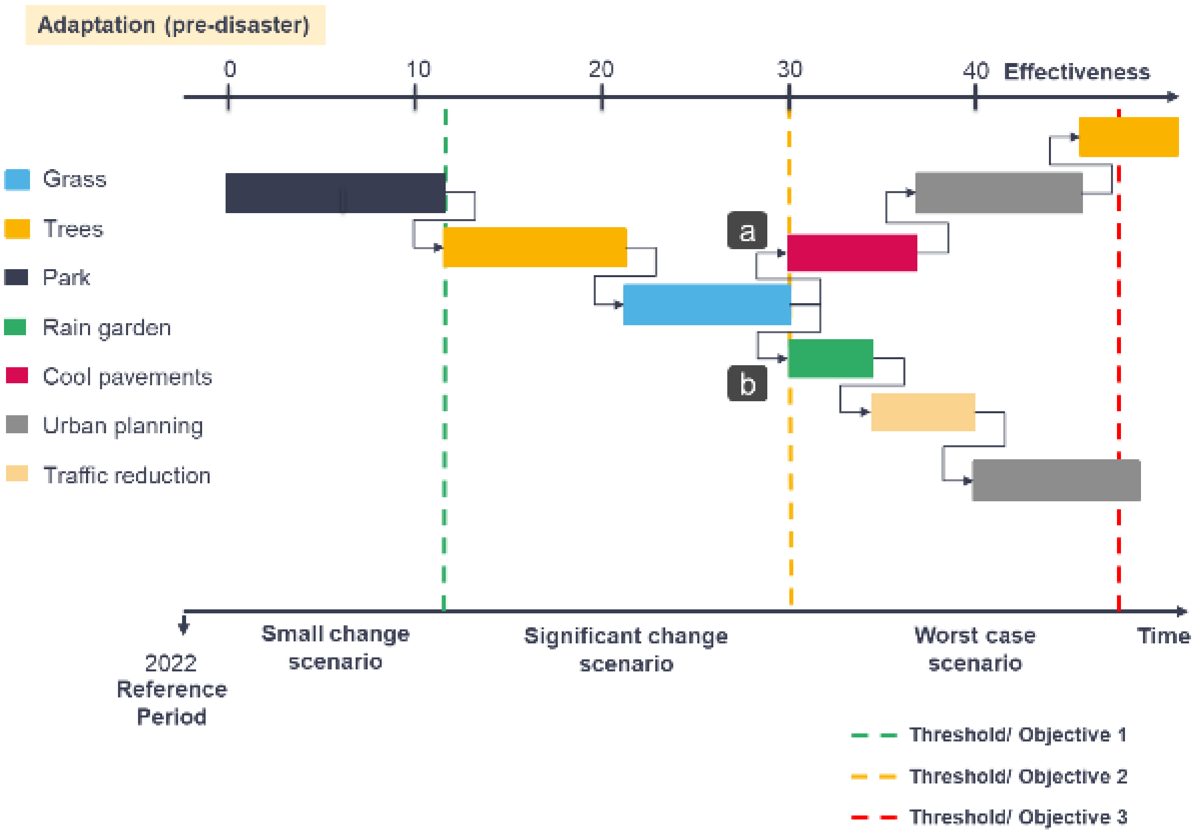


Figure 30. Example of the sequencing graphical display of an Adaptation Pathway (pre-disaster)

TIP!

In an evidence-based (quantitative) pathway approach, the individual and/or cumulative resilience measures' effectiveness are represented as a sequence over time. In qualitative pathways (often stakeholder-led pathways, which may be used to create narratives towards heritage resilience), performance is not represented in this way, rather just the order in which the measures should be deployed and assigned to different hazard scenarios.

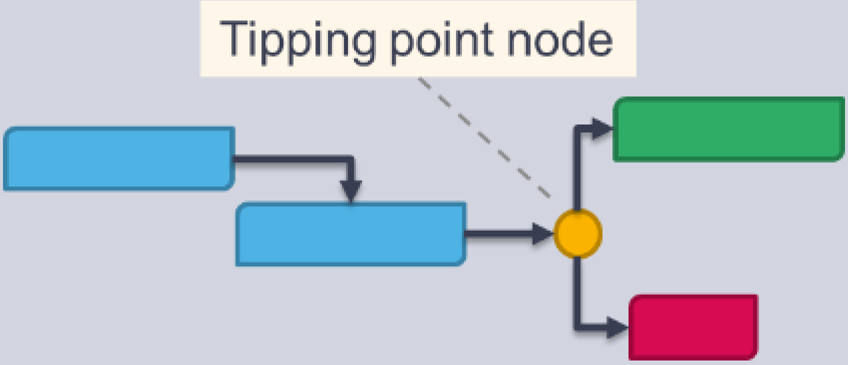
2. Thresholds/ tipping points or objectives.

In Adaptation Pathways, different future scenarios are considered and planned for – and generally those which are linked to thresholds (dashed vertical lines in Figure 30) or tipping points. Thresholds represent the point at which the system is no longer effective or when the impacts associated with a hazard are deemed not to be bearable. In this instance, the system would reach a "tipping point" which implies a decision needs to be taken. At this moment the pathway alternative is reinforced with another set of measures.

For example, in Figure 30 a tree graph-like design is presented when reaching the worst-case scenario (vertical yellow dashed line). In this case, it should be decided which of the two possible routes (a) or (b) to implement. However, it should not be forgotten that Adaptation Pathways are a representation of a plan designed well ahead to prepare for future envisioned climate change impacts while their deployment is initiated once certain “tipping point” conditions occur.

TIP!

There are different representation forms of tipping-points in the diagram. The most common ways are as a decision node or with thresholds lines like in Figure 30.



3. **Flexibility with measures deployment time and roadmap possibilities**

Flexibility is considered within the Adaptation Pathways in various forms, and which depends on the availability of new or more precise knowledge:

- Measure deployment. Adaptation pathways ensure the consideration of various future scenarios and, depending on the evolution of the problem, the road map is reinforced with another set of measures, modified or even delayed. In other words, in Figure 30 it may happen that after deploying measures like parks, trees and grass, there is no need for further measures deployment as the result of a successful policy, *e.g.*, climate change mitigation actions. Thus, maladaptation would be avoided by avoiding measures that are not needed such as cool pavement, urban planning associated measures and extra trees (route a) or those included in route b.
- Thresholds. These are related to scenarios of change or conditions that negatively impact the historic or urban area. These scenarios are bound to an estimated timeline which can be affected by uncertainty as to when they will take place. Thus, thresholds may need to be shifted, as the likelihood of reaching them earlier or later is known. This will help to avoid an inappropriate use of resources by acting too early or too late.
- Route of deployment. As seen in Figure 30, when tree-like pathway design is possible and various routes have been designed for a pathway alternative, when reaching threshold/ objective 2 (yellow dashed line), the decision-makers can choose to reinforce the pathway with route (a) or (b). This will enable to take into considerations the historic area and local context at the point of decision and not only on planning.
- Maladaptation. As implementation of past adaptation measures and their impacts are observed via a monitoring and evaluation strategy, the pathway approach should inform best practices to guide decisions away from maladaptation. Thus, the pathway approach allows “steering the wheel” when necessary for better adaptation.

What are the similarities and differences with Adaptation Pathways when drawing Resilience Pathways?

The most important difference is that resilience accounts as well for disaster planning and management, through the lens of sudden risks as well as slow-onset (future) risks. The ARCH Resilience pathways are conceived based on the ARCH Resilience definition for historic areas, which takes a holistic perspective, where dimensions such as the social, cultural or political are considered.

> ARCH Definition: Resilience of a historic area
> "The sustained ability of a historic area as a social-ecological system[16] (including its social, cultural, political, economic, natural and environmental dimensions) to cope with hazardous events by responding and adapting in socially just ways that maintain the historic area's functions and heritage significance (including identity, integrity and authenticity)."

1. Performance and appraisal of the pathway alternatives

Adaptation pathways, when data-driven, have been focused on reducing the hazard impact mainly by structural measures (mainly the environmental dimension of resilience[17]). The performance of the pathway alternatives in these cases have been assessed by either environmental or economic indicators. However, Resilience Pathways aim at incorporating the community and institutional[18] sphere of resilience more explicitly. Environmental metrics are generally not suitable to assess the performance of these two relevant spheres of resilience. Thus, in the case of Resilience Pathways, economic efficiency-related metrics are indicated both for pre-disaster as well as during and post-disaster phases.

Resilience pathways can plan the future deployment of measures based on cost efficiency, on how climate is expected to unfold, or on scenarios of change in the frequency or intensity of geophysical hazards (pre-disaster phase). Thus, when economic performance is used, the necessary measures to safeguard the historic area's functions are identified while maintaining the cost efficiency per scenario (quantitative approach). When quantitative approaches are not available, the resilience measures can be assigned to each scenario, setting specific objectives for each scenario (semi-quantitative approach). In this case, it is desirable to document how the objectives were determined and the reasons behind the decisions and assumptions made need to be documented then.

The graphical display of the pre-disaster phase is similar to the one for Adaptation Pathways as seen in Figure 31. However, a Resilience Pathway complements the pre-disaster figure with a second graphical display dedicated to planning for during and post-disaster phases,

---

[16] "[complex systems of people and nature, emphasising that humans must be seen as a part of, not apart from, nature." Source: (32)

[17] Structural resilience, which corresponds to the resilience of the ecological system and consists of: (i) resilience of (built) environment and services; (ii) resilience of natural ecosystems.

[18] Community resilience, which covers the socio-cultural part of the social system and consists of: (resilience of social systems, meaning people and communities; (ii) resilience of cultural systems, meaning resilience of cultural identify, local knowledge and intangible heritage; Institutional resilience, which covers the political and economic part of the social system and consists of: (i) resilience of government institutions, policies, and processes; (ii) resilience of economic institutions and processes. Source (16)

which can also represent the performance of the resilience measures by an economic indicator such as Benefit-Cost ratio. A decision tree structure representation can be used in the planning of during and post-disaster phases to acknowledge the different routes depending on the severity of the disasters.

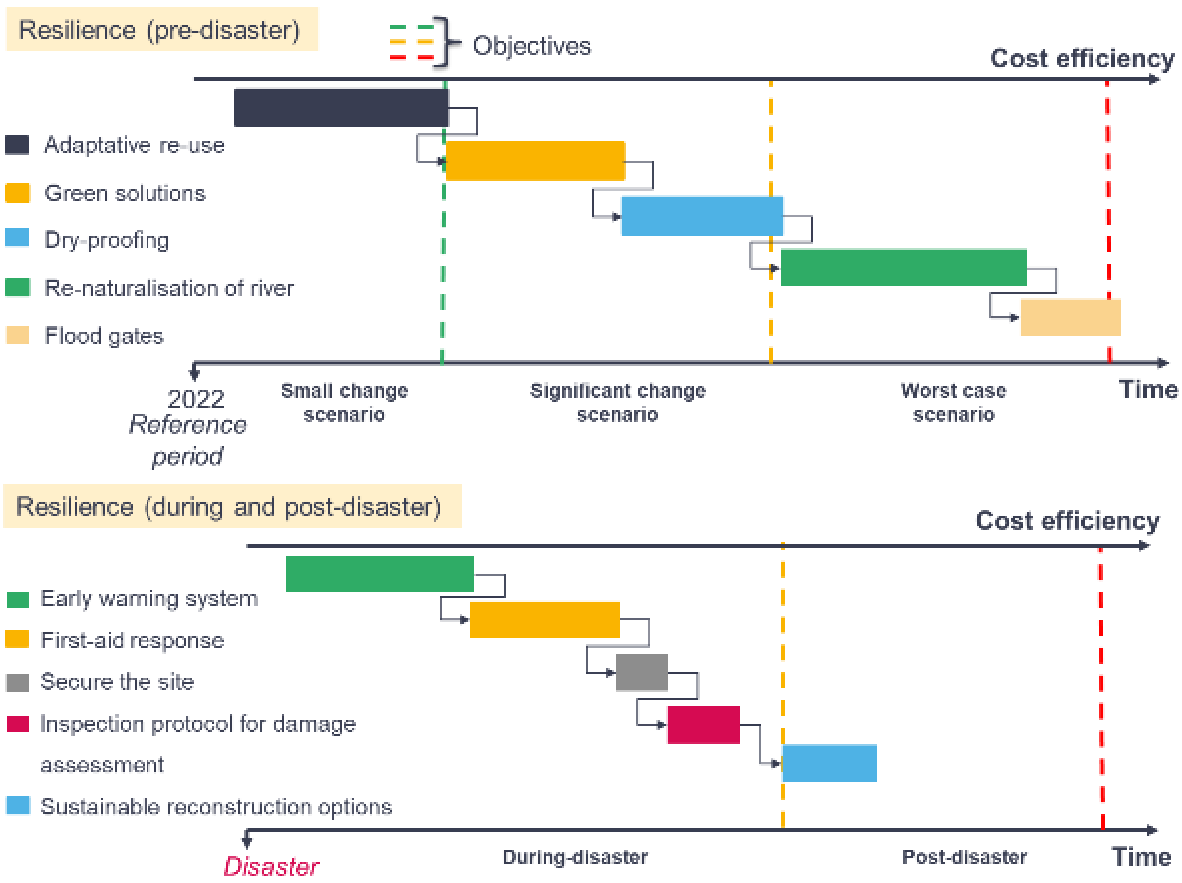


Figure 31 Example of the sequencing graphical display of a Resilience Pathway. Pre-disaster on top and during and post-disaster on the bottom

2. Tipping points or objectives

Resilience pathways have two types of tipping points:

- Pre-disaster tipping point or objectives: Similar to adaptation tipping points, these represent when the past implemented measures lose their effectiveness, or their effectiveness is no longer sufficient to the new conditions. Pre-disaster tipping points or objectives of resilience can be represented in a similar way to adaptation thresholds (see Figure 31).
- Disaster tipping point: When a disaster occurs, that is when the emergency operating phase needs to be activated. At this point the during and post-disaster measures need to be deployed (bottom graph in Figure 31). Disaster tipping points are not represented in the pathway approach, but in the Resilience Management Framework (Figure 4).

3. **Flexibility with measure deployment timelines and road map possibilities**

The conditions and premises of flexibility applied to Adaptation Pathways are equally valid for resilience measures. As conditions evolve, the pathway may a) be reinforced with another set of measures either for the pre-disaster or the during disaster period, then to be followed by post-disaster measures, b) modifications or even c) delays.

Step 4: Selection of best pathway alternative

Objectives	
Objectives	• Reflect on which of the pathway alternatives (roadmap) best aligns with the resilience needs (step 1.3), the vision (steps 1.4 & 1.5) and the local context in terms of feasibility (e.g. step 1.6) • Discuss and assess the expected outcomes of each pathway alternative • Determine the methodology for the selection of most suitable pathway alternative • Select the resilience pathway to be implemented

This step consists of the selection of the most suitable Resilience Pathway alternative for the historic area or municipality, depending on the focus of the work. This starts with the selection of the methodology by which the most appropriate pathway alternative is to be selected. The most common methodologies are:

- Multi-criteria analysis: In this exercise the criteria to be selected may be associated with the impact of the pathway alternative, heritage significance preservation, its co-benefits and implementation cost, or management. Investment cost or available financing mechanisms (Step 1.6) for the included measures may be relevant as a way to ensure the long-term sustainability of resilience planning. Furthermore, it also allows for the consideration of barriers, stakeholder preferences and policy priorities and is meant to be incorporated into the decision-making process in a structured, systematic and transparent way (33).
- Cost effectiveness or Benefit-Cost analysis of each Resilience Pathway: This methodology is used if pathways were assessed by environmental effectiveness or other non-economic methodologies. This may imply the realisation of an ad hoc study to perform this evaluation with its subsequent expenses. However, the combination of environmental and economic performance analysis will result in more robust decision making.
- Stakeholder participatory workshop: This methodology promotes discussion of stakeholders from different knowledge areas, backgrounds and competencies within the resilience-building process. This will promote a consensus on the best way forward on resilience building among different perspectives. An example of a supporting tool that may be used is shown in Toolbox [4].

TOOLBOX 4:
Decision loop is a tool that helps to define how the work that has been done (*e.g.* the definition of resilience pathways) informs what to do next, in this case the pathway selection. This tool is an example of the type of methodologies that could be used in a stakeholder participatory workshop. The tool offers a framework based on methods, systems and processes to help with decision making in a collaborative way.

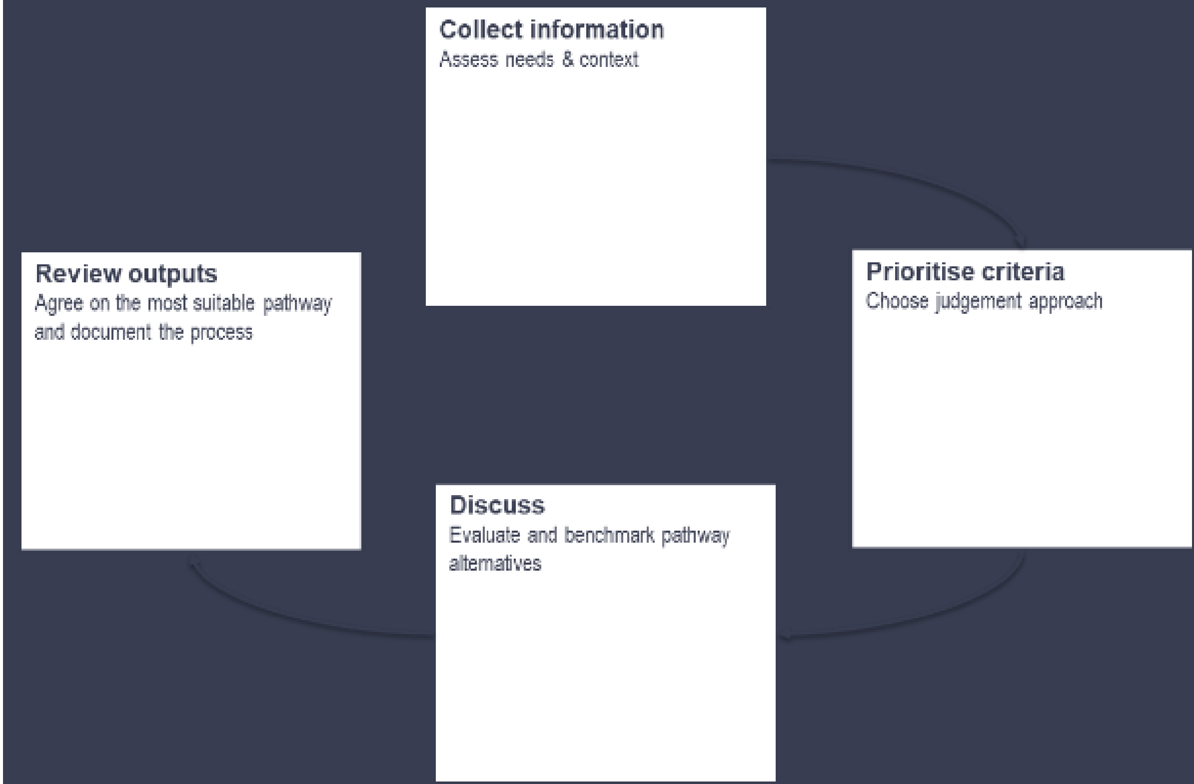


Figure 32. Example of a co-creation tool to select the most suitable pathway alternative

At the end of the Resilience Pathway development, it is important to document the process, methodologies, and the final outputs to facilitate the process of revision in the future. Afterwards, it can be relevant to communicate and disseminate the outputs of the process to maintain the engagement and ownership of the results among stakeholders. This can also be a chance to communicate with other parties about the work done so that the vision can be shared. This buy-in will in turn reduce the risks for the pathway's future implementation.

Furthermore, monitoring and evaluation of Resilience Pathways is key for various reasons:

- To understand when new measures should be deployed (related to thresholds and "points of no return"[19] as shown in Figure 15 and objectives) and be economically efficient (34)

[19] Often known as "tipping points"

- To monitor the implementation of resilience measures
- To assess the outcomes of the deployment of the selected Resilience Pathway

TIP!

This step does not necessarily need to be the last one. Depending on the available resources, or on the Step 3.3 expected outcomes, the selection of the most suitable Resilience Pathway can be done prior to the design of the sequencing of the pathway

Chapter 3: Resilience Pathway Visualisation Tool in the Context of the Handbook

The ARCH project aims to enhance the resilience of areas of historic and cultural value to climate change-related and other hazards. One of its objectives is to offer an integrated framework and guide for resilience management which integrates both climate change adaptation and disaster risk management (ARCH Resilience Management Framework (16) and ARCH Standardisation activities (20)). Furthermore, ARCH also supports resilience building of historic areas through supporting tools such as the Resilience Measures Inventory (RMI) and the Resilience Pathway Visualization Tool (RPVT).

The ARCH RPVT is web-based tool to create and visualize **Resilience Pathways.** It provides a user-friendly digital interface with which users interact to **select, prioritize and sequence potential resilience measures** over time, which can be deployed as circumstances evolve. Measures can be selected and prioritised according to various performance metrics (35).

The aim of the RPVT is to support the Resilience Pathway development for use by city administrators, heritage managers and/or decision makers in the context of historic areas, and help these stakeholders with the visual representation of pathways.

The RPVT, as it is based on the RMI, focuses on (i) heritage building & structures as well as (ii) cultural heritage landscapes, with a focus on agricultural heritage.

This chapter will briefly explain how and in which steps of Resilience Pathway development the RPVT can be used for support.

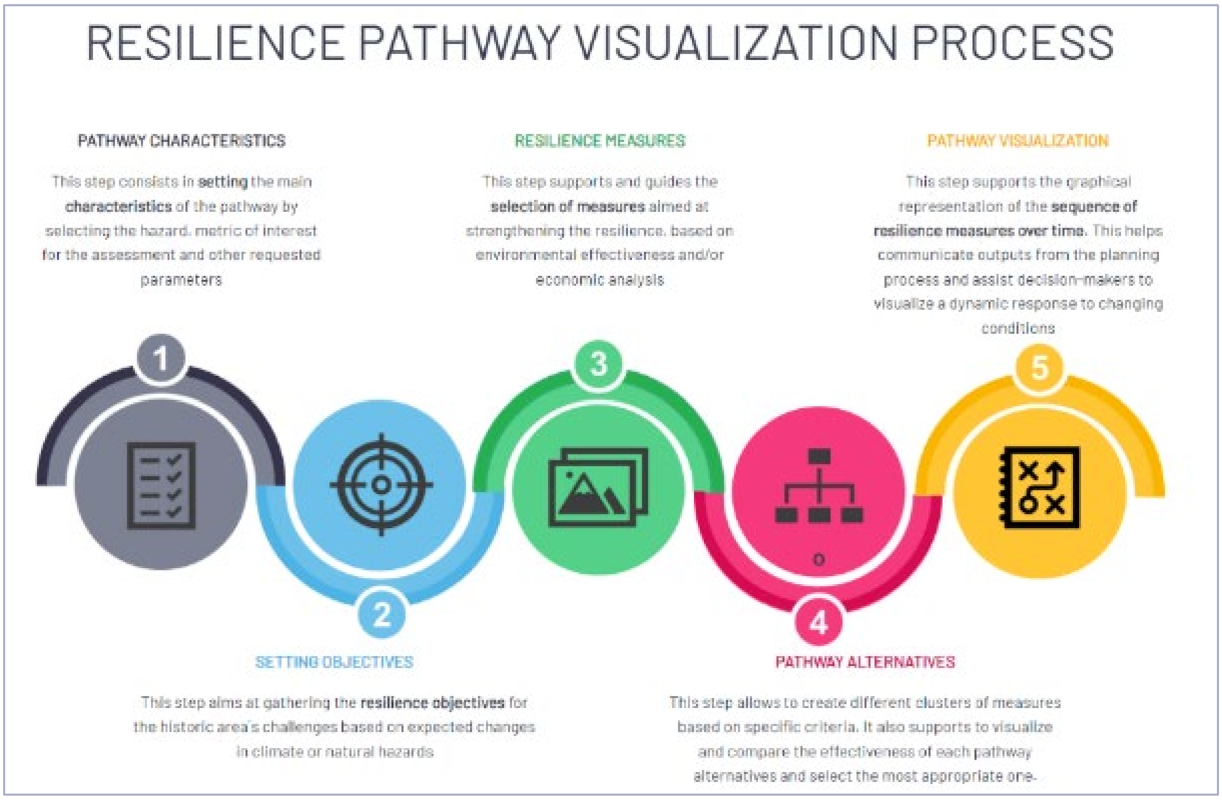


Figure 33. The RPVT process for pathway graphical representation

The RPVT can help:

- To select and compare measures based on environmental effectiveness and/or economic analysis,

This handbook describes in Chapter 2 the relevant information to prepare the ground for resilience building and setting objectives (see **Step 1: Preparing the ground and setting objectives**) which could serve as an input when using the RPVT in setting the pathway characteristics and objectives (Figure 33). On the other hand, in ***Step 2: Selecting resilience measures*** of this handbook, some resources have been included: For example, the RMI provides general information around 261 resilience measures, but does not include environmental effectiveness or economic efficiency information. The RPVT, on the contrary, includes performance information for 99[20] of these resilience measures (See example in Figure 34). This information can also support decision making during the selection of resilience measures to be considered in Resilience Pathway development.

[20] Those available through literature search in (35)

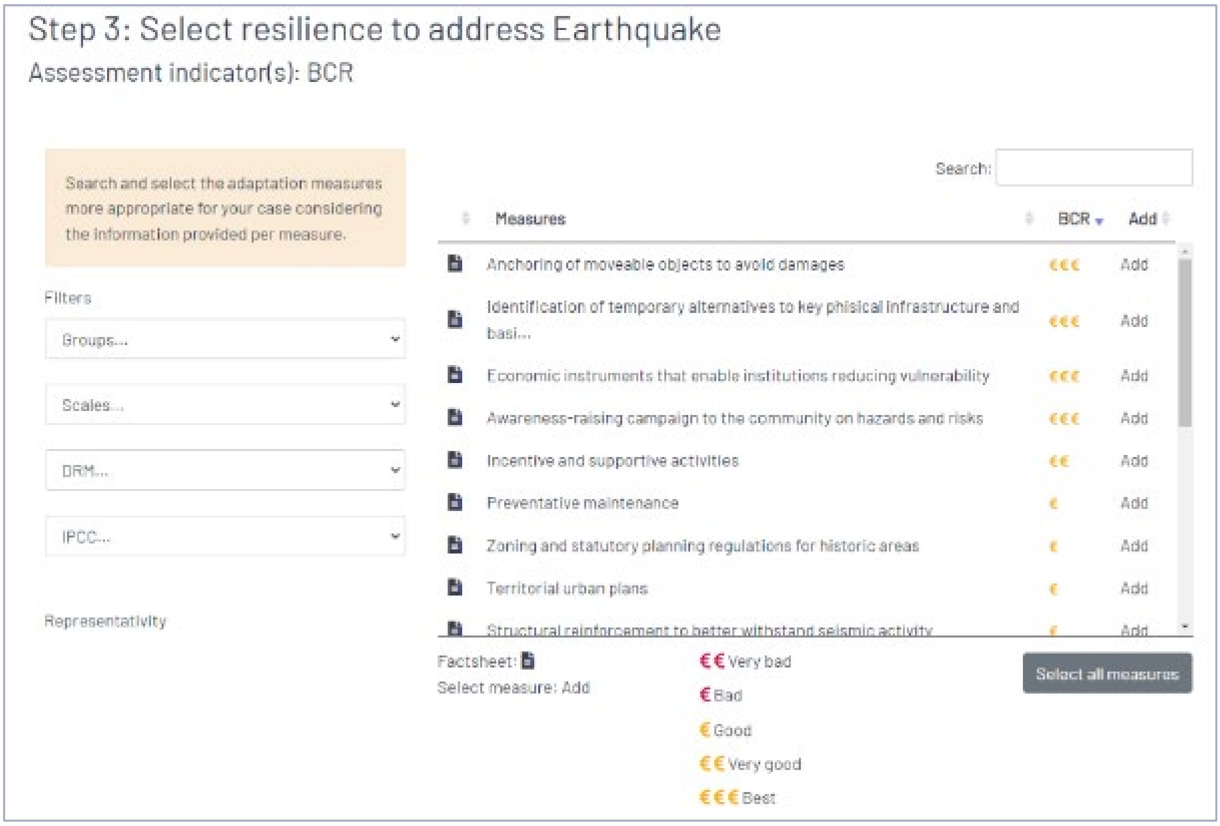


Figure 34. Screenshot of the qualitative economic performance information available from Step 3 from the RPVT

- to create and benchmark different **pathway alternatives** (clusters of measures) based on different performance metrics

The RPVT allows for the clustering of resilience measures based on different available criteria, such as the nature of the measure, as shown in Figure 35. The RPVT also helps to visualize the cumulative effectiveness per pathway. This permits users to benchmark which cluster of measures will be more economically efficient or more effective to target the hazards. This is covered in ***Step 3.1 Resilience pathway alternative development*** and ***Step 3.2 Assessment of effectiveness*** of this handbook.

The RPVT includes different metrics[21] to assess the performance of the individual resilience measures and pathway alternatives as shown in Figure 36. Thus, the RPVT can help develop data-driven Resilience Pathways when metrics presented in Figure 36 are of interest.

Furthermore, when metrics present in the RPVT are not suitable for the development of the Resilience Pathway or other assessment methods are preferred (see *Table 4. Characteristics of the different pathway approaches and methodology*), the RPVT can show the representativeness of resilience measures, as shown in Figure 37.

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[21] a standard for measuring or evaluating something

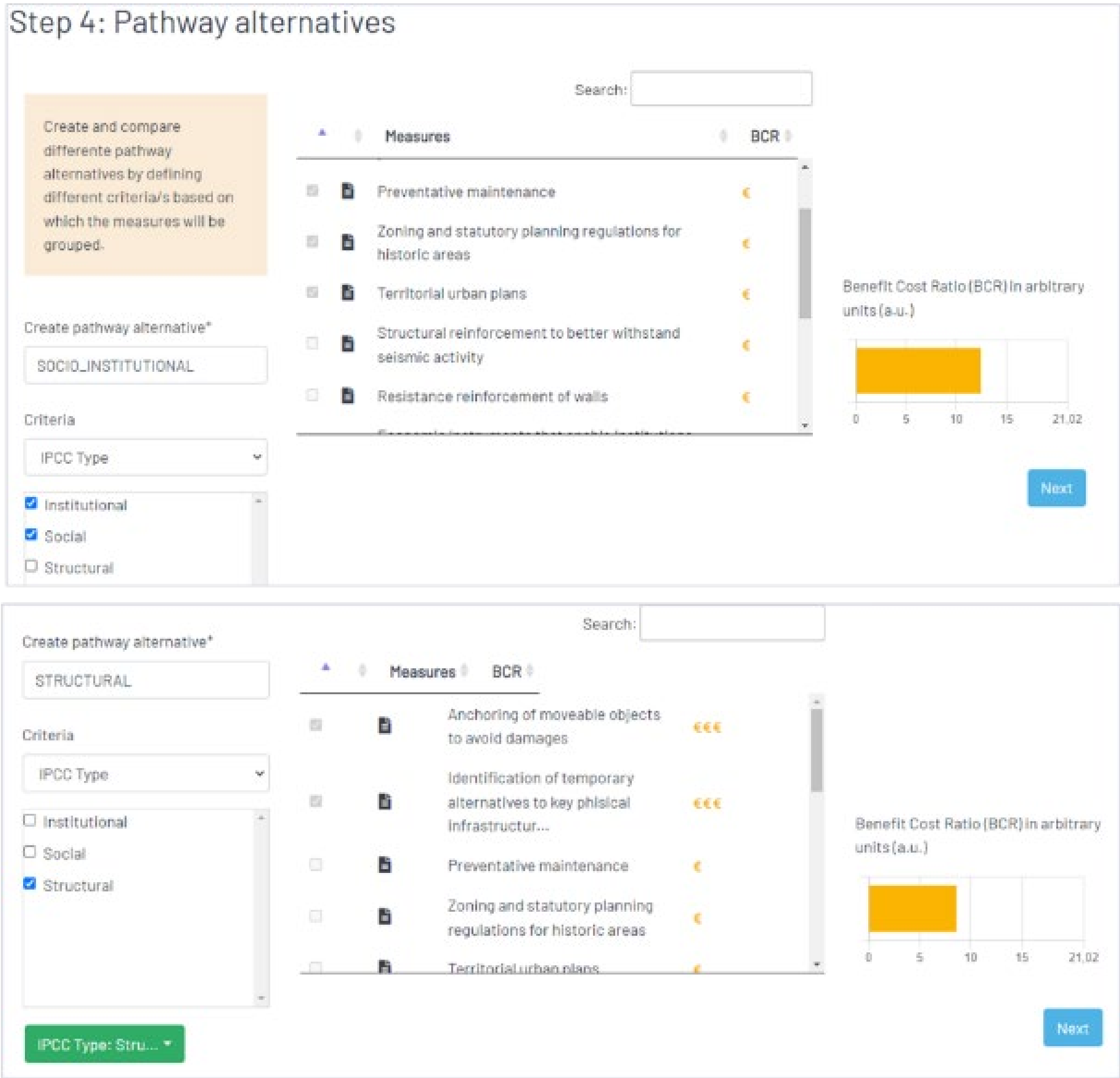


Figure 35. Resilience pathway alternatives based on institutional and social measures (top) and structural measures (bottom) and their cummulative performance (yellow bars)

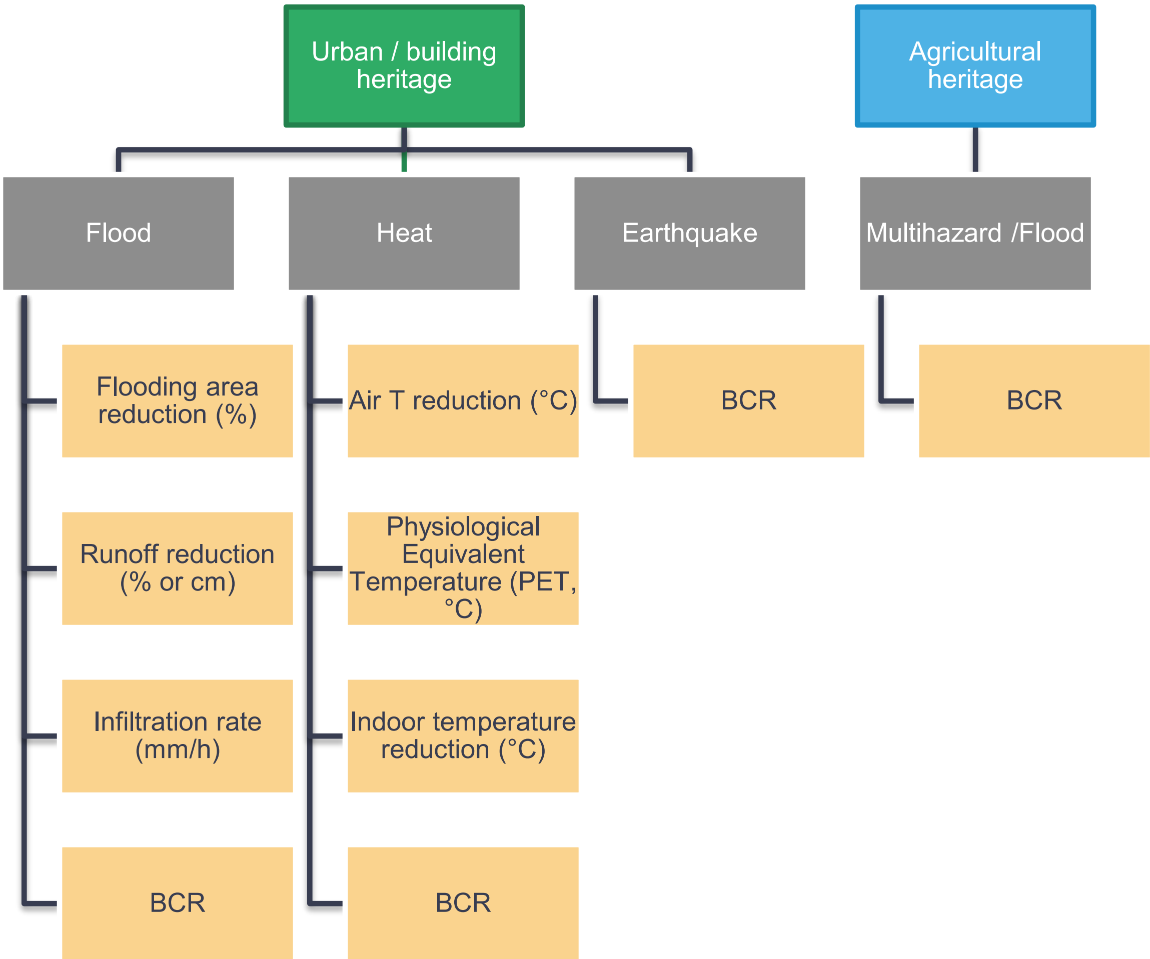
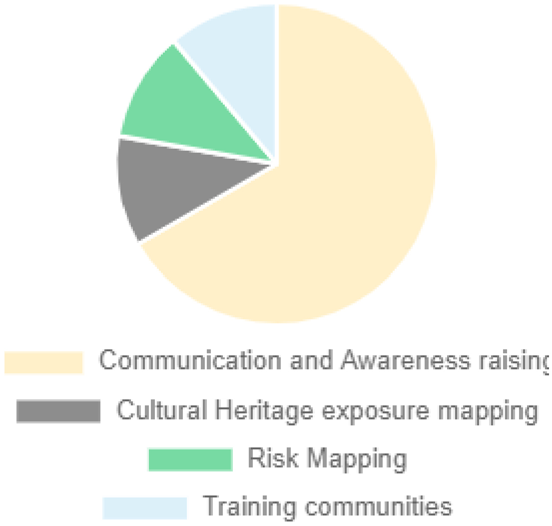


Figure 36. Metrics included to assess the performance of the resilience measures per inventory sections and hazard. BCR: Benefit cost ratio. PET is suited to the evaluation of the human thermal comfort



Measure Subgroup	Description
Communication & Awareness raising	Measures that aim at promoting information exchange and disseminating knowledge about climate change-related hazards and risks, DRM and adaptation measures and good practices
Cultural Heritage exposure mapping	Cultural Heritage exposure mapping
Risk Mapping	Risk maps provide visual data for identifying, prioritizing and communicating specific risks by analysing the hazard, exposure and vulnerability, likelihood to occur and the destructive capacity that certain hazard may have in a territory with presence of vulnerable Cultural Heritage
Training communities	Training instruments that aim at skill learning from the community in order increase preparedness against climate change hazards and their impacts and disaster management

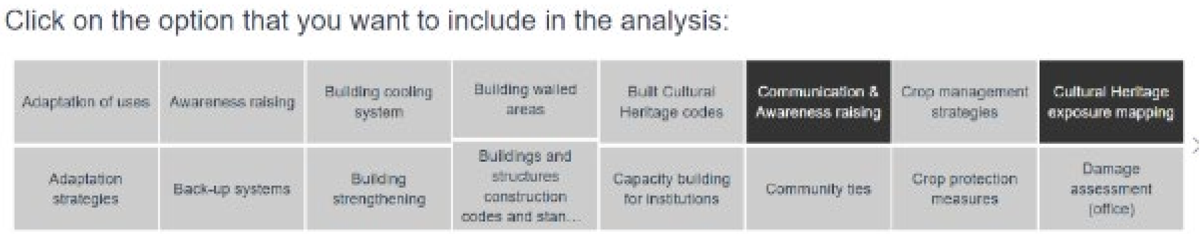


Figure 37. Screenshot of an example of representativeness chart of selected measures (top). The representativeness of measures is based on the RMI subgroup of resilience measures (in the bottom a screen showing the RMI subgroups' description)

- to build Resilience Pathways (roadmaps) by sequencing **the potential measures over time,** considering different scenarios or changing circumstances.

Step 3.3 Sequencing over time in the Resilience Pathway Handbook describes what factors may be relevant to consider when sequencing the resilience measures, *i.e.* how to prioritize the order of measures. The RPVT helps graphically represent this order (see Figure 38, Figure 39) and clarifies under which scenario they should be deployed. Resilience pathways are meant to have a flexible deployment as climate or geophysical conditions evolve. To simplify the planning of the implementation of resilience measures, some of the graphical representations included in the RPVT show scenarios in terms of time periods that can be associated with specific dates. The user should note that these dates should be considered flexible and may be modified as conditions evolve and/or more accurate knowledge becomes available. In other words, near, medium and far future timelines should be considered as representing small change, significant change and worst-case scenarios.

The graphical displays can also help communicate and assist decision-makers to visualize a dynamic response to changing conditions.

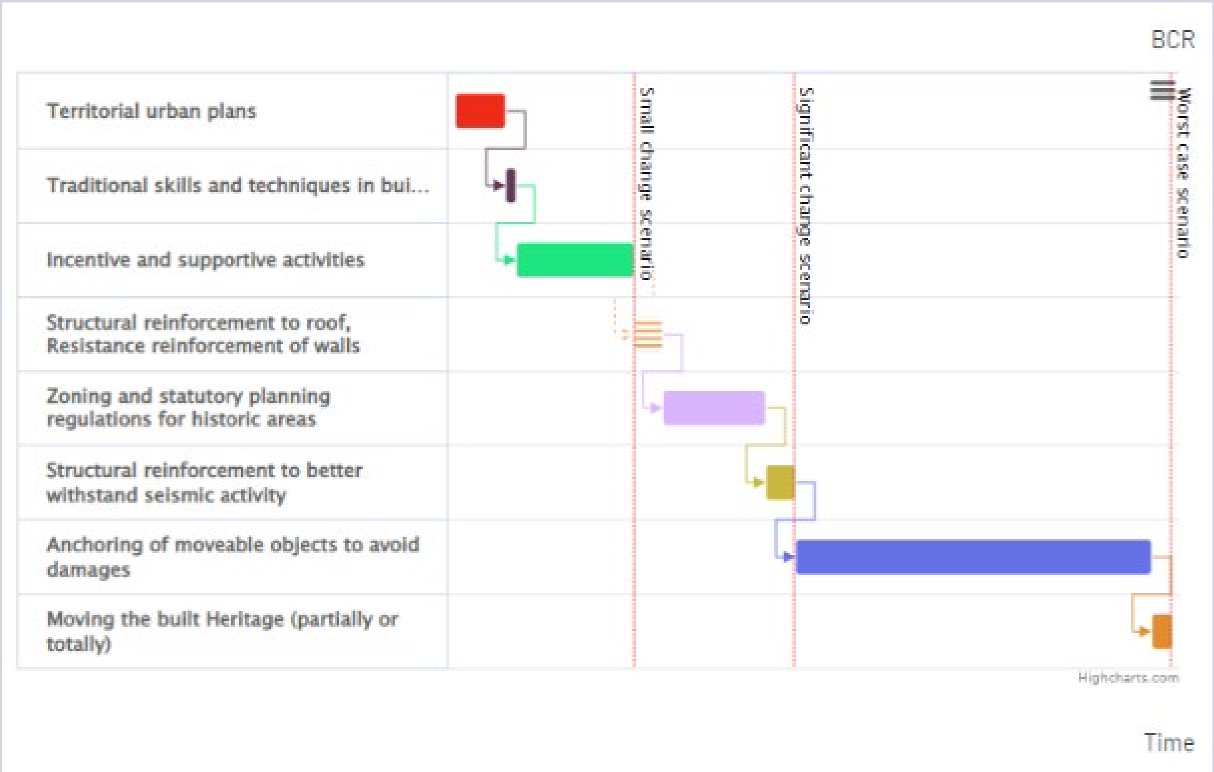


Figure 38. Example of the type of graphical display that the RPVT allows to perform

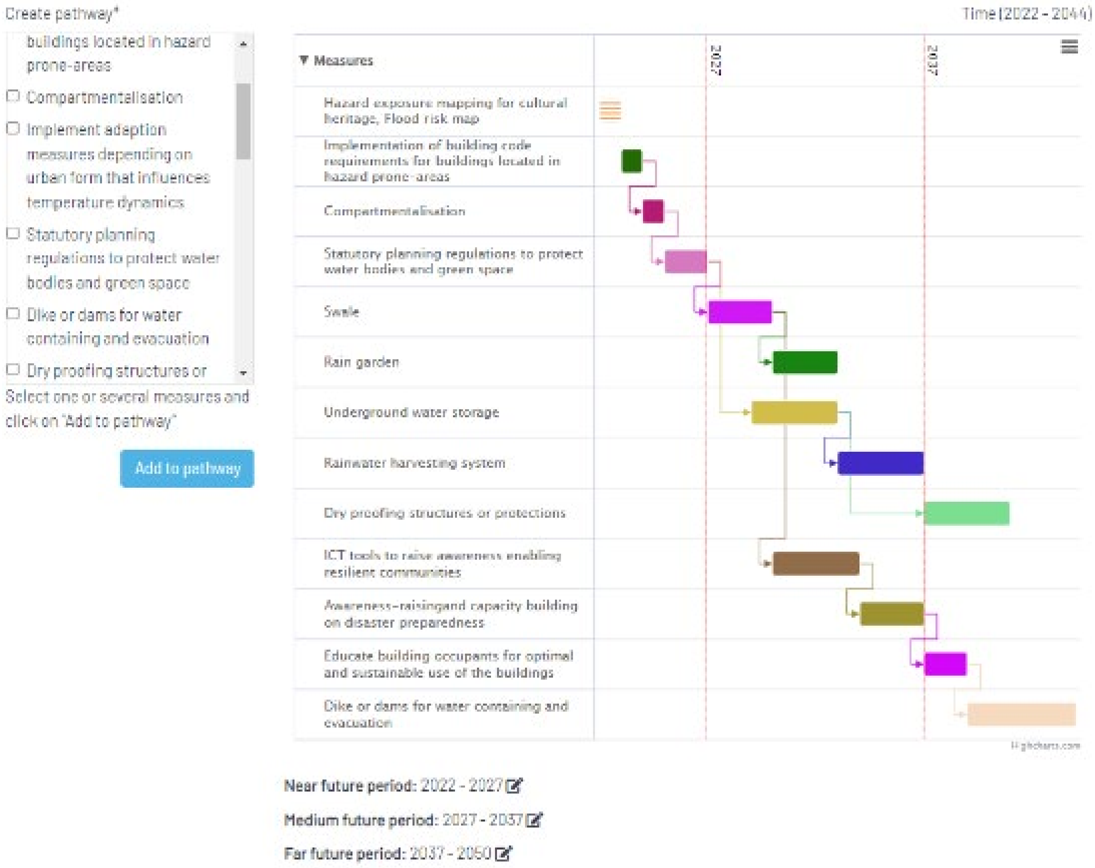


Figure 39. Qualitative representation example of a Resilience Pathway (pre-disaster)

Chapter 4. Co-creating and testing activities

Co-creation processes, despite having different definitions and methodologies, have been identified as valuable tools to bring greater research impact and to allow better local knowledge uptake. This is especially true in the case of research applications dedicated to support local policies. Thus, the ARCH project team has adopted a co-creation process and created a guideline on co-creation (36) to ensure that project results are applicable and relevant in practice.

The testing activities on the pathway approach have had different levels of intensity and different degrees of ownership over the results. This has been the result derived from the content of the ARCH Grant Agreement and the stakeholder engagement possibilities.

Three degrees of testing have been applied for the different ARCH pilot cities:

- Valencia: The pathway approach has been tested involving the local ARCH partner, LNV, as well as some local stakeholders, and has aligned with current policies
- Bratislava: Three sessions combining theoretical information and co-creation exercises have been carried out to showcase the main steps of the pathway approach with the local ARCH partners
- Camerino and Hamburg: Transferability workshops have been performed to share the outputs from Valencia and Bratislava and discuss how the methodology could potentially be applied to each context

Prior to the testing activities, two training sessions were carried out to explain the theoretical background of Adaptation Pathways and how it was applied to Antwerp and Bilbao in the RAMSES and RESIN projects. At the start, it was observed (see Figure 40) that most of the participants know the basics about Adaptation Pathways, but this was followed by 39% participants having no or very little knowledge on Adaptation Pathways. This confirmed that this area of knowledge was new to the majority of ARCH city and research partners. After the training sessions, the level of understanding of attendees was assessed by asking them how well they understand the Adaptation Pathway methodology with a scale from 1-5. All respondents scored either a 3 or 4 with an average score of 3.4.

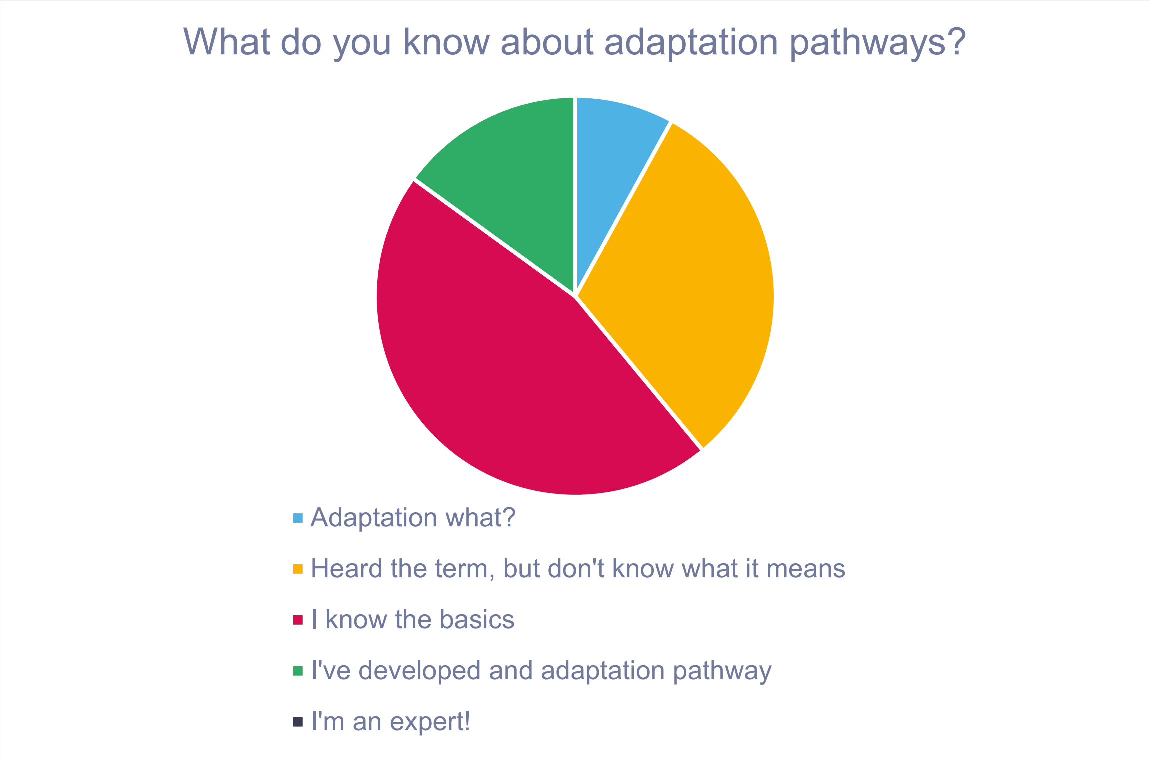


Figure 40. Initial knowledge on the concept of Adaptation Pathways by participants to the ARCH training session 1. 13 respondents.

Valencia case study: Adaptation pathway towards heatwaves

The City of Valencia selected two large cultural landscapes as their target historic areas: the Huerta irrigated peri-urban farmland, one of six remaining such landscapes in Europe and the Albufera, a large coastal lagoon, supporting a diverse range of species including bird life and fish, and bordered by land for rice cultivation. These two cultural landscapes are part of Valencia's socio-ecological system as its social, cultural, natural and economic spheres are closely linked to these areas.

Furthermore, within ARCH, Valencia identified three priority objectives with respect to building resilience of both the Huerta and Albufera cultural landscapes: 1) to acknowledge and explore how the Huerta and Albufera help to mitigate the effects of climate change in the urban environment of Valencia, 2) to understand and demonstrate in detail the impacts of possible climate change scenarios on the Huerta and Albufera, and 3) to design detailed resilience strategies in order to cope with these identified impacts. This last objective is fed by one of its strategies: Improving resilience in the socio-ecological system Huerta / Albufera / City of Valencia through Adaptation Pathways.

Step 1. Preparing the ground and setting objectives

Step 1. Preparing the ground and setting objectives

- Preparing the ground & context analysis
- Long-term vision &objectives
- Threshold definition

- **Step 1.1. Setting the purpose of the Adaptation Pathway**

The effect of extreme heat and heatwaves in agriculture, tourism, and the whole socio-ecological system at the end is a major concern for Valencia. Thus, the aim of the Adaptation Pathway was set to increase the thermal comfort of the urban and peri-urban open spaces, including the Huerta, so that the **areas can be as liveable as possible and for as long as possible throughout the year** (an adaptation perspective rather than a Resilience Pathway perspective). This is especially important for the intangible heritage associated to agricultural practices as this needs to be sustainable over a long period of time. By increasing the thermal comfort around agricultural practices, as well as for residents, will allow this intangible heritage to endure over time.

Furthermore, the Adaptation Pathway was set to have a special emphasis on the following co-benefits:

(1) increasing the natural connectivity and biodiversity (Albufera and the Huerta). Biodiversity improvements will improve the ecosystem services (e.g., healthy soils, pollinators, and pest control). This leads to better crops, making agriculture more sustainable, and thus protecting this heritage landscape, the agriculture sustainability in the Huerta and Albufera and their ancient practices.

- Designing a pathway favouring green and blue solutions.

(2) the promotion of sustainable tourism and mobility

- Designing a pathway that helps to connect places of interest through *e.g.* climate shelters and comfortable routes.

These co-benefits were considered to contribute to safeguarding the cultural landscape's activities by increasing the thermal comfort of agriculture workers, tourists and residents in general, as well as promoting biodiversity which is key as much for agriculture as the natural environment. Thus, the pathway approach was set to work in a holistic way, that is as a socio-ecological system[22] considering the connections between La Huerta, Albufera and the city of Valencia.

[22] complex systems of people and nature, emphasising that humans must be seen as a part of, not apart from, nature

- **Step 1.2. Preparing the ground**

In view of the objective of the ARCH project[23], in terms of decision-making, the goal for the pathway was to set a roadmap of measures with various alternatives to promote a change towards a strategic aim: to make the urban and periurban areas more resilient towards heat extremes (Table 2). Given the research nature of the ARCH project, the pathway approach followed a "hierarchical with scientific knowledge" decision making approach (see Table 5), with Tecnalia as technical expert and LNV as the ARCH project's local stakeholder representative. These partners led the process with specific inputs form various local stakeholders already belonging to one of Valencia's ARCH working groups.

- **Step 1.3. ARCH: Context analysis**

Climate context

There is plenty of evidence of global warming and expected climate projections which can be consulted through different resources, as shown in Figure 41. However, local regionalized data may not always be available or scattered. The ARCH project, in the framework of work packages 4 (37) and 5 (38), has continued advancing on the generation of evidence for Valencia on how climate will evolve (*e.g.* how often will the heatwaves occur) and a meso scale thermal modelling considering different "typical days," corresponding to different periods of the century. Outputs from this work showed that the number of heatwaves will increase in intensity and frequency (Figure 42) and displayed how the maximum temperatures will evolve and how they will be spatially distributed in Valencia (Figure 43). Thus, there is a need to prepare for these changes, especially as the effects of heatwaves on human health are well known. For example, the 2003 heatwave shown in Figure 43 presented an increase of deaths by 4-fold.

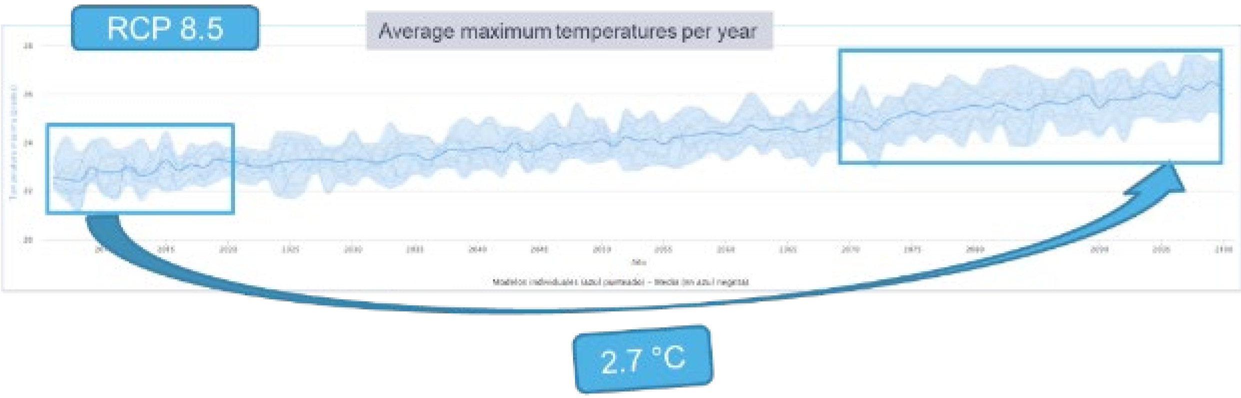


Figure 41. Climate projections under RCP 8.5 for the maximum temperatures from 2010 to 2100 in Valencia city. Source Adaptecca[24]

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[23] ARCH is a European-funded research project that aims to better preserve areas of cultural heritage from hazards and risks. The project will present various models, methods, tools and datasets to support decision-making.
[24] https://adaptecca.es/

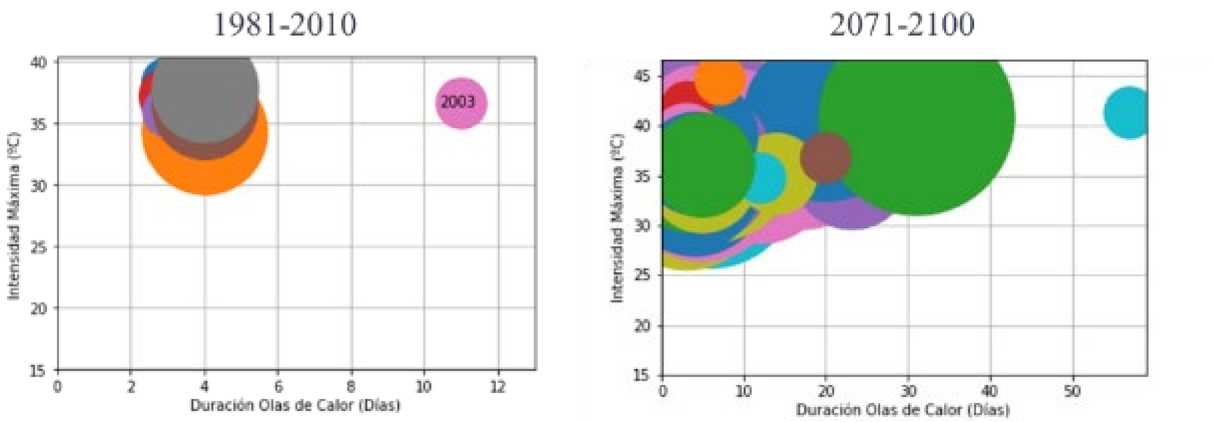

Figure 42. Heatwave intensity (vertical axis) and duration (horizontal axis) of heatwaves for the historic period and far future period considering RCP 8.5 projections. Source: (37)

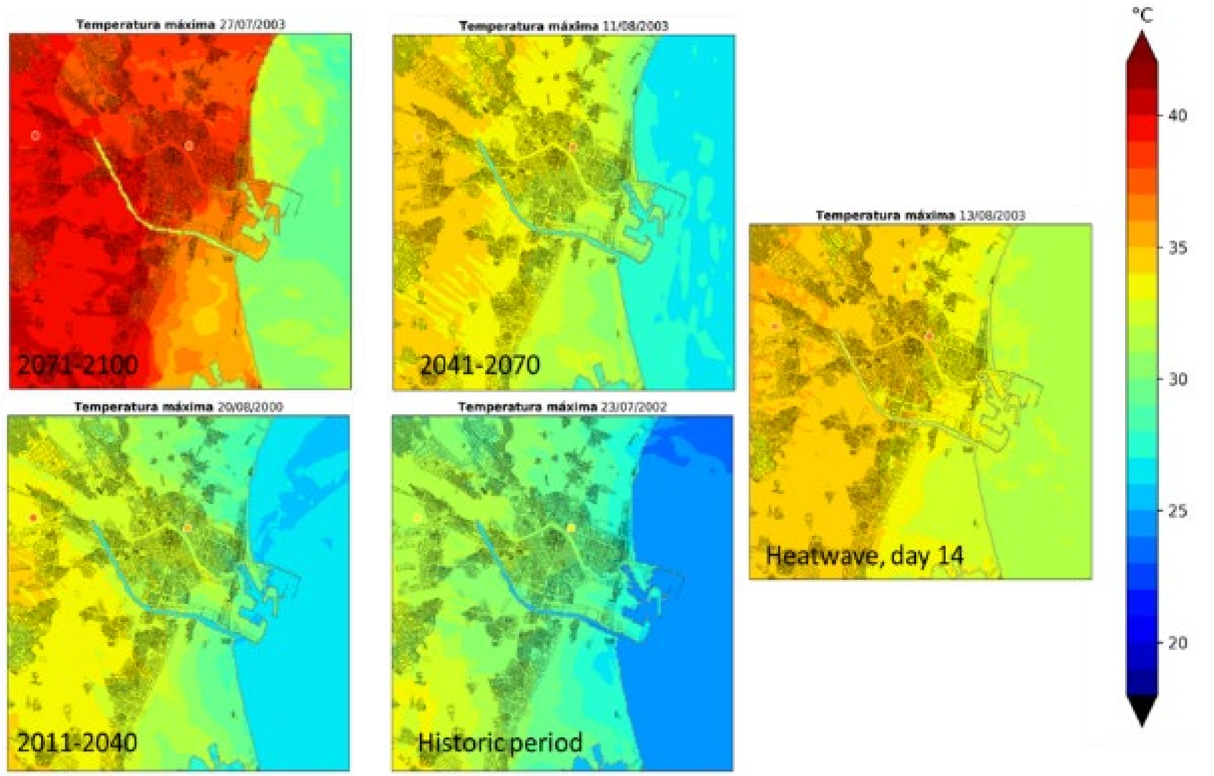

Figure 43. Maximum temperature of a typical tropical day of each period considering the RCP 8.5 (worst-case scenario). Source: (38)

The GrowGreen EU H2020 project analysed the vulnerability and risk of the impacts of heat stress to populations as seen in Figure 44 and Figure 45, respectively. This work identified the areas where population may have higher risk to heat stress in the urban area.

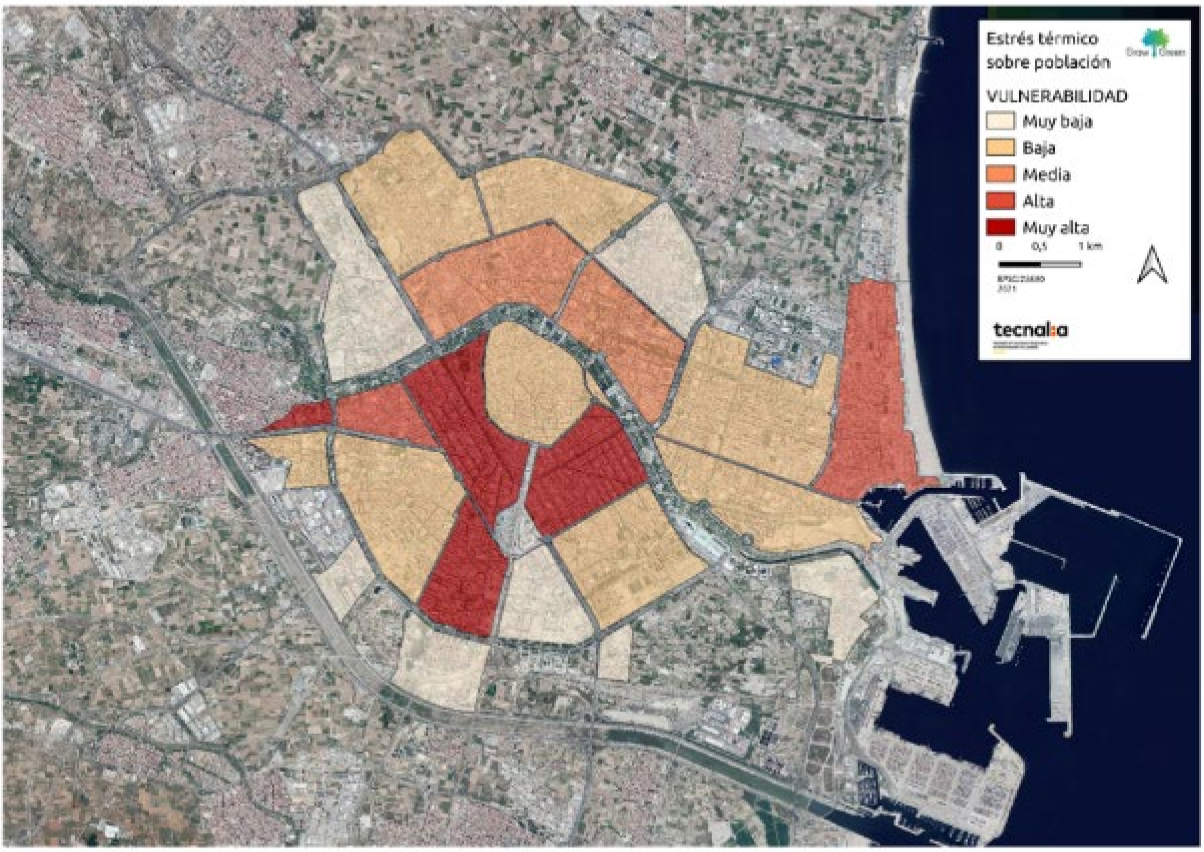

Figure 44. Vulnerability of the population to heat stress. Unit of analysis: the Administrative Functional (AF) urban areas of Valencia. Source: GrowGreen project

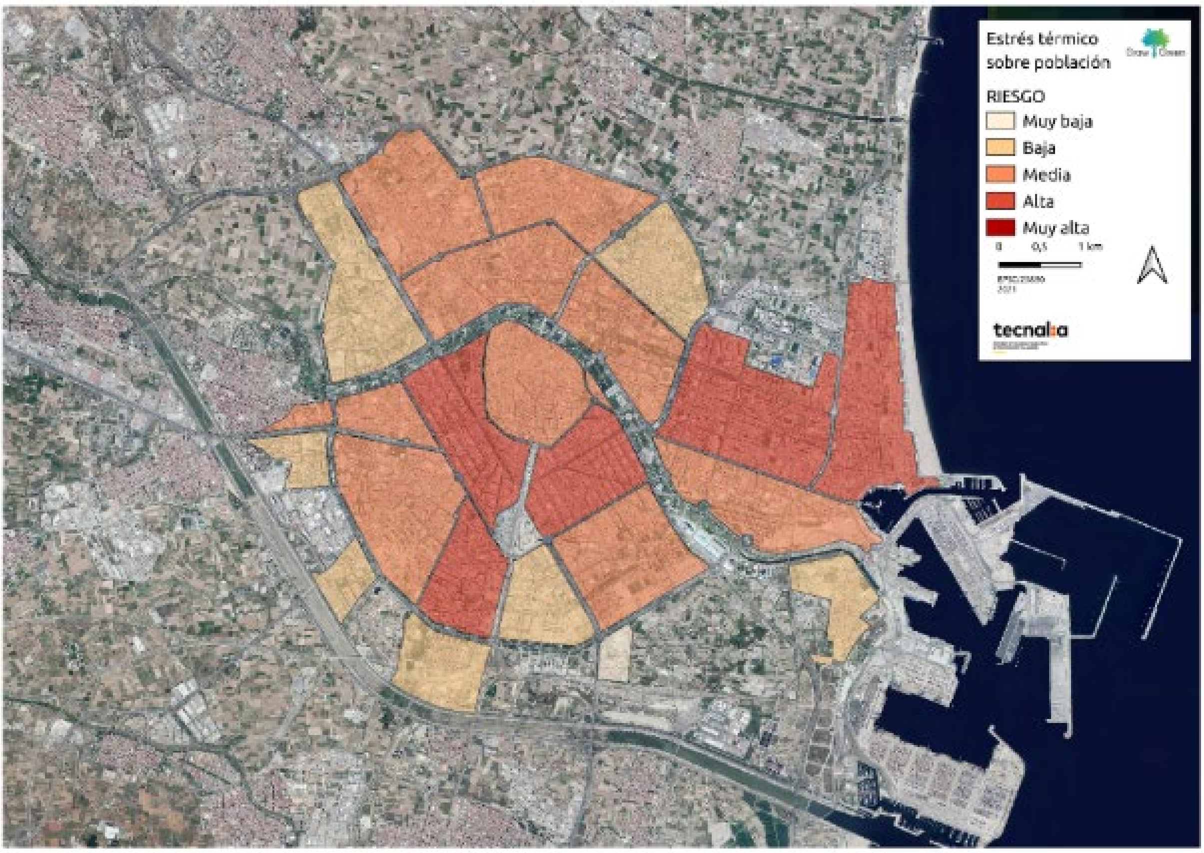

Figure 45. Risk posed by heat stress to residents in different areas of Valencia. Unit of analysis: the administrative functional urban areas of Valencia. Source: GrowGreen project

- **Step 1.4. Define resilience threshold or objectives**

Based on existing knowledge, it was difficult to define a specific threshold. To overcome this challenge, it was decided to work with minimum targets for adaptation, that is, to focus on improving the percentage of land use classification in terms of thermal comfort using the Physiological Equivalent Temperature (PET, °C) indicator (See Step 2.3 *Spatial planning* for further clarity).

- **Step 1.5. Alignment of the Adaptation Pathway with long-term vision of the system**

There are several plans that have similar objectives and compose different pieces of a puzzle to achieve those objectives. The proposed Adaptation Pathway is aligned with them in the following terms:

1. **Regional Plan for the Huerta of Valencia**[25]

[25] Source: https://politicaterritorial.gva.es/es/web/planificacion-territorial-e-infraestructura-verde/huerta-de-valencia. [Last accessed on 28th July 2022]

This plan is framed under the Law of the Huerta of Valencia, which has different objectives and actions, one of these objectives being the public use of the Huerta of Valencia. The Adaptation Pathway envisioned for Valencia is aligned with two of the actions included in this objective: (i) creating a network of green routes all over the Huerta; and (ii) promoting sustainable mobility. The only difference is that the Adaptation Pathway is dedicated to this purpose not only in the Huerta but also in the urban area.

2. **Programme for the prevention and attention to health problems derived from extreme temperatures in the Valencian region**[26]

The Adaptation Pathway aims to help bridging the gaps identified by this programme by improving environmental risk factors associated with mortality such as:

- The lack of trees in residential areas the area around the house
- Lack of access to cool areas during the working day (outdoor workers)
- Lack of climatic refuges for the general population and tourists
- Highly built-up environment (asphalt over permeable soils)

3. **Valencia's Green and Biodiversity Plan**[27]

Similar to this plan's objective, the Adaptation Pathway aims also to contribute to the protection and improvement of green infrastructure and biodiversity with the following purposes:

- Adapt Valencia to the effects of climate change
- Increase urban ecosystems' biodiversity
- Connect urban green areas
- Connect with regional green infrastructure

4. **NbS Strategy in the city of Valencia. Climate proofing urban planning through NbS (GrowGreen Project Output)**

The GrowGreen Project is supporting the new NbS Strategy development mainly through local planning, *e.g*. Local Master Plan. Among the considered strategic objectives the Adaptation Pathway can also answer their needs by:

- Improving environmental health and comfort (Objective 2, theme area 4. Public space security and health)
- Ecological and multiscale connectivity and accessibility (Objective 3, themes area 6. Relationship with ecosystems in the environment, mainly the Huerta and theme area 7. Sustainable mobility and accessibility to green areas)

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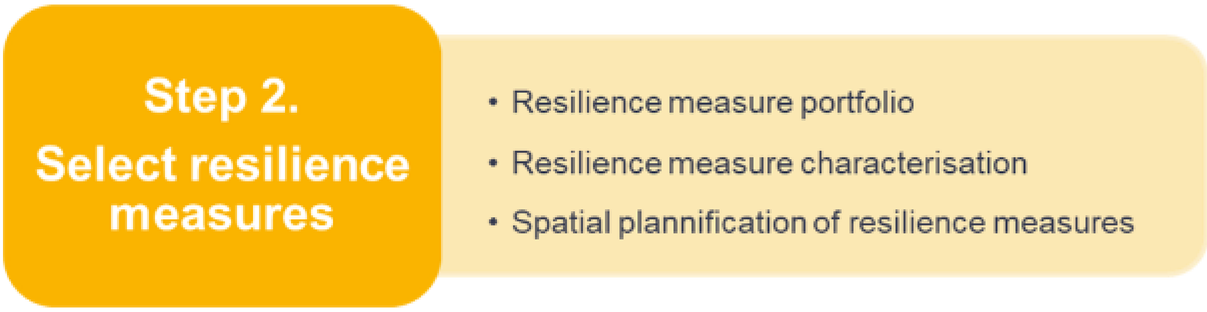
[26] Source: https://www.san.gva.es/web_estatica/index_va.html [Last accessed on 28th July 2022]

[27] Source: https://plaverdvalencia.com/ [Last accessed on 28th July 2022]

Step 2. Selecting adaptation measures



- **Step 2.1. Identification of adaptation measures**

In order to identify possible adaptation measures that could tackle heatwaves, the first step was twofold: first, to create a problem tree representing the conceptual model of the impact chain (Figure 46); and then to create an adaptation canvas identifying the main groups of measures that could be applied to address the impacts of heatwaves (Figure 47). Only structural measures were selected, as seen in Figure 47, as the aim was to assess how these measures could improve the thermal comfort in the public spaces in the city, as well as in La Huerta. The indicator selected to assess human thermal comfort was the Physiological Equivalent Temperature (PET, °C) as previously mentioned. Social and institutional measures do not directly address the temperature and humidity challenges that contribute to thermal comfort, and thus were not selected for the pathway assessment. The identification of adaptation measures was mainly performed using the databases RMI and RESIN Adaptation Option Library.

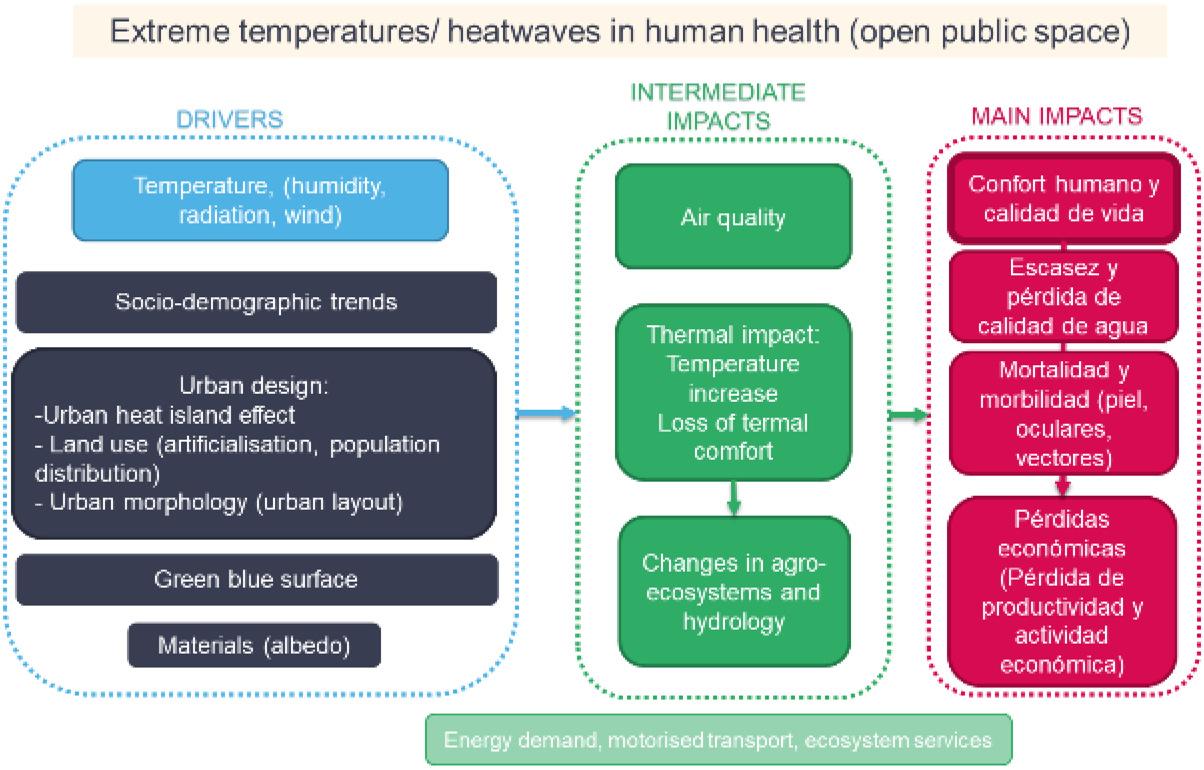


Figure 46. Problem tree representing the conceptual model of the impact chain: heatwaves in human health

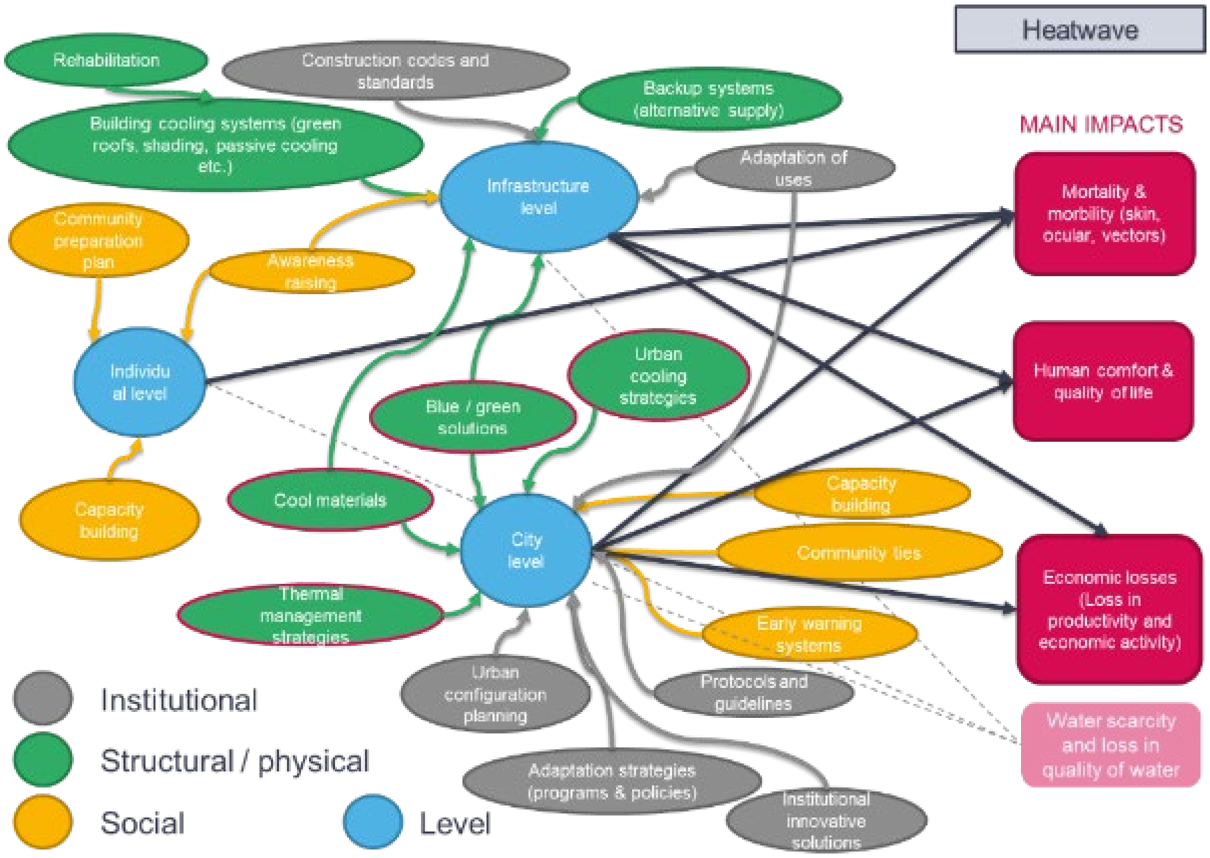


Figure 47. Adaptation canvas at different level. Adaptation measures in grey (institutional), green (structural) and yellow (social). Adaptation measures with red line were selected for the Adaptation Pathway

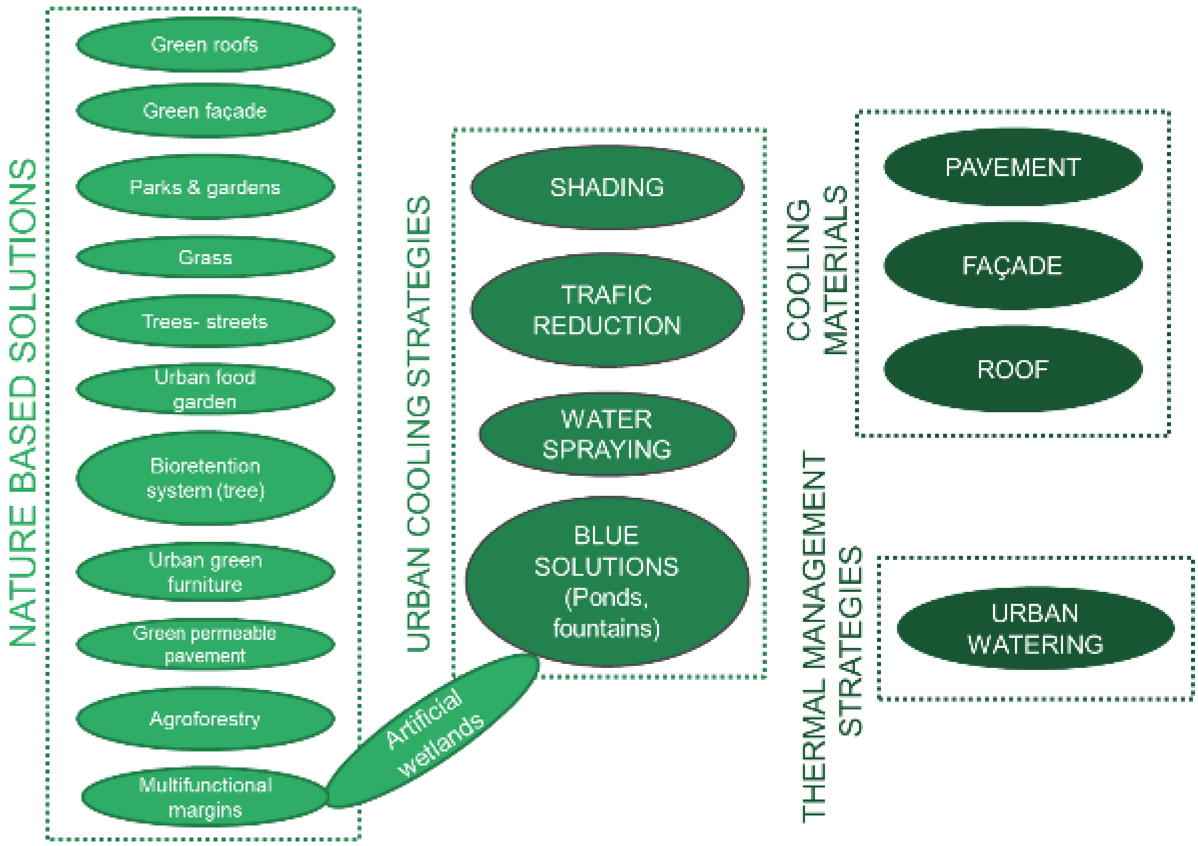


Figure 48. Final list of adaptation measures by subgroup of measures

- **Step 2.2. Selection and characterisation of adaptation measures**

The next step was to characterise and prioritise the adaptation measures based on relevant criteria for the Valencia case study. This was done by a multi-criteria analysis. The selection and weighing of the criteria was performed together with local stakeholders (Table 11). As eight criteria were selected, there were not a particularly large difference in the weighing of the different criterion, but environmental effectiveness was the most relevant out of those selected (Figure 49). The final score of each of the adaptation measures can be seen in Figure 50.

Once the multi-criteria analysis was performed and a ranking of measures was obtained based on the selected criteria, the results were cross-checked with local stakeholders. The barriers, general consideration and synergies with existing strategies were as well discussed, after which some barriers were considered to have more niche applicability and excluded from further analysis. Those adaptation measures that could have higher mainstream potential were considered for the opportunity mapping (spatial planning).

The reason for excluding the measures were:

- Grass: Despite the fact that it could be implemented in areas where there is seasonal flooding, it was considered to have a high-water demand and cost. This was particularly relevant to the choice to exclude the measure because water scarcity is also a concern in Valencia.
- Urban food garden: Despite the great synergy with the urban agriculture plan and the fact that such a garden could be ideal for the transition areas between city and the

Huerta, it was not considered the most effective adaptation measure towards heat stress.

- Artificial wetland: Due to the technical and spatial requirement it was considered not easily manageable in Valencia, with focus being instead shifted toward recovering and restoring natural wetlands. Other measures were prioritised in the more rural areas.
- Bioretention systems, which include trees, have the advantage of improving water infiltration, but as for the heat stress they would have similar effects as urban trees. Thus, to simplify, this type of measure was included under the trees category.
- Water spraying, due to its cost and high-water demand, was only considered to be applicable in specific sites and not as a mainstreamed solution.
- Blue solutions, including open swimming pools, were also considered to be applicable only in specific sites, and therefore not considered as a mainstreamed solution.
- Pavement watering was excluded as it had the lowest score, and it implies the use of a large amount of water
- Traffic reduction had a neutral reaction among the stakeholders, despite the fact that as a measure, it may help improve air quality and thus lessen the impact of heatwaves.

Table 11. Criteria for characterisation and prioritisation of the measures

1	Cost (€/m2)	**Economic**	euros	Min
2	Biodiversity	**Environmental**	"1-5"	Max
3	Contribution to the connectivity of natural areas	**Environmental**	"1-5"	Max
4	Contribution to climate change mitigation	**Climate**	"1-3"	Max
5	Thermal effectiveness	**Climate**	"1-5"	Max
6	Generating opportunities for recreation, education and people gathering	**Social**	"1-5"	Max
7	Tourist activity enhancement	**Economic**	"1-3"	Max
8	Other co-benefits	**Other**	"1-10"	Max

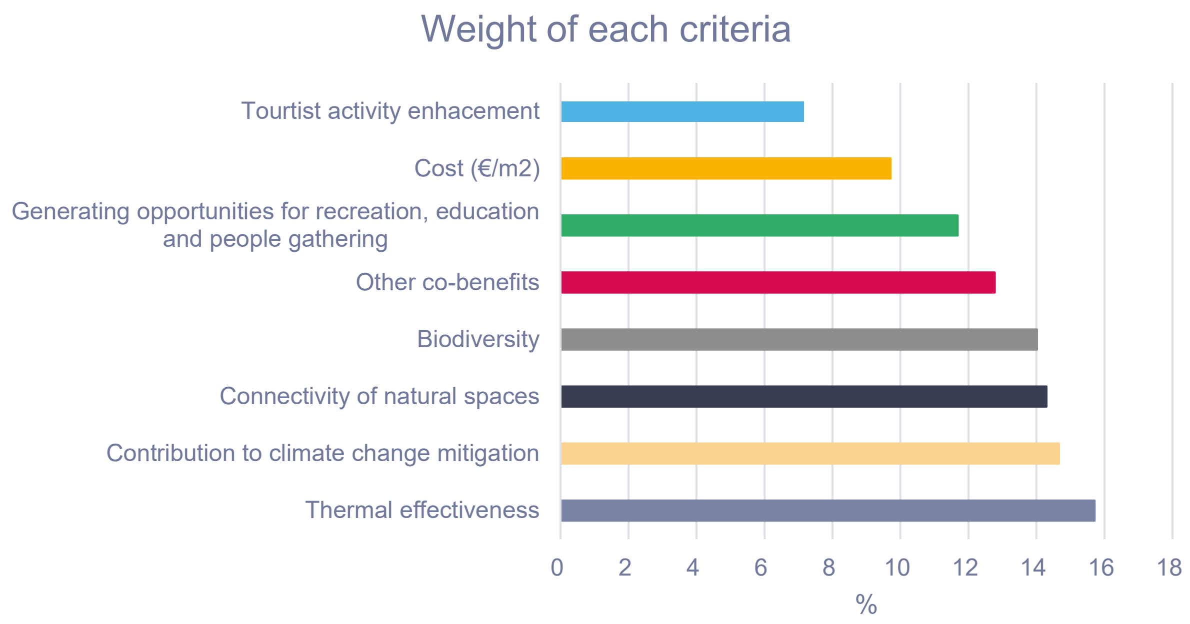


Figure 49. Weight of each criteria representing their relative importance as average to all stakeholders

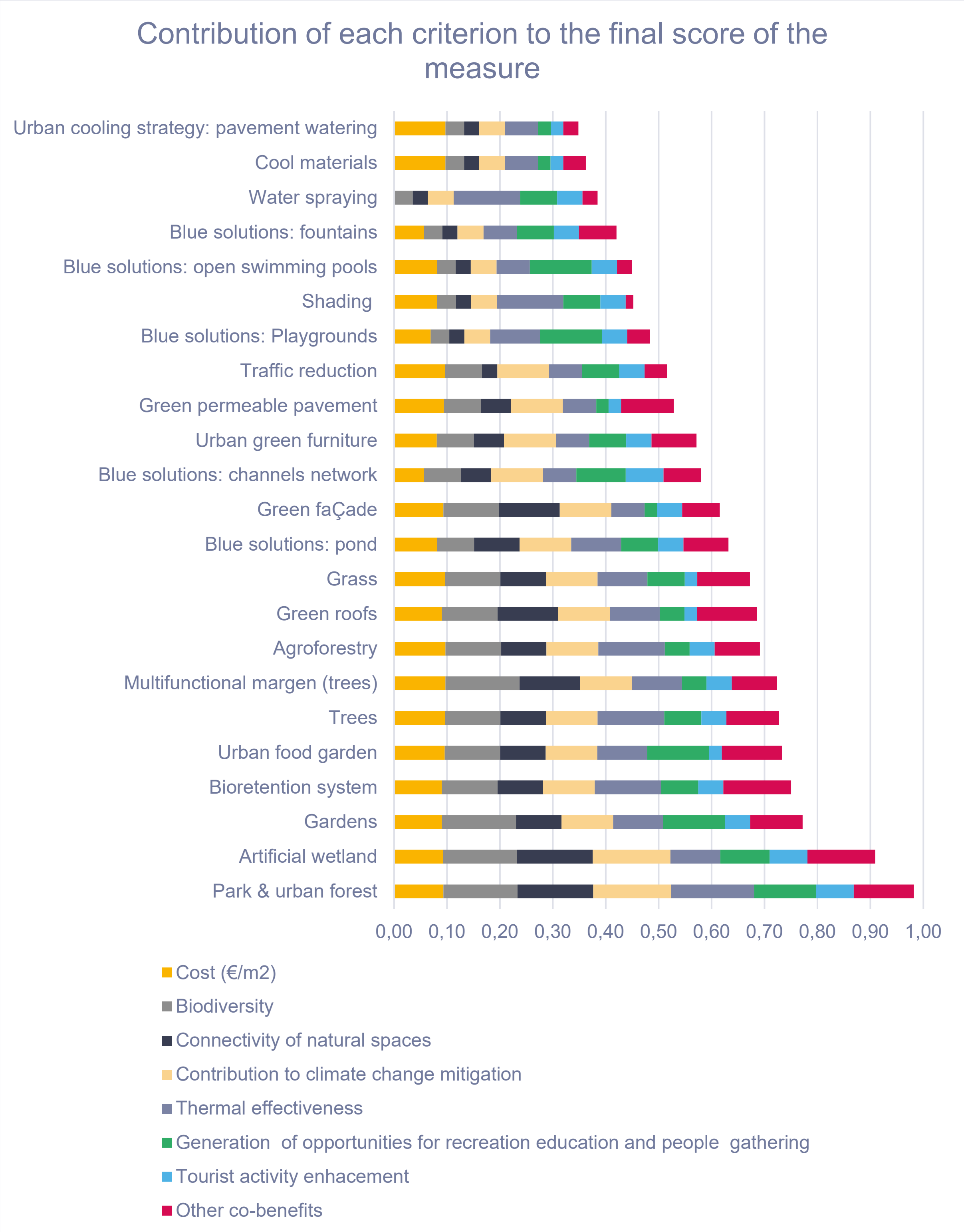


Figure 50. Final score in the multicriteria analysis and the contribution of each criterion in the final score

- **Step 2.3. Spatial planning**

This step was dedicated to create an opportunity mapping considering the administrative functional areas (depicted in Figure 44), in order to identify what type of adaptation measures can be implemented where. It should be noted that the methodology was built around the functional areas aligned with the GrowGreen project's outputs, due also in part to the fact that urban planners could not join in this work at the time of this project due to other commitments.

This analysis will allow for spatial consideration of the different pathway alternatives and link to the area of thermal comfort improvement. The methodology that was followed to build this opportunity mapping can be divided into six steps:

1. Download the Master Plan's land use classification (Figure 51)
2. Assign each land classification to a use
    a. Road network
    b. Building
    c. Public spaces
    d. Public spaces - green
    e. Orchard
3. Trim the building areas from the cartography to obtain what was defined as the area between buildings. This was done as the initial information considered not only the buildings areas but small areas adjacent to them. Figure 52 shows the six-land re-classification.
4. Use an algorithm for calculating vegetation areas within each land classification as shown in Figure 53. This was done to be able to calculate the available area for new adaptation measures.
5. Characterise functional areas according to surface area and available area per type of land use.
6. "Cluster" functional areas by typology. This clustering was based on the degree of artificialisation, green areas and amount of available land for future adaptation measures (Figure 54).
7. Preliminarily allocate potential adaptation measures according to land-use classification. This step was developed together with local stakeholders. The outputs of this work can be seen in Table 12.

Figure 51. Master plan land use classification

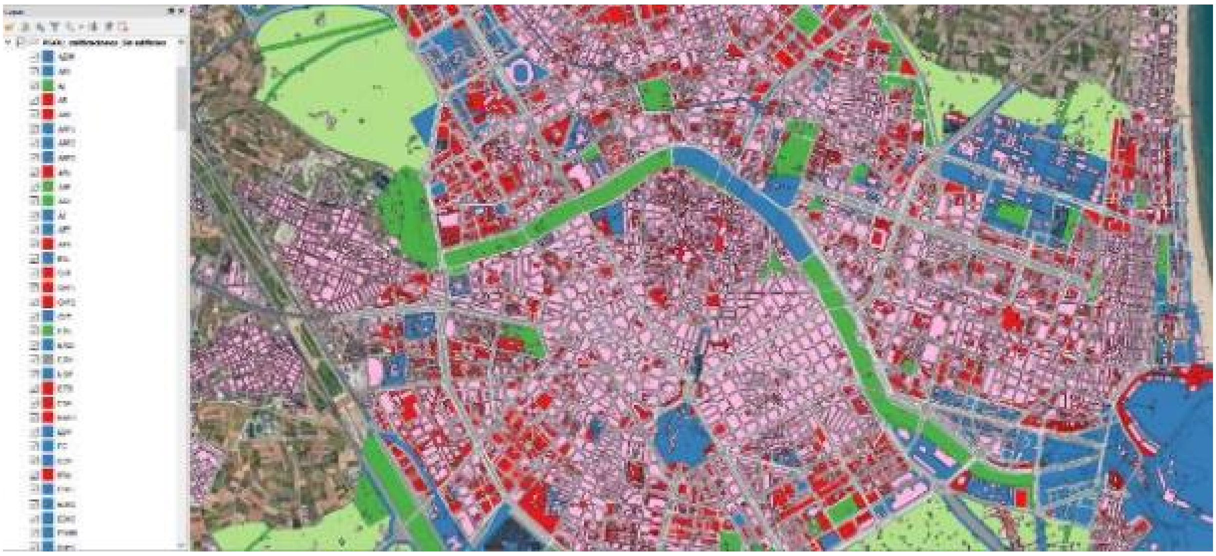


Figure 52. Re-classification of the land use in 5 main categories: pink as building, red as “interblock” areas, blue as open spaces, dark green as green open spaces, grey as the road network and light green as the Huerta

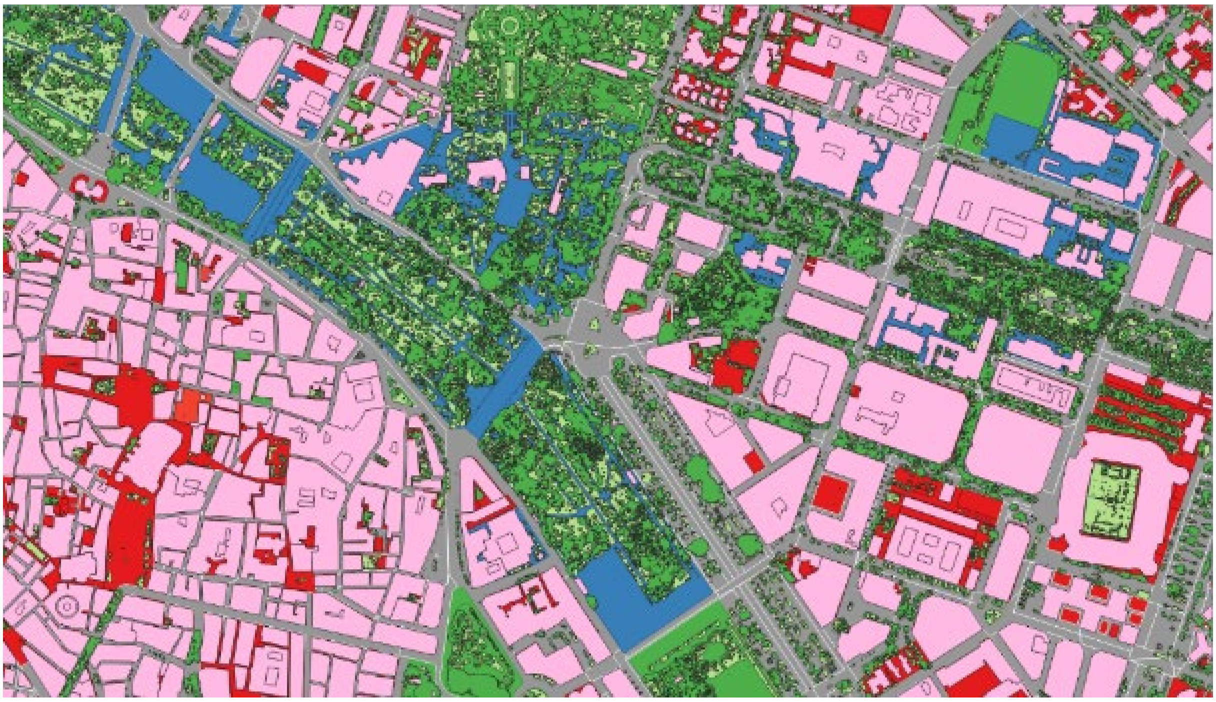


Figure 53. Vegetation area determination per land use classification

RISK

High risk, little scope for action	High risk, some room for improvement	High risk, high scope for action
2, 3, 13	7	8
Medium risk, little scope for action	Medium risk, some room for improvement	Medium risk, high scope for action
1	5, 14, 15, 17, 18	6,9, 11, 16, 23
Low risk, little scope for action	Low risk, some room for improvement	Low risk, high scope for action
	19, 21	4,10,12, 20, 22

SCOPE FOR ACTION

Figure 54. Clustering of functional groups by typology. Clustering based on the degree of artificialisation, green areas and amount of available land for future adaptation measures

Table 12. Assignment of potential adaptation measures according to land-use classification based on the stakeholder's vision. Darkest green is the most preferable adaptation measure per land-use while the lightest green is the least preferable solutions

	Road network (footpath, roundabout, parking etc.)	Green areas	Open public areas	Interblock building spaces	Bike path	Building	Huerta (Orchard)
Trees							
Shading							
Cool materials							
Parks /urban forest							
Green permeable pavement							
Garden							
Urban green furniture							
Green roofs							
Green façade							
Fountains							
Water playground							
Multifunctional margins							
Agroforestry							

After the opportunity mapping development, it was easier to set adaptation objectives (*Step 1.4 Define resilience threshold or objectives*) as knowledge on available surface in terms of percentage and Km^2 was made available. This information was confronted with local context knowledge to define the objectives as shown in Table 13. Scenario 3, which would be implemented in the worst-case climate scenario, involves a change of around 8% of the total urban area (not just the available or feasibility areas for further improvement). The amounts of area prone to be improved in each scenario are as follows:

- Scenario 1: 1.36 Km^2
- Scenario 2: 2.72 Km^2
- Scenario 3: 4.31 Km^2

Table 13. Target scenario for land use qualification change (improve adaptation).* Excluding Ciutat Vella due to heritage value of the area,% considering the available area for further improvement**

Huerta	Building*	Urban area**	Huerta	Building*	Urban area**	Huerta	Building*	Urban area**
1%	1%	10%	2.5%	2%	20%	5%	5%	30%

Step 3. Developing pathway alternatives

Step 3.

Develop pathway alternatives

• Aggregation of different resilience pathways into the pathway alternatives
• Performance assessment of the pathway alternatives
•Sequencing the resilience measures over time

- **Resilience pathway alternative development**

Pathway alternatives are groups of measures, or clusters, which are considered simultaneously to address challenges. This aggregation of previous identified adaptation measures was built considering stakeholders' reflections. The selected pathway alternatives and their aggregation criteria can be seen in Figure 55. Pathway alternative 2 was defined as many of the adaptation measures require water and this may promote water stress in the whole socio-ecological system. Nature based solutions are key elements of the policies that are being developed as it was presented in Step 1.5 *Alignment of the Adaptation Pathway with long-term vision of the system* (page 95), thus developing pathway alternative 3 with green adaptation measures. On the other hand, lack of economic finance for adaptation has been identified as a barrier. Therefore, the last pathway alternative (no 4) only considers the most economic solutions.

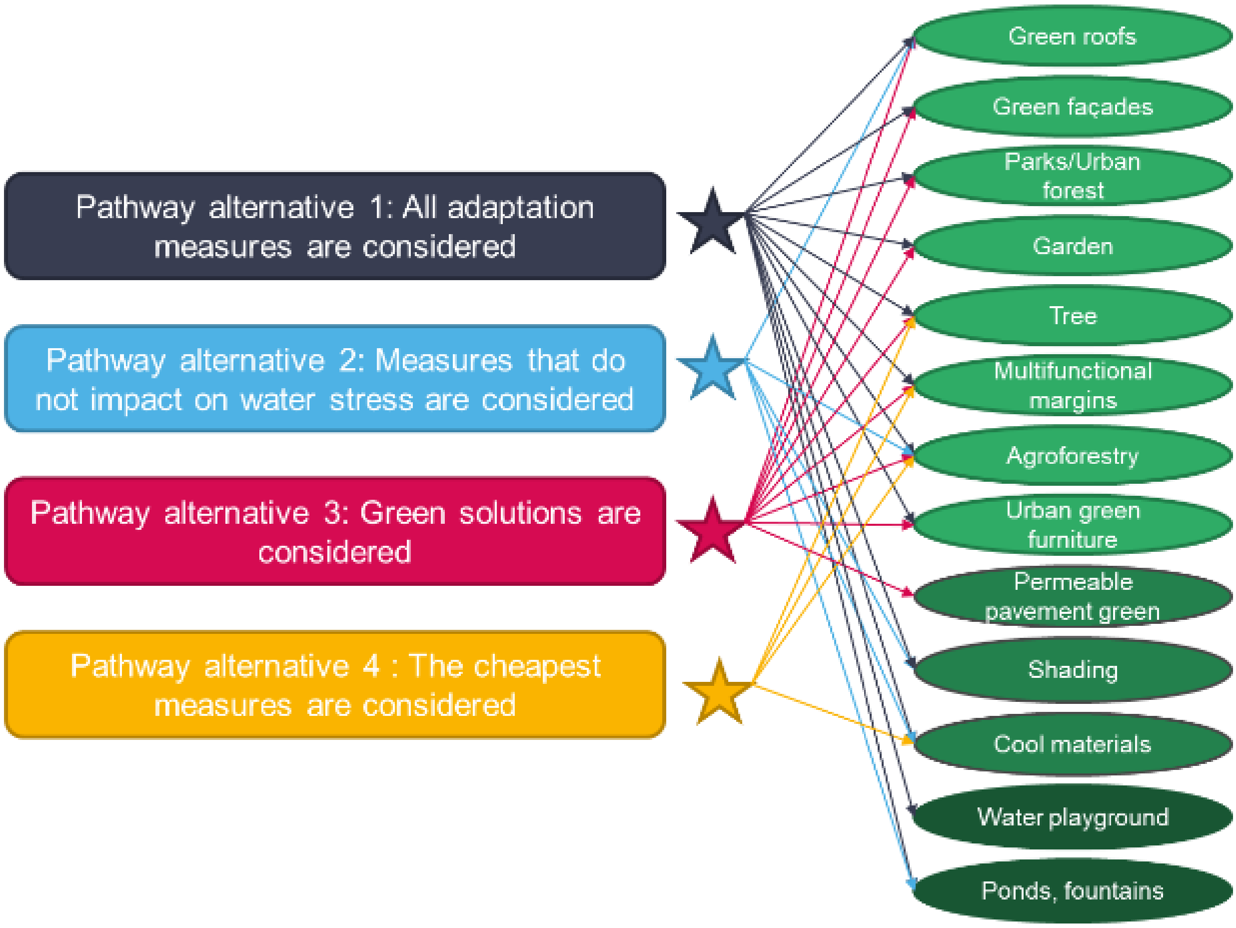


Figure 55 Defined pathway alternatives for Valencia and their characteristics considering the local stakeholder inputs

- ### Assessment of effectiveness

Micro-modelling exercises for all measures, except for multifunctional and agroforestry, were performed using envi-met software[28] to benchmark their effectiveness in terms of PET reduction (ºC) compared to actual status (baseline) of the modelled areas. Figure 56 shows where the modelling was performed and Figure 57 an example of the modelling exercise. Measures were classified as low effective, medium effective and high effective considering the thresholds shown in Table 14. The overall effectiveness for each pathway alternative was assessed using an effectiveness index, the calculation of which is based on how much area is improved per effectiveness range, as seen in Figure 58. Results are presented in Table 16. Pathway alternative 1 showed the best effectiveness followed by pathway alternative 3. The selection of the most suitable pathway was done prior to the sequencing of the pathways.

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[28] A high-resolution commercial microclimate modelling system

Figure 56. Modelled areas. A: Green roofs, green façade, extra trees and grass (as garden) were modelled in a street. B: Urban forest, grass as green permeable pavement, urban vegetable garden, pergola as shading, fountain, pond, water spraying as playground

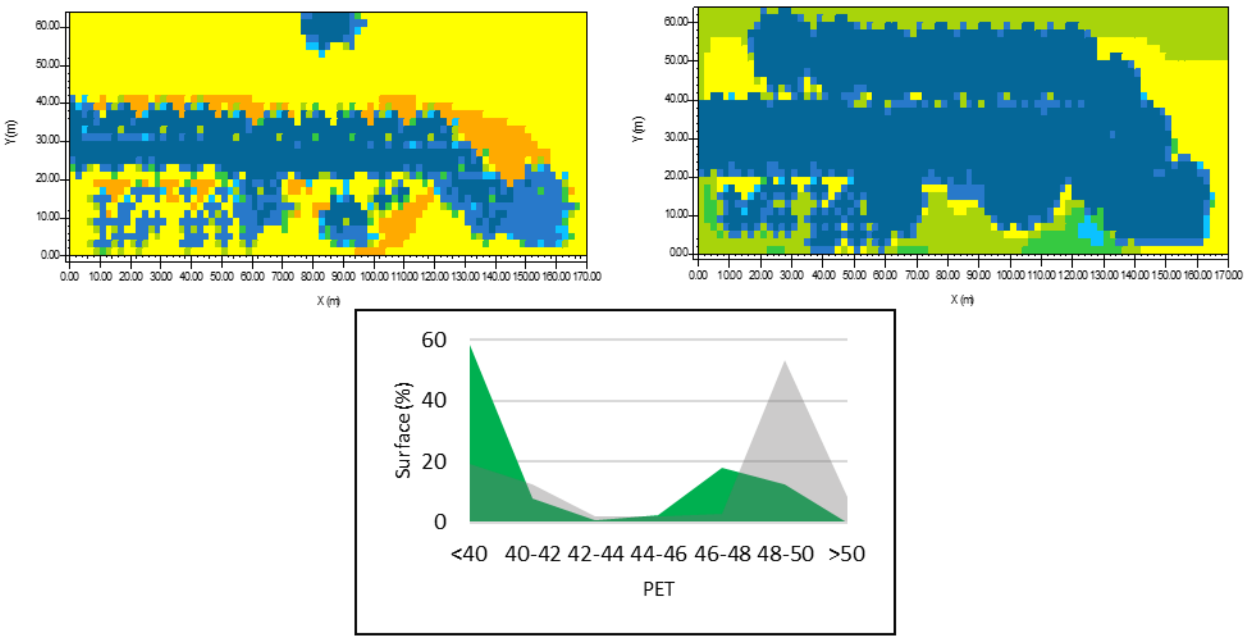

Figure 57. Modelling outputs for the baseline (upper left) and the urban forest (upper right) in terms of PET. Differences in the distribution in PET ranges by surface area within the baseline and tree cover scenario (bottom image)

Table 14. PET reduction (ºC) values characterising each threshold of effectiveness

Threshold range	Performance
PET Reduction ≥ 3.5 ºC	High
0.75 ºC ≤ PET Reduction < 3.5ºC	Medium
0ºC < PET Reduction < 0.75 ºC	Low
PET Reduction <.0	Not effective

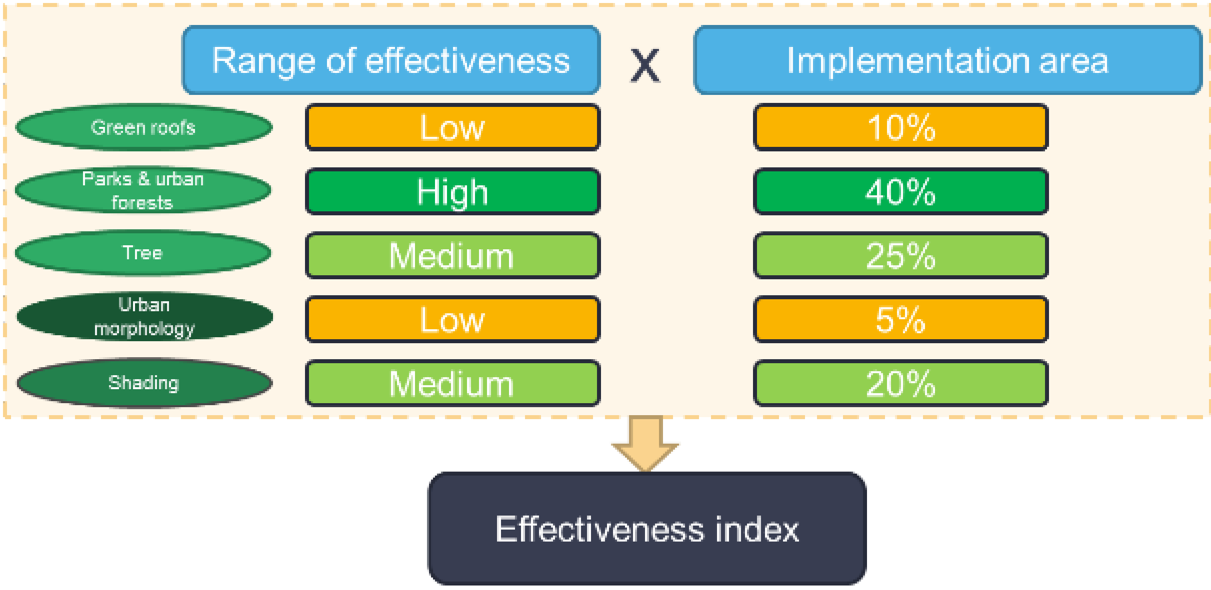

Figure 58. Conceptual example of how the overall effectiveness was calculated for each pathway alternative

- **Sequencing over time**

This step was done after the preferable pathway alternative was established.

The order by which the adaptation measures can be deployed is linked to the vision and understanding of the local stakeholders of how the risk should be addressed. It represents the measures' priority given by the stakeholders to tackle the challenge. In the case of Valencia, the criteria for this sequencing were (by order of relevance):

- Urgency of action: The implementation of the measures should be prioritised in areas at high risk (see Figure 54).
- Touristic areas: one specific area, AF 1: Ciutat Vella, was given more importance as it has heritage importance and tourists visit this area more frequently. It was deemed important to provide comfortable open spaces for tourists.
- Effectiveness of the measures and the preferences of the stakeholders (Table 12).

A detailed sequencing of the measures was performed which accounted for what type of measure should be implemented where (AF) and how much deployment would be envisioned in that area. A section of the graph can be seen in Figure 59 and Table 15 includes all the potential interventions in the sequencing. The cumulative performance of the pathway alternative 3, if all measures are implemented, can be summarized as:

- 3.6% of the planned intervention areas improve thermal comfort in the high range of effectiveness
- 65.9% of the planned intervention areas improve thermal comfort in the medium range of effectiveness
- 30.5% of the planned intervention areas improve thermal comfort in the low range of effectiveness

Figure 59. A section of the graph including the measures in scenario 1 (small change scenario), see Table 13

Table 15. Order of the implementation of the adaptation measures corresponding to the pathway alternative 3: only NbS are considered. AF: Administrative Functional urban area

No.	Adaptation measure	Where	Implementation area (m^2)	Scenario
1	Tree	AF 8, 1, 7 Road Network	419,649	1
2		AF 2, 3, 13 Road Network	232,802	
3		AF 8, 1, 7 Public Spaces	16,361	
4		AF 2, 3, 13 Public Spaces	2,835	
5		AF 8, 1, 7 Area between buildings	56,247	
6		AF 2, 3, 13 Area between buildings	17,062	
7		AF 8, 1, 7 Green Areas	7,721	
8	Park	AF 8, 1, 7 Public Spaces	13,088	
9		AF 2, 3, 13 Public spaces	2,268	
10	Garden	AF 8, 1, 7 Area between buildings	56,247	

No.	Adaptation measure	Where	Implementation area (m^2)	Scenario
11		AF 2,3, 13 Area between buildings	17,062	
12	Green urban furniture	AF 8, 1, 7 Public Spaces, A. between buildings	59,519	
13		AF 2,3, 13 Public Spaces, A. between buildings	17,629	
14	Retention Pond	AF 8, 1, 7 Green Areas	5,147	
15	Trees	AF 5, 6, 9, 11, 14, 15, 16, 17, 18, 23 Road Network, Public Spaces, A. between buildings, Green Areas	230,297	
16	Parks	AF 5, 6, 9, 11, 14, 15, 16, 17, 18, 23 Public Spaces	14,286	
17	Garden & Green urban furniture	AF 5, 6, 9, 11, 14, 15, 16, 17, 18, 23 Public Spaces, A. between buildings	59,266	
18	Retention Pond	AF 5, 6, 9, 11, 14, 15, 16, 17, 18, 23 Green areas	6,957	
19	Trees	La Huerta	445,980	
20	Green roofs	All AF Buildings	111,937	
21		AF 8, 1, 7 Road Network	83,930	
22		AF 2,3, 13 Road Network	46,560	
23		AF 8, 1, 7 Public Spaces	41,965	
24	Tree	AF 2,3, 13 Public Spaces	23,280	
25		AF 8, 1, 7 Area between buildings	11,249	
26		AF 2,3, 13 Area between buildings	3,412	
27		AF 8, 1, 7 Green Areas	1,544	
28	Park	AF 8, 1, 7 Public Spaces	2,618	
29		AF 2,3, 13 Public spaces	454	
30	Garden	AF 8, 1, 7 Area between buildings	11,249	
31		AF 2,3, 13 Area between buildings	3,412	2
32	Green urban furniture	AF 8, 1, 7 Public Spaces, A. between buildings	11,903	
33		AF 2,3, 13 Public Spaces, A. between buildings	3,525	
34	Retention Pond	AF 8, 1, 7 Green Areas	1,029	
35	Trees	AF 5, 6, 9, 11, 14, 15, 16, 17, 18, 23 Road Network, Public Spaces, A. between buildings, Green Areas	690,891	
36	Parks	AF 5, 6, 9, 11, 14, 15, 16, 17, 18, 23 Public Spaces	8,242	

No.	Adaptation measure	Where	Implementation area (m^2)	Scenario
37	Garden & Green urban furniture	AF 5, 6, 9, 11, 14, 15, 16, 17, 18, 23 Public Spaces, A. between buildings	23,568	
38	Retention Pond	AF 5, 6, 9, 11, 14, 15, 16, 17, 18, 23 Green areas	2,985	
39	Trees	AF 4, 10, 12, 19, 20, 21, 22 Road Network, Public Spaces, A. between buildings, Green Areas	92,343	
40	Parks	AF 4, 10, 12, 19, 20, 21, 22 Public Spaces	8,242	
41	Garden & Green urban furniture	AF 4, 10, 12, 19, 20, 21, 22 Public Spaces, A. between buildings	23,568	
42	Retention Pond	AF 4, 10, 12, 19, 20, 21, 22 Green areas	2,985	
43	Trees	La Huerta	668970	
44	Green roofs	All AF Buildings	111,937	
45	Trees	AF 5, 6, 9, 11, 14, 15, 16, 17, 18, 23 Road Network, Public Spaces, A. between buildings, Green Areas	460,594	3
46	Parks	AF 5, 6, 9, 11, 14, 15, 16, 17, 18, 23 Public Spaces	28,572	
47	Garden & Green urban furniture	AF 5, 6, 9, 11, 14, 15, 16, 17, 18, 23 Public Spaces, A. between buildings	118,531	
48	Retention Pond	AF 5, 6, 9, 11, 14, 15, 16, 17, 18, 23 Green areas	13,914	
49	Trees	AF 4, 10, 12, 19, 20, 21, 22 Road Network, Public Spaces, A. between buildings, Green Areas	461,713	
50	Parks	AF 4, 10, 12, 19, 20, 21, 22 Public Spaces	41,210	
51	Garden & Green urban furniture	AF 4, 10, 12, 19, 20, 21, 22 Public Spaces, A. between buildings	117,839	
52	Retention Pond	AF 4, 10, 12, 19, 20, 21, 22 Green areas	14,927	
53	Trees	La Huerta	1,248,744	
54	Green roofs	All AF Buildings	335,811	

Step 4. Selection of best pathway alternative

Step 4. Recommend a pathway

- Decide for the best pathway or rank them & communicate the outputs of the resilience pathway develoment

Pathway alternative 1 showed the best thermal effectiveness, however other criteria were considered relevant to assess the overall performance of each pathway alternative. The pathway alternative most suitable to Valencia should promote recreational spaces, help or be aligned with mitigation to climate change objectives, promote biodiversity and natural connection, and have as little impact as possible on local water stress. Furthermore, ideally it should be as economic as possible in terms of implementation cost, and have low maintenance cost. Table 16 presents the performance of each of the pathways for each of the criteria. With this information a multi-criteria analysis was carried out, and the outputs of this multi-criteria analysis (Figure 60) showed that overall pathway alternative 3 was the most suitable one considering all the mentioned factors. At this point pathway alternative 3 was selected and proceeded to its sequencing.

Table 16. Selected criteria to rank the pathway alternatives (PA) and their values

	PA1	PA2	PA3	PA4
Effectiveness index	0.64	0.80	0.58	0.48
Recreational index	0.64	0.57	0.65	0.48
Mitigation index	0.55	0.38	0.68	0.48
Biodiversity index	0.60	0.38	0.67	0.48
Cost (M€)	312	282	168	61
Maintenance index	0.67	0.62	0.66	0.64
Hydric stress index	0.59	0.34	0.39	0.33

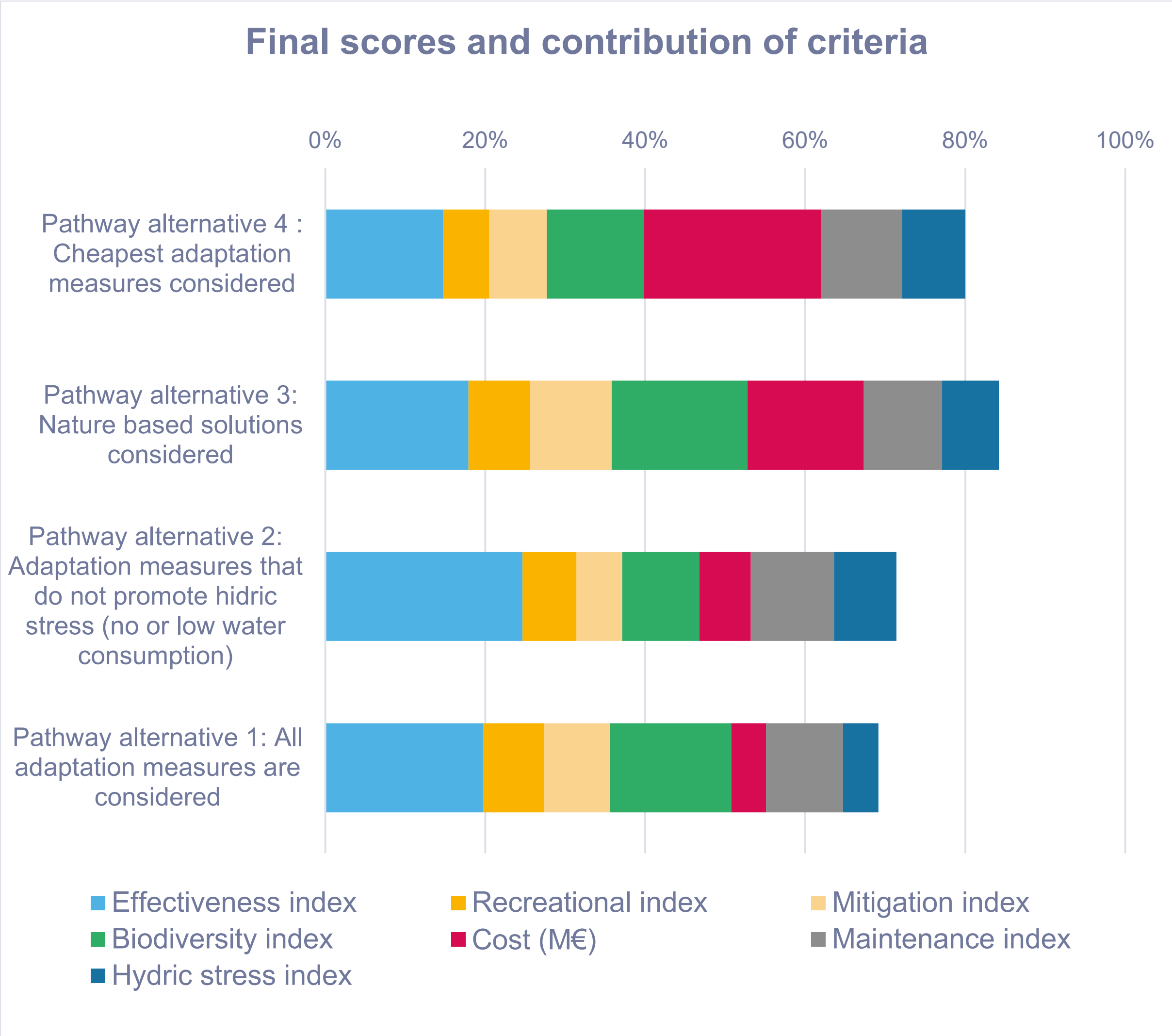

Figure 60. Contribution of each criterion to the final score of the multicriteria analysis for the pathway alternative

Lessons learned through the co-creation activities with Valencia, Bratislava, Camerino and Hamburg

Adaptive policymaking, in particular climate Adaptation Pathways, is creating great interest as tools develop to anticipate and plan for the impacts of climate change and associated disasters. However, there is a gap in knowledge around the concepts and methodologies as they relate to Adaptation Pathways, especially in the heritage field. And since Resilience Pathways have been developed within the ARCH project to respond to the ARCH Resilience Management Framework (Figure 4), the knowledge of Resilience Pathways is even at an “embryonic” stage.

A few conclusions and lessons learned can be concluded from the testing and co-creation activities with ARCH City partners and Valencia’s local stakeholders which have been structured in five main topics:

1. **Acquired knowledge through the training, co-creation and testing activities**

The concept and data-driven methodology, often unknown for the ARCH City partners and local stakeholders, was initially perceived as complex. The training sessions proved to be a good starting point to bridge the knowledge gap and raise interest, as mentioned at the beginning of the chapter.

As expected, the deeper the co-creation and testing work that was done between Tecnalia and the ARCH City partners, the better the understanding of the whole process progressed. This better understanding translated to higher understanding of the full potential of the adaptation approach as a decision-making strategy to help with planning for adaptation and resilience.

More precisely the ARCH City partners expressed their learning uptake as:

“*A logical step by step approach for creating a roadmap for increasing resilience*”

“*A framework with which we can assess the potential resilience of different actions for pre-during or after natural disasters*”

Figure 61 shows various features of the Resilience Pathway approach that were of interest by the ARCH City partners.

Figure 61. Elements of the methodology that the ARCH City partners valued most

2. **Use of the pathway approach to your local context**

All ARCH City partners perceived the potential applicability of the pathway approach. While in some cases, the link and support to current policies and initiatives such as the Covenant of Mayors for Energy and Climate and its Sustainable Energy and Climate Action Plan (SECAP) was clear, in other cases the applicability of the pathway approach was linked to different performance indicators than the ones considered within this handbook.

3. **Adaptation vs. resilience approaches**

Both approaches were of interest. In some cases, a the broader or more holistic approach (resilience) was preferred, but for practical reasons the pre-disaster or Adaptation Pathway would be selected as a starting point. Resilience pathways were seen as a bit more complex, but at the same time with more opportunities as "*it provides more options also for "bouncing back" and building certain capacity*".

4. **General barriers of development and implementation of the pathway approach**

During the training, testing and co-creation activities several barriers were identified in the development and implementation of Resilience Pathways. Since in the ARCH project the focus was on data-driven pathways, the main barrier identified by multiple ARCH partners or local stakeholders was the lack of data or the level of the detail required in the data for the successful deployment of a Resilience Pathway, especially when considering historic areas. The second most frequently mentioned barrier was the monetary and resource limitation that municipalities, regions or organisations managing heritage may have. A summary of other identified barriers is shown in Figure 62.

Figure 62. Other relevant obstacles in the development and implementation of Resilience Pathways

5. Heritage perspective in the pathway approach

The testing activities carried out in ARCH Cites were cases where historic areas were understood as social-ecological systems. However, this approach may not always be transferrable to other historic areas where the pathway approach is sought just for the physical demarcation of the historic zone. This shows the importance again of the local context in resilience and adaptation building, especially when considering heritage.

Another relevant consideration for historic areas is the importance of maintaining the authenticity of the historic areas which may conflict with several structural resilience measures. This brings another requirement for historic areas and shows the need for new performance indicators that may focus on heritage or account for criteria relevant to historic areas. This is especially relevant for World Heritage Sites.

> *"The performance indicator for this cultural heritage cannot be environmental and economic but has to be the sustainably protected heritage with the least possible loss of substance and traditional use."*

Therefore, there is a need to continue working and exploring other heritage case studies to further refine the Resilience Pathway methodology if it is to be applicable to historic areas and draw broader conclusions.

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Annex A. Glossary

A

- **Adaptation** (to climate change): The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.

C

- **Climate change** refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer.
- **Climate model**: A numerical representation of the climate system based on the physical, chemical and biological properties of its components, their interactions and feedback processes, and accounting for some of its known properties.
- **Climate projection**: A climate projection is the simulated response of the climate system to a scenario of future emission or concentration of greenhouse gases and aerosols, generally derived using climate models.

D

- **Disaster** is a serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources
- **Disaster risk management**. The systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster.

H

- **Historic area**: Any groups of buildings, structures and open spaces including archaeological and palaeontological sites, constituting human settlements in an urban or rural environment, the cohesion and value of which, from the archaeological, architectural, prehistoric, historic, aesthetic or sociocultural point of view are recognized. Among these `areas', which are very varied in nature, it is possible to distinguish the following 'in particular: prehistoric sites, historic towns, old urban quarters, villages and hamlets as well as homogeneous monumental groups, it being understood that the latter should as a rule be carefully preserved unchanged

I

- **Impact**: Effects on natural and human systems (…) the term impact is used primarily to refer to the effects on natural and human systems of extreme weather and events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services and infrastructure due to the interaction of climate changes of hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Note: Impacts are also referred to as consequences and outcomes

R

- **Resilience**: The capacity of a social ecological system to cope with a hazardous event or disturbance, responding or reorganizing in ways that maintain its essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation. Building resilience needs to account for: the degree to which the community comes into contact with a hazard capable of causing harm; the amount of inherent susceptibility to harm in that community; and the extent to which people in the community are able to make adjustments in order to avoid negative consequences, taking into account existing imbalances in power distribution in that community and ensuring that neither the impact of the hazard, nor the policies and actions themselves exacerbate existing or create new inequalities across different groups
- **Risk**: The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard.

S

- **Scenario**: A plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g. rate of technological change, prices) and relationships.

U

- **Uncertainty**: A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable
- **Urban (Urban area)**: Urban 'is a function of (1) sheer population size, (2) space (land area), (3) the ratio of population to space (density or concentration), and (4) economic and social organization.'

V

- **Vulnerability**: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

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Annex C. RPVT User's Guide

User guide

ARCH Resilience Pathway Visualization tool

Table of contents

List of Abbreviations

ARCH	Advancing Resilience of historic areas against Climate-related and other Hazards
EU	European Union
IPCC	Intergovernmental Panel on Climate Change
SECAP	Sustainable Energy and Climate Action Plan
RPVT	Resilience Pathway Visualization Tool
RMI	Resilience Measure Inventory
BCR	Benefit-Cost Ratio
PET	Physiological Equivalent Temperature

1. Introduction

The ARCH project (Advancing Resilience of historic areas against Climate-related and other Hazards) aims to enhance the resilience of areas of historic and cultural value to climate change-related and other hazards. One of its objectives is to offer an integrated framework (ARCH Resilience Management Framework[29]) for planning both for the climate change adaptation[30] and disaster risk management cycles[31]. ARCH Work package 6 aims at supporting resilience building through, among other things, the development of an inventory of resilience measures targeting heritage and Resilience Pathways for historic areas. In line with this objective, the Resilience Pathway Visualization Tool (RPVT) has been developed.

A Resilience Pathway is a decision-making strategy, closely related to planning, that addresses both slow-onset climate change and natural disasters management. It is a roadmap - sequences of potential actions/choices that can be implemented progressively as conditions evolve (on how the future unfolds and the development of knowledge)

2. What is the RPVT?

The ARCH Resilience Pathway Visualization Tool (RPVT) is an easy-to-use web-based tool to create and visualize **Resilience Pathways.** It provides a user-friendly graphical interface through which users interact to **select, prioritize and sequence potential resilience measures** over time that can be deployed as circumstances evolve. Measures can be selected and prioritized according to various performance metrics (ARCH D6.2[32]).

The RPVT is a data-driven tool supported by a relational database that stores and provides access to the different type of measures characterization (RMI) as well as to effectiveness and economic performance.

3. What is the RPVT for?

The aim of the RPVT is to support the Resilience Pathway development to city administrators, heritage managers and/or decision makers in the context of historic areas. The RPVT should be used in conjunction with the Resilience Pathway Handbook, which will guide on the steps and give examples to enable building ad-hoc Resilience Pathways to each historic area typology covered within the RPVT.

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[29] Milde, K.; Lückerath, D. and Ullrich, O. ARCH Deliverable D7.3: ARCH Disaster Risk Management Framework. ARCH Project, GA 820999, 2020

[30] RAMSES, “Transition Handbook” 2018, H2020 GA No. 30849.

[31] R. Jigyasu, J. King and G. Wijesuriya, Managing disaster risk for world heritage, United Nations Educational, Scientific and Cultural Organisation, 2010

[32] Matesanz Parellada, A.; Nicolás Buxen, O.; Peña Cerezo, N.; Sopelana Gato, A.; Turienzo López, E.; Zorita Castresana, S.; Pedone, L.; Rosca, C.; Giovinazzi, S.; Morici, M.; Dall’Asta, A.; Barchetta, L. ARCH Deliverable D6.2: Assessment of long-term implementation options. ARCH Project, GA 820999, 2020

The RPVT is conceived for both climate change adaptation and disaster risk management with focus on (1) heritage building & structures as well as (2) cultural heritage landscapes with focus on agricultural heritage.

It is conceptualised to support and guide practitioners:

- to gather **evidence-based information** about resilience measures identified in the RMI;
- to select and compare measures based on **environmental effectiveness and/or economic analysis**;
- to create and benchmark **different alternatives** (cluster of measures) based on different performance metrics;
- to build Resilience Pathways (**roadmaps**) by sequencing **the potential measures over time** considering different scenarios or changing circumstances;
- to communicate and assist decision-makers to visualize a **dynamic response** to changing conditions.

These outcomes may be used:

- to understand which pathway may be more efficient to target our goals of resilience;
- to support awareness raising and capacity-building;
- to communicate and assist decision-makers to visualize a progressive and dynamic response to changing conditions~~;~~
- to support SECAP development in the framework of the EU Covenant of Mayors.

4. How to navigate and use the RPVT

This section contains a short manual of the ARCH RPVT tool. It describes the structure of the tool, its functionalities and the logical steps for using the tool with the intention of helping end-users understand the usage of this product and achieve its objectives.

4.1. Description of the tool format and technical requirements of use

The RPVT tool is a web application built with the Django framework v3.2.10 (www.djangoproject.com/) and Python language v3.10 (www.python.org). For the web view, JQuery v3.5.1 (jquery.com), Bootstrap v4 (getbootstrap.com), Highchart v10.1.0 (www.highcharts.com) and Chart.js v3.8.0 (www.chartjs.org) have been used. In turn, for the storage and management of information, a MySQL relational database (www.mysql.com) is used. Therefore, once deployed, there are few technical requirements for optimal performance by the user.

This tool works on all modern browsers and mobile devices. Legacy browsers - primarily IE 6-8 - are supported using polyfills and the old IE module.

Browser compatibility. We test our software on many browsers using the latest versions.

Brand	Versions supported
Firefox	2.0 +
Chrome	1.0 +
Safari	4.0 +
Opera	9.0 +
Edge	12.0 +
Internet Explorer	6.0-8.0 partial support using polyfills
Internet Explorer	9.0 +

4.2. The RPVT structure & sequence

The landing page to the RPVT presents the essence of the tool in two sentences. It also makes reference to the ARCH Resilience Measure Inventory (RMI) and to the Resilience Pathways Handbook that provides detail information about the Resilience Pathways concept and methodological process. It also provides direct access to this guide by clicking on "User's Guide" link (See Figure 63).

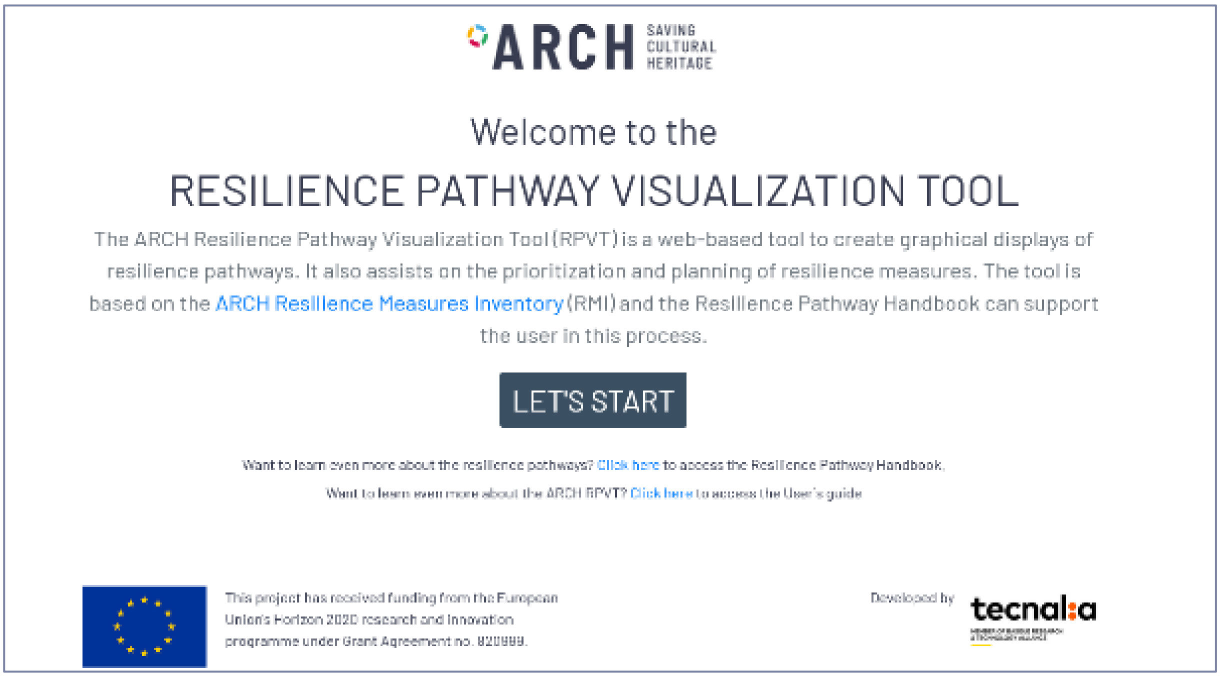
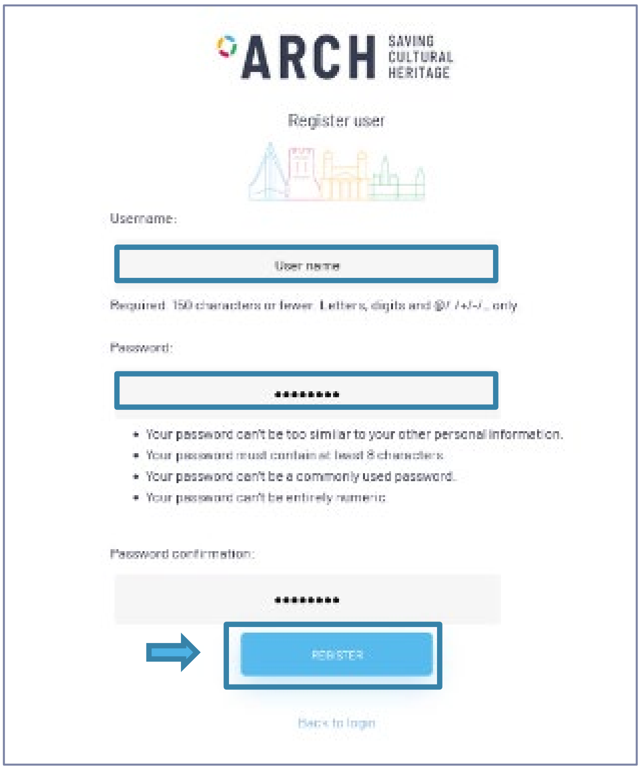


Figure 63. Landing page to the RPVT

Click on the "Let's start" button to arrive to the user login/registration page (Figure 64). You require an account to get access into the tool. First, create an account by clicking on the "Register" button to create a new personal account. Then the new user registration page will open (See Figure 65).

Figure 64. User login/registration page



To create an account to get access into the RPVT tool is very simple, you just need a few minutes of your time to type a new *user_name* and a *password*, afterwards click on the "Register" button. Please, follow the recommendations and specification provided in this page to set the username and the password correctly. This information will be requested next time you enter into the RPVT and all your RPVT projects will be linked to your user account That is, to access and revise all pathways you create, you will need to remember your username and password in the future.

Figure 65. RPVT new user registration page

Once you've finished the registration process, click on "Back to login" and you will be redirected to the login page (Figure 64). Enter your user/password and click on the "Log in" button to enter the introduction page (Figure 66) where each step of the Resilience Pathway visualization process is summarized.

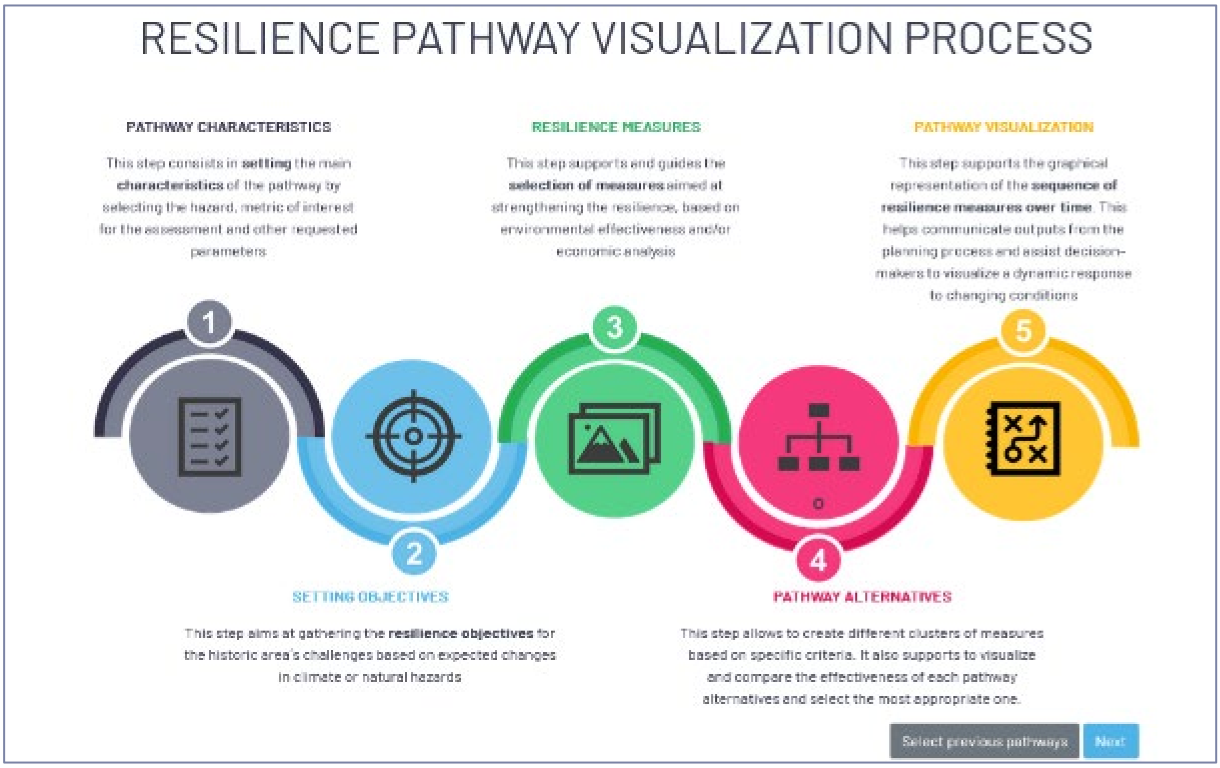


Figure 66. RPVT short introduction page, where the Resilience Pathway visualization process is described.

The Resilience Pathway process introduction page summarizes the aim of each of the steps needed to design a Resilience Pathway, ideal to be reviewed by first-time users. See subsections 4.2.1 to 4.2.5 for further information about the steps and the RPVT's functionalities.

Click on the "Next" button to start the creation of a new Resilience Pathway or click "select previous pathways" button to search for previously designed Resilience Pathways.

4.2.1. Step 1: Setting pathway characteristics

This step requests you to set the main characteristics of the pathway project that you are about to design in the next minutes. Setting the characteristics of the pathway is a very simple process, as the RPVT offers an integrated approach where drop-down menus are pre-configured according to the previous settings.

First, type the *pathway_name*, (Figure 67.a), note that the information linked to this project will be stored based on that name.

Next, type the description and/or aim of your pathway in the pathway_*description* input_text or any other relevant information (Figure 67.b), such as involved stakeholders. Note this input text is not mandatory so you can skip it at this moment.

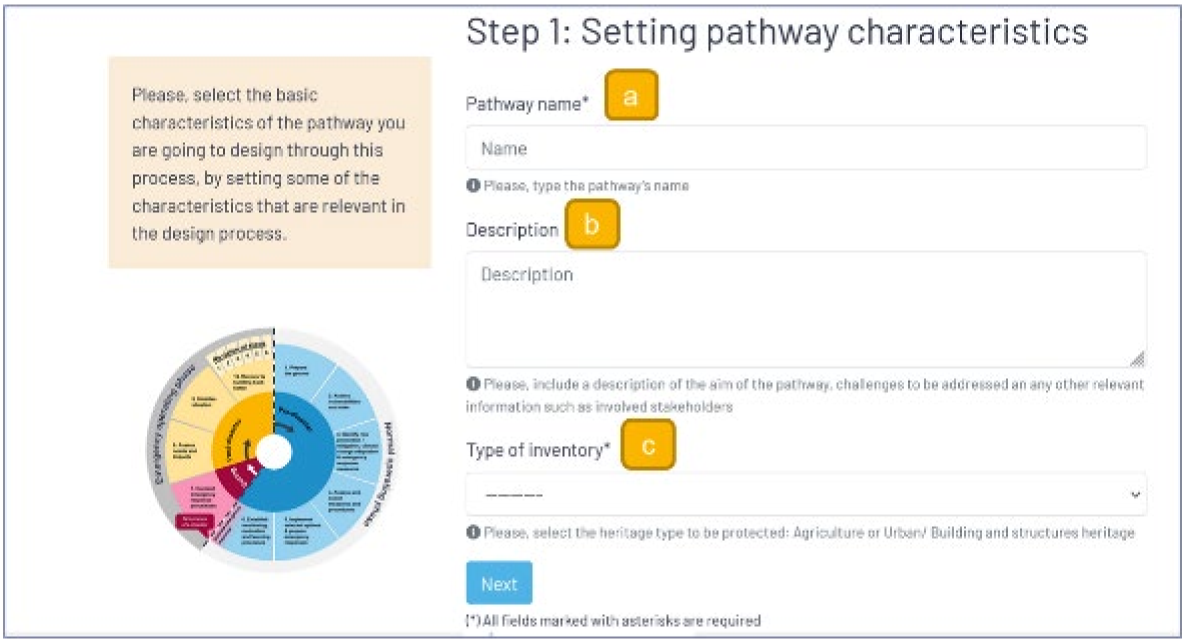


Figure 67. Step 1 page - initial setting

Third, select the *type_of_inventory,* you are willing to base your pathway on (Figure 67.c). As you can see this input is requested through a drop-down menu where you can select from two types of heritage:

(i) urban heritage building & structures

(ii) agricultural heritage

Depending on your selection, the RPVT automatically pre-configures the next input drop-down menus, where different hazards affecting that type of heritage will be available for your next selection (Figure 69). Note that at this stage the RPVT can design pathways considering three individual hazards (flood, heat extremes, and earthquake) for the urban heritage. Instead, for agricultural heritage, only the flood hazard is selectable, however a multi hazard approach is also available to consider multiple hazards that may impact agriculture at the same time: heat, flood, biological activity, soil erosion, salinization of soil, water scarcity etc.

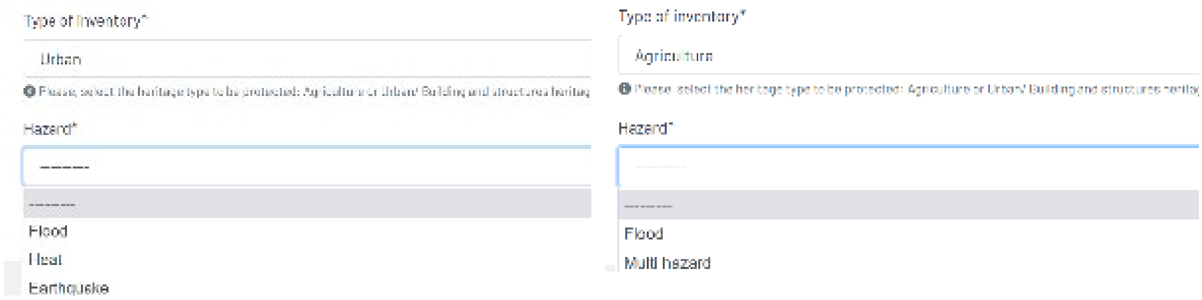


Figure 68. Hazards available per type of heritage

ARCH provides a resilience integrated framework to deal with both adaptation to climate change and disaster risk management (for more detail, see Section 1.2.1 from the Resilience Pathway Handbook). Based on this integrated framework , the RPVT offers the user to design a pathway considering two options, (1) an adaptation strategy approach (Figure 70) to address adaptation to climate change or (2) a resilience approach (Figure 69) to address both climate change adaptation and risk management of potential natural disaster events.

Therefore, once the hazard is selected, you have to define the type of pathway strategy you are willing to design by choosing from the available options: *adaptation or resilience*:

- *Adaptation Pathways approach* (Figure 70) is a decision-making strategy to address slow-onset processes resulting from climate change and preparedness to sudden weather extremes (pre-disaster)
- *Resilience Pathways approach* (Figure 69) is a decision-making strategy to address both slow-onset processes resulting from climate change adaptation (pre-disaster) and natural disasters (pre-, during and post disaster)

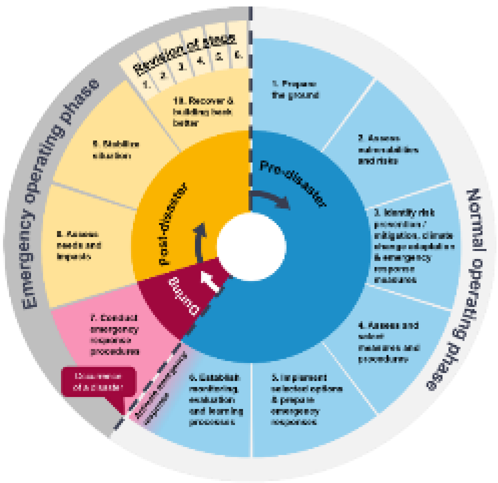


Figure 69. Resilience pathway approach where resilience measures available in the RPVT are considered (pre-, during and post disaster)

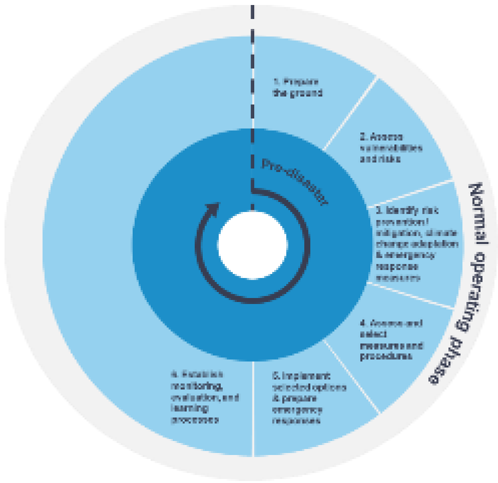


Figure 70. Adaptation pathways approach where adaptation measures available in the RPVT are considered (pre-disaster)

Once you select a pathway strategy (adaptation or resilience), the RPVT automatically requests you to choose the indicator over which the performance can be assessed. Figure 9 provides you an example of settings for an urban Adaptation Pathway.

Note that there are multiple options available depending on the previous type of pathway, hazard and/or strategy. For example, selecting the *resilience* strategy, the benefit-cost ratio indicator (for now on, BCR) is always considered to measure the economic performance, although additional physical indicators can be considered. On the other hand, selecting the adaptation strategy, a physical indicator has to be mandatorily selected, and the BCR is an optional indicator to include additional social or institutional measures considering their benefit cost ratio analysis. Note that there is also a qualitative approach where no metric is needed.

You can play with the different options available until you choose the most suitable selection for your case. Figure 72 provides you the decision tree behind the RPVT available options.

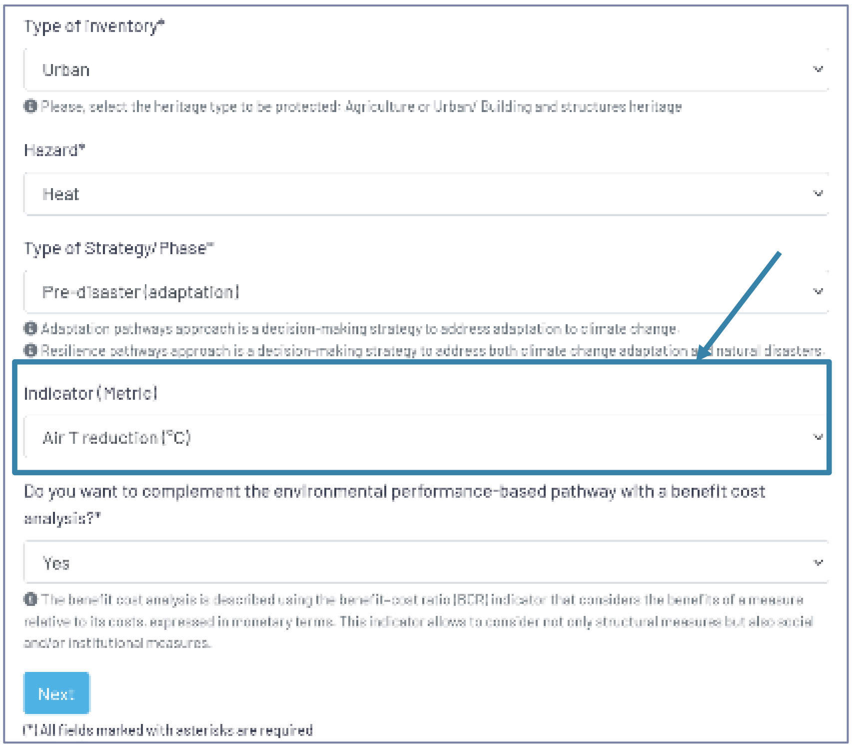


Figure 71. Step 1 page –settings for an urban heritage adaptation approach

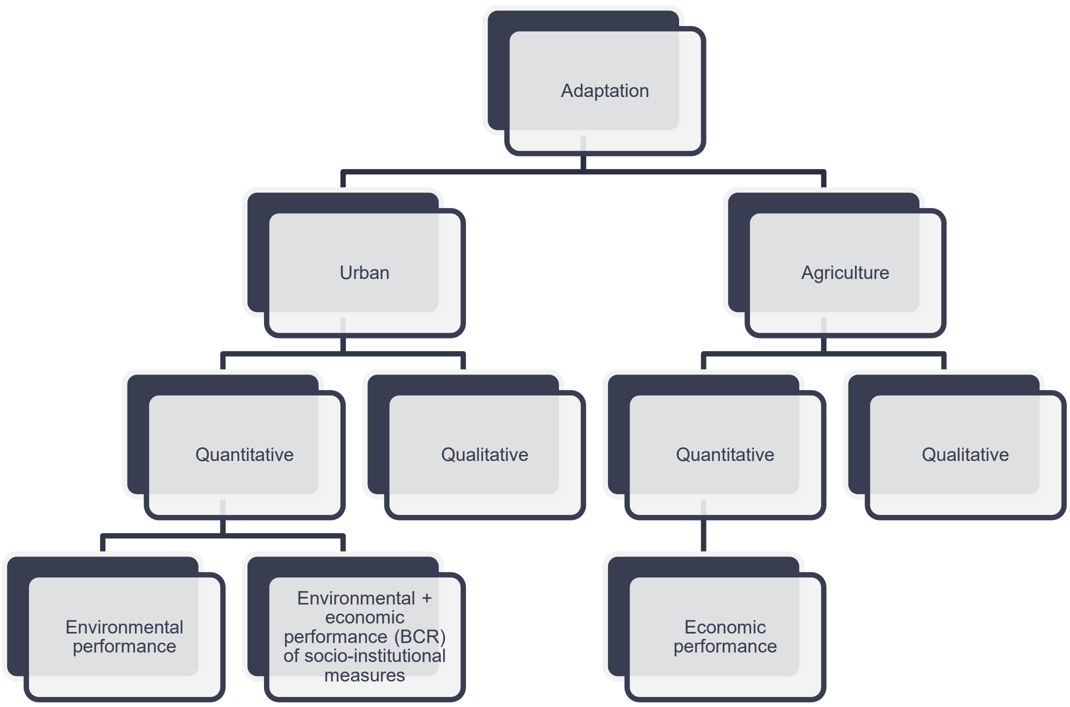


Figure 72. Decision- tree behind the RPVT

4.2.2. Step 2: Vision construction and setting up objectives

At this page (Figure 73) you have to describe the objectives regarding adaptation or resilience for your historic area. An objective can be quantitative or qualitative and describes a desired result that wants or needs to be achieved in the future (See Step 1 and more in particular Step 1.4 from the Resilience Pathway Handbook). The degree of detail depends on how much previous work has been done at historic or urban area. At first stage the settings of these objectives can be ambiguous, but the design of a new pathway can also help to better define more context-oriented objectives.

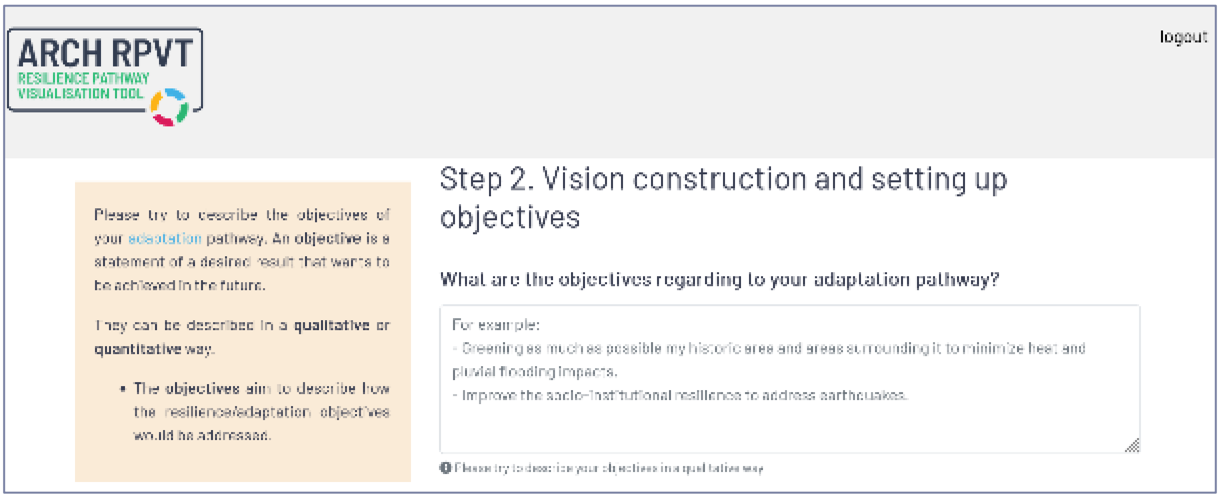


Figure 73. Step 2 page to describe the objectives to be reached

4.2.3. Step 3: Select resilience/adaptation options

At this step the RPVT automatically provides you the list of resilience measures available and applicable for the specific characteristics of your pathway (step 1).

As it is showed in Figure 74, the **central part of this page** provides the environmental effectiveness and economic efficiency of each of the measures (if available). The economic performance is assessed using the *BCR indicator* that considers the benefits of a measure relative to its costs, expressed in monetary terms. Various environmental indicators, which can be selected in Step 1, can be chosen to characterise the measures' effectiveness.

You can re-organize the measures in this central window by ordering them considering their environmental or economic performance. Or look for a specific one by typing the text you are looking for. Close to each measure you can also click on the factsheet link to see in detail the characteristics of the measure.

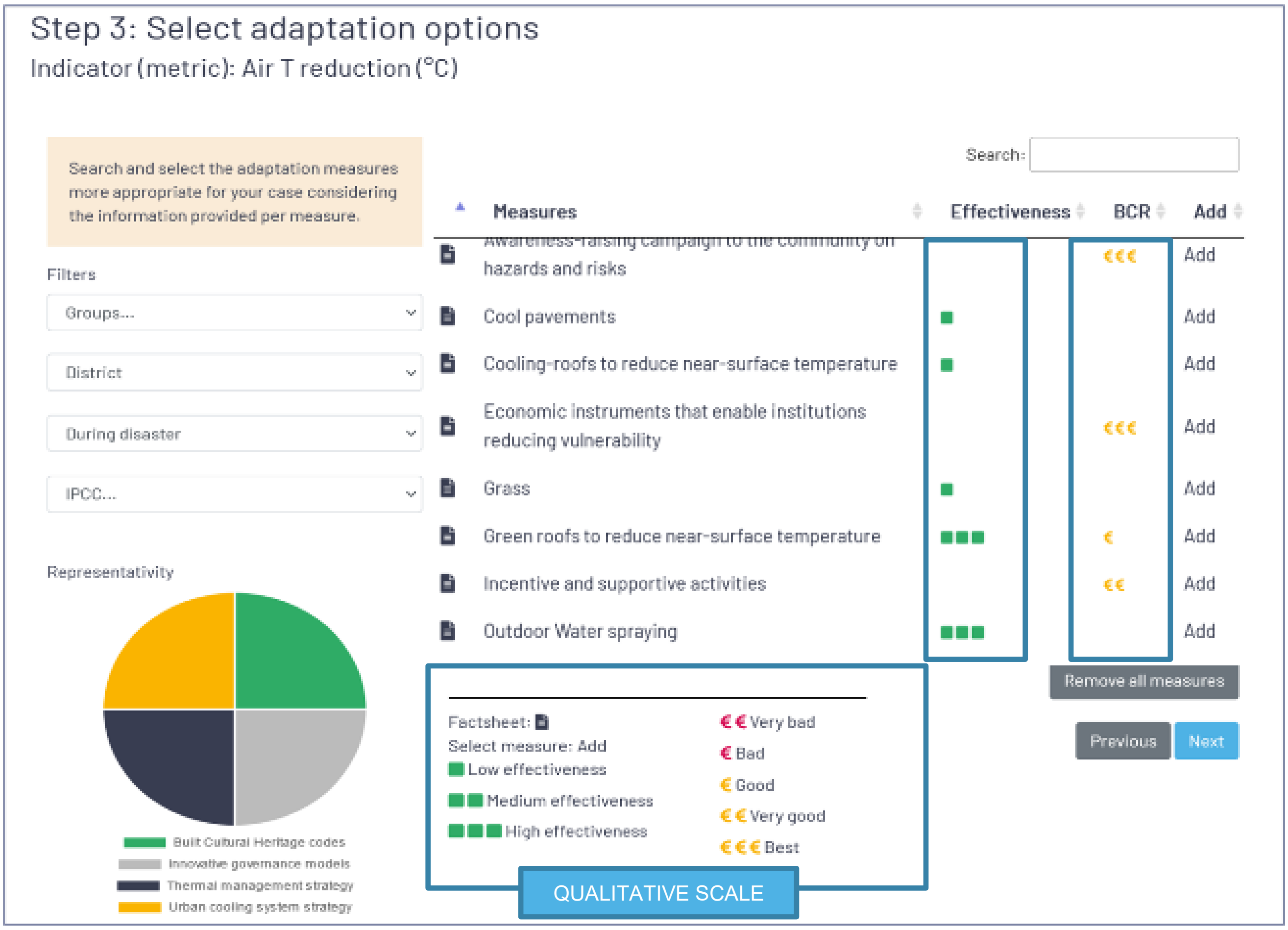


Figure 74. Functions and information provided in Step 2 page

Note that measures have been classified depending on the *average* performance per metric achieved in the analysed case studies following assigned threshold ranges. As environmental and economic performance can depend on the local context it is more desirable to present the performance using qualitative scales. Next tables show the metrics (Table 17 and Table 18) and qualitative scales (Tables 19-25) for each indicator available at the RPVT.

Table 17. Metrics used for heat related environmental indicators at the RPVT

Air Temperature Reduction	ºC
PET (Physiological Equivalent Temperature) reduction	ºC
Indoor air Temperature Reduction	ºC

Table 18. Metrics used for flood related environmental indicators at the RPVT

Flooding area reduction	%

Runoff Reduction	% or cm
Infiltration rate	mm/h

Table 19. Qualitative performance scale for air temperature reduction

Air Temperature Reduction > 2 ºC	High
1 ºC < Air Temperature Reduction ≤ 2 ºC	Medium
0 ºC < Air Temperature Reduction ≤1 ºC	Low
Air Temperature Reduction = 0	Not effective

Table 20. Qualitative performance scale for PET reduction

PET Reduction > 3.5 ºC	High
0.75 ºC < PET Reduction ≤3.5 ºC	Medium
0 ºC < PET Reduction ≤ 0.75 ºC	Low
PET Reduction = 0	Not effective

Table 21. Qualitative performance scale for indoor temperature reduction

Indoor Temperature reduction > 4 ºC	High
2 ºC < Indoor Temperature reduction ≤ 4ºC	Medium
0 ºC < Indoor Temperature reduction ≤ 2 ºC	Low
Indoor Temperature reduction = 0	Not effective

Table 22. Qualitative performance scale for flooding area reduction

Flooding area reduction > 50%	High
20% < Flooding area reduction ≤ 50%	Medium
0% < Flooding area reduction ≤ 20%	Low
Flooding area reduction = 0%	Not effective

Table 23. Qualitative performance scale for runoff reduction

Runoff Reduction > 30%	High

10% < Runoff Reduction ≤ 30%	Medium
0% < Runoff Reduction ≤10%	Low
Runoff Reduction = 0%	Not effective

Table 24. Qualitative performance scale for infiltration rate

Infiltration rate > 35 mm/h	High
10 mm/h < Infiltration rate ≤ 35 mm/h	Medium
0.5 mm/h < Infiltration rate ≤ 10 mm/h	Low
0 mm/h ≤ Infiltration rate ≤ 0.5 mm/h	Not effective

Table 25. Qualitative performance scale for BCR economic indicator

BCR > 10	Best
5 ≤ BCR ≤ 10	Very good
1 ≤ BCR < 5	Good
0 ≤ BCR < 1	Bad
BCR <0	Very bad

The **left-hand side of this window** provides you different types of filters to help narrowing down the search for suitable resilience measures, if necessary. If measures have been already identified using the RMI, you can just directly select by clicking the “add” button on the right side of the effectiveness or BCR column. Please, note that in Step 3, only resilience measures with associated effectiveness or efficiency will be shown, unless a qualitative pathway approach has been selected in Step 1.

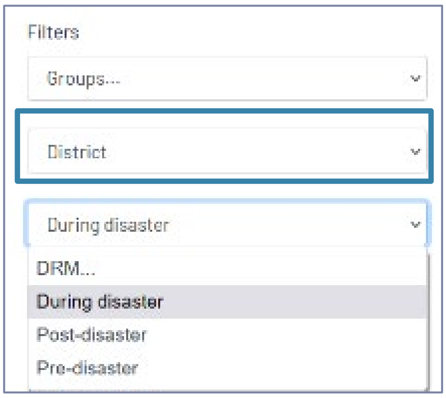


Figure 75. Filters categories

To select the appropriate choice for each filter, click on the filter you are interested on and select one of the listed categories. For example, as seen in Figure 75, the category *District* has been selected under "Scale" filter. In the same manner, if "DRM[33]" category is selected a list of available options (pre-disaster, during-disaster, post-disaster) are listed and the user can select from them. It has to be highlighted that the more filters are used the more restrictive the search will be. Note that an iterative search can be made until the final selection of desired and suitable measures is achieved. In case there is a need to amend the selection of the filters, there is a way to erase the filter selection by going back to the filter and removing that option.

You can select the desired options within one or more filters, afterwards the list of available measures will appear in the central part of this window (See Figure 76). Click on the "Add" button to add a specific measure into the portfolios of measures or click on "Select all measures" to add all your filtered measures into the portfolio.

Please note that all your selected measures appear in the "Selected measures" panel (at the bottom of the screen). You can go back at any moment by removing any of the previously selected measures or by removing all of them and start again.

Figure 76. Central part of the window to visualize the factsheet of the measure, select the measure by clicking the "Add" button or remove it by clicking on the "remove" icon.

[33] Disaster Risk Management

The last functionality of this window is to provide a graphical information of the representativity of the selected measures (Figure 77) with regard to the group to which they belong (groups are explained in the RMI, for further information, please visit the RMI tool or its user guide), so, you can easily visualize the balance of the different type of measures selected. This representation is especially important when a qualitative approach pathway is performed and there is no information available regarding the environmental or economic performance. You can always perform a selection of measures based on stakeholder knowledge and ad-hoc prioritisation exercises, which can be an input on the pathway development process using the RPVT.

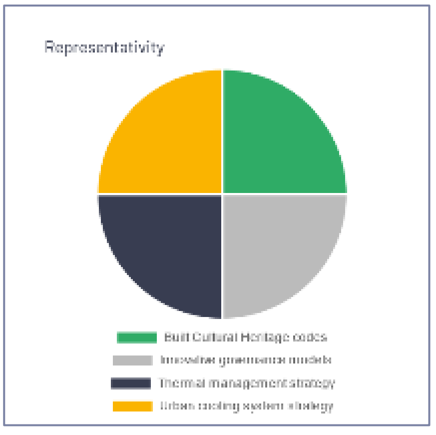


Figure 77. Example of graphical representativity of the selected measures. See also Figure 74, where this part of information appears at the bottom left-hand corner.

For more information on these, go to the RMI or directly click on this link to get access to the list of ARCH groups and subgroups for the urban/ building & structures heritage.

4.2.4. Step 4: Pathway alternatives

This step will support you to build various pathway alternatives[34] in order to benchmark them and help you to identify which group of measures are best to achieve the resilience goals (For further information see step 3.1 from the Resilience Pathway Handbook).

Once you have selected a list of suitable resilience measures there are two different options on how to proceed:

1. **You can manually create a pathway alternative by individual selection of measures** (the approach by which measures are selected are either not included in the RPVT or it is based on stakeholder knowledge). To work on this option, you don't need to set a criterion, you just need to manually select or deselect the measures based on expert criteria and/or the predefined portfolio from the RMI (information provided by the RMI factsheet). This option allows the user to graphically visualize the performance of each individual measure as well as the total pathway alternative performance by

[34] A pathway alternative is a cluster of resilience measures, similar to a resilience or adaptation strategy

using the bar-chart (shown in Figure 78 in the green box) graphical interfaces that appear on the right-hand side of this window.

2. **You can create and compare different pathway alternatives based on specific criterion/ia**. To work on this option the user will need to select the criteria settings available on the left-hand side of this window (shown in Figure 16 in the blue box). Depending on the criteria applied, the central part of the window will be filled with the measures that fulfil the criteria previously identified. The user can easily remove or modify the criteria but cannot manually select the measures as they are filtered according to the specified criteria. Similar to previous option, the right-hand side window automatically shows the performance of each pathway alternative that is created.

Figure 78 presents the overall Step 4 page with the different parts of the window. The unique mandatory input requested is the *name* of the pathway alternative. If you create more than one alternative, then you need to add a different name for each pathway alternative.

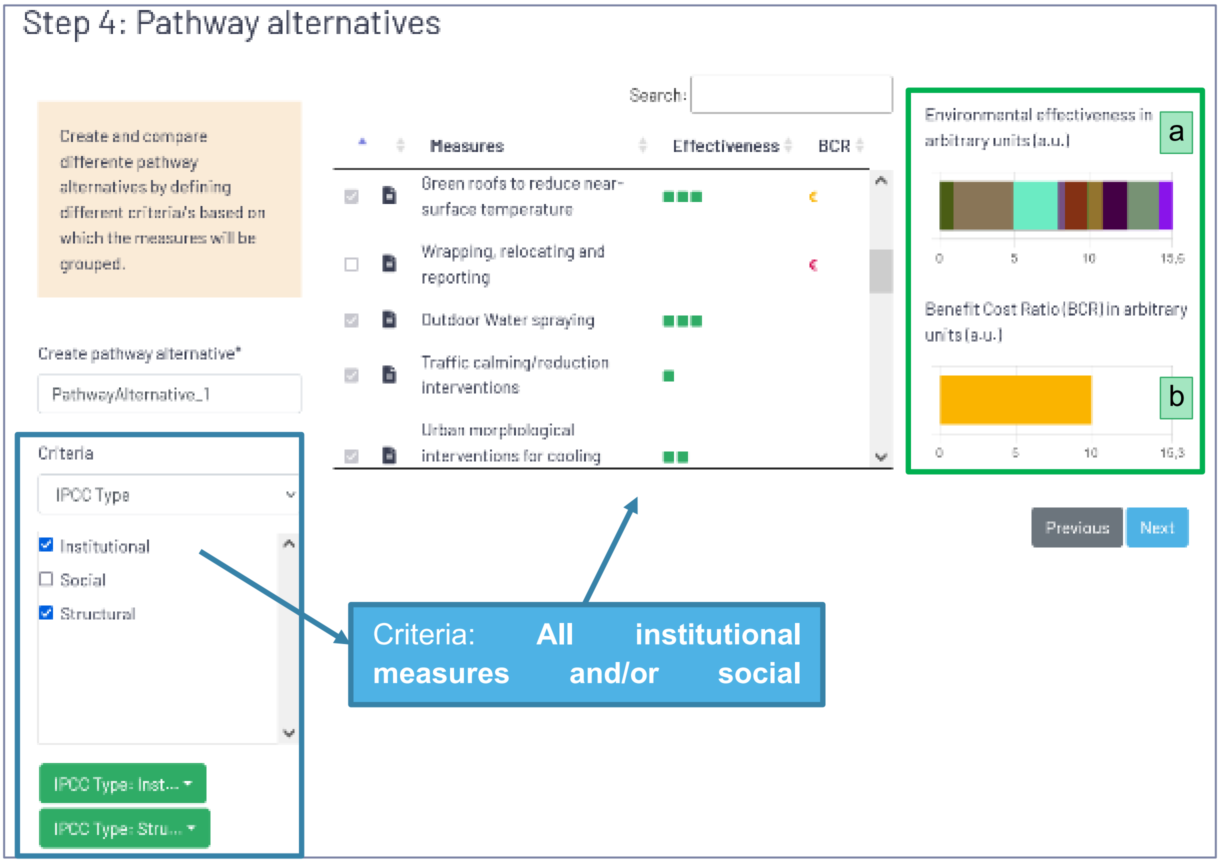


Figure 78. Step 4- page, left-hand side contains the criteria filter window, the central side provides the list of available measures window and right-hand side provides the performance window.

Based on the list of available measures (manually selected or based on a specific criteria) the right-hand side window shows either or both, (i) the physical environmental effectiveness of the pathway alternative (cluster of measures) and (ii) the cumulative economic efficiency of the pathway alternative based on a benefit-cost ratio analysis. See as an example the Figure 78(a) and (b) which allows you to compare different pathways alternatives at glance.

If you want to specify a criterion, click on the “**Criteria**” drop-down input menu and select one of the available categories. Once a category is selected the list of available options for that category are presented. Next, Figure 79-Figure 85 present each category and the description of the options available for each. A criterion is defined by several categories constraints and based on the established criteria the list of available measures fulfilling that criterion is presented in the central window. Note that each new category settings into the criteria imply more restrictions and therefore less measures will be available.

You can modify the criteria applied by removing any of the restrictions to any of the categories previously established. This information is available at the bottom of left-hand side window (green boxes) so that the user can easily visualize the established criteria.

There is a total of 7 different types of categories to define a criterion:

Group category. You can select any of the groups defined in the RMI. Note that if more than one option is selected the criteria is established by selecting the measures that fulfil any of the selected options.

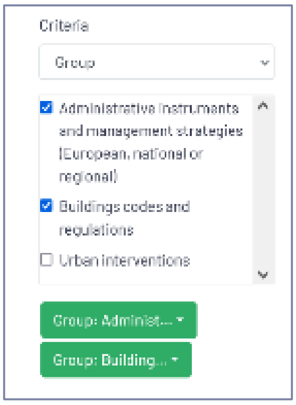


Figure 79. “Group” category

IPCC Type: This category refers to the categories of resilient options defined by the Intergovernmental Panel on Climate Change (IPCC). You can choose from structural, social or institutional. Note that if more than one option is selected the criteria is established by selecting the measures that fulfil any of the options.

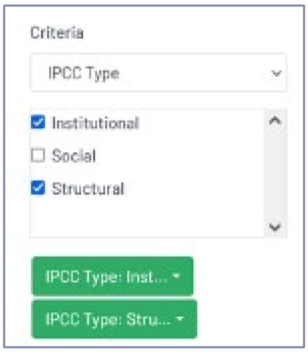


Figure 80. “IPCC Type” category

Spatial Impact: Spatial impact refers to the changes occurred in the distribution or occupation of an area or space due to arrangements made by the application or implementation of the described solution. You can select from major, minor, N/A, None or outstanding options to set a criterion.

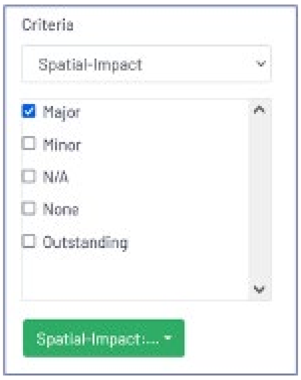


Figure 81. “Spatial Impact” category

Visual Impact: Visual impact refers to the aesthetic or appearance change resulted when applying the described solution. You can select the degree of visual impact, ranging from: *major change*: remarkable <u>*negative*</u> visual effect in the heritage resulted from applying the described solution to *no change (N/A)* where no visible changes can be appreciated in the heritage element to which the solution has been applied or implemented.

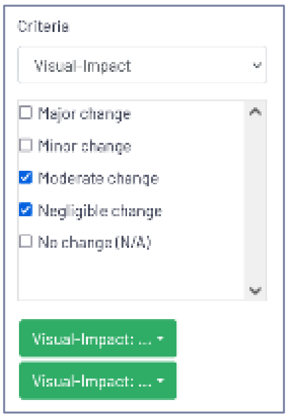


Figure 82. Visual Impact category

Physical Impact: This category refers to the aspects that the solution may influence on the mechanical performance and moisture performance. You can select from *positive impact* : when the physical properties are improved to *negative impact where a* harmful physical damage may occur in the heritage resource or *none impact.*

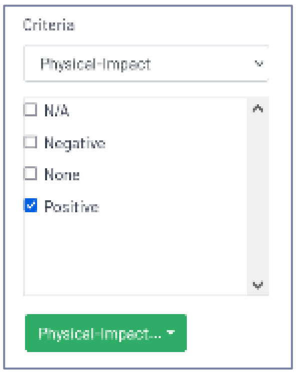


Figure 83.Physical Impact

Contribution to climate change (CC): This category refers to how the solution or implementation of the solution contributes to mitigate climate change, by for example reducing CO_2 emissions. The options available are *yes*, *not* or *not applicable*.

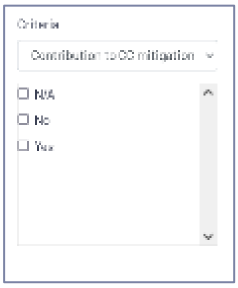


Figure 84. Contribution to CC category

Avoid negative effects: This category refers to possible negative effects of the solution. The options available are the whole list of negative effects that different measures may have. In this case, by selecting in any of the listed negative effects the measures having those negative impacts will be removed from the list.

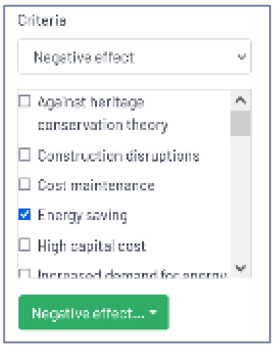
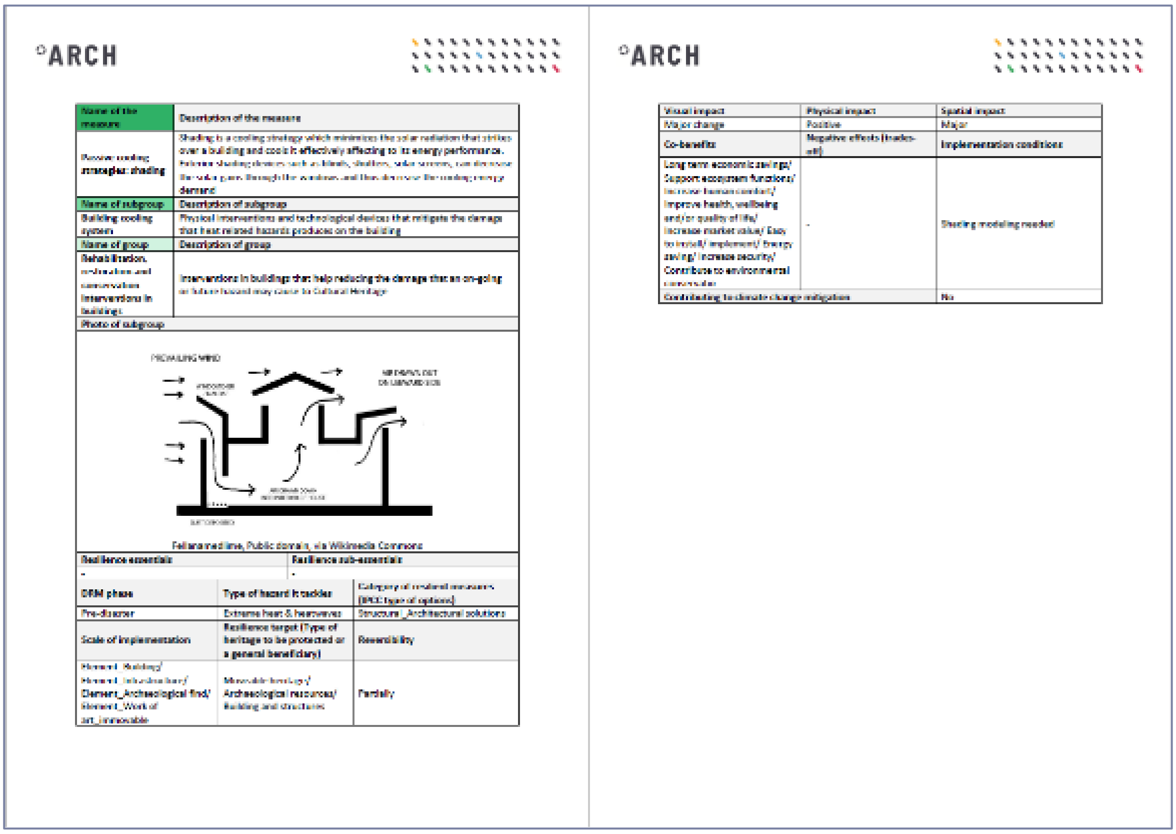


Figure 85. Negative Effects category

Apart of the above criteria categories to gather *clusters of measures* sharing the same criteria, the user can check the detailed information of each of the listed measures by clicking on the "factsheet" button available at the left-hand side of each measure. Next Figure 24 shows an example of the information available for each available measure. In this case, "*Passive cooling strategies: shading*" adaptation measure has been selected. The factsheets explains how this measure minimizes the solar radiation that strikes over a building and cools it effectively, but additionally it provides more information regarding the measure, such as group and subgroup to which belongs, as well as the type of hazard it tackles, in this case "*Extreme heat & heatwaves*", or scale of implementation, type of heritage to be protected, reversibility, visual impact, physical impact, spatial impact and the rest of information. Note, this information is stored in the RMI.



Name of the measure	Description of the measure
Passive cooling strategies: shading	Shading is a cooling strategy which minimizes the solar radiation that strikes over a building and cools it effectively affecting to its energy performance. Exterior shading devices such as blinds, shutters, solar screens, can decrease the solar gains through the windows and thus decrease the cooling energy demand
Name of subgroup	Description of subgroup
Building cooling system	Physical interventions and technological devices that mitigate the damage that heat related hazards produces on the building
Name of group	Description of group
Rehabilitation, restoration and conservation interventions in buildings	Interventions in buildings that help reducing the damage that an on-going or future hazard may cause to Cultural Heritage
Photo of subgroup	

Fellanamedlime, Public domain, via Wikimedia Commons

Resilience essentials	Resilience sub-essentials
-	-

DRM phase	Type of hazard it tackles	Category of resilient measures (IPCC type of options)
Pre-disaster	Extreme heat & heatwaves	Structural_Architectural solutions
Scale of implementation	Resilience target (Type of heritage to be protected or a general beneficiary)	Reversibility
Element_Building/ Element_Infrastructure/ Element_Archeological find/ Element_Work of art_immovable	Moveable heritage/ Archeological resources/ Building and structures	Partially

Visual impact	Physical impact	Spatial impact
Major change	Positive	Major
Co-benefits	Negative effects (trade-off)	Implementation conditions
Long term economic savings/ Support ecosystem functions/ Increase human comfort/ Improve health, wellbeing and/or quality of life/ Increase market value/ Easy to install/ implement/ Energy saving/ Increase security/ Contribute to environmental conservation	-	Shading modeling needed
Contributing to climate change mitigation		No

Figure 86. Example of a downloaded PDF factsheet

In this step, the user can work only with a unique pathway alternative or create several pathways. To do so, click on the button "*Add another Pathway alternative*" Add another Pathway alternative and a new window will appear to specify new criteria based on which a different cluster of measures will be listed. This option allows you to visualize and compare the effectiveness of each pathway alternative and to select the most appropriate one to continue.

4.2.5. Step 5: Sequencing of resilience measures

Once a pathway alternative has been chosen, this step provides a canvas to support the sequence of resilience measures over time. There are three types of visual representations available depending on the type of pathway and specific objectives:

1. **Qualitative representation**
2. **Quantitative representation based on the environmental effectiveness**
3. **Quantitative representation based on the economic efficiency: Benefit Cost Ratio (BCR) analysis**

Qualitative representation

This type of representation is provided when no metric is chosen by the user (in step 1). The aim of this graphical representation is to offer a visual way to plan different type of measures over time.

To start this pathway representation, you just need to set the *timeline (start and end year)* of the different possible scenarios: *“small change scenario”, “significant change scenario” and “worst case scenario”* that will be part of your pathway representation. Next figure (Figure 87) shows you the “by default” values for each scenario. To change these values, click on the input text and set any other year. These values can also be modified later on by the user as conditions evolve or new knowledge is available. These dates should therefore be indicative as it is important to have the necessary flexibility to act and deploy new measures when needed.

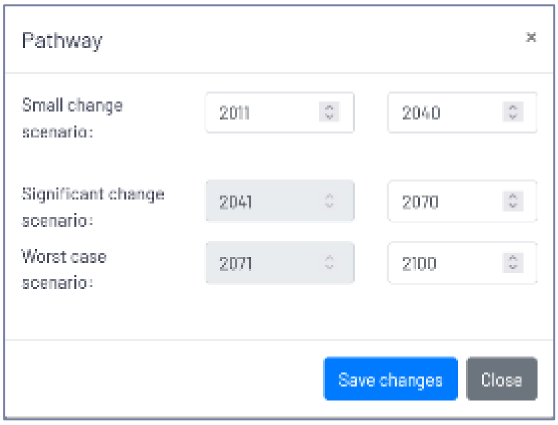


Figure 87. Definition of the timeline of the reference period per each scenario

Next, you only need to click on any of the available measures to sequence/plan it into the scheduled timeline. The RPVT will request through a pop-up window (Figure 88) the *start/end year* based on which the measure will be scheduled in the canvas. Being the first measure, there is no previous measure to select from.

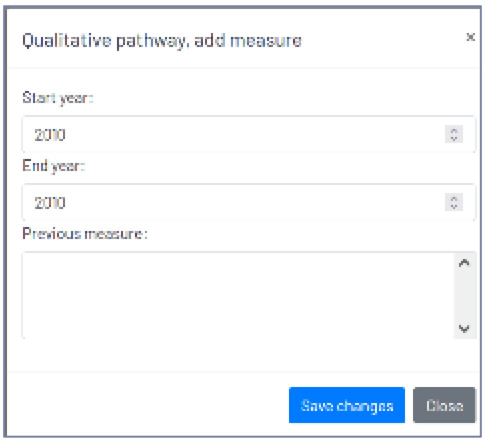


Figure 88. First measure of a Qualitative pathway

From now on, once you select a new measure to be scheduled in the canvas, you repeat the same action as before, apart from that to set the *start/end year.* In addition, you need to specify the previous measure to which this new measure follow. Figure 89 shows an example of how measures can be scheduled over different years.

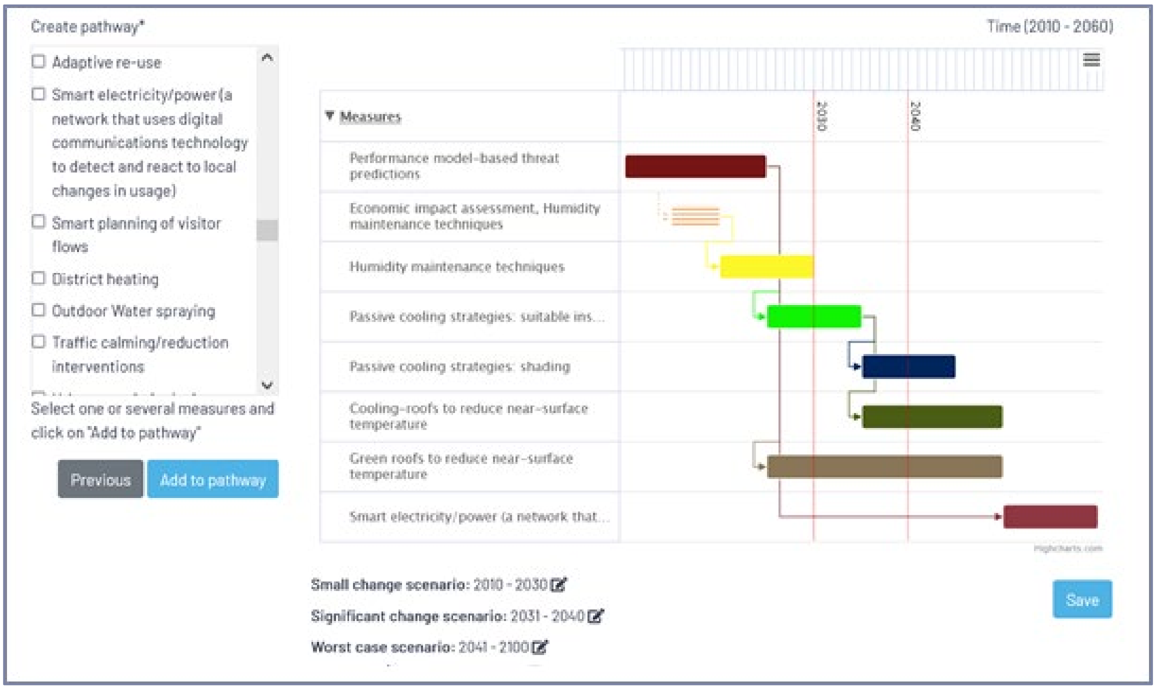


Figure 89. Example of qualitative pathway

The user can modify or remove any of the planned measures by directly clicking on the canvas and selecting it. Also, the timelines of each of the reference periods can be modified at any moment.

Please note, that more than one measure can be deployed simultaneously (e.g. economic impact assessment and humidity maintenance techniques). These measures will be shown as striped lines. When names are very long, these will not be completely shown. In order to see the full name, the user needs to leave the mouse over the name for few seconds and a new box with the full name will appear as shown in Figure 90.

Figure 90. Long name measures in the canvas

Quantitative representation based on the physical performance.

This representation allows to graphically represent and plan different types of options taking into account the environmental physical performance of the measures considering a physical metric (previously chosen, in step 1).

To start this pathway representation, click on one of the listed measures. Just afterwards, the RPVT requests your three inputs parameters (see Figure 91) that allow you to characterize the measure in your specific context. You will need to enter the location where this measure will be implemented, the exact number of square meters to be implemented, as well as the scenario in which the measure is planned to be implemented. These “small change scenario”, “significant change scenario” and “worst case scenario” options aim to represent the intensity or frequency of the hazard. They are linked to different temporal periods (that can be pre-configured), the farther in time, the more intense or frequent the hazard would be.

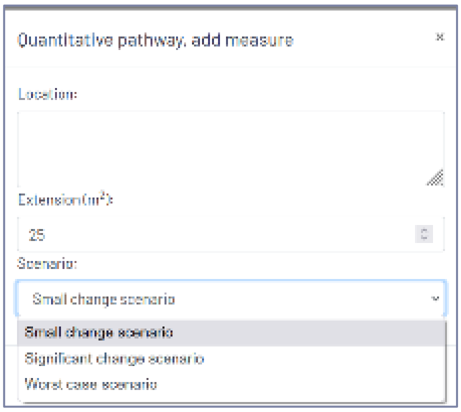


Figure 91. Requested parameters for a new measure in a quantitative pathway

Once you click on “Save changes”, the measure is placed into the canvas, and you can select a new measure and repeat the previous process to configure the rest of the measures. Each measure is configured accordingly with the specific needs and objectives to be reached. Next figure (Figure 92) shows the graphical representation of several planned measures over the canvas. As it can be observed, this window offers two important parameters to the user: the cumulative square meters where resilience measures have been deployed and the performance assigned to the difference areas.

The user can modify or remove any of the planned measures by clicking on directly on the canvas and selecting the measure to be modified or removed.

To save the changes on this pathway, click on “Save” button. If later on, you continue adding new measures over this pathway, remember to press again the “Save” button to save last changes. Note that different pathways can be stored in the database, so that you can visualize different possibilities.

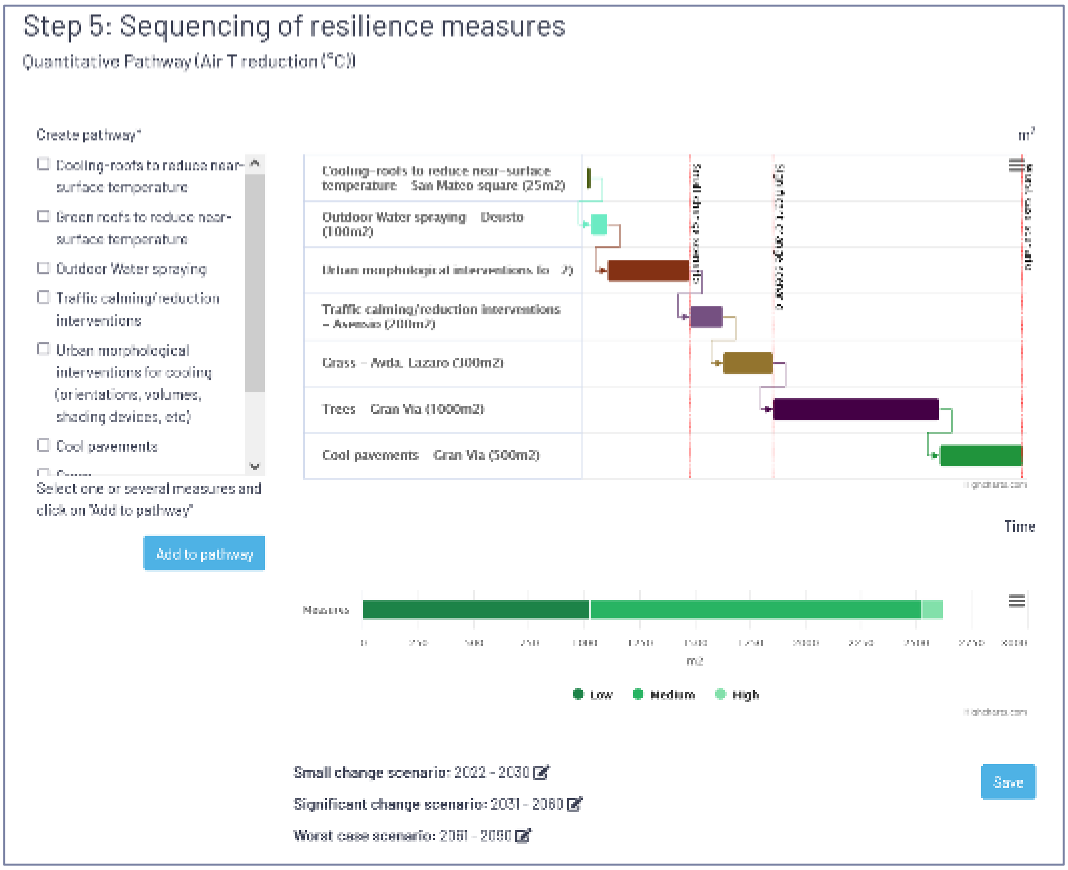


Figure 92. Example of quantitative pathway

Quantitative representation based on the BCR analysis

This type of representation is provided by the RPVT when the metric chosen is the BCR indicator. Similar to the previous representations, to start this pathway, you just need to set the *timeline (start and end year)* of the different scenarios: *"small changes scenario", "Significant changes scenario" and "Worst case scenario"*. Next figure (Figure 93) shows an example of dates per scenario, but these dates are only tentative to plan as it is important to have the necessary flexibility to act and deploy new measures when needed. But these dates can be changed very easily, by clicking on the input text and setting any other year.

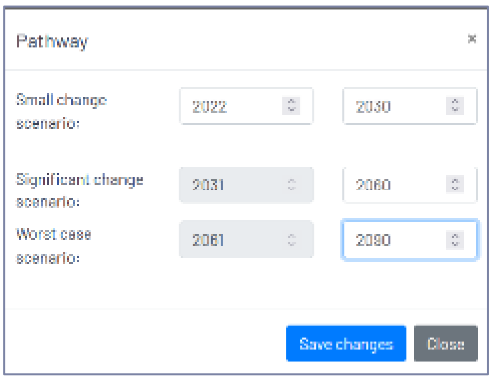


Figure 93. Example of start and end dates per scenario

First, click on “Save changes”, to start the sequencing of measures into the canvas. Next click on one of the listed measures (on the left-hand side part of the window) and click on “Add to pathway” to enter that measure into the roadmap, after that you will only need to select in which of the possible scenarios you are willing to implement the measure *“small changes scenario”, “Significant changes scenario” and “Worst case scenario”*, by selecting on one of them and clicking on “Save changes”. The measure will be automatically placed into the canvas, and you will easily visualize its economic performance based on the BCR indicator.

You can repeat exactly the same for the rest of the measures. Next figure (Figure 94) shows the graphical representation of several planned measures over the canvas.

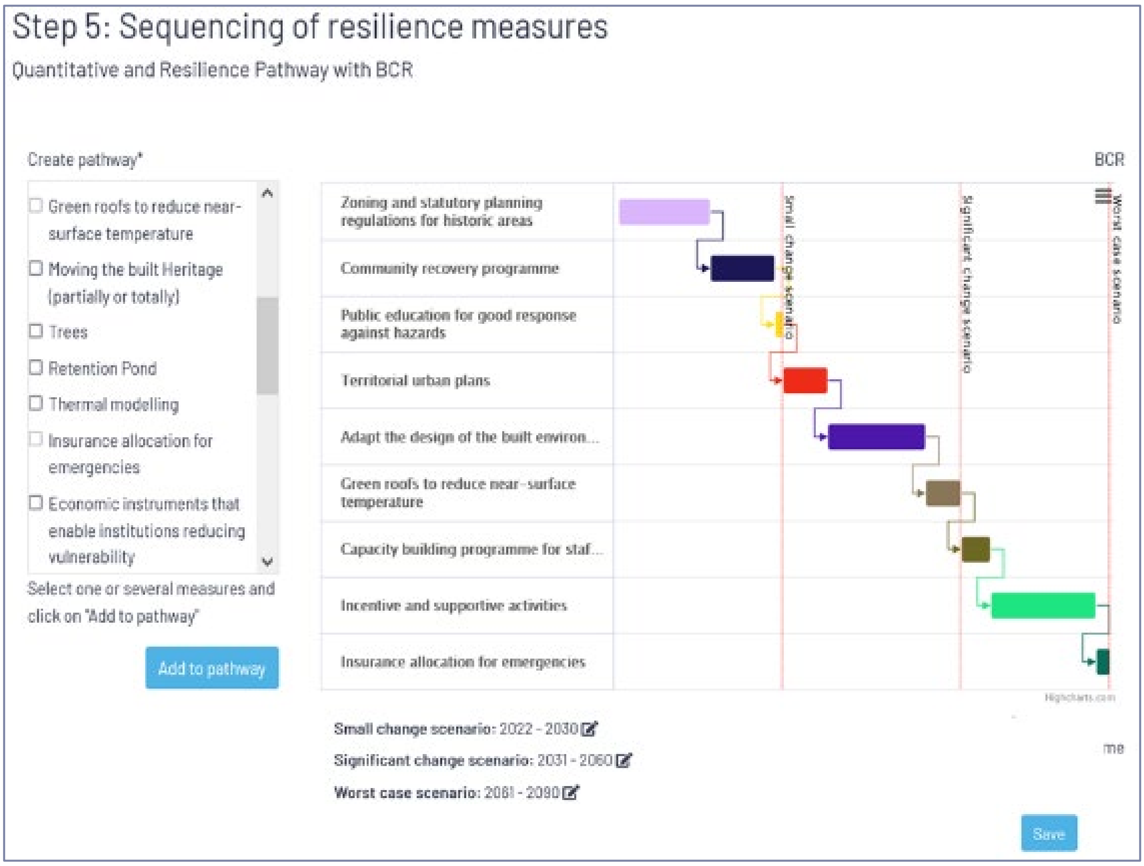


Figure 94. Example of quantitative pathway based on BCR

Similar to the previous canvas representation, you can modify or remove any of the planned measures by clicking on directly on the canvas and selecting the measure to be modified or removed, and to save the changes, click on “Save” button. If later on, you continue adding new measures over this pathway, remember to press again the “Save” button to save last changes.

5. Use cases of the RPVT

5.1. Use case 1: Improve social and institutional resilience for seismic risk

You would like to improve both social and institutional resilience for better management of seismic risk

You firstly need to set the main characteristics of this pathway by providing the requested input parameters. As showed in Figure 95, you just need to select an *urban* type of pathway and *earthquake* as hazard. As you can see in Figure 96, the RPVT automatically provides you the unique approach available for this type of pathway ("*resilience*"), and the "BCR" (benefit-cost-ratio) indicator is selected by default.

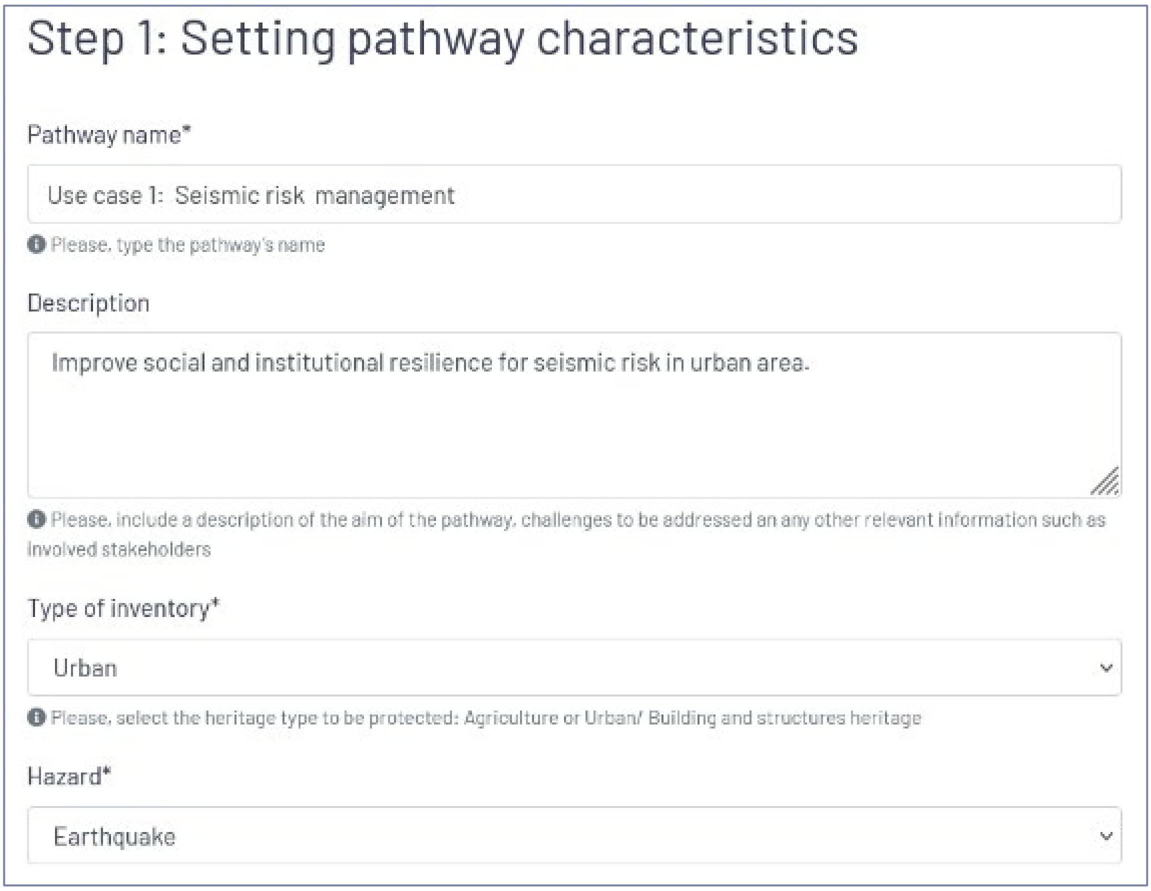


Figure 95. Setting the characteristics for the seismic risk case based on BCR analysis (I)

Figure 96. Setting the characteristics for the seismic risk case based on BCR analysis (II)

Click on “Next” button to enter into Step 2 (Figure 97) where the objectives and aim of the pathway have to be described.

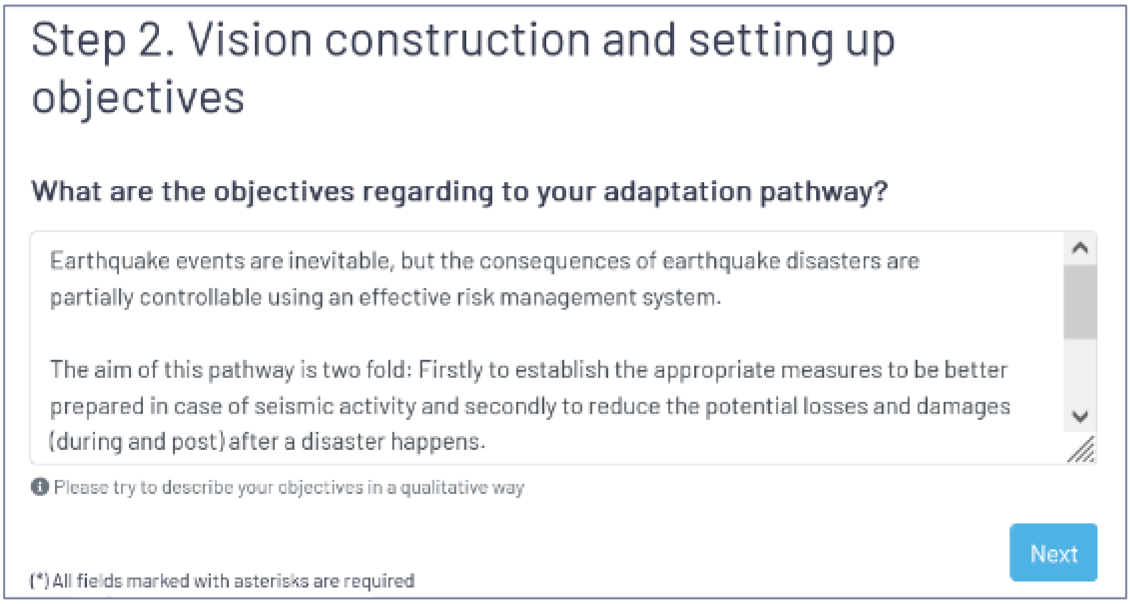


Figure 97. Description of the aim and objectives for this pathway

Click on “Next” button to enter into Step 3. The Step 3 window (Figure 98) provides the list of measures available together with the economic efficiency of each measure (as you can see, only measures for which BCR has been gathered) based on a 5-ranged scale.

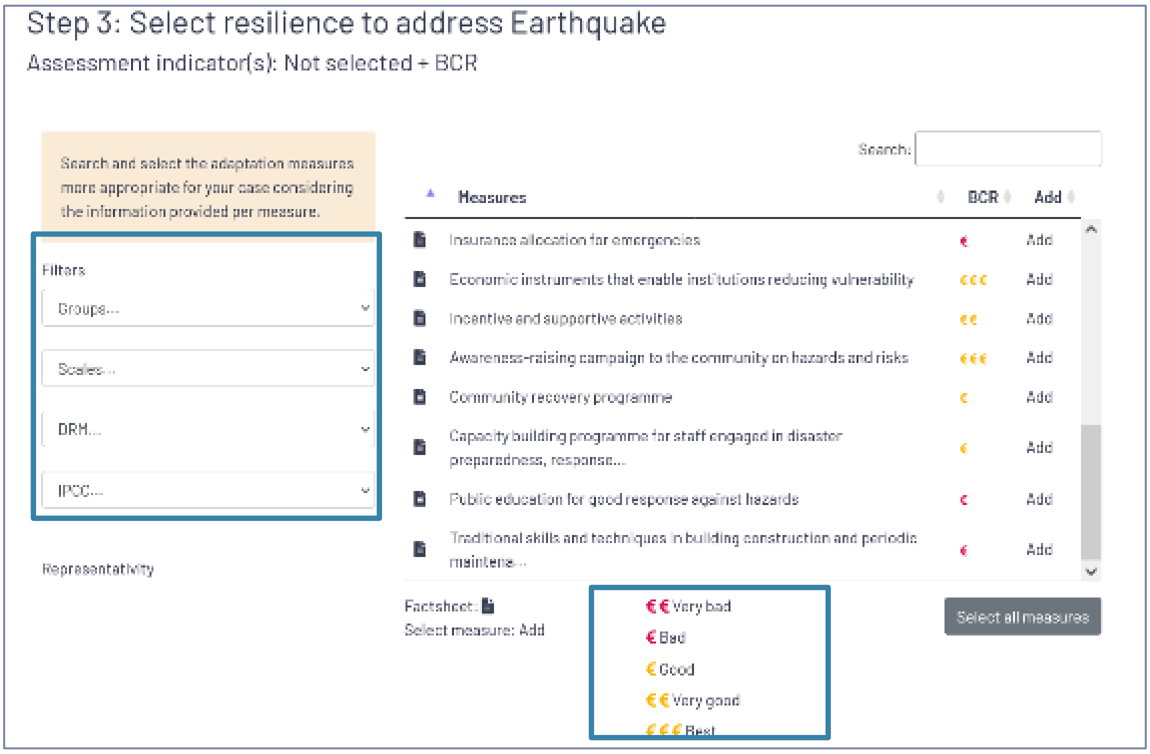
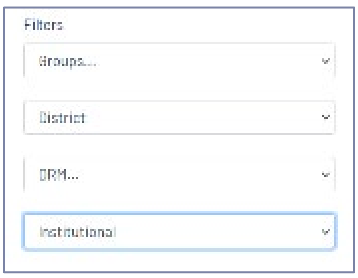


Figure 98. List of available measures of seismic risk management

At this step, you can set different *filters* to search for different types of measures. Since in this case you are only interested in the social and institutional measures, these two filters are applied by selecting these two options in the IPCC category, See Figure 99 and Figure 100, where those filters are set, and the available measures for each filter are showed.



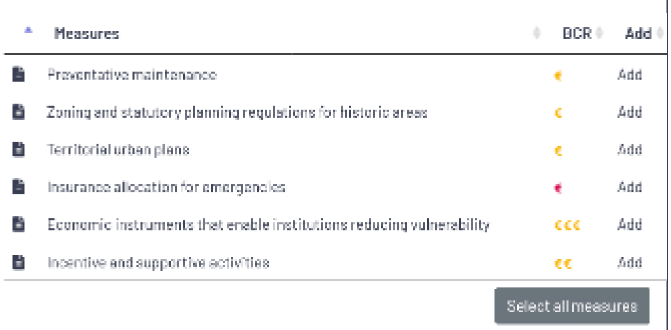


Figure 99. Filter-I. Institutional measures

Figure 100. Filter-II. Social measures

Once the different available measures are listed on the left-hand side, you can click on the "*Select all measures*" button to add all filtered measures into the portfolio of measures for the next step.

As the user is interested in *pre-, during and post-disaster*, the DRM filter is not used in this case, but could also be used to restrict the portfolio of measures to any of these phases in any other case. Meanwhile, the left-hand side of the window displays the representativity of each measure, by showing the subgroup of measure to which they belong. This also allows the user to react by removing or adding additional measures not well represented or balanced. See next Figure 101, with different representativity charts considering different measures.

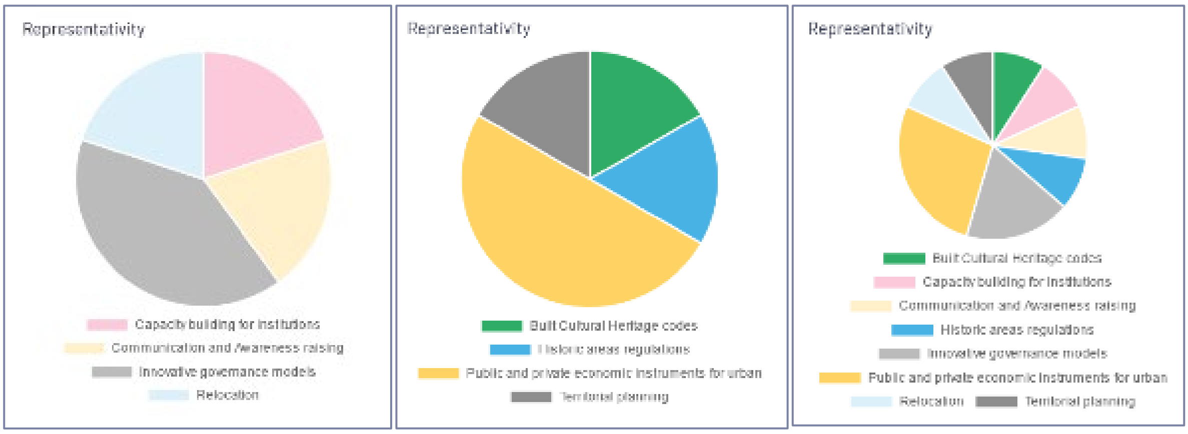


Figure 101. Representativity of the social measures (a) and representativity of the institutional measures (b) and social + institutional measures representativity

Click on "Next" button to enter into Step 4, where the central part of this window provides the selected measures in previous step. In this step 4 you are allowed to benchmark different pathways alternatives by considering different combinations of measures based on a specified criterion. In this case (Figure 102, Figure 104) the user creates two pathway alternatives by naming them as Alternative 1 and Alternative 2 to compare the bundle BCR effectiveness.

Figure 102. Pathway alternative 1 – where only administrative instruments are considered, – (left) total BCR of measures considered

Figure 103. Pathway alternative 2. Where all except administrative instruments are considered – (left) total BCR of measures considered

At this step, you can see at glance that administrative instruments are best option. So, you can click on the "Next" button of any of the created alternatives to design the pathway of that alternative.

In the next window – Step 5 (Figure 104), you are able to see all selected measures on the left-hand side of the window, that you can select to drop it into the canvas.

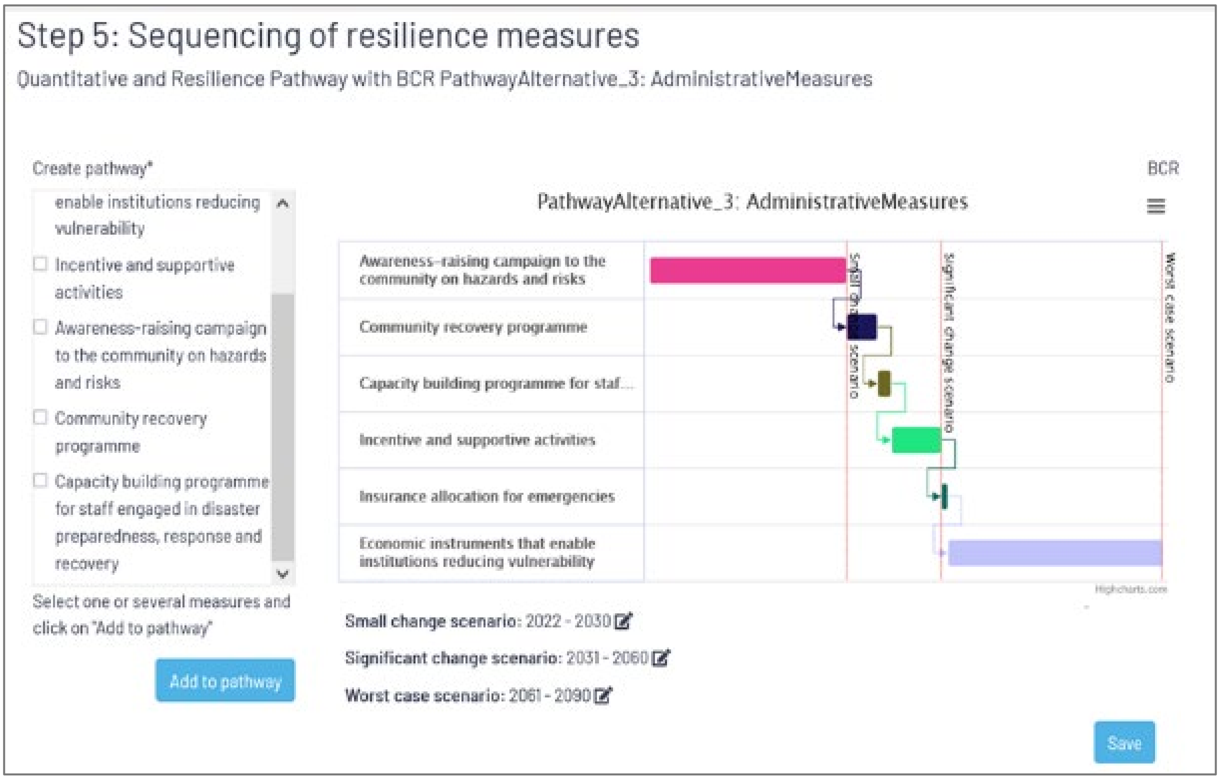


Figure 104. Pathway created to prepare the city to seismic risk events considering administrative instruments only

By adding the measures into the canvas, you can easily create a quantitative roadmap representation and easily visualize the economic efficiency of each based on the BCR analysis.

You can adapt or modify this pathway in this step, but you can also go back to the previous step and select additional measures to be included in this roadmap in case you are interested in doing so, for example by adding other type of measures.

In the previous canvas the timeline of the *"small changes scenario", "Significant Changes scenario" and "Worst case scenario"*, are linked to 2022-2030, 2031-2060 and 2061-2090, but you can configure and change at any moment these *timelines (start and end year)* of the different scenarios by clicking on the icon close to each scenario. Then a new window will appear to change these values (Figure 105).

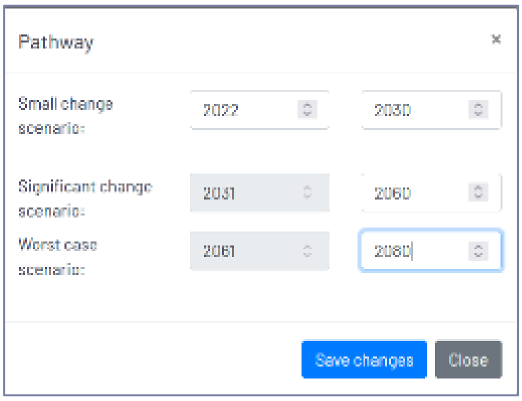


Figure 105. Pop-up window to modify the time periods linked to each scenario

5.2. Use Case 2: Improve resilience in agricultural management

I would like to increase both social and institutional resilience by developing agricultural resilient communities and improving the water management techniques. Which subgroup of measures would be appropriate for this purpose? How to create a roadmap to best organize these measures considering a qualitative approach?

Firstly, the user needs to set the main characteristics of this pathway, such as the name of the pathway "*Use case 2: Multihazard Agricultural Management*", as well as the type of pathway. In this case, as the user is interested in a multi-hazard and qualitative approach, these options are selected in step1 (See Figure 106 below). As you can see below, in this case, the type of strategy is automatically set to *adaptation,* as for agriculture type of heritage resilience approach is not considered. Last selection is to set no metric, as in this case we are interested in a qualitative analysis.

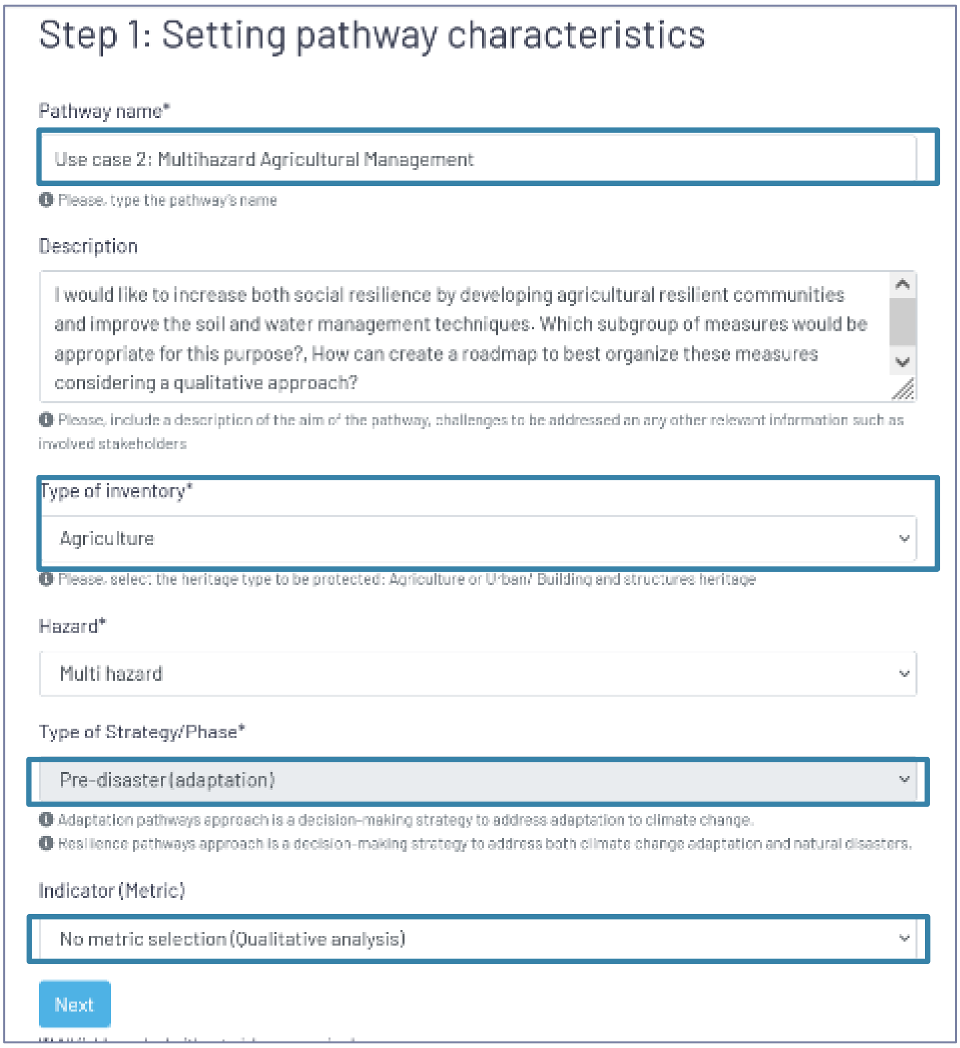


Figure 106- Use case 2 - Setting the pathways characteristics of Use Case 2

Click on "Next" button to continue the process and specify the specific objectives to be achieved as well as any other aim by other stakeholders.

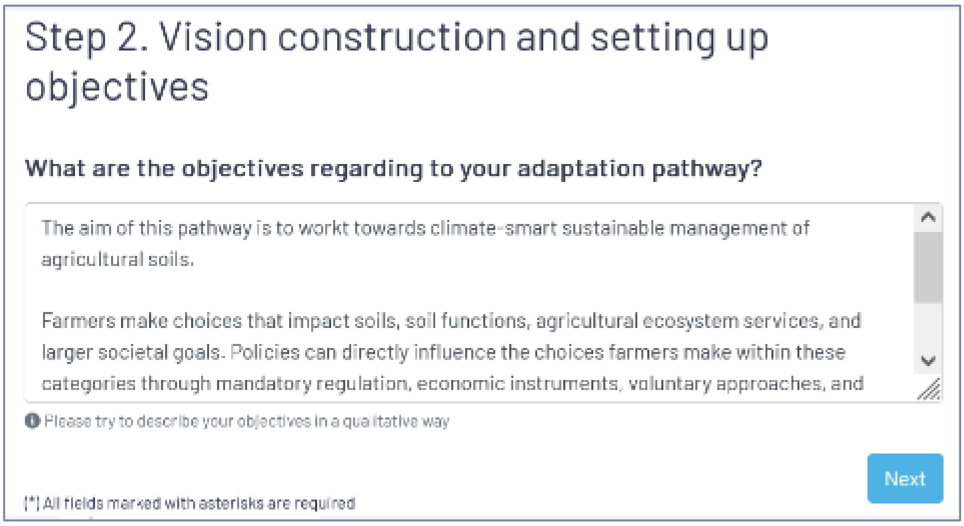


Figure 107. Description of the aim and objectives for this pathway

By clicking on “Next” button the RPVT process continues in Step 3 (Figure 108), this window provides the list of all available options, a total of 30 possible options that can be taken for multi-hazard adaptation.

To facilitate your final selection, you can search by filtering (Figure 108 (a)) considering the type of group, the implementation scale or the reversibility.

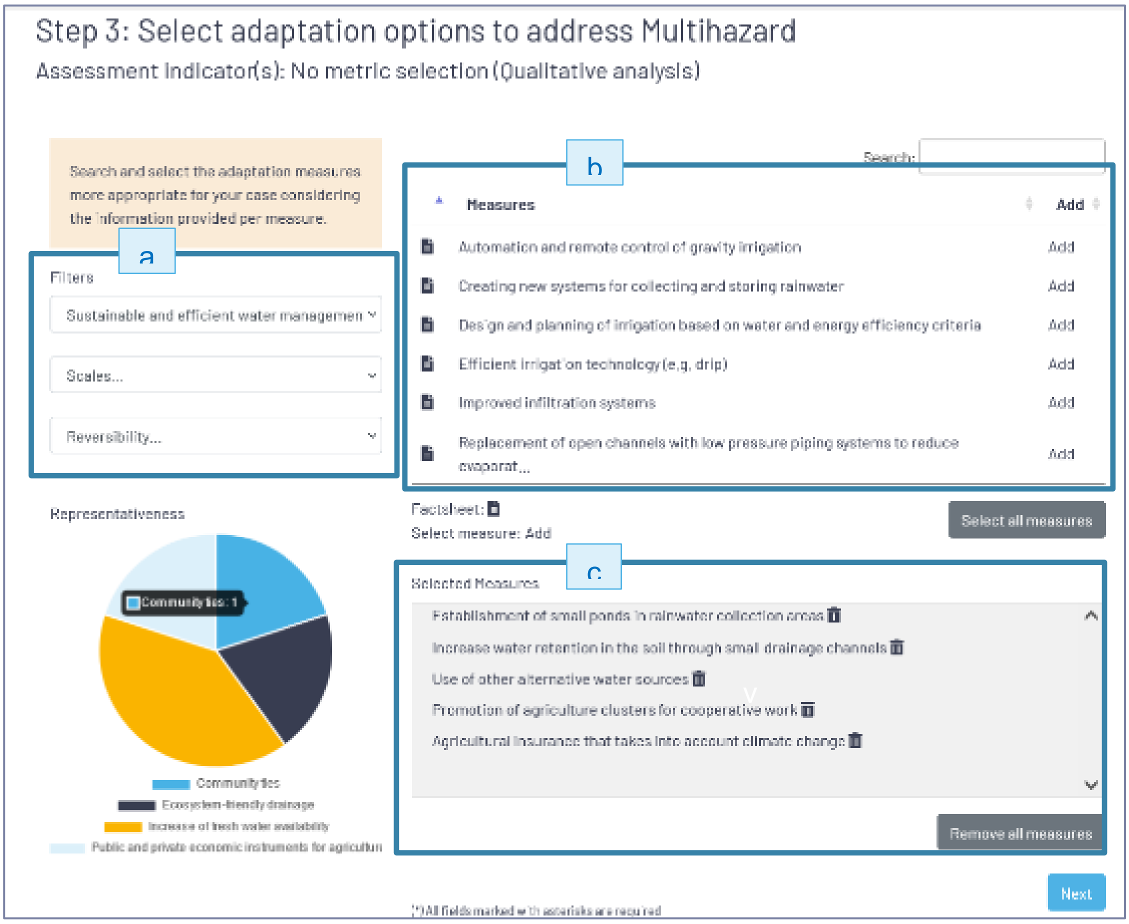


Figure 108. List of available groups for an agricultural type of pathway.

By selecting the “*Developing Resilient Communities”* group filter, the central window (Figure 108 (b)) provides the list of available measures. A similar response happens when selecting *the “Administrative instruments”, “Forecasting, monitoring and Early Warning System”* and *“Sustainable and efficient water management” groups.* For each filter category, the user can select all or select specific adaptation measures based on previous expert knowledge as no additional information is provided in this qualitative pathway design. The measures added are listed in the window below (Figure 108 (c)). They can be removed by clicking the bin icon 🗑 .

If no additional changes are needed, click “Next” to enter into the Step 4 to generate different alternatives. This step allows to create different pathways alternatives (clusters of measures) In this specific case, the user creates two alternatives (See Figure 109 (a) and (b)) to visualize on one side the social and structural measures, and the institutional and structural measures on the other. The right-hand side window (c) provides information of the subgroups to which the measures belong.

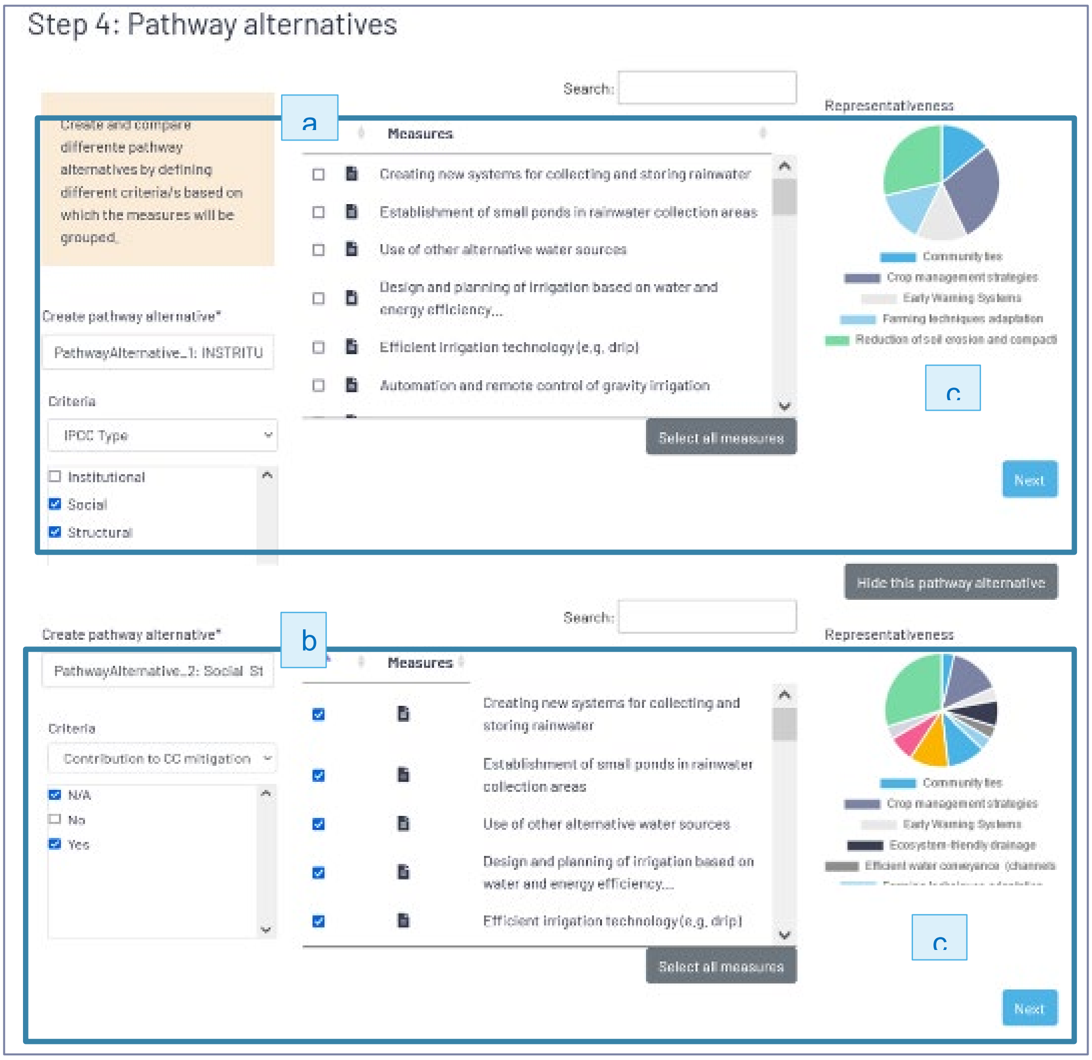


Figure 109. Pathway Alternative 1 (a) configured by this pathway considering Social or Structural measures and Pathway Alternative 2 (b) configured by this pathway considering Institutional or Structural measures contributing to CC mitigation or N/A

In this case, when the qualitative approach is chosen, the criteria to create the pathways alternatives can be based on expert judgment, multicriteria analysis or stakeholders' participatory workshops.

Once an alternative is valid for you, click on the "Next" button, behind the alternative selected. Then the RPVT drives you to the last step where the pathway can be designed for the selected pathway alternative. Figure 110 shows an example of pathway created for the next timelines linked to different possible scenarios: small change scenario [2011-2040], significant change scenario [2041-2070], worst case scenario [2071-2100]. The different options can be sequentially added, modified or removed.

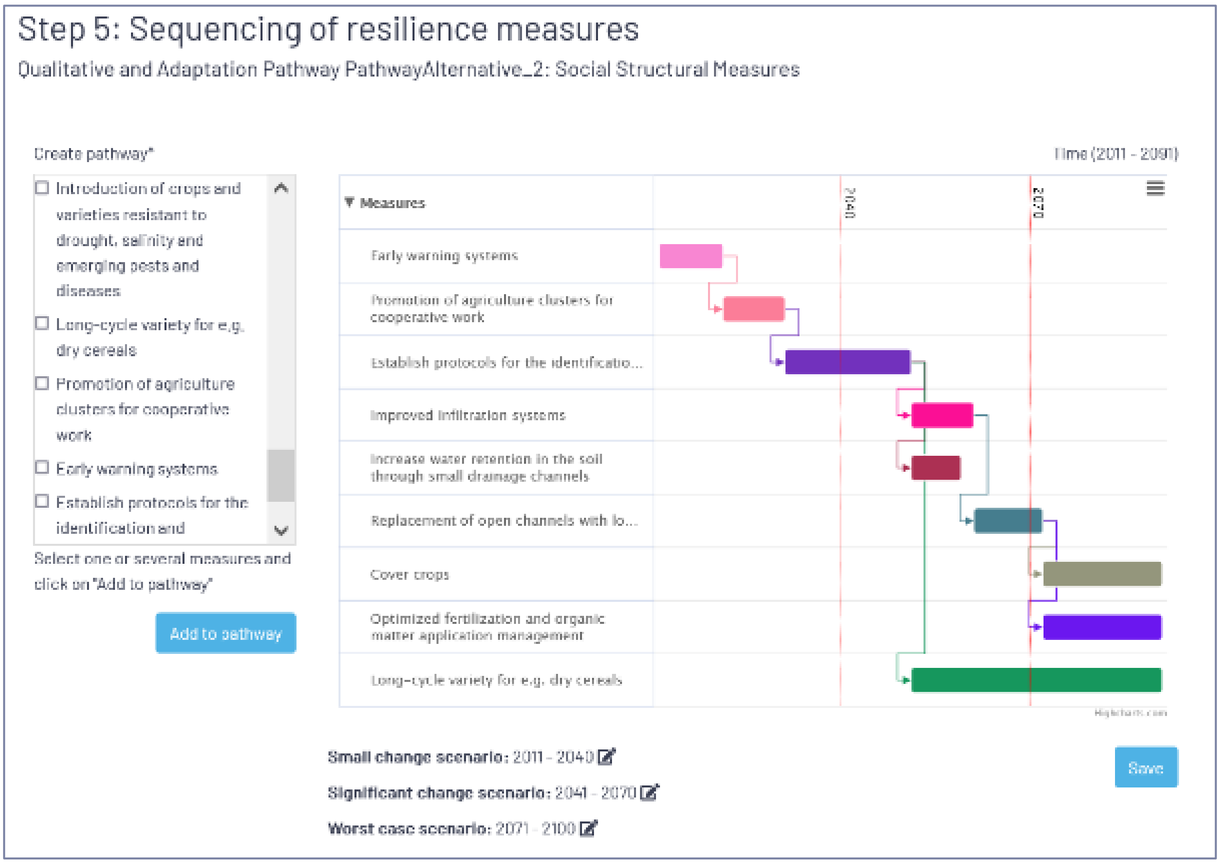


Figure 110. Example of pathway visualization

5.3. Use Case 3: Urban heat management

I would like to know which measures can be applied to better adapt my city to extreme heat events. I would also like to explore how to develop a comprehensive long-term plan to reduce the thermal discomfort and how to incorporate relevant sectoral legislation, particularly for new and existing buildings, transport, and urban planning.

This use case focuses on the analysis on how to improve the thermal comfort in a urban context, therefore you need to select (Figure 111) heat (b), as hazard and PET (c) (Physiological Equivalent Temperature) as the indicator to measure the biometeorological assessment of the thermal environment to assess how different possible measures can be used to reduce the thermal discomfort in an urban context (a). Note that in this case, the settings don't include the option to complement the environmental performance-based pathway with a benefit cost analysis (d). So, in the next windows only structural measures will be considered. If additional social and/or institutional measures want to be considered, then this option has to be modified.

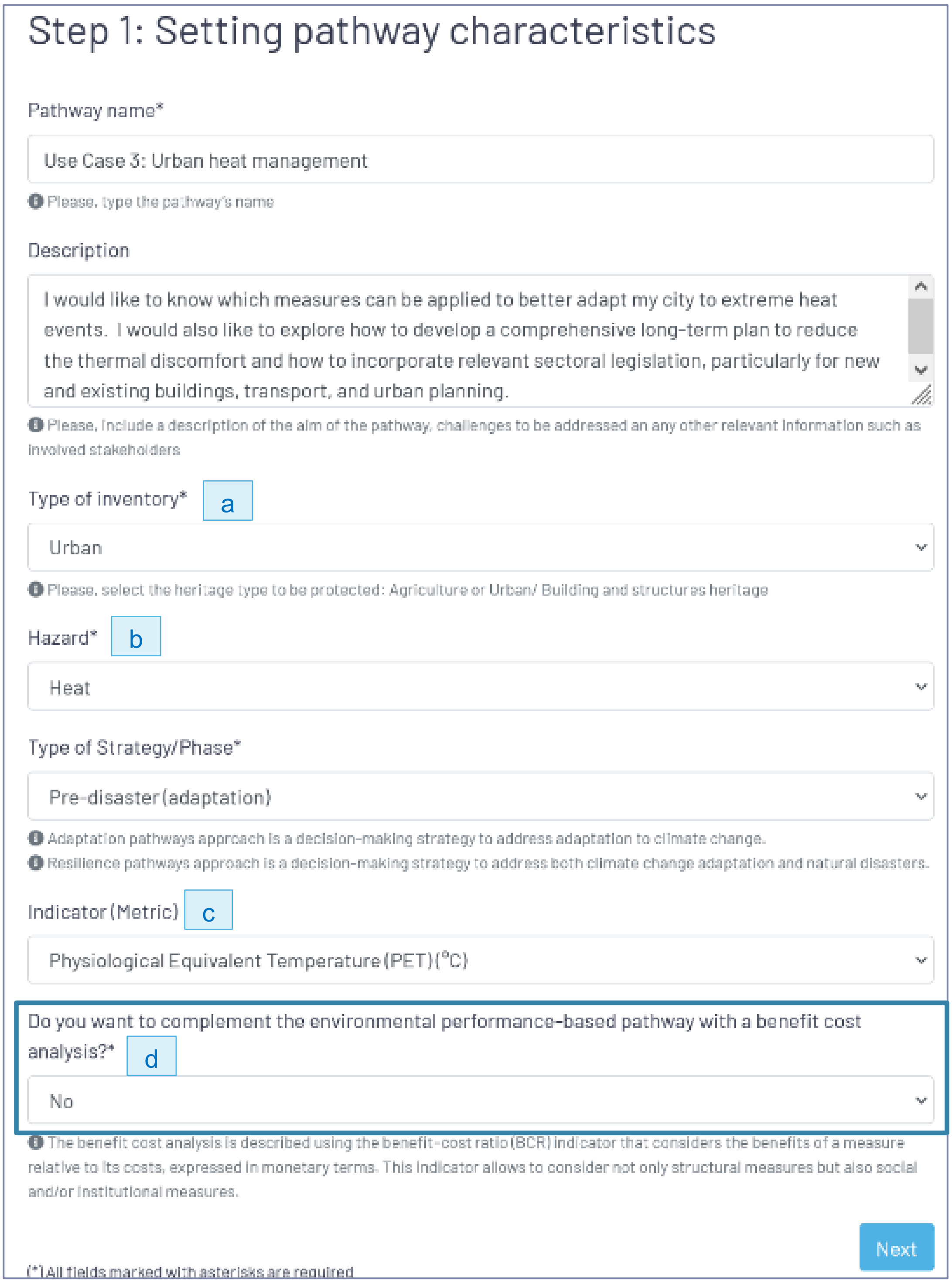


Figure 111. Settings for the Use case 3. Urban heat management

By clicking on the “Next” button the RPVT leads you to the Step 2 (Figure 112), where the aim and objectives of this pathway are described.

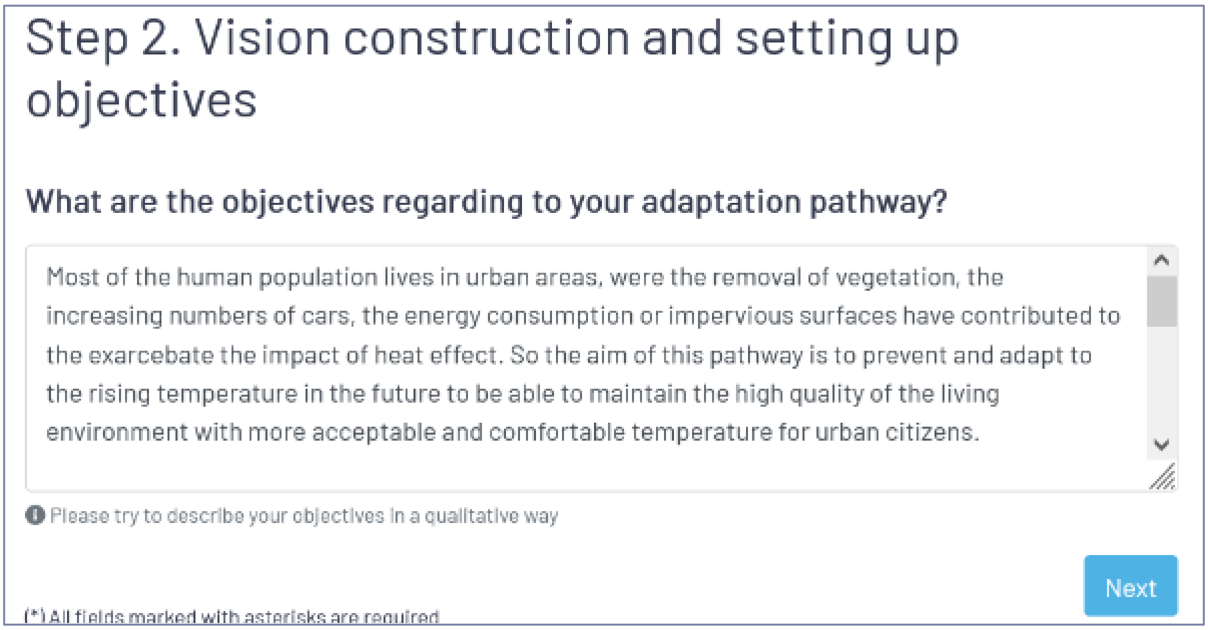


Figure 112. Description of the aim and objectives for this pathway

Click on Next to enter into the next step, where the list of available measures will be showed (Figure 115). This window allows you to use different filters to search and compare measures' performance. As it can be observed in the Figure 115, the benefit cost ratio indicator is provided per measure if the information is available in the knowledge database. If it is not, the information doesn't appear.

As it can be observed in the group filter (Figure 113), the available measures belong to two different categories, the urban interventions and the building interventions. At this pathway urban interventions are more relevant, but as there is also interested to know about other building interventions both categories are chosen.

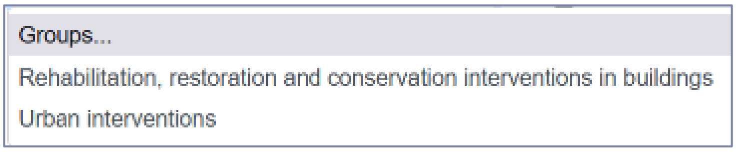


Figure 113 Group filter categories available

There is also the possibility to filter the measures per type of scale (Figure 114), so in this case both district and element are selected to filter and select the appropriate measures.

Figure 114. Filter categories available for scales.

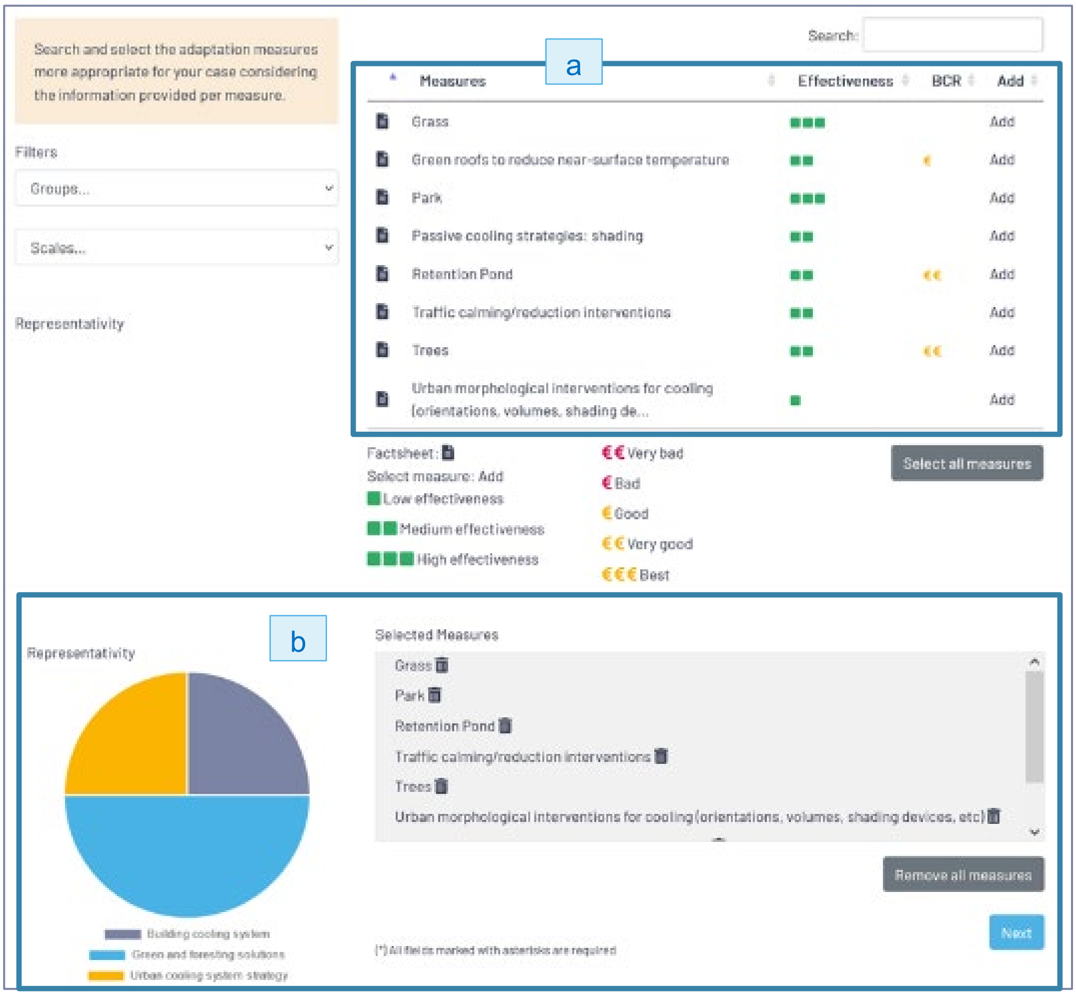


Figure 115. (a) List of available measures with performance assessment available at the RPVT and (b) List of selected measures and their sub-group representativity

Once the measures are selected, press “Next” button to go to the next step.

In Step 4 (Figure 116 and Figure 117) different pathways alternatives are created to compare the effectiveness of each.

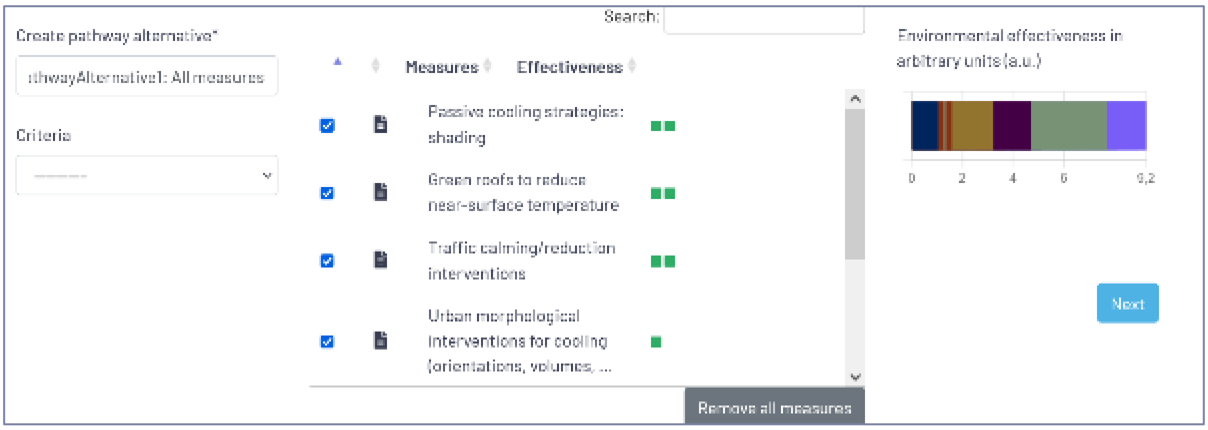


Figure 116. Pathway Alternative 1. All measures manually selected.

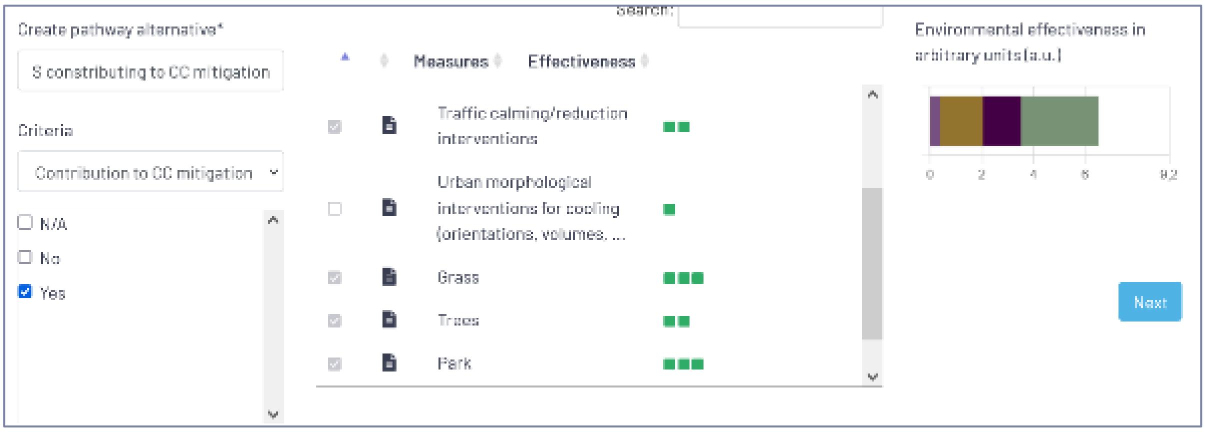


Figure 117. Pathway Alternative 2. Only measures that contribute to CC mitigation are selected.

Once an alternative is chosen, click on Next button to start the pathway design.

Figure 118 visualizes an example of pathway where different measures have been parametrized according to the urban context to create a plan of urban appropriate interventions. The bottom bar char allows to visualize how the different interventions allow to improve the thermal comfort in the implemented square meters. In this case, the planned interventions allow to improve at low performance 1500 square meters, at medium performance on a slightly larger area, and high performance at over 2000 square meters.

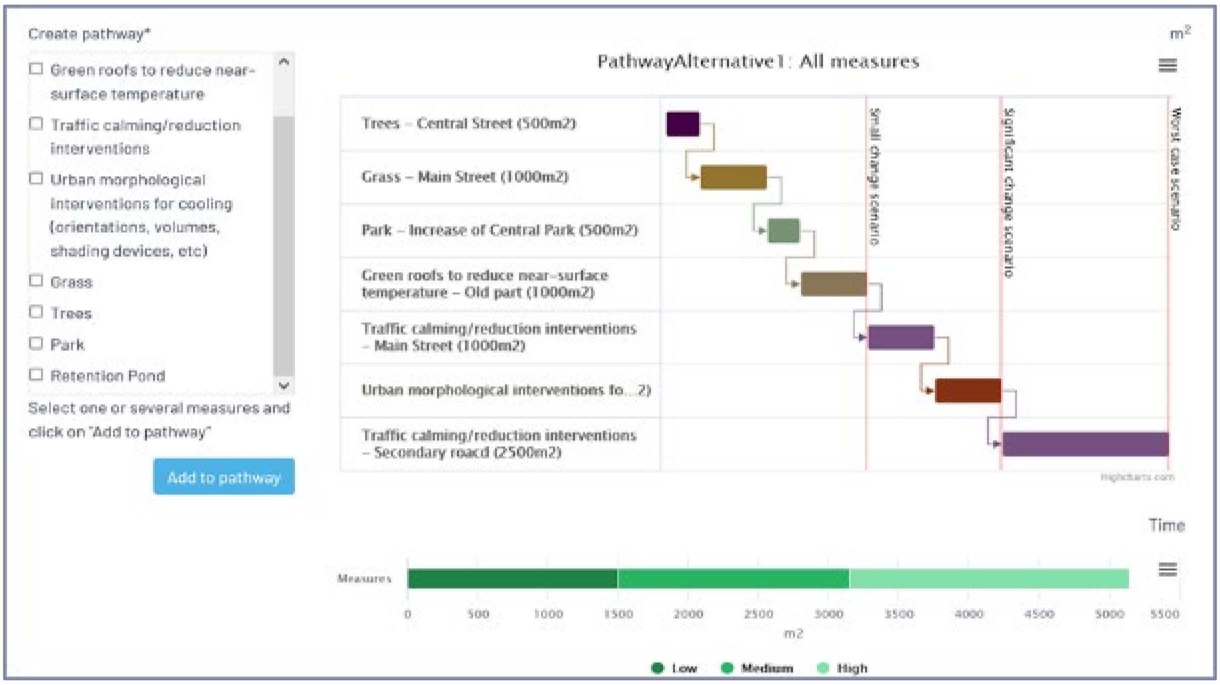


Figure 118. Example of pathway design done for Use case 3

As it can be observed in the figure below, the different scenarios are set considering the timeline periods are established from 2021 to 2080, considering 20 years per period. These settings can be change at any moment by clicking on the icon . Next pop-up window (Figure 119) will appear to enter new dates.

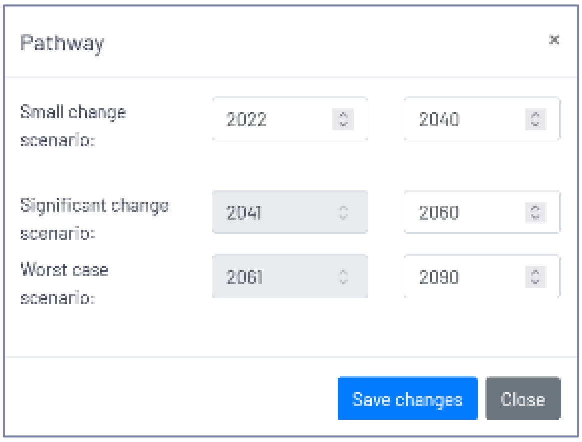


Figure 119. Settings for the future periods established to design the pathway

5.4. Use case 4: Urban flood management

The torrential rainstorms and flash floods create flooding events, with serious impacts for cities and their surroundings. These impacts may happen on cultural heritage sites including historic buildings or infrastructures, town sites, important archaeological sites or works of monumental sculpture or painting. Given the reality of climate change, these flooding disasters will increase so it is important to be prepared to mitigate the consequences of this type of events.

This use case focuses on a resilient approach on a urban context and therefore is important to set in the Step1 (Figure 120), these settings (a) urban, (b) Flood hazard and (c) resilience approach, which automatically imply that the BCR indicator is considered (e). Additionally, the RPVT in this step allows you to select another physical metric to assess the performance, so in this case the metric chosen is the *infiltration rate (mm/h) (d).*

There are different indicators and metrics available to address floods, depending on the chosen indicator (metric) different measures will be available. Note that the tool assessment is based on a literature review of more than 150 papers, 200 case studies and more than 1000 effectiveness assessments that have been revised and validated during the ARCH project.

Note also, that a Resilience Pathway can also be designed considering only the BCR indicator and no physical metric.

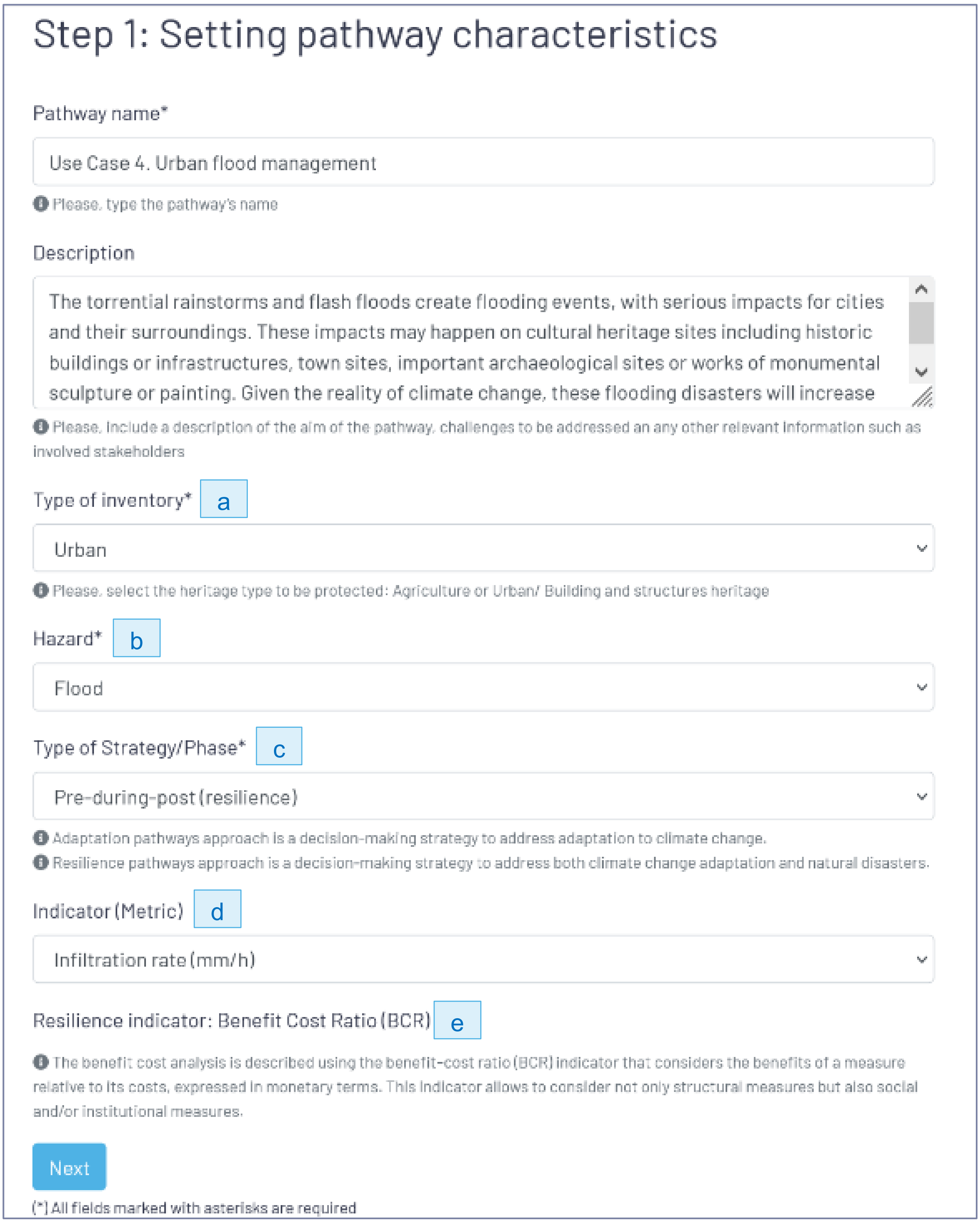


Figure 120. Settings for the Use case 4. Urban flood resilient management

Click “Next” button to enter into Step 2 (Figure 121) where the main objectives of this pathway are described, as well as activities needed to design this pathway with other stakeholders.

Figure 121. Description of the aim and objectives for this pathway

Next step provides the list of available measures in the RPVT knowledge base. See figure below (Figure 122) where the physical effectiveness is provided for the measures that have effectiveness on "*infiltration rate*" as well as other available measures for flood management from which benefit cost ratio indicator is available in the RPVT knowledge base. In some cases, both indicators are available, in others only the physical indicator or BCR is available.

Figure 122. List of available resilience measures to address flood effectiveness, considering both physical performance over infiltration rate and BCR indicator

This window allows to search for specific measures based on the filter categories available (Figure 122 - b). In this case, as you have selected the resilience approach, apart from the group filter there is also a DRM filter, where you can filter considering pre-disaster, during and post disaster measures. Two additional filters are also available to select the scale of implementation of the measure, and the type of measure based on the IPCC classification.

So, the user, firstly apply the IPCC type to filter (Figure 122(b)) the structural measures, once they are showed in the central panel (Figure 122(a)) by pressing the “Select all measure” button they are added into the selected measures panel (Figure 122(c)).

The next figure shows how the window looks like once the measures are selected.

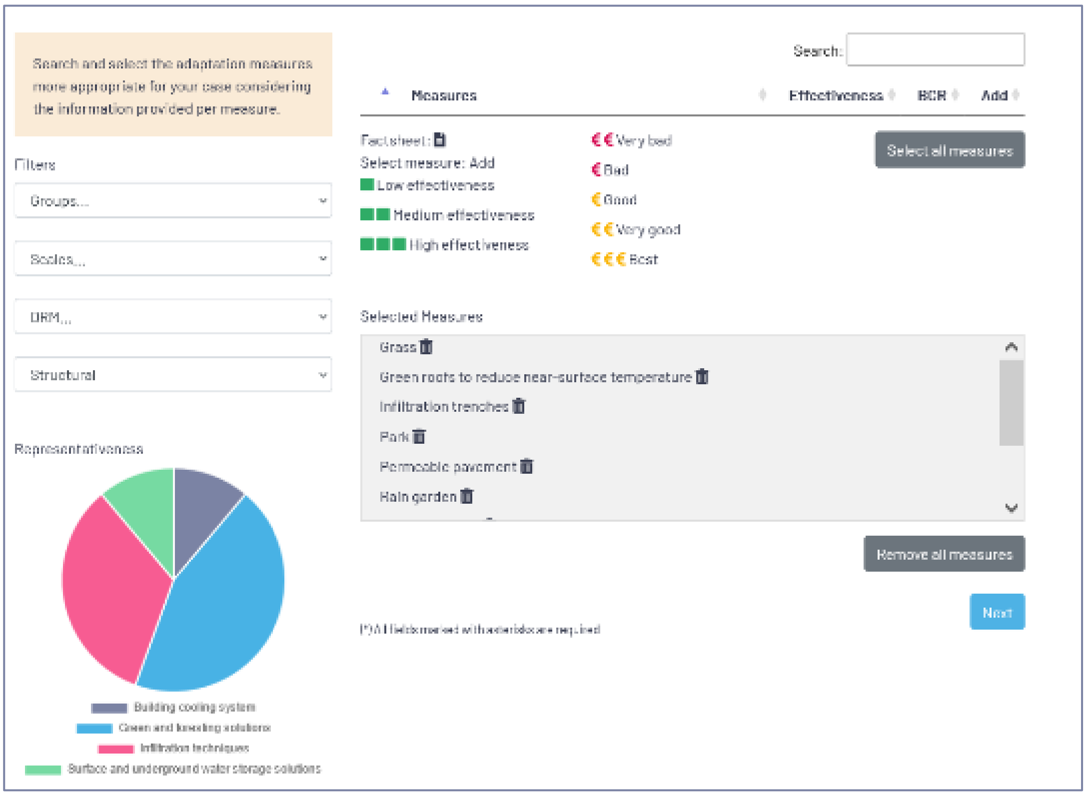


Figure 123. List of structural measures added into the Selected Measures panel, as well as the representativity chart of the selected measures.

Following, the user manually selects from the rest of social and institutional measures available the ones with good, very good or best BCR economic assessment. The ones with bad BCR values are not selected and click on "Next" to continue.

In step 4, the user can create different alternatives, in this case the option with all measures is taken.

Figure 124. All measures are taken as pathway alternative

Finally click on “Next” to continue and design the pathway. In this case as there is a Resilience Pathway two panels appear, one to design the preparation phase, and another panel to prepare de during and post-disaster phase.

Next figure shows an example of pathway designed considering the BCR assessment.

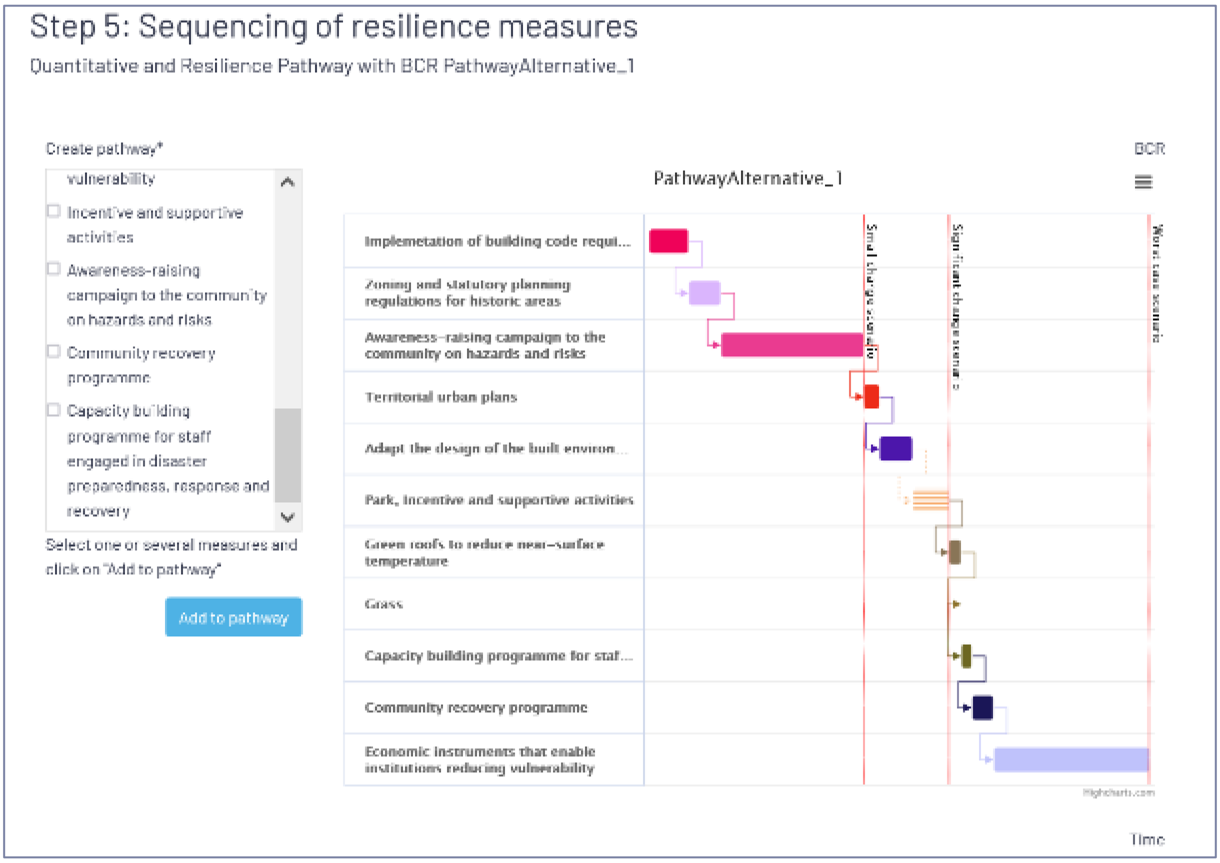


Figure 125. Example of pathway considering BCR assessment of social and institutional measures