Multi-hazard and risk informed system for Enhanced local and regional Disaster risk management

MEDiate

Deliverable D1.1

Validation of the MEDiate concept model through literature and workshops with stakeholders from the testbeds

Author(s):	Nadejda Komendantova (IIASA), Femke Mulder (ARU), Mats Danielson (IIASA), Adriana Mihai (IIASA), John Douglas (USTR), Christopher White (USTR), Catalina Gonzalez-Duenas (UCL), Gemma Cremen (UCL), Carmine Galasso (UCL), Francesca Bozzoni (EUC), Barbara Borzi (EUC), Paolo Gallorini (RINA), Cecile Barrere (R2M)
Responsible Partner:	IIASA and ARU
Contributing authors:	Erna Rakel Baldvinsdóttir (AUS), Sólveig Thorvaldsdóttir (UIce), Esther Hlíðar Jensen (IMO), Tinna K. Halldórsdóttir (AUS), Ian Simon Gjetrang (OSL), Osman Mohammad Ibrahim (OSL), Romain Gitenet (NICE), Yannick Revel (NICE), Zahida Yousaf (ECC), Marc Inman (ECC)
Reviewers:	Abdelghani Meslem (NOR), Chen Huang (NOR), Ivan Van Bever (NOR) and Keith Jones (ARU)
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LIST OF PARTNERS

Participant	Name	Country
NOR	NORSAR	Norway
DEL	Deltares	Netherlands
IIASA	International Institute for Applied Systems Analysis	Austria
BRGM	Bureau de Recherches Géologiques et Minières	France
EUC	Fondazione Eucentre	Italy
IMO	Icelandic Meteorological Office	Iceland
IMT	Institut Mines-Telecom	France
UIce	University of Iceland	Iceland
R2M	R2M Solution	France
RINA-C	RINA Consulting	Italy
IUSS	Istituto Universitario di Studi Superiore Pavia	Italy
OSL	Oslo kommune	Norway
NICE	Metropole Nice Cote d’Azur	France
AUS	Austurbrú	Iceland
UStr	University of Strathclyde	UK
UCL	University College London	UK
ARU	Anglia Ruskin University	UK
ECC	Essex County Council	UK

GLOSSARY

Acronym	Description
ABM	Agent Based Modelling
AHP	Analytic Hierarchy Process
AOGCM	Atmosphere-Ocean General Circulation Models
BCRP	Business Continuity and Resilience Plan
CDRI	Community Disaster Resilience Index
DMP	Disaster Management Plan
DR	Direct Rating
DSS	Decision Support System
ESMIC	Earth-System Models of Intermediate Complexity
IPCC	Intergovernmental Panel on Climate Change
MAUT	Multi-Attribute Utility Theory
MAVT	Multi-Attribute Value Theory
MCDA	Multi-Criteria Decision Analysis
PA	Point allocation
PAR	Participatory Action Research
RAIF	Resilience Assessment and Improvement Framework
SCM	Simple Climate Models
SLA	Sustainable Livelihoods Approach
SLEUTH	Slope, Land cover, Excluded regions, Urban land cover, Transportation, and Hillshade model
SOW	State of the World Concept
SSP	Shared Socioeconomic Pathways
UN	United Nations

MEDiate

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1 INTRODUCTION

1.1 Description of the MEDiate concept model

The MEDiate project sets out to develop a robust framework that guides the co-design, co-development, implementation, and operational phases of a multi-hazard disaster-resilience decision-support system. It aims to demonstrate how enhancing understanding and modelling of future projections of multi-hazard risk will facilitate improving the resilience of societies, significantly reducing potential social and economic losses from future disasters. In considering disaster risk management, research will focus on the framing of resilience and risks from a local government, organization and citizen perspective to better support development strategies, policies and coping capacities related to preparing for, responding to and managing risks.

The aim of the MEDiate project is to develop a decision-support system (DSS) for disaster risk management by considering multiple interacting natural hazards and cascading impacts. This DSS will be using a novel resilient-informed and service-oriented approach that accounts for forecasted modifications in the hazard (e.g., climate change), vulnerability/resilience (e.g., aging structures and populations) and exposure (e.g., population decrease/increase).

The MEDiate DSS will be in the form of service-orientated web tool. It will be accompanied by the disaster risk management framework which will provide end users (local authorities, businesses etc.) with the ability to build accurate scenarios to model the potential impact of their mitigation and adaptation risk management actions.

The aim of the MEDiate DSS is to facilitate development of scenarios, which can be customized to reflect local conditions and needs (e.g., demographics, deprivation, natural resources etc.). These scenarios will be based on a combination of the historical record and future climate change projections to forecast the location and intensity of climate related disaster events and to forecast their impacts, including cascading impacts, on the vulnerability of the local physical, economic, and social systems, considering that pre-existing vulnerability is a key factor that shapes impact. The aim of scenarios is to allow end users evaluating the potential impact of different risk management strategies to reduce vulnerability and enhance community resilience.

The development of DSS will include an analysis of relevant data from testbeds as well as co-development with testbeds decision-makers. This should enable more reliable resilience assessments, accounting for risk mitigation and adaptive capabilities to be made, therefore reducing losses (human, financial, environmental etc.) from future climate-related and geophysical disasters. The development of DSS will also include knowledge and ideas of a multi-disciplinary team of geophysical and meteorological scientists, risk engineers, social scientists, information technologists and end- users.

The aim of this deliverable is to provide the conceptual review of the described concept of the DSS model in the MEDiate proposal. This review includes insights from various angles of resilience research as well as information from testbeds on existing hazards, risk assessment procedures and decision support tools as well as on involved stakeholders.

1.2 Methodology to validate and refine the MEDiate concept model

The objectives of the MEDiate concept model are to develop a DSS for disaster risk management of multiple interacting hazards and impacts. This DSS should be: a) Resilience informed with strategic focus, b) People centric with tactical focus, c) Service oriented with operational focus.

The aim of the MEDiate concept model is to integrate theoretical models into a business model that can be applied at the strategic, tactical, and operational levels within organisations and across communities to improve resilience. It should address three following requirements:

- Be applied to a range of natural hazards and their cascading impacts
- Reflect local exposure, vulnerability, and resilience characteristics
- Support scenario models to identify disaster risk management mitigation interventions

The current report aims to validate and refine the MEDiate concept model through a series of literature reviews conducted by the project partners seeking to identify the factors that affect community resilience but also other factors such as multi-hazards, decision support systems etc. that the project builds upon for enhancing disaster risk reduction management, understanding and implementation capabilities. The methodology of this deliverable on the validation of the MEDiate concept through literature review and workshops with stakeholders from testbeds included three steps. The review of the literature started from the MEDiate consortium-wide meeting which was help to discuss and finetune the MEDiate concept model. The questionnaires and discussions with testbed leads followed from December to February 2023. Participatory Action Research (PAR) is the methodology used in the MEDiate for interactions with stakeholders.

The MEDiate Concept Model has several modules (Figure 1).

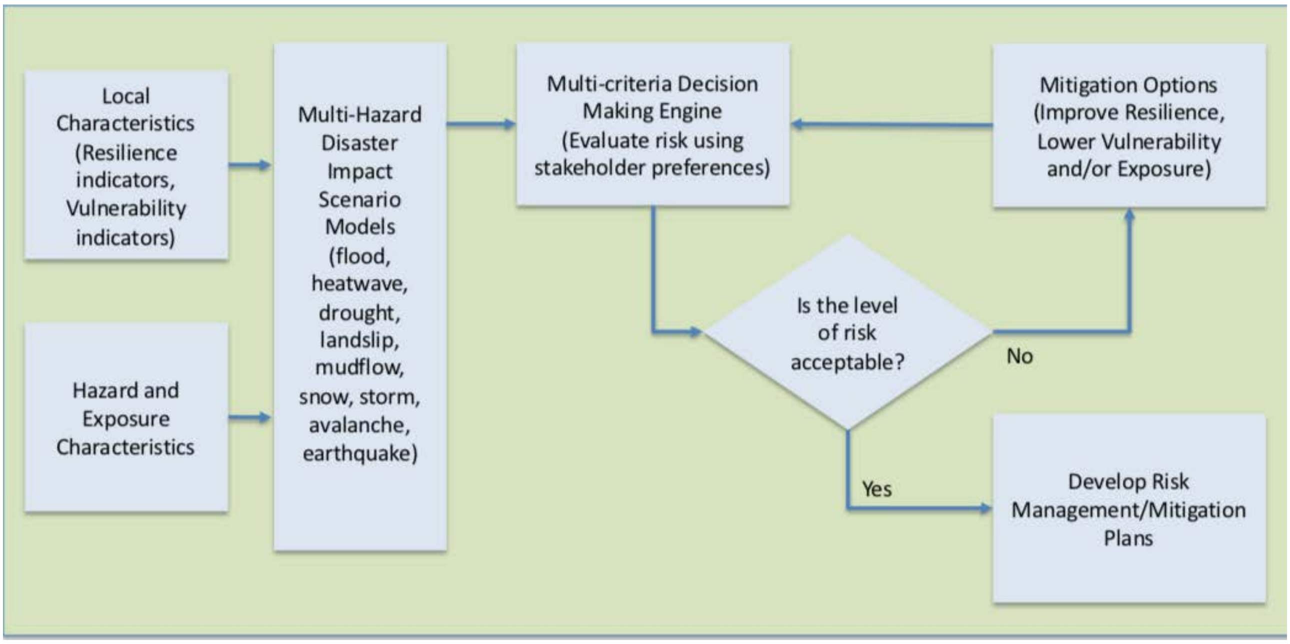

Figure 1: MEDiate Concept Model. Source: Anglia Ruskin University, 2022

The local characteristics of the resilience and vulnerability indicators will include following input data:

- Population Distribution (Demographics, Ethnicity etc.)
- Economic activity (Businesses, Wealth/Poverty etc.)
- Physical Characteristics (Buildings, Geography, Infrastructure etc.)
- Resilience and Vulnerability Indicators (Physical, Social, Economic, Institutional, Infrastructure, Community etc.)
- Adaptive Capacity, etc.

The Hazard and Exposure Characteristics module will include the following input parameters:

- Past, Current and Future Hazard Characteristics including Greenhouse Gas Emission Scenarios, Climate, Weather etc.
- Past, Current and Future Exposure Characteristics such as Population Demographics, Land use Planning, Business Sector Changes etc., Built Asset Management (Refurbishment and Rehabilitation plans) etc. and Housing, Transport and Communication Networks, Critical Infrastructure (Health, Power, Water) etc.

The Multi-Hazard Scenario Models will include:

- Multi-Hazard Scenario Models including Combined Impacts (e.g. heatwave and drought) and Cascading Impacts (e.g. rainfall and landslips)
- Risk Metrics including Resilience Scores (Physical, Social, Economic, Institutional, Infrastructure, Community etc.), Adaptive Capacity, etc., Vulnerability Scores and Physical, Social, Economic, Institutional, Infrastructure, Community etc.

The Multi-Criteria Decision-Making Engine will include two parts.
Part 1: Risk Attitudes and Risk Metrics:

- Risk Attitudes, including Stakeholder preferences (regional authorities; critical infrastructure providers; local businesses; communities)
- Risk Metrics including Stakeholder Priorities on Resilience, Vulnerability and Adaptive Capacity

Part 2: Aggregated Risk Profiles:

- Physical, Social, Economic, Institutional, Infrastructure, Community etc
- Overall (weighted) Risk Profile

The Multi-Criteria Decision-Making module should lead to the answer of the question if the level of the risk is acceptable, namely:

- Can the risks be effectively managed before, during and after the event?
- Is there sufficient adaptive capacity for recovery or constructive reorganization?

If the level of risk is not acceptable then the mitigation options to improve resilience and to low vulnerability and/or exposure should be considered including development of short-, medium- and long-term mitigations interventions to improve resilience and vulnerability indicators. These mitigation interventions may affect a range of indicators in different ways (e.g. some positive, some negative). Then the impact of mitigation plans on aggregated and overall risk profiles will be assessed again within the Multi-Criteria Decision Engine with evaluation of risk using stakeholders' preferences. After this, the answer is being raised again if the level of risk is acceptable. If it is not acceptable, then with mitigation options and multi-criteria evaluation repeats again.

If the level of risk is acceptable this leads to the development of management and mitigation plans to use the risk metrics to develop disaster risk management plans and to communicate and test these plans with local stakeholders.

PAR provides the overarching research methodology for the co-development and co- evaluation of the MEDiate DSS (Figure 2). The objectives of PAR are 1) to develop and further fine-tune the initial MEDiate conceptual model provided with input from MEDiate's testbed leads, its technical/scientific work packages, and stakeholders drawn from the four MEDiate testbeds.

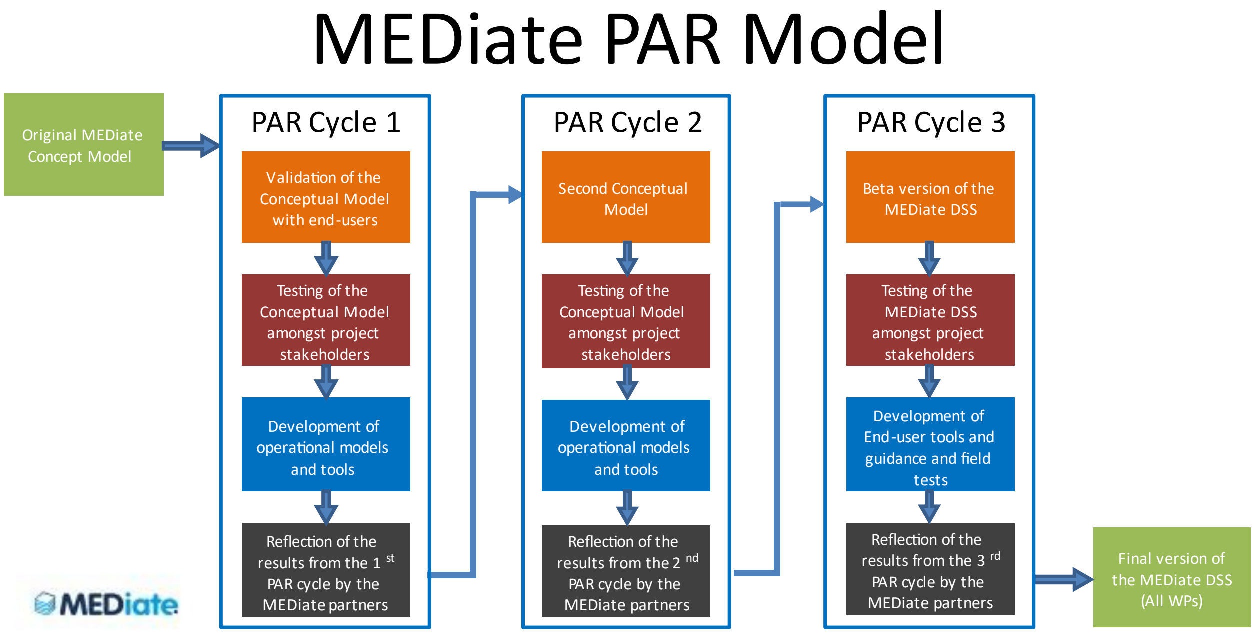

Figure 2: MEDiate PAR Model. Source: Anglia Ruskin University, Briefing Paper on the workshop on 07.03.2023

PAR is a cyclical research activity that seeks to develop solutions through dialogue with end-users, researchers and designers responsible for delivering change. Each cycle of PAR consists of four stages: planning, acting, observing and reflecting. This project will be based on three PAR cycles, one per year.

Multi-hazard disaster resilience requires a multi-disciplinary perspective that integrates socio-economic, organizational, and physical infrastructure impacts, therefore we have structured the literature reviews along seven different domains corresponding to the MEDiate work packages structure and planned activities (see Figure 3), to obtain the theoretical and practical baseline of gaps and best practices in existing research for every interrelated field of the proposed framework. The first step involved analyzing the current state of knowledge on resilience, which included various aspects of the concept and existing research on the topic. The results and recommendations from this step are based on the desk review of existing studies, publications, databases, reports and other printed evidence on resilience and various requirements of resilience. Also, each MEDiate work package contributed a six-pager document on the state of the art in community resilience and disaster risk reduction as well as on factors which are relevant for multi-hazards and decision support systems from various perspectives including socio-economic, multi-hazard interactions and cascading impacts, people-centred resilience modelling, multi-hazard decision support systems and business perspective. Insights and requirements were also provided from the point of view of dissemination and communication with decision-makers and wider community as well as from ethical, legal and societal aspects.

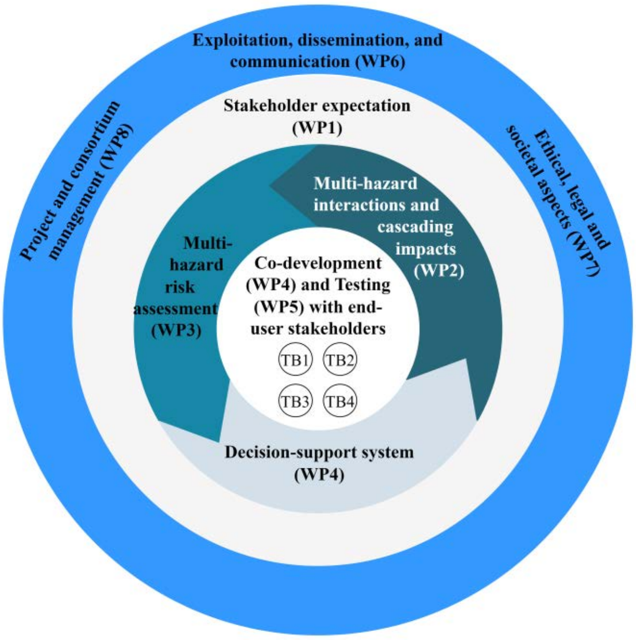

Figure 3: MEDiate work package structure and concept

First, the MEDiate concept was validated from the point of view of the socio-economic factors that affect community resilience and disaster risk reduction. The validation of the concept provides an overview of existing policy and scientific frameworks that combine livelihoods thinking with a complex adaptive systems approach to define resilience. Predominantly seen as an emerging, ongoing capacity of socio-economic and environmental systems to cope with a hazardous event, while maintaining their essential function, identity, and structure, but also the ability to adapt, learn, and transform (IPCC, 2022), resilience is influenced by both objective factors and subjective ones. Specifically, community resilience is currently determined by indicators that include economic and physical assets, education, health and economic capacity, social and institutional protection, but also cognitive and subjective factors such as social trust, social learning, risk perception, civic engagement, cultural norms, and values. Many socio-economic factors that influence community resilience are locally embedded and depend on a community's ability to share a mutual goal, to learn, self-govern and self-organize. Moreover, various indices of community resilience have started to include socio-economic vulnerability as well, since problems of power and inequality, for instance, typically pose differentiated risks to social groups' resilience. Therefore, both community resilience and vulnerability attributes given by structural inequalities, climate change (mis)adaptation or environmental justice should inform resilience evaluation frameworks and mitigation efforts for multi-hazard scenarios.

Second, the MEDiate concept was validated from the point of view of existing state of the art regarding assessing current and future multi-hazard interactions and cascading impacts, which shows that probabilistic approaches to characterize hazards are preferred to deterministic ones and are applicable to all natural hazards considered by MEDiate. Multi-hazard indicators should support not only risk assessments, but also decision-making on policy and hazard response. Another important element in assessments is the acknowledgement and inclusion of epistemic uncertainty in present models, which need to use confidence limits or estimates. The latest multi-hazard risk evaluation frameworks take into account the interactions between different hazards, as well as cascading and compounding effects, both in present and future conditions. They also consider the knock-on effects of hazards, use multiple methods and data sources, and have a wide geographic applicability. These frameworks also provide vector descriptions and scenario representations of the hazard. The state of the art in multi-hazard risk evaluation frameworks considers interactions beyond a siloed approach, as well as cascading events and compounding impacts, both current and future conditions, 'knock-on' effects of hazards' impacts, multiple methods and data sources, a wide geographic applicability, vector descriptions and scenario representations of the hazard.

Third, the MEDiate concept was validated from the state of the art in research on present interactions of the social, economic, built, environmental and organizational systems, but also future ones, potentiated by a changing world. The literature analysis had focus on risk analysis associated with future multi-hazards, exposure, and vulnerability analyses. Climate change uncertainties, increases in population, socio-economic growth or different land uses can affect future risk analysis. Therefore, MEDiate's forward-looking, people-centred framework builds upon existing methods for analysing future developments and datasets derived from projections, forecasts, scenario storylines, agent-based modelling and others. In modelling future risk, the key challenges are how to account for deep uncertainties and how to inform decision-making through robust, people-centred solutions derived from decision science.

Forth, the MEDiate concept was validated from the state of the art in existing decision support systems on compounding and cascading effects under risk and resilience assessments and how it can be implemented in an online platform for end users. Enhancing their capacity to build accurate scenarios based on real world data and projections reduces future risk and strengthens community resilience. Another purpose of the IT system is to reduce the potential irrationality in decision-making processes, that is widely documented in decision theory and practice. The decision support system will provide decision-makers the possibility to visualize the components of disaster risk and resilience, as well as stakeholder preferences and mitigation strategies' effects in time, for multiple hazards. The system is built on state-of-the-art risk assessment and includes a multi-criteria decision analysis module, which will be tested in the four testbeds and refined for wider geographic uses as well.

Fifth, the MEDiate concept was validated from the point of view of the state of the art in research on organizational resilience in the context of multi-hazard risk reduction, which is, just as community resilience, multi-dimensional and context specific. Various resilience models and operational toolkits look at various strategies to preserve operations and to drive adaptation capabilities, considering that an organization's recovery depends in part to extra-organizational factors such as sectoral and economic conditions. Strategic business continuity and disaster management planning are shown to increase organizational resilience; therefore the MEDiate concept will include a Business Continuity and Resilience Plan as well as a Disaster Management Plan for organizational resilience planning.

Finally, the MEDiate concept was validated from the point of view of the up-to-date standards in research outputs exploitation and valuation, as well as the ethical, legal and societal safeguards that are implemented in MEDiate across its data collection, processing and storage activities. The monitoring and ensuring of personal data protection are guaranteed both by EU and national level regulation, and by a commitment to put stakeholders at the centre of the overall project framework and expected benefits.

1.3 Interaction with stakeholders

There are two main approaches to community resilience and disaster risk reduction that are made explicit in this report from the onset: the multi-disciplinary one and the multi-stakeholder and people-centred one, both of which tap into a systems perspective on resilience and disaster risk management. The first question that is necessary to ask to have a clear definition of the current problems in reducing multi-hazard impacts is how to define resilience and community resilience, both of which having rendered highly transdisciplinary answers in the past decades. The inclusion of social sciences and humanities in designing a conceptual framework and a decision-support system for multi-hazard disaster resilience is not only justified by recent policy and resilience frameworks starting with the Sendai Framework for Disaster Risk Reduction 2015-2030, but also by a crucial element within the MEDiate project methodology that informs all stages of the project from concept design to DSS evaluation through PAR methodology.

Using group research activities that involve communities who have been and could be impacted by multi-hazards as stakeholders and end-users of the DSS allows us to closely examine the interaction between technical and social systems and to enhance the effectiveness and utility of our proposed framework and DSS in, across and even beyond the geographical areas included in the project (Oslo - Norway, Nice - France, County of Essex – UK and Austurbrú – Iceland).

Therefore, the second and third validation steps included participation of stakeholders from testbeds. At the second step data were collected from stakeholders in four testbeds (Austurbrú, Essex, Nice and Oslo) with the help of questionnaires which were developed based on literature review as well as the MEDiate concept and through qualitative in-depth stakeholders' interviews. The questionnaire had several parts.

First, the representatives from the test beds were asked to provide information about hazards and risks as well as exposure and vulnerability in their test beds. The hazard was identified, according to UNDRR, as a process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption, or environmental degradation. The risk was identified as the potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society, or a community in a specific period, determined probabilistically as a function of hazard, exposure, vulnerability, and capacity. The exposure was identified as the situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas. The vulnerability was identified as the conditions determined by physical, social, economic, and environmental factors or processes which increase the susceptibility of an individual, a community, assets, or systems to the impacts of hazards.

The representatives from test beds were also asked to provide information on multi-risks including their interacting, interconnected, compounding and cascading character. Interacting risks were understood as how did different hazards trigger with each other. The provided example was heavy rainfall triggers landslides. The interconnected risks were understood as interdependencies between human, natural and technological systems and how they shape risk. The example was drought which puts food production at risk. The compound risk was understood as how simultaneous or successive extreme events affect risk. The example was earthquake which occurs during a period of severe flooding. The cascading risk was understood as how a disruption of a closely interconnected systems affect risk. The example was when collapsed buildings and bridges disrupted the supply chain of key businesses.

At the second part of the questionnaire, the representatives from the test beds were asked to provide information about disaster risk assessment which was identified as a qualitative or quantitative approach to determine the nature and extent of disaster risk by analysing potential hazards and evaluating existing conditions of exposure and vulnerability that together could harm people, property, services, livelihoods, and the environment on which they depend.

The third part was on disaster risk management and governance which was understood as the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk, and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses. The capacity was identified as a combination of all the strengths, attributes, and resources available within an organisation, community, or society to manage and reduce disaster risks and strengthen resilience. The community resilience was identified as the ability of a community to prevent, prepare for, respond to, and recover from disasters.

At the third step the validation workshop was organised with participation of stakeholders from all four testbeds where various aspects of the MEDiate concept were discussed and validated through a serie of stakeholders focus group discussions. The validation was co-produced in the so-called PAR teams which included members of each work package as well as from testbeds. More details on the PAR teams are provided in the Annex. The workshop which took place on the 7th of March 2023 online via Teams program lasted for the entire day and included all PAR teams members. During the workshop findings from the testbeds questionnaires and interviews were presented to participants. Prior to the workshop an annotated briefing note outlining these findings and technical work packages was sent to participants. Further on, findings were discussed after three presentations: on exposure, hazards, vulnerability, and risks in testbeds, on disaster risk assessment in testbeds and on disaster risk management and governance in testbeds. After the discussion of these findings the ideas and thoughts on development of the MEDiate platform were provided to participants.

The interactive sessions took place after these two sessions when participants worked in a virtual post-it notes session and in breakout rooms. During the virtual post-it notes session participants were asked to prioritize importance of attributes/features (1-5 scoring scale) and ease of delivery (technical and operational issues on 1-5 scoring scale) that the MEDiate DSS could offer in: 1) Disaster risk assessment, 2) Disaster risk management, 3) Platform user interface, 4) Integration with existing processes and systems in the testbeds & compliance with existing laws and 5) Generic / miscellaneous. During the breakout rooms participants discussed requirements and attributes and features in their testbeds.

During the final session early thoughts on how the MEDiate system might work, including end-used business model, conceptual risk and resilience model and scenarios, were presented.

2 Socio-economic resilience

2.1 Introduction

Disaster risk reduction efforts have been focusing in the past decade on increasing resilience and reducing vulnerability of individuals, households, communities, and environments. The Sendai Framework for Disaster Risk Reduction 2015-2030 puts forward the objective of increasing economic, social and cultural resilience, among others, so as to save lives, prevent or reduce losses caused by hazards, in a cost-effective manner. Developing social safety nets and livelihood enhancement programmes are among the disaster risk reduction measures that are envisioned at global and regional levels.

Alongside the Plan of Action on Disaster Risk Reduction for Resilience (UN, 2017) that stipulates commitments to strengthen the institutional system to support and prioritize disaster risk reduction, the UN has more recently (2020) defined the core principles that need to inform resilience-building actions and strategies: leaving no one behind and reaching "those most in need and at risk", as well as ensuring "equality, non-discrimination and a human rights-based approach". UN's Sustainable Development Goals include target 1.5 that states "by 2030 build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters".

Policy papers and efforts, therefore, have been integrating socio-economic factors in increasing resilience for disaster risk reduction, following the evidence in disaster literature from the past decade where the problem of reducing disaster impacts has no longer been predominantly concerned with technical, natural, and environmental processes, but also with social, economic and governmental ones. Current research on resilience and community resilience in particular bridges the gap between different modes of thinking that have been taking turns in informing disaster risk reduction processes: 'livelihoods thinking' or the sustainable livelihoods approach (SLA) (Chambers and Conway, 1992), the 'disaster vulnerability' paradigm (Blaikie et al., 1994; Wisner et al., 2004) and the complex adaptive systems theory (CAS).

The relationship between community resilience and socio-economic vulnerability, two paradigms and epistemologies that have often seemed scientifically, practically, and politically disjunctive, becomes apparent when looking at resilience through a systems approach, which has started to inform social science perspectives on disaster risk reduction. Therefore, in what follows, we will firstly review the state of the art in what concerns working definitions of resilience and community resilience, followed by a mapping of current community resilience frameworks and measurements. Then, we will look at the socio-economic vulnerabilities within the social and environmental systems that can provoke unequal risks, impacts and losses in the case of natural hazards such as floods, earthquakes, pandemics, in the preparedness phases and in disaster response and recovery. Since resilience-building has been shown to be constrained or undermined by vulnerability (Gurtner and King, 2021), the two sets of attributes of communities are clearly interlinked; therefore, we will lastly review current vulnerability evaluation methods and mitigation for multi-hazards.

For the current literature review, we used the 'Preferred Reporting Items for Systematic Reviews and Meta-Analyses' (PRISMA, 2009) methodology by which we identified, screened for eligibility, and included the most relevant studies on community resilience and socio-economic vulnerability from the period 2017-2022, to which we added influential grey literature and previous work that conceptualized key notions as they are used in current studies.

2.2 Community resilience

Resilience is an ambiguous term that is sometimes deemed to be a “wicked problem” (Forrester et al., 2019), since it resists simple solutions and definitions, even within the same field, such as disaster risk reduction. It is safe to say, however, that it is a complex and multidimensional concept that can been seen as either an outcome, that is easier to measure, or an adaptive and ongoing process or property of individuals and communities (Abeling et al., 2019). Most structural socio-economic resilience characteristics, for instance, are outcome-oriented, while coping, adaptive and transformative capacities, as well as more cognitive dimensions of social resilience such as social trust, risk perception, civic engagement and attitudes and values are process-oriented (Sajaa et al., 2019) and need to be assessed as adaptive capacities or “intangibles” (Tariq et al., 2021) over longer periods, longitudinally, and preferably using participatory methods to ensure equitable resilience (Matin et al., 2018; Herrera and Kopainsky, 2020).

Resilience seen as a capacity or ability is at the heart of the most commonly used definitions of resilience in disaster risk reduction and sustainable development (UNISDR, 2017; OECD, 2014; IPCC, 2012), the latest proposed by the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) being: “the capacity of social, economic, and environmental systems to cope with a hazardous event, trend or disturbance, responding or reorganising in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation. Resilience is a positive attribute when it maintains such a capacity for adaptation, learning, and/or transformation.” (IPCC, 2022) A shorter definition that maintains the key elements of multidimensional capacities and systems’ change is “the ability to prepare and plan for, absorb, recover from, and more successfully adapt and transform in response to adverse events.” (OECD, 2020; Cutter et al., 2013).

The emphasis on adaptation and transformation, originally connected to social resilience by Walker et al., (2004) and by Keck and Sakdapolrak (2013), is called for in current systems framings of resilience that dominate both in policy (European Commission, 2017; UNDP, 2017; UNDRR, 2022-2023) and in scientific literature adopting a socio-ecological systems (SES) approach (Talubo et al., 2022; Walker et al., 2004; Nelson et al., 2007). However, there are other dimensions that have been either interconnected or in contrast with the socio-ecological systems approach, with separate lines of scientific inquiry, conceptual frameworks, and evaluation of resilience (Talubo et al., 2022: 4; Assarkhaniki et al., 2020). One of the main critiques brought to this approach is its vague relationship to social vulnerability and context including cultural norms and values (Wisner, 2004; Abeling and Huq, 2015; Drolet et al., 2015), power, human agents and social practices (Keck and Sakdapolrak, 2013).

The Sustainable Livelihoods Approach (SLA) that focuses less on the system’s capacity to adapt and transform, and more on households’ resources and assets that can help them cope with shocks and hazards and recover, has also been prominent in informing community resilience and vulnerability studies since it pays attention to the relationship between people’s tangible assets, their social or intangible capital and their livelihood capabilities (Sanderson, 2012). SLA’s implicit concern is with the local context and embeddedness of social capabilities and subjective factors such as perceptions and beliefs, sharing of knowledge in the social network and non-market activities, but also with the institutional environment and governance setting. The relational feature of resilience has become part of the most recent sustainable livelihoods framework (Natarajan et al., 2022), which suggests that there are six interlinked elements: the livelihood context and landscape, which includes the characteristics, vulnerabilities and opportunities of local livelihoods, the climate and environmental context, individuals' and households' financial and physical assets, as well as their relational power in terms of human, social and political capital, and the governance and systemic elements that shape the politics of access and influence, on the one hand, and the local, regional and global transforming structures and processes.

Current social resilience frameworks and indices aim at including both the people-centred approach derived from the SLA and the focus on systems' adaptive capacity, by looking at five main dimensions: social, economic, institutional, infrastructural, and environmental (Assarkhaniki et al., 2020). Out of these, the social aspects that are measured in some indices are population and demographics, people's education, health and economic capacity, as well as community strength and social protection, while the economic factors that indicate social resilience are people's income, employment levels, household capacity, assets and the availability of financial services to support them, as well as the government's financial capacity including income, expenditure, business activity and other macroeconomic indicators (Assarkhaniki et al., 2020).

In composite resilience indices such as the City Resilience Framework (Rockefeller Foundation and Arup, 2014), the Disaster Resilience Scorecard for Cities (UNDRR, 2017) or OECD's Indicators for Resilient Cities (2018), alongside more 'fixed' socio-economic status and ecosystem services (UNDRR, 2017), the social indicators include the social subjective or intangible aspects of social capital, as well as social cohesion aspects such as social connectedness and engagement of vulnerable populations.

The most recent community resilience frameworks follow a similar principle as the abovementioned resilience indices do, namely they look at both the socio-ecological systems in which local communities are embedded and the social subjective factors that distinguish one community from the other, whether it be a place-based community, a virtual community of interest or practice within a more extended spatial network or an 'imagined community' that shares a common identity, that is relevant especially in a globalized and technology-mediated communicative environment (Mulligan et al, 2016; Deeming et al., 2019). Mulligan et al. draw the distinction between resistant and adaptive communities, where community resilience becomes the ability to effectively negotiate the different tensions that arise between "exclusive/inclusive; individual/collective; static/dynamic; conservative/progressive; and bound/unbound". A focus on community resilience mainly supplements existing 'general' resilience frameworks with a few capacities of social groups that have been shown to increase or decrease resilience: education and awareness, social learning, risk awareness and training, risk perceptions, as well as trust in authorities, previous experience in hazard coping and recovery, or personal faith and attitudes (Tariq et al., 2021; Sajaa et al., 2019). A community's ability to exchange information improves social learning, innovation, solidarity and efficacy in the disaster preparedness, in early warning systems (Sufri et al., 2020) and in emergency response and recovery stages, thus has become one of the core characteristics that increase resilience (Sharpe et al., 2019).

Hazard-specific indices, such as the Composite Community Resilience Index for earthquakes, or geographically-specific ones, such as the Community Resilience to Disasters in Saudi Arabia (CRDSA), the Coastal Community Resilience Index Resilience Assessment in Kenyan Slums or the Community Disaster Resilience Index (CDRI), South Korea, include these two dimensions that are more often than not missing from general resilience indices and that encompass the subjective aspects mentioned above, which are different from the social capital measured by sustainable livelihoods frameworks: the "social and interconnected community resilience dimension" and the "cognitive dimension of social resilience." (Sajaa et al., 2019), the latter referring to trust, perceptions, place attachment, engagement, identity and values (Aldrich and Meyer, 2015).

Because of these dynamic, multi-dimensional aspects in the subjective approaches, that are interconnected to psychological and well-being variables as well, community resilience is understood in, for instance, the emBRACE community resilience framework (Deeming et al., 2019) as a product of the interaction between individuals, social practices and institutions, an "emergent attribute" or property, which in the wake of a hazard, ensures adaptation or transformation, but sustains "key functions and core identity and integrity" within the community (Almedom, 2013).

While such socio-cultural dimensions are being measured through subjective assessments and participatory tools, it is more difficult to point out actions and strategies for increasing community resilience along these lines, in particular for evidence-based policy making. Almedom points out that for this reason, community resilience cannot be created by experts and outsiders, but rather it needs to be given the appropriate conditions (such as institutional access, support, spaces for community meetings and exchange of information, but also improvements of structural aspects in the socio-economic domains, engagement of stakeholders in decision-making processes) that are conducive to self-governance and self-organization.

This is the reason why recent frameworks and activities aiming to increase community resilience put a large emphasis on bottom-up and self-organizing changes that increase resilience, in particular on co-produced and shared learning experience, through facilitating engagement, interactions and conversations that can enact "transformations of thoughts, intention, and behaviour and which enable increased adaptability and resilience to hazards faced by communities" (Sharpe et al., 2019).

Several components that improve the outcomes and process of social learning are diversity and inclusion, levels, and nature of participation, established mechanisms for stakeholders to express themselves, influence of opinion leaders and motivation for participation – creating and supporting the belief that citizen expertise, even if derived only from lived experience and is anecdotal in nature, will contribute to the overall common goal of increasing community resilience. Such 'soft' self-protection measures are seen as doubling traditional measures aiming to improve inequality and other socio-economic indicators.

The most addressed dimensions of community resilience are social, economic, community, institutional, housing/infrastructure, and environmental (Cutter et al., 2014; Kontokosta and Malik, 2018; Sajaa et al., 2019). In their review of social resilience frameworks developed in the disaster management sector since 2005, Sajaa et al. notice that hazard or context-specific frameworks can be resource and time consuming, while adaptable generic, multi-dimensional frameworks at national or community levels can improve consistency and comparability in resilience measurements. Moreover, they point out that key dimensions such as community goals, social institutions, equity or education are missing from two thirds of the existing frameworks, while the most common social resilience indicators are social demography, social cohesion and support, social networks, community engagement and values, access to health and community competence in understanding risk.

Exceptions exist from the most frequently employed indicators, for instance in (Cutter et al., 2014), where a spatially variable community index is presented, social resilience evaluates the existence of English language competency, mental health support and health insurance, then for evaluating community resilience specifically, it looks at place attachment, political engagement, social capital in religious, civic or disaster volunteering organizations, while for the evaluation of economic resilience, it looks at race/ethnicity income equality, non-dependence on primary/tourism sectors, gender income equality.

The Rural Resilience Index focuses on three main domains, namely social fabric, community resources and disaster management, measuring, alongside the typical socio-economic indicators, self-reliance and resourcefulness, the traditional and indigenous knowledge sharing, the existence of consultation mechanisms, and governance structure and processes. (Cox and Hamlen, 2015).

The emBRACE integrated framework for evaluating community resilience to natural hazards (Kruse et al., 2019) proposes a set of three layers, whose first core components look at resources and capacities, actions such as civil protection and social protection, and learning processes on risk perceptions and losses; these components are embedded in two extracommunity processes and structures, namely disaster risk governance and the social, economic, political and environmental factors and disturbances.

Furthermore, the recent assessment framework of community resilience to pandemics (Suleimany et al., 2022) brings together both objective and subjective indicators, interestingly not only from community resilience frameworks, but also from socio-economic vulnerability literature; the social dimension, for instance, includes safety and protection, social justice and distribution equality, the economic dimension adds economic development and financial readiness for care, nursing and providing required medicine, goods and services, while demographic resilience domain explicitly includes human vulnerability.

Community engagement in infectious diseases has been shown to be embedded and at times dependent upon the vulnerability context, given by the history and situatedness of the community, and in the system and structures that govern it (Osborne et al., 2021); the analysis of information provision, consultation activities and community empowerment are influenced by the general trust in the health system, while the involvement of local networks can be challenged by the existence of heterogeneous communities, social and political unrest and pre-existing power relations caused by political instability and the negative effects of capitalism (Osborne et al., 2021).

Many issues that have been signalled in resilience thinking, especially coming from the field of social vulnerability, have started to be integrated in the most recent community resilience frameworks and in policy reports on disaster risk reduction (UN, 2021); the gap between treating resilience from a normative standpoint, whereby it becomes a policy instrument to promote disaster risk reduction, and seeing it analytically, which opens the doors to assessing, evaluating and identifying options for building resilience, is narrowing down, at least in what concerns socio-economic dimensions.

The UN Common Guidance on Helping Build Resilient Societies states that "the power and inequality dimensions that are driving risks, and the differentiated vulnerabilities and capacities of different groups (women, men, youth, elderly, people with disabilities, minority groups, etc.)" are "part of a given system at risk" (UN, 2020), which shows that previous critiques brought to resilience rhetoric and policy adopting a more positivistic approach made the field expand and integrate problems related to power, governance, historical and political conflicts, as well as the responsibility of political authorities to mitigate social vulnerabilities and imbalances.

2.3 Integrating socio-economic vulnerability in community resilience frameworks

If community resilience refers to "the abilities of populations to anticipate, absorb, accommodate, and recover from the effects of a hazardous event in a timely and efficient manner," (Almedom, 2013; Deeming et al., 2014; Kruse et al., 2019), vulnerabilities represent pre-existing demographic, economic and social characteristics that influence these abilities of populations (Burton and Toquica, 2020; Burton et al., 2022) or that "create differential hazard impacts and losses within and across communities." (Wisner et al., 2004). Consequently, synergies between the two fields exist and the paradigm shift in resilience thinking accommodates more socio-economic vulnerabilities in building resilience for disaster risk reduction so as to reduce earthquakes, floods, pandemics and other hazards' impacts on people's lives and livelihoods.

In vulnerability indices, for instance, the composite indicators for social vulnerability include age, gender, race, socioeconomic status, special needs (physical or mental challenge, homelessness, transience), as well as access to education, to healthcare or institutional capacities; the economic vulnerability indicators include economic exposure, openness, export concentration or over-reliance on exports, working status, dependency ratio, level of poverty and income inequality, data that is generally accessible in annual reports such as the Global Gender Gap Report (World Economic Forum, 2022), the Inform Risk Index (European Commission, 2023), the Gini Index (World Bank, 2023) or the Economic Vulnerability Index (UN, 2023).

A recent focus on gender and disasters (UN, 2021), triggered by the effects of the Covid-19 pandemic on women, showed four main areas where gender inequality impacts women and where differential risks must be addressed: indirect impacts on health care including reproductive health services, gender-based violence, discrimination in hazard preparedness, response and recovery, and unpaid care and labour burden. Alongside structural inequalities, vulnerabilities can reside in climate change adaptation processes, social and environmental justice, exposure to frequent disasters or inequalities in development (Gurtner and King, 2021).

The Livelihood Vulnerability Index used to analyse socioeconomic vulnerability to urban floods (Kashyap and Mahanta, 2021; Shahzad et al., 2021), climate change or earthquakes (Burton et al., 2022) has three main components that characterize vulnerability: exposure, sensitivity, and adaptive capacity. The consideration of vulnerability indices can shed light upon inequalities and community factors that are less measured by resilience frameworks; for instance, (Birkmann et al., 2022) have shown that "mortality per hazard event from floods, drought and storms is 15 times higher for countries ranked as highly vulnerable compared to those classified as low vulnerable." It is therefore important to evaluate the merits of both lines of inquiry and policy areas in assessing pathways towards community resilience in the wake of single and multi-hazard scenarios.

3 ASSESSMENT OF CURRENT AND FUTURE MULTI-HAZARD INTERACTIONS AND CASCADING IMPACTS

3.1 Introduction

Currently the MEDiate concept in regards to the assessment of current and future multi-hazard interactions and cascading impacts includes the following elements: a) Development of a framework for the assessment of current and future multi-hazard interactions; b) Assessment of the primary interacting hazards for European areas; c) Assessment of the primary cascading impacts for European areas; and d) Development of multi-hazard indicators that are suitable for risk assessments and the decision support system (DSS). The multiple hazards considered include hydrological (e.g. surface water, and flash and fluvial floods), meteorological (e.g. storm, and wind), climatological (e.g. heatwave, forest fire, and drought), and geophysical (e.g. landslides, earthquake, and volcanic).

3.2 The state of the art

In this section, the state of the art in the assessment of current and future multi-hazard interactions and cascading impacts is briefly described. This summary draws heavily on recent reviews published by Gill and Malamud (2014), Merz et al. (2020), Simmonds et al. (2022) and others.

An evaluation of the risk to an exposed element (e.g., a building or a population) from an event such as a flood or an earthquake requires a consideration of the element's vulnerability, which expresses its propensity to suffer damage, as well as an assessment of the hazard, the natural phenomenon itself. The assessed hazard is often presented in the form of a series of maps presenting the expect intensity of a characteristic of the hazard (e.g., peak ground acceleration for the case of an earthquake) for different return periods (e.g., 100 years).

These characteristics are often called intensity measures, parameters, or indicators. This assessment is made using various combinations of statistical analysis of past events and numerical simulations (from semi-empirical approaches to fully physics-based methods) of potential future events. The assessment methods vary depending on the hazard considered because of their complexity and the amount of empirical data available (e.g., Douglas, 2005). Assessments for hazards with richer empirical databases often rely more heavily on statistical approaches whereas those with limited databases rely more heavily on simulations. Expert judgement is almost always required within any hazard assessments due to limited data.

The characteristics considered are chosen based on their usefulness in conducting risk evaluations using the hazard results. For example, it has been shown that peak ground acceleration is reasonably well correlated with propensity of an earthquake to cause damage to a structure. There is considerable research undertaken to identify which parameters best characterise each type of hazard in terms of their use within risk assessments or impact forecasts, e.g., peak wind speed for hurricanes. This concept allows the assessed level of hazard to be translated to an estimated level of risk and is often used to evaluate the risk from earthquakes and hurricanes. For other natural perils, such as mass movements, coastal erosion, and volcanoes, however, the incorporation of vulnerability within risk assessment is not well established (Douglas, 2007). The MEDiate concept is concerned with improving the translation of hazard results to risk evaluations.

There has been a move in the past couple of decades towards the use of probabilistic approaches to characterise hazards and away from deterministic (also known as scenario-based) approaches. This means that, rather than presenting a map of the considered parameter for a representative or worse-case scenario, probabilities are computed for all possible scenarios and then maps presented with different probabilities of exceedance (or return periods). It has been shown (e.g., Douglas, 2005) that this general framework is applicable to most, if not all, natural hazards considered by MEDiate. The assigning of probabilities to different scenarios accounts for the aleatory variability in a hazard. In other words, it accounts for the fact that hazardous events, e.g., floods, do not occur at regular intervals nor are their magnitudes constant. In some sense, their occurrence rates and magnitudes are random, and this variability needs to be accounted for. For many natural and anthropogenic hazards, the exceedance probabilities for different parameter levels can be expressed in the form of a power law (e.g., Mignan, 2022).

Generally hazards are classified using either considering the intensity of an event for a given return period (the usual approach), e.g. what is the peak ground acceleration for a 475-year return period?, or what is the return period of a given event? (an alternative approach that is not commonly used but can have advantages in some situations), e.g. what is the return period for a peak ground acceleration of 0.1g? The difference between the approaches is illustrated in Figure 4.

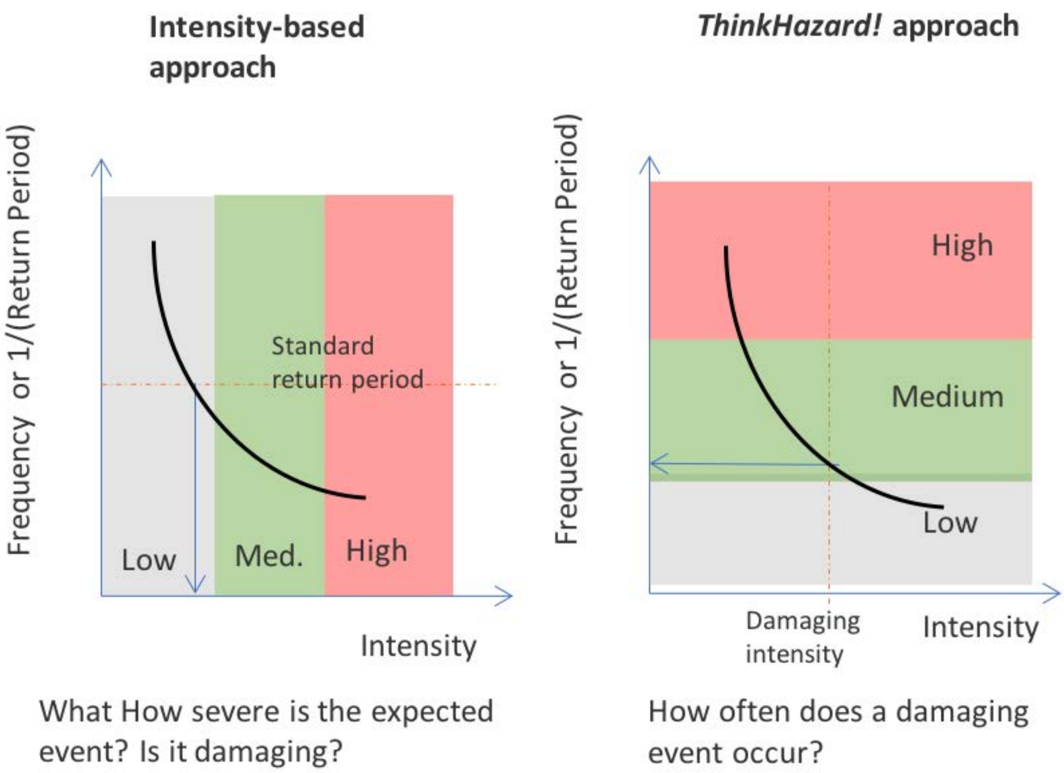

Figure 4: Classification of hazard by either frequency or intensity. Source: Douglas et al. (2017)

In the past decades there has been a move towards accounting for epistemic uncertainties within hazard assessments. Because we lack knowledge and understanding about hazardous events and the observational record is short (a few decades or centuries at most) and often only qualitative (i.e., written records rather than quantitative measurements), there is considerable doubt over the inputs to hazard assessments. Therefore, modern hazard assessments account for this doubt by assigning weights to different inputs based on the hazard analyst's belief in the value being the true one. The resulting assessed hazard is then surrounded by confidence limits showing that the results are not precise but only an estimate.

The assessment of natural hazards has traditionally been conducted independently for an individual phenomenon and separate hazard maps produced for a region for floods, earthquakes, extreme wind etc. Examples of such maps can be accessed through the World Bank's Think Hazard online tool. In the past decade there has been a realisation that natural hazards are often highly coupled and the occurrence of one type of event triggers or can make another more likely (e.g., Gill and Malamud, 2014). It has also been realised that hazards are not static, but their probabilities of occurrence and magnitude can be increased or decreased by human activity, e.g. climate change (e.g. Gill and Malamud, 2017). Both types of interactions are not, however, routinely considered in hazard assessments.

As shown by Simmonds et al. (2022), using a narrative approach for Scotland, weather-driven events (e.g., floods) often arise from a combination of contributing, interacting physical processes and that these processes have complex spatial and temporal links. Failure to consider the multiple causes and drivers behind an event and the associated cascading impacts can lead to an underestimation of risk. Due to our changing climate, it is expected that many weather-related hazards will increase in intensity, occur more widely and more often than before, thereby increasing exposure to emerging hazards. These interactions, as well as the interactions with vulnerabilities, have been identified (Merz et al., 2020) as the next challenge within multi-hazard risk evaluation.

3.3 Validation of the MEDiate concept from the point of view of the state of the art

Moving beyond a siloed approach: Most natural hazard assessments are conducted for a single peril (e.g. earthquake ground motions) or a limited number of effects connected with a single phenomenon (e.g. storms). This leads to a siloed approach, where each hazard is seen individually, and it is difficult to compare between different hazard types or their impacts. It can lead to a biased viewpoint of the hazard and risk profile for a location. The validation showed the need to focus on a board range of multiple natural hazards and their effects rather than just a single or a limited number.

Considering interacting and cascading events and compounding impacts: Often natural hazard assessments consider a single event (e.g. extreme rainfall) but not how this interacts with other phenomena (e.g. extreme rainfall on an already saturated region would have a different effect than the same rainfall in a very dry region). In addition, it is rare that a study considers compounding impacts of a hazard (e.g. extreme rainfall may lead to a flood or a landslide). The validation showed the need to have a particular focus on this type of interaction between events and their impacts and it will develop a framework to consider them.

Considering the future as well as the present: Natural hazard assessments are generally undertaken for present conditions. The drivers for climate/weather-related hazards, however, are changing and there is evidence that these changes are accelerating. For example, due to climate change there are modifications to the frequency and size of extreme-weather events. Changes in land-use (either due to climate change or for other reasons) can also modify interactions between hazards and modifications of their impacts. The validation showed the need to consider both current and future conditions within the multi-hazard assessment framework being developed.

Assessing 'knock-on' effects: Often hazard assessments stop at the potential to cause an impact and pass this information on to risk analysts who estimate that impact on a particular asset. This classic approach means that 'knock-on' effects, in otherwise an impact triggering a further effect, can be missed. This can lead to underestimating the potential impact of an event. An example of this is extreme rainfall triggering a flood that in turns causes a chemical spill. The validation showed the need to include these potential 'knock-on' effects to give a better description of hazards.

Using multiple methods and data sources: Hazard assessments often use a small subset of available data and one or two methods of analysis. This can lead to inaccurate or incomplete hazard assessments. The validation showed the need to employ multiple methods (including machine learning) and various data sources (remote sensing and in-situ data and historical observations) to assess the potential evolution of hazards and impacts.

Focus on general procedures with wide applicability: Many projects are focused on assessing the natural hazards for a specific location and, hence, the procedure followed may not have a wide applicability to other locations. The validation showed the need to focus on developing general procedures and assessment methods that are not tied to a particular location. These procedures are then tailored in the rest of the project to the tests.

Considering the whole of Europe rather than a specific location: On a related point, hazard assessments for different locations often vary in terms of what input data are used, what methods are used, what hazard metrics are used and how the results are presented. The validation showed the need to develop a consistent approach that can be applied throughout Europe to ensure consistency and allow comparisons.

Going beyond susceptibility maps: Hazard assessments are often restricted to producing maps of the susceptibility of a location to a scalar indicator for a given return period (e.g. flood water depth for a return period of 100 years). This does not give a sufficient description of what could happen in a future event. This is because multiple parameters may be relevant to describing the hazard (e.g. flood water depth, water speed and the presence or not of debris) and because it does not provide information on the distribution of event sizes. The validation showed the need to go beyond producing maps of scalar parameters and towards vector descriptions as well as towards a scenario-representation of the hazard.

Producing multi-hazard indicators to support risk assessments and decision making: In current practice hazard assessments often adopt indicators that characterise a single hazard without consideration of whether those indicators are appropriate for different end users (e.g. risk analysts and decision makers). These indicators also are not necessarily appropriate when considering multiple interacting and compounding hazards. The validation showed the need to propose a set of multi-hazard indictors that are tailored to the needs of the end-users using the DSS. Developing this set will be part of the DSS co-development with testbed stakeholders.

4 FORWARD-LOOKING AND PEOPLE-CENTERED RISK ANALYSIS: A REVIEW OF THE STATE OF THE ART

4.1 Introduction

The advent of climate change and its intensifying effects on some natural hazard events, as well as increasing urbanization, population growth, and the general aging of infrastructure systems around the world, have emphasized the need to not only evaluate current disaster risk to our interacting built-natural-social systems, but also to understand its potential amplification in the decades to come. Moreover, policies targeted at mitigating future natural-hazard risks need to promote people-centred strategies to ensure climate justice, equity, transparency in the decision-making process, and participatory management of risk that promotes the well-being and resilience of our communities. Furthermore, considering the notable uncertainties associated with evaluating future risks, these policies should be robust across a set of plausible futures to achieve solutions that are insensitive both to assumptions and modelling errors related to how the future will evolve.

The need to consider the long-term future implications of natural hazards is recognized by well-established intergovernmental organizations, such as the United Nations (UN), the European Union (EU), and the World Bank, among others. For example, the EU encourages a forward-looking approach to assessing disaster risk, particularly highlighting the importance of accounting for climate change impacts (European Commission, 2020). The World Bank underlines the obligation of disaster risk managers to "move instead towards risk assessments that can guide decision-makers towards a resilient future" (Fraser et al., 2016). Furthermore, the Intergovernmental Panel on Climate Change (IPCC) states that "effective risk reduction and adaptation strategies (must) consider the dynamics of vulnerability and exposure and their linkages with socioeconomic processes, sustainable development, and climate change" (IPCC, 2014). Nevertheless, most studies of natural-hazard risks do not consider their long-term evolutionary nature, relying instead on past or static observations of society within current environmental conditions (Gallina et al., 2016). A somewhat recent examination of 80 open-source risk assessment tools for natural hazards (GFDRR, 2014) found that none accounted for future risk in an explicit sense. Even catastrophe loss models used by the re-insurance industry tend to disregard the dynamic relationship between built-environment portfolios and the natural hazards that affect them (Fraser et al., 2016).

This chapter discusses the relatively sparse literature on natural-hazard risk assessment frameworks for a changing world, providing a general overview of the state-of-the-art on the topic. We define the term 'risk' as the convolution of hazard, exposure, and vulnerability, as in many previous studies of natural hazards like flooding and earthquakes (Birkmann and Welle, 2015; Erdik, 2017). In line with this definition, a natural-hazard risk assessment methodology typically involves a (1) hazard definition, in which the natural hazards posing a threat to the region/community are identified and characterized; a (2) exposure characterization, which involves the description of the systems (built, natural, and/or social) that can be potentially affected by the identified hazards; a (3) vulnerability analysis, that quantifies the potential effects of the hazard on the exposed systems through a set of impact metrics; and a (4) decision-making stage in which different mitigation policies are tested to reduce/manage the risk. Following this general structure, the next sections of this document provide a broad overview of the state-of-the-art on future hazard analysis, future exposure, and future vulnerability modelling. The short review finishes by discussing key challenges in modelling future risk as well as introducing the forward-looking people-centred MEDiate conceptual framework for risk assessment, highlighting its novelty and contributions to the field of future natural-hazard risk modelling.

4.2 Future multi-hazard analysis

In general terms, a hazard can be defined as “a process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation” (UNDRR, 2020). Natural hazards are classified under several categories, 1) geophysical (which covers earthquakes, landslides, tsunamis, and volcanic eruptions); (2) hydrological (which includes avalanches and floods); (3) climatological (which accounts for extreme temperatures, drought, and wildfires); (4) meteorological (which incorporates cyclones/hurricanes and storm surges); and (5) biological (consisting of disease epidemics and insect/animal plagues) (Cremen et al., 2022). The hazard analysis component of any risk and resilience assessment framework typically aims to identify, model, and characterize the natural-hazard events that could potentially affect a region. The output of this component is a hazard curve or map in which the intensity of the hazard or multi-hazard scenario for a particular region or system is depicted (Cremen et al. 2022; González-Dueñas and Padgett, 2021).

The quantification of tomorrow’s natural hazards commonly involves accounting for future climatic conditions (Esmaeili et al., 2022; Jevrejeva et al., 2019; Sepúlveda et al., 2021). Climate change raises sea levels globally, affects the intensity/frequency of the strongest storms, increases extreme temperatures, and modifies precipitation patterns (Dessler, 2021). Therefore, climate change projections are frequently used as input to models for heat-, drought-, wind-, fire-, and flood-related risk assessments (Zscheischler et al., 2018; Kwadijk et al., 2010; Dowdy et al., 2019). These data are derived from so-called climate models that are combined with information on possible future emissions scenarios. The term climate model used here incorporates a variety of approaches for quantifying climate dynamics (in line with Van Vuuren et al., 2011), including (in order of increasing complexity) Simple Climate Models (SCMs), Earth-System Models of Intermediate Complexity (ESMIC), and Atmosphere-Ocean General Circulation Models (AOGCMs). SCMs (such as the Model for the Assessment of Greenhouse-Gas Induced Climate Change; e.g., Wigley and Raper, 2001) describe the ocean-atmosphere system as a collection of global or hemispherical boxes and may be used to provide dynamic estimates of global mean temperature and sea-level rise. AOGCMs are the primary tool used for climate projections and comprehensively capture dynamics of the atmosphere-ocean system and other physical phenomena (e.g., land-surface processes). Uncertainties are typically incorporated in climate change predictions via ensemble modelling (Stewart et al., 2014) to provide more informative risk assessments than those produced using discrete scenarios (New et al., 2007). Ensemble modelling may use a series of data from a variety of climate models (Mortin et al., 2014), simulating data from sets of different internal parameters of a single climate model (Murphy et al., 2007) or generating data using a range of input parameters for the same model (Murphy et al., 2004). The first two methods capture modelling uncertainty, while the latter is used to quantify climate variability (which can be natural or otherwise, depending on the range of input parameters used). Examples of future risk modelling efforts that have leveraged climate ensemble modeling include Rojas et al. (2013), Ward et al. (2014), and Muis et al. (2015).

While the literature on hazard modelling is heavily skewed toward the single-hazard scenario analysis (Cremen et al., 2022; Mayo and Lin, 2022; Sepúlveda et al., 2021; Vu and Mishra, 2019), there has been a recent shift to the analysis of multi-hazard conditions driven by the observed severity of damages as a result of major multi-hazard events (e.g., Hurricane Sandy) and their increasing rate of occurrence (Nofal et al., 2021; Tilloy et al., 2019; Zaghi et al., 2016). When considering multi-hazard interactions in a changing climate, the sixth assessment report of the Intergovernmental Panel on Climate Change (IPCC, 2021) report states that "the probability of compound events has likely increased in the past due to human-induced climate change and will likely continue to increase with further global warming". In the last decade, there has been an increasing interest in modelling the impacts of a changing climate on multi-hazard interactions (Feng et al., 2022; Heo and Manuel, 2022; Naseri and Hummel, 2022; Ridder et al., 2020).

Time-dependent approaches are also available for projecting future hazards that are not directly related to climate change, such as earthquakes. In this case, long-term time-dependent hazard assessment procedures condition the expected duration until a fault's next event on the amount of time that has elapsed since its last earthquake (or the occurrence of an event on a neighbouring fault) to account for changes in elastic strain energy. Iacoletti et al. (2021) provide a comprehensive review of these methods. Short-term time-dependent seismic hazard assessments account for the spatial and temporal clustering of aftershock events that follow the occurrence of a mainshock earthquake (Papadopoulos et al., 2020; Iacoletti et al., 2022).

4.3 Future exposure analysis

Exposure is defined as "the people, property, systems, or other elements present in hazard zones that are thereby subject to potential losses" (UNISDR, 2009). In this component, the region's future urban development, population growth, socioeconomic characteristics, infrastructure, and nature-based development are characterized. Therefore, future exposure to natural hazards will be driven by increases in population (such as urbanization, i.e., the movement of people from rural to urban areas), socioeconomic growth (Angel et al., 2011), as well as choices on land use (Santini and Valentini, 2011).

Future population and economic growth are commonly modelled based on socioeconomic scenario storylines (Hammond, 1998; De Vries et al., 1994). These narratives detail alternative characterizations of how the world may evolve depending on political, economic, technical, and social developments at global and regional levels. For example, O'Neill et al. (2014) developed the shared socioeconomic pathways (SSPs) framework that contains five plausible alternative means by which society and ecosystems will evolve in the 21st century (in both narrative form and using a quantified set of socioeconomic metrics that define scenarios). Examples of studies that have leveraged SSPs are Arnell and Lloyd-Hughes (2014); Dottori et al. (2018); Huang et al. (2019), as well as the most recent IPCC report (IPCC, 2021; 2022). Other socioeconomic storylines include the UN Environment Programme's Global Environmental Outlook, the Millennium Ecosystem Assessment, and the World Energy Outlook; a comprehensive review of these and other scenario families is provided by Van Vuuren et al. (2012).

Socioeconomic scenario storylines are highly aggregated and are, therefore, often downscaled to obtain finer-resolution data. For example, population and economic growth forecasts can be proportionally downscaled to the national or regional level, which assumes that the growth rates are consistent at both scales (Gaffin et al., 2004; van Vuuren et al., 2007). Other methods for population downscaling explicitly account for urbanization trends, prioritizing growth in urban regions (Grübler et al., 2007; Nicholls, 2004). Economic growth downscaling can also be determined based on convergence approaches, which ensure consistency with local average values (van Vuuren et al., 2007), and more finer downscaling may differentiate between urban and rural gross domestic product (GDP) (Grübler et al., 2007) or involve stakeholder input (Carter et al., 2004). Population projections can also be quantified or obtained in other ways. Single "best-guess" forecasts of country-wide populations are available from agencies such as the World Bank and the Population Reference Bureau, for example (Lutz and KC, 2010).

For natural-hazard risk assessments, land-use change is typically interpreted as urban growth (Penning-Rowsell et al., 2013), which has been modeled in the literature in various ways. Bottom-up procedures can include the use of cellular automata (CA) or agent-based modeling (ABM). An example of this kind of approach is the SLEUTH (Slope, Land cover, Excluded regions, Urban land cover, Transportation, and Hillshade) model (Chaudhuri and Clarke, 2013). SLEUTH uses previous maps of historical growth (containing the first five features of its acronym) to probabilistically determine future land use according to relatively simple simulation rules founded on spatial autocorrelation and neighbourhood effects. It has recently been applied to simulate urban growth in the city of Istanbul (Sarica et al., 2020), the state of California (Clarke and Johnson, 2020), the Kathmandu Valley in Nepal (Mesta, Cremen, and Galasso 2022), and at a global scale (Zhou et al., 2019). Urban growth may also be simulated using empirical (Hu and Lo, 2007) or semi-empirical (Santini and Valentini, 2011) methods, landscape metrics (Taubenböck et al., 2009), machine learning approaches (such as artificial neural networks, Tayyebi et al., 2011), coupled Markov chain-genetic algorithm models (Tang et al., 2007), weight of evidence (Soares-Filho et al., 2004), socioeconomic storylines (Te Linde et al., 2011), as well as integrated top-down, bottom-up approaches that capture interactions at various scales (Verburg and Overmars, 2009; Promper et al., 2014).

4.4 Future vulnerability modelling

Vulnerability is broadly defined as "the characteristics and circumstances of a community, system, or asset that make it susceptible to the damaging effects of a hazard" (UNISDR, 2009). Herein, we particularly focus on physical vulnerability, which may be interpreted in this context as the tendency of exposed elements (assets) to suffer adverse effects when impacted by natural hazards (Cardona et al., 2012). Risk assessment methods account for the future vulnerability of physical infrastructure to natural hazards from two main perspectives. The first of these outlooks assumes that vulnerability will increase in time because of unplanned/informal modifications or maintenance/degradation challenges. In contrast, the second focuses on the reduction in vulnerability that can be achieved by adapting infrastructure to future conditions.

One of the foremost attempts to quantify dynamically increasing building-level physical vulnerability is the work of Lallemant et al. (2017). This study developed a framework for modeling the time-dependent earthquake fragility (i.e., the probability of collapse as a function of the hazard intensity) of incrementally expanding construction, which is a commonly adopted strategy for accommodating ever-increasing urban growth in developing countries (Amoako and Boamah, 2017). In addition, several reviews on approaches for modeling/quantifying the environmental degradation of physical assets have been released in recent times (Kashani et al., 2019; Amaya-Gómez et al., 2019; Guo et al., 2019). Moreover, research on the effects of environmentally driven deterioration on the built environment is beginning to account for future climactic conditions (Bastidas-Arteaga and Stewart, 2015, 2016; Wang et al., 2012; Stewart et al., 2012; El Hassan et al., 2010; Yang and Frangopol, 2020; Sevieri and Galasso, 2021). This is important, given that rising carbon dioxide levels associated with global warming will increase the likelihood of carbonation-induced corrosion (Stewart et al., 2011). The work of Yang and Frangopol (2019a) recently leveraged various general circulation models to determine future scour-induced failure probabilities of bridges (and the associated long-term risks).

Work that has focused on a potential reduction in the future vulnerability of the built environment is often framed within the context of dynamically increasing climate risks and termed “climate adaptation engineering” (Stewart et al., 2014; Stewart and Deng, 2015; Mondoro et al., 2018). For example, Stewart (2015) assessed the risk, costs, and benefits of climate adaptation strategies for reducing the vulnerability of new housing to evolving wind-induced risk for three cities in Australia under three emission scenarios. Qin and Stewart (2020) probabilistically examined two adaptation options for reducing the vulnerability of Australian housing to non-cyclonic windstorms in a changing climate, i.e., reinforcing the building envelope or increasing the water resistance of the building interior.

4.5 Risk quantification

Risk metrics (i.e., impact metrics) act as a crucial bridge between the quantitative risk assessment and the decision-making process that they are used to inform (Johansen and Rausand, 2014). High-level preliminary assessments have used relative risk indices to identify potential future natural-hazard risk hotspots (Hawchar et al., 2020). Most future-focused approaches to quantifying natural-hazard risk have concentrated on measuring risk in terms of conventional asset losses. For example, Stewart et al. (2018) examined the consequences of climate-induced extreme wind loading on residential roofs in terms of its percentage of the house value. Both Forzieri et al. (2018) and Dawson et al. (2009) quantified the effects of future natural-hazard events as the expected annual cost of damage to physical infrastructure and/or agricultural land, while Salmanidou et al. (2021) measured risks from future tsunamis in terms of their effect on the value of household- level assets. Other authors (Gaslikova et al., 2011; Schwierz et al., 2010) have focused exclusively on insured property losses.

Some authors have offered wider perspectives on risk and have quantified the impacts of future natural-hazard events in terms of multiple metrics and/or based on a broader network-level perspective. Stewart (2016) examined structural, non-structural, and business interruption losses associated with roof cover damage to industrial and commercial buildings in future wind events. Stewart et al. (2014) considered both the direct and indirect losses (in the form of, for example, residential clean-up, alternative household accommodation, disaster response and relief, injuries and fatalities, and business and economic disruption) associated with projected wind-related damage to residential buildings. Yang and Frangopol (2019b) quantified the societal risk of the impacts of climate change on transportation networks, which accounted for the costs incurred by users due to necessary detours and the loss of time. Both Liu et al. (2020) and Yang and Frangopol (2019a) considered the societal risk metric in addition to the direct economic cost associated with transportation-network bridge failure. Verschuur et al. (2020) measured the risk associated with future Bangladesh flooding events using a Composite Development Index, which incorporated information on welfare losses, the relative extent to which policy interventions reduce these losses for poor households, and resilience (i.e., the ratio of the asset to welfare losses).

4.6 Modeling future risk from natural hazards: key challenges

Accounting for deep uncertainties: A key challenge that is shared among the relatively small body of existing literature on modeling future risks from natural hazards is the deep uncertainty associated with projections of climate, future societal development (e.g., population dynamics, socioeconomic development patterns, changes in land cover, infrastructure development), and the changes in vulnerability of existing and future built-natural-social systems (Doss-Gollin and Keller 2022; Giudici et al. 2020; Kopp et al. 2019; Shepherd et al. 2018). Deep uncertainty scenarios arise when it is not possible to characterize the future using a single trajectory, and the likelihood of different trajectories and the models describing them cannot be unequivocally assigned (Jevrejeva et al., 2019; Kopp et al., 2019; Stein and Stein, 2013).

To handle the deep uncertainty associated with future projections of climate and development variables, climate risk management studies commonly implement the "states of the world" (SOWs) approach to describe possible trajectories of the future (Doss-Gollin and Keller, 2022; Hinkel et al., 2019). These trajectories can be defined in terms of future climate, socioeconomic, population, or other key parameters (e.g., energy pathways, land use) projections relevant to the analysis. The SOWs concept embraces the idea that the future may unfold in different ways (especially on increasing timescales) and attempts to broadly capture these different plausible futures to provide a representative "sample" of the future. The selection of plausible future trajectories using the SOWs concept will ultimately depend on the type of questions to be answered, such as: "what would happen if…", "how could we get to…", "what are the response options we could take to…", "what are the major sources of uncertainty in…". This makes the SOW concept a helpful modeling tool by providing the means to tailor the analysis toward the bespoke needs/concerns of the stakeholders involved while considering the specific aspects of future projections (e.g., climate change, infrastructure development, population) for the problem at hand.

Several methodologies have been proposed in the literature to characterize plausible future trajectories (i.e., SOWs), such as the narrative and storyline approaches (Shepherd et al. 2018). An example of a narrative approach is the Shared Socioeconomic Pathways (SSP) introduced in the *Future exposure analysis* section, in which different pathways of societal development are explored to understand how human choices might affect greenhouse emissions in the future. The storyline approach is usually implemented to answer more regional/local problems associated with climate change by choosing climate projections (output from GCMs as specified in the *Future multi-hazard analysis* section) and constructing a "self-consistent unfolding of events" (Shepherd et al., 2018) to represent uncertainty. For example, a storyline approach might start from the question of how climate change will affect the water infrastructure of a region and define climate projections, choose models (a global climate model, a regional climate model), and the important climate variables to characterize (sea-level rise, precipitation) by constructing "stories" (i.e., a qualitative characterization of events) around them (Shepherd et al., 2018).

Decision-making: Decision makers of today have a remarkable opportunity to positively influence tomorrow's risks through their choices in implementing strategies/policies that control future risk drivers. The selection of risk-management interventions as part of this decision-making process must consider the dynamic nature of hazard, exposure, and vulnerability. In other words, given the deep uncertainties associated with how the future will evolve, mitigation and adaptation solutions (e.g., structural retrofitting, accessibility to recovery funds to vulnerable populations) must be robust across a set of plausible future trajectories (i.e., different SOWs). Herein, a robust solution (e.g., design, policy) is defined as one that "performs reasonably well under a variety of possible future scenarios (i.e., SOWs) and is insensitive to errors and uncertainties in the parameter assumptions" (Brockway et al., 2022; Hinkel et al., 2019). Furthermore, a people-centred, participatory decision-making approach should be encouraged and implemented to reduce any potential negative effects of climate change on our communities (i.e., avoid maladaptation (IPCC, 2022)), especially on vulnerable and marginalized populations (Brockway et al., 2022).

Techniques such as scenario discovering (also called exploratory modeling), signposts and tipping points (a key technique of adaptive planning), and participatory modeling have been proposed in the literature to address the challenge of developing robust solutions and engaging multiple stakeholders in a people-centred decision-making process (Brockway et al., 2022; Doss-Gollin and Keller, 2022; Hinkel et al., 2019). For instance, the scenario-discovering strategy systematically develops a set of future trajectories to implement mitigation strategies that are not sensitive to the SOW chosen (Brockway et al., 2022; Hinkel et al., 2019). On the other hand, signpost and tipping point analysis is an adaptative planning approach that, through the continuous monitoring of some predefined indicators (tipping points), identifies the point where a mitigation policy would stop being effective (signpost; Brockway et al., 2022). Participatory modeling strategies aim to facilitate multistakeholder engagement to co-produce mitigation strategies and impact metrics, monitor the performance of the proposed solutions/policies, increase transparency in the planning process, seek active support and consensus on decisions being made, and incorporate different perspectives in the decision-making process (Brockway et al., 2022; Cremen et al., 2022).

Brockway et al., (2022) conducted an exhaustive literature review on decision science under deep uncertainty. They outlined how adaptative planning, robustness, and multistakeholder engagement could be incorporated into the design and capacity expansion of the electricity sector while considering climate-related uncertainties. Hinkel et al., (2019) described the type of sea-level rise data needed to inform robust decision-making methods (e.g., exploratory modeling) and flexible decision-making (i.e., adaptive planning). Doss-Gollin and Keller (2022) proposed a methodology that combines exploratory modeling and Bayesian analysis to synthesize deep uncertainties across different states of the world. They applied it to the problem of how much to elevate a coastal house, considering multiple climate models and their associated sea-level rise predictions.

4.7 The validation of the MEDiate concept and the proposed MEDiate framework

Despite clear and numerous efforts to model individual risk components associated with future natural-hazard events, there remains a lack of a commonly accepted analytical framework for complete end-to-end risk quantification. This gap in the state-of-the-art is addressed through the proposed conceptual framework for MEDiate. Figure 5 displays the main components of this framework. The first four components of the framework constitute the "Conceptualization" stage of the framework, in which plausible trajectories of the future are defined based on development (e.g., socioeconomic, demographic) and climate projections for the region under analysis. "Impact Analysis" constitutes the second stage of the framework and involves the analysis of the effects that future climatic and development conditions will have on the built-natural-social systems of the region and their quantification through a set of impact metrics. Finally, the last step of the framework aims to evaluate how different strategies and policies can help to mitigate the risk posed by natural hazards to the region and the community to support climate and development-aware decision-making.

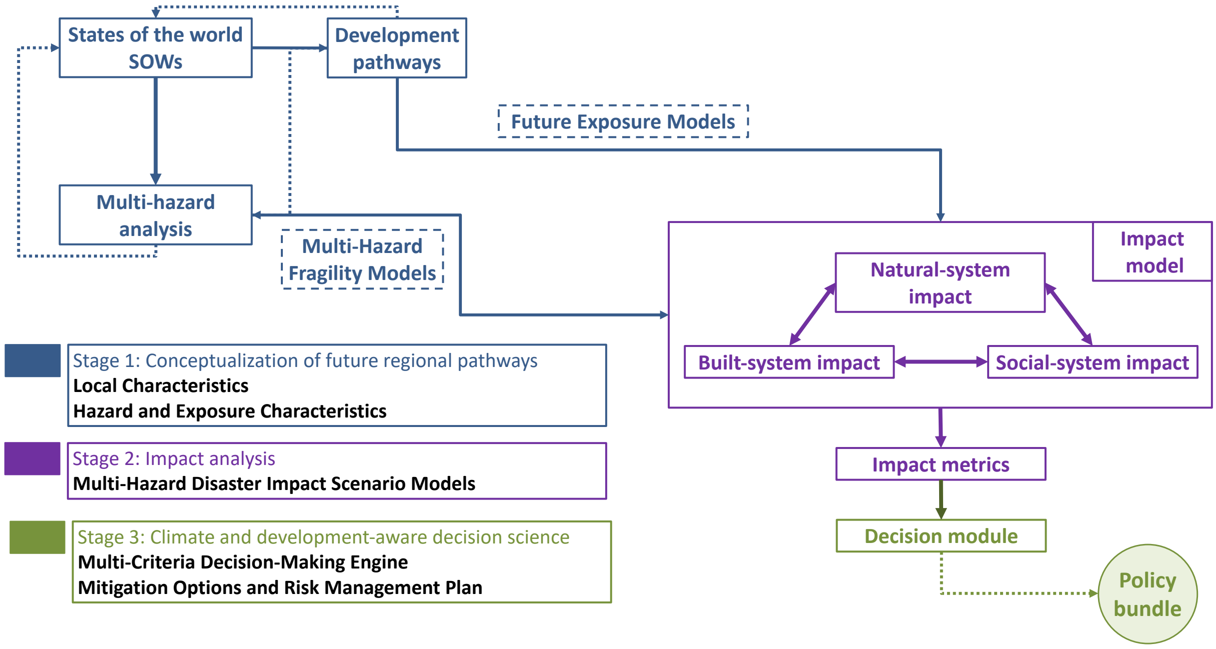

Figure 5: Forward-looking people-centred natural-hazard risk assessment framework.

The proposed MEDiate conceptual framework deviates from existing risk analysis frameworks by (1) highlighting potential trends in natural hazard characteristics and occurrence due to climate change; (2) accounting for interactions among hazards; (3) evaluating cascading consequences of disasters due to system interdependencies; (4) proposing and evaluating novel people-centered impact metrics that encompass the multidimensional impact of natural hazards and different end-user perspectives; and (5) providing the means to analyze the impact of mitigation strategies across the range of "plausible futures" defined by the different potential climate and development patterns. The framework will form part of a broader decision support system in which different policies can be tested across different possible climate, urban, and socioeconomic trajectories in a participatory process, leading to the implementation of risk mitigation strategies that are robust and adaptable. Implementing the proposed framework to testbed sites can contribute to shedding light on the evolving risks of different regions in Europe exposed to multi-hazard events, supporting informed decision-making that accounts for critical uncertainties in system response and the effects of climate change on hazard and societal development.

5 ORGANISATIONAL RESILIENCE IN THE CONTEXT OF NATURAL HAZARDS

5.1 Organizational resilience

This section provides an input to finetune and to further develop the MEDiate concept from the point of view of the literature and the state-of-the-art in organisational resilience management in the context of natural hazards. Organisational resilience refers to the ways in which organisations resist, absorb, accommodate, adapt to, transform, and recover from a disaster event (Jones et al., 2020, PreventionWeb, 2020, Denyer, 2017). Organisations rely on both physical and human assets in their efforts to provide goods and services to their communities through their supply and distribution chains. As such, organisational resilience in the context of natural hazards depends on the effective management and design of both physical and social organisational structures and processes.

Early work by Holling (1973, 1996, 2001) sees resilience as a complex system, comprising two types of resilience: engineering resilience and socio-ecological resilience. The former measures a system's resilience by assessing how long it takes to go back to its *original equilibrium* point, after a disturbance. The latter measures a system's resilience instead by the magnitude of an external shock that a system can recover from by reorganizing to a *new equilibrium*. A similar distinction was made by Tiernan et al. (2019) who looked at the relationships between resilience and disaster risk reduction in the context of the UNDRR Sendai Framework for Disaster Risk Reduction 2015-2030 (UNDRR, 2015). They distinguished between *adaptive resilience* and *engineering resilience* when describing a system's ability to remain stable, recover from external shocks and adapt to new circumstances. Cutter et al (2016) made a similar distinction in their work. They distinguished between *inherent resilience* and *adaptive resilience*. Whereas the former refers to static features of resilience that can be used to measure inherent (or baseline) resilience, the latter refers to the dynamic (socio-ecological) features of resilience that can be used to assess a system's ability to cope after a disaster event (such as learning and responding). Both inherent and adaptive resilience determine how a system will cope with external shocks. This is depicted in Figure 6.

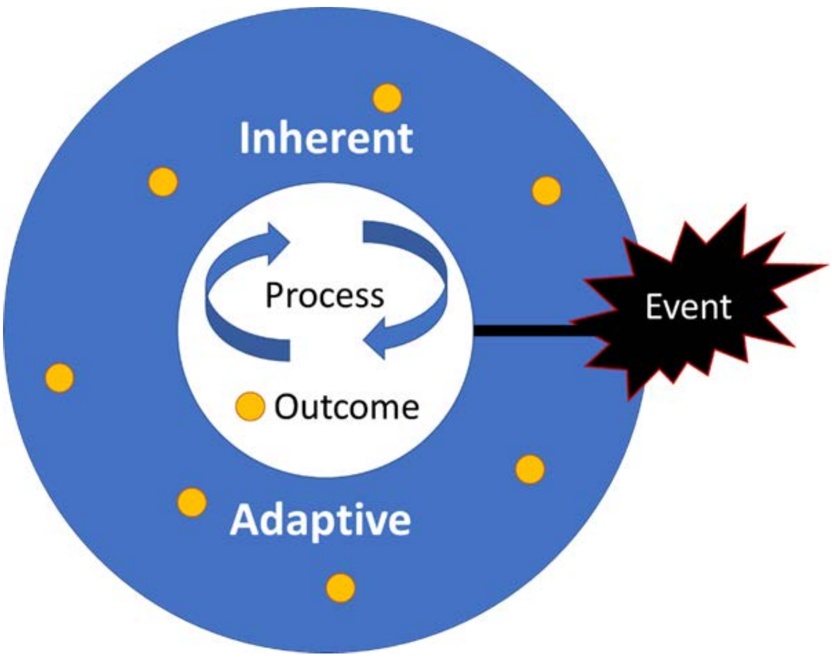

Figure 6: Inherent (engineering) resilience, measured against a static benchmark (the system's original equilibrium) and adaptive (socio-ecological) resilience, measured against the magnitude of the external shock the system can recover from by dynamically reorganizing to a new equilibrium. In this figure dynamic features of resilience are blue and static features are yellow. (Source figure: Cutter, 2016)

Organisations exhibit similar attributes to the ones studied by Holling, Tiernan, and Cutter to develop their insights into resilience. As such, organisational resilience benefits from being studied both through the lens of inherent (engineering) resilience and through the lens of adaptive (socio-ecological resilience) (Jones et al., 2020).

5.2 Factors affecting organisational resilience and business continuity

Tierney and Webb (2001) reviewed five studies into business organisations' vulnerability to disasters, conducted in the 1990s. These studies used survey research, sometimes followed up by in-person interviews. They involved around 5000 businesses and focused on how organisations prepare for and recover from disasters. Regarding preparation, they found that most businesses did little to prepare for disaster events. When businesses did prepare, their preparations were mainly low-cost and easy to implement operational interventions; most did not develop strategic disaster recovery plans to reduce business disruption and improve post-disaster recovery.

This lack of a strategic approach was a problem: Tierney and Webb (2001) found that what mattered most for recovery was not the level of overall preparedness, but whether organisations had taken preventative measures that had a direct impact on either short-term or long-term business recovery. Most businesses surveyed recovered in a relatively quick time after a disaster event. However, Tierney and Webb (2001) identified several risk factors that negatively affected recovery: 1) organisational size: smaller organisations were less likely to recover; 2) the degree of disruption to business operations: the indirect losses caused by disrupted operations had a greater impact than the direct losses caused by physical damage and a loss of production; 3) damage to the surrounding area: businesses located in areas that sustained a high level of damage recovered more slowly, even if they had not sustained damage themselves. 4) economic conditions: the state of the sector and wider economic conditions were more important than 5) an individual organisation's financial condition (the relationship between the latter and economic recovery was shown to be complex); 6) sectoral effects: businesses in the construction and manufacturing sectors recovered more quickly than those in other sectors; 7) business market: business with national and international markets recovered on average more quickly than businesses that relied primarily on their local market. As such, Tierney and Webb (ibid) concluded that how an organisation fares during and after a disaster depends only in part on firm-level attributes and the decisions made by management: it is also largely shaped by factors that are outside of the control of individual organisations.

5.3 Inherent and adaptive organisational resilience

Tierney (2007) further built on this research by looking at organisations' inherent and adaptive resilience. She defined the former as characteristics that mitigate the effects of disasters on business operations and the latter as characteristics that facilitate adaptation and improve business options following a disaster. She argued that inherent business resilience relates to the impact a disaster has on the functional performance of a business, i.e., on the relationship between business disruption and income streams. As such, she linked inherent business resilience to displaying fewer of the negative risk factors outlined above (i.e., lower vulnerability), which can be brought about through strategic business continuity and disaster management planning. This planning should not centre on actions to improve workplace preparedness, but instead focus on actions to reducing exposure to the hazard and mitigate against the potential damage and disruption caused by the disaster. Tierney (2007) argued that an organisation's adaptive resilience relates to its ability to limit the negative impact of a disaster on its business through mitigation actions aimed at safeguarding its supply chain, and through innovations that improve its response and recovery options during and after the disaster. She repeated the conclusions from her earlier research, highlighting the interconnectedness between businesses, governments, and local communities, and pointed out that many factors that affect business resilience are beyond the control of individual business organisations.

5.4 The role of decision makers

Han and Nigg (2011) confirmed the risk factors described above, but also highlighted the central role of decision makers in organisational resilience. They found that decision makers' attitudes towards risk as well as their perception of risk were important risk factors. They developed an analytical framework whereby they linked organisational features and attributes of decision makers to disaster preparedness (see Figure 7). They relied hereby on a detailed study by the University of Delaware Disaster Research Centre, as well as a critical review of the literature. They developed an index based on 17 disaster preparedness activities and applied this retrospectively to organisations affected by the Loma Prieta earthquake in 1989. They awarded organisations one point for each activity, giving each organisation a disaster preparedness score, between 0 to 17. They also developed an index to assess the risk perception of decision makers, who were asked to score on a scale of 0 to 3 (whereby 0 represented the lowest and 3 the greatest) 1) the likelihood of a potentially damaging earthquake event (in the next year, the next 10 years, and the next 30 years) and 2) how much damage they thought would result. The product of the perceived probability and severity formed the basis of the risk perception index. They analysed the relationship between organisational features, the characteristics of decision makers and disaster preparedness using 4 regression models. They found that decision makers perceptions of the risk of future disasters played an important role in disaster preparedness. Having lost lifelines (electricity, phone, water, sewer, gas) in a previous disaster was also an important driver.

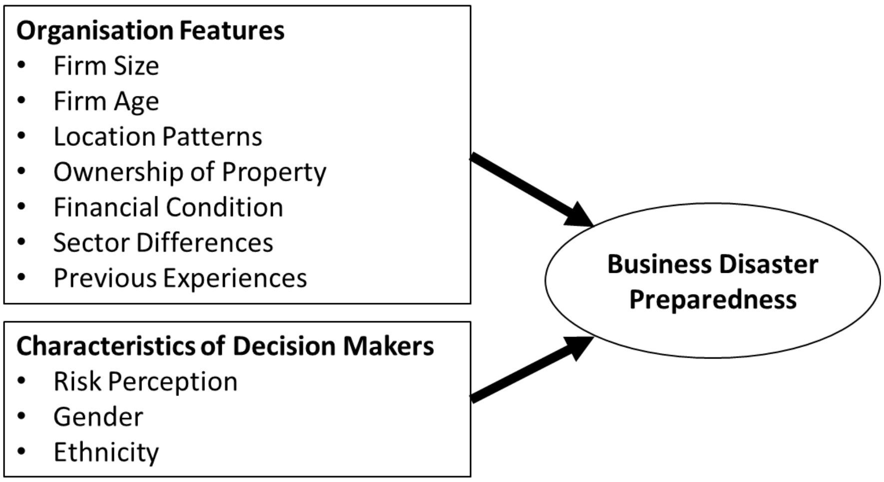

Figure 7: How organisational features and characteristics of decision-makers shape disaster preparedness (based on Han and Nigg, 2011)

5.5 Organisational resilience as multidimensional and context-specific

Gibson and Tarrant (2010) outlined six key principles of organisational resilience based on which they critiqued existing models. They argue that, 1) *resilience is an outcome*: it is not a management system or a predictive measurement, 2) *resilience is not a constant*: it dynamically varies with context, 3) *resilience is a combination of factors*: it is not a single trait, 4) *resilience is multidimensional*: models need to reflect different complementary perspectives, 5) *resilience is reactive, prepared, or adaptive*: it varies within and across organisations facing the same disaster, 6) *resilience is based on effective risk management*: it is based on the evaluation, treatment, monitoring and communication of risk. Based on these principles, they questioned measuring attributes that indicate resilience at a single point in time, as these attributes (such as resources, infrastructure) may be different in times of disaster to when they were measured. They argue that organisational attributes should instead be seen as its resilience capability. Organisational resilience is an outcome and depends on how these capabilities perform in a disaster situation. In their view, risk management plays hereby a coordinating role by integrating business continuity, disaster, and security management with organisational strategy and capabilities.

Gibson and Tarrant (ibid) developed three variants of an organisational resilience model (see Figure 8): a composite model in which strategy informs operations and emergent leadership drives adaptation; a herringbone model in which the activities, capabilities, and characteristics that are critical to the organisation's functioning in normal times can adapt and continue to function after a disaster; and the triangle model which highlights the need to continuously review and adapt to ensure that capabilities remain fit for purpose, flexible to changing conditions, and able to continue to perform in times of disaster.

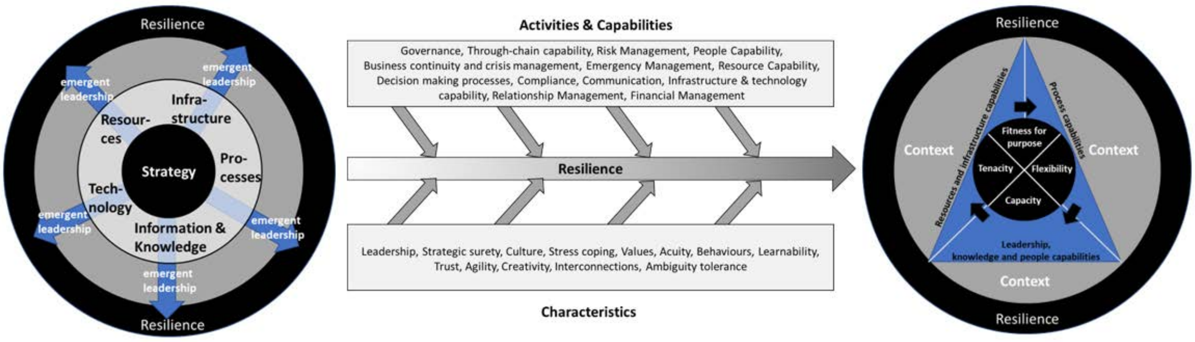

Figure 8: Composite Resilience Model, Herringbone Resilience Model, and the Resilience Triangle Model, (Source: Gibson and Tarrant, 2010)

They also identified four different types of organisational strategies to improve resilience: one focusing on resistance, one on reliability, one on redundancy and one on flexibility. Strategies that centre on *resistance* aim to enable the organisation to continue to perform 'normally' in times of disaster (or as closely to that as possible) by predicting the impact and by implementing mitigation actions (e.g., land use planning). Strategies that focus on *reliability* try to ensure that key processes and structures continue to provide an 'acceptable' level of performance after a disaster until the organisation has fully recovered (e.g., business continuity planning). *Redundancy* strategies aim to set up alternative approaches to continue to provide performance to an 'acceptable' level in times of disaster (e.g., back-up systems). Finally, strategies that centre on *flexibility* give organisations the ability to adapt to disaster events. These strategies focus on 'soft' issues, such as training for disaster situations and establishing an environment for emergent leadership, trust, loyalty, and a unified purpose. Gibson and Tarrant (ibid) conclude that organisations that are resilient show a well-developed understanding of the disaster risks they face (regardless of how they are modelled) and have a clear strategy for addressing these risks.

5.6 Defensive and progressive organisational resilience strategies

Denyer (2017) conducted a review of the state-of-the-art in organisational resilience, analysing 181 papers and five case studies, for the British Standards Institute and Cranfield University. He used the BS 65000 (2014) definition of organisation resilience: to "anticipate, prepare for, respond and adapt to incremental change and sudden disruptions to survive and prosper". He identified the four distinct approaches shown in Figure 9. Starting in the bottom left corner, *preventative control* aims to protect the organisation from threats, supporting its recovery to the original (pre-disaster) equilibrium. Moving right, *mindful action* extends preventative control, highlighting the central role of people in identifying and responding to threats. In the top left corner, *performance optimization* centres on the importance of continuously improving the services provided to customers. *Adaptive innovation* extends this idea to new markets. Organisational resilience depends on the effective balancing of these approaches and managing the tensions between them.

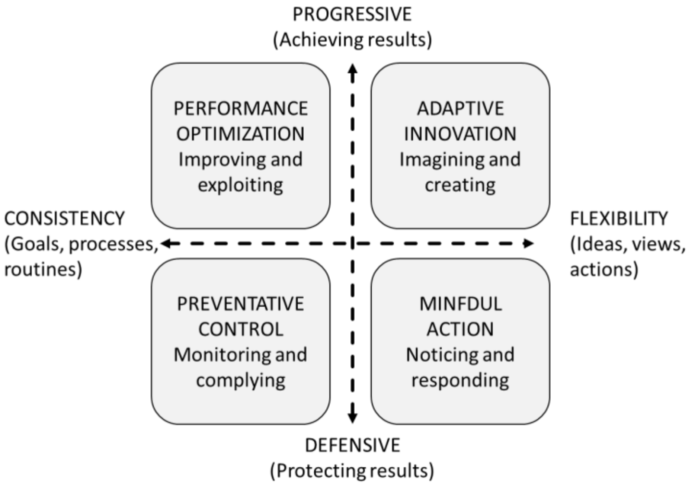

Figure 9: The Organizational Resilience 'Tension Quadrant' (Source: Denver, 2017)

Denyer (ibid) argued that organisations need to move beyond defensive resilience behaviours to minimise threats and embrace progressive behaviours to adapt to new opportunities. To this end, he developed tools for decision makers to develop and maintain organisational resilience. These tools centre on four perspectives (4Sight): 1) *foresight* enables organisations to identify threats - and opportunities to mitigate them, 2) *insight* enables organisations to understand how a threat would affect the organisation in its entirety as well its constituent parts, 3) *oversight* entails putting processes in place to manage the risks that have been identified, and 4) *hindsight* enables an organisation to learn from past experiences.

5.7 Operational toolkits for organisational resilience

Several other toolkits have been developed to help organisations understand, evaluate, and manage their organisational resilience. For example, Lee et al. (2013) developed an operational toolkit based on the *relative overall resilience* (ROR) model developed by McManus (2008). The ROR model is based on three factors: 1) situational awareness, 2) the management of key vulnerabilities; and 3) adaptive capacity. Lee at al. (2013) added one factor: 4) resilience ethos. They also added eight indicators to the original 15 identified by McManus (2008). The factors and indicators are listed in Table 1; the factors are in bold font, the items added by Lee at al. have a grey background.

Table 1: Indicators of Relative Overall Resilience. Source: Lee et al.2013 (adapted from McManus 2008)

Resilience ethos		
Commitment to resilience Network perspective		
Situational awareness	**Management of keystone vulnerabilities**	**Adaptive capacity**
Roles and responsibilities	Planning strategies	Silo mentality
Understanding and analysis of hazards and consequences	Participation in exercises	Communications and relationships
Connectivity awareness	Capability and capacity of internal resources	Strategic vision and outcome expectancy
Insurance awareness	Capability and capacity of external resources	Information and knowledge
Recovery priorities	Organizational connectivity	Leadership, management, and governance structures
Internal and external situation monitoring and reporting	Robust processes for identifying and analysing vulnerabilities	Innovation and creativity
Informed decision making	Staff engagement and involvement	Devolved and responsive decision making

The indicators identified by Lee at al., (2013) are based on an analysis of organisational resilience from four different business perspectives. The indicators are designed to 1) demonstrate progress towards resilience, 2) lead progress towards resilience, 3) connect improvements in organisational resilience with competitiveness, and 4) show the business case for investing in resilience. The indicators meant to capture in a concrete tangible manner a complex multidisciplinary sociotechnical phenomenon (i.e., organisational resilience) enabling organisations to use them to evaluate their own resilience. Both the original ROR model by McManus (2008) and the extended one by Lee at al. (2013) were tested on 68 organisations based in New Zealand[1].

Another important toolkit for organisations is the Disaster Resilience Scorecard for Industrial and Commercial Buildings (UNDRR, 2020). It has been designed to be used by a wide range of organisations to help them understand the resilience of their built assets to disaster events. The scorecard is structured around UNDRR's Ten Essentials for Disaster Risk Reduction (see Table 2). It facilitates a holistic evaluation that includes not only building-specific factors but also factors that pertain to the interdependencies between buildings and the wider organisational and socio-economic context. The toolkit includes a summary scorecard that covers 33 assessment areas, an in-depth scorecard that covers 116 areas, an action guide, and spreadsheets for collecting data[2].

[1] Their resilience toolkit can be accessed here: http://orgrestool.resorgs.org.nz/orgres-tool/

[2] The toolkit can be accessed here: https://www.preventionweb.net/publication/disaster-resilience-scorecard-industrial-and-commercial-buildings-use-building-owners

Table 2: The UNDRR Ten Essentials for Disaster Risk Reduction

The UNDRR's Ten Essentials for Disaster Risk Reduction				
Essential 1: Organise for Resilience	**Essential 2:** Identify, Understand and Use Current and Future Risk Scenarios	**Essential 3:** Strengthen Financial Capacity for Resilience	**Essential 4:** Pursue Resilient Urban Development	**Essential 5:** Safeguard Natural Buffers
Essential 6: Strengthen Institutional Capacity for Resilience	**Essential 7:** Increase Social and Cultural Resilience	**Essential 8:** Increase Infrastructure Resilience	**Essential 9:** Ensure Effective Disaster Response	**Essential 10:** Expedite Recovery and Build Back Better

Organisational resilience toolkits can take various forms, such as metric-based or checklist-based approaches. The researchers responsible for operational testing, co-evaluation, and business modelling within the MEDiate project (Anglia Ruskin University) developed the organisational resilience framework depicted in Figure 10. The Resilience Assessment and Improvement Framework (RAIF) is a decision support tool for organisations to (1) evaluate their antecedent vulnerability and resilience to a hazard, (2) evaluate the impact that the hazard could have on the ability of the organisation to deliver its core services, and (3) assess the effect of different mitigation and adaptation actions on the organisation's vulnerability and resilience to the hazard. The toolkit also encompasses a procedure for establishing the costs and benefits of different actions, identifying the most effectives ones and integrating them into business continuity and disaster recovery plans. The RAIF was developed for the purpose of improving organisational resilience to liquefaction but can also be applied to other natural hazards.

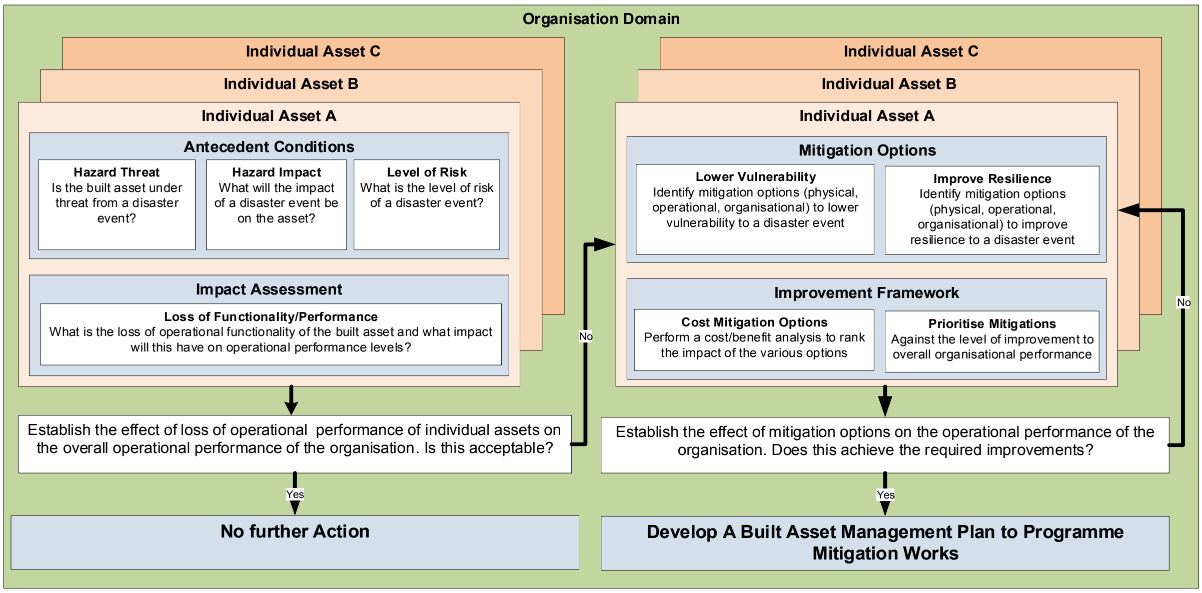

Figure 10: The Resilience Assessment and Improvement Framework (adapted from Morga et al., 2020)

5.8 Validation of the MEDiate concept and going forwards

The MEDiate project will develop a decision-support system (DSS) for disaster risk management by considering multiple interacting natural hazards and cascading impacts using a novel resilience-informed and service-oriented approach. Building on the research outlined above, Anglia Ruskin University (ARU) will work with end-user stakeholders to ensure that the MEDiate platform is 'fit for purpose' and addresses stakeholders' needs and requirements. ARU will develop an exemplar Business Continuity and Resilience Plan (BCRP) and Disaster Management Plan (DMP) framework that local authorities, businesses and critical infrastructure organisation can use as the basis for integrating the MEDiate platform into their organisational resilience planning. Templates will be developed for BCRP and DMP that individual businesses, critical infrastructure organisations and regional authorities can customise to reflect their own specific circumstances. When developing this framework, the focus will be on the cost and business options available to exploit, support and maintain the DDS. Consideration will also be given to quantifying the benefits that would accrue from the use of the MEDiate DSS in terms of organisational and community resilience. The outcome will be a model BCRP/DPM framework (implemented within the MEDiate DSS) to support short-term impact and pathways to support post-project medium/long-term impacts.

6 MULTI-HAZARD AND RISK INFORMED SYSTEM FOR ENGAGED LOCAL AND REGIONAL DISASTER MANAGEMENT

6.1 Introduction

This chapter focuses on the validation of the MEDiate concept from the point of view of co-development with decision-makers of a multi-hazard disaster risk decision-support system. It discusses the need to create a scenario-based web platform to integrate the hazard, exposure, and vulnerability information of social and physical components to compute and visualise integrated risk. To do this, it will implement the algorithms and models developed in frames of the MEDiate project and co-develop, as part of the Participatory Action Research (PAR) cycle, a decision-support system (DSS) to provide multi-hazard scenarios and allow stakeholders to understand the impact of their planned actions.

The overall ambition of MEDiate (represented in Figure 11) is to consider multiple interacting and compounding hazards, particularly those predicted to get more frequent and more intense due to climate change and predict how the components of risk will change over time. Co-design, co-development, and co-evaluation of the DSS, based on close and long-running interactions with end users located in four European testbeds, is central to the project's vision. This DSS will allow end users to model and visualise potential disaster scenarios and understand how potential physical and social actions will influence the scenarios and their communities' resilience to current and future natural hazards.

Indeed, MEDiate will analyse relevant data and co-develop the DSS with decision-makers to enable more reliable resilience assessments, accounting for risk mitigation and adaptive capabilities, therefore helping to reduce losses from future disasters in Europe. The project will consider the most important natural hazards in Europe: hydrological-meteorological-climatological (e.g., storms, floods, drought, and forest fires) and geophysical (earthquakes and landslides).

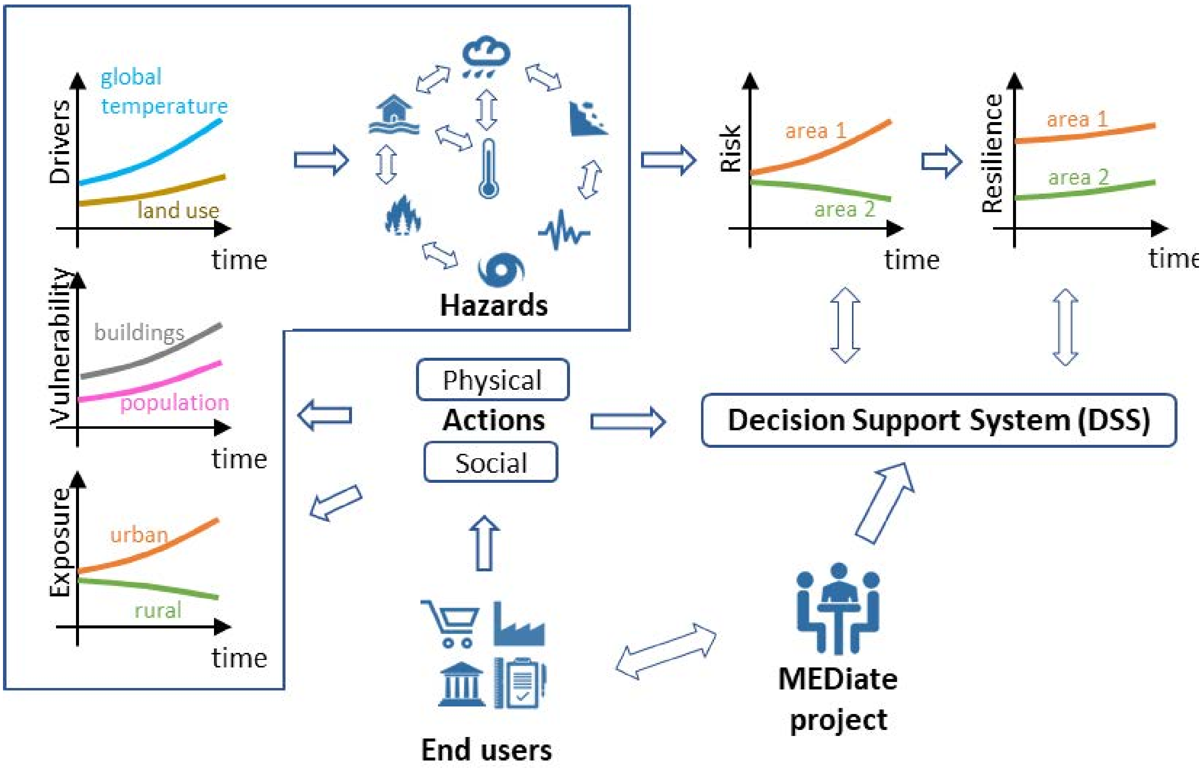

Figure 11: Overall ambition of MEDiate project

6.2 Validation of the MEDiate concept with respect to the state of the art

Different risks are usually tackled following a siloed approach. Different phases of the process – from the analysis of climatic scenarios to local adaptation processes – are often addressed separately and floods and droughts are not considered with an integrated approach. Furthermore, vulnerability and risk analyses are not performed from a multidisciplinary perspective, integrating physical, economic, and social impacts. Compounding and cascading effects of hazards, although extensively reviewed and visualised (Gill and Malamud, 2014), are not regularly included within risk and resilience assessments. Consequently, decision makers struggle to comprehensively understand local climate change impacts, thus failing to successfully plan integrated adaptation and impact mitigation strategies. MEDiate will be one of the first projects in Europe to develop models of compounding and cascading effects and to apply these within risk and resilience assessments and, finally, to implement these models within an accessible, user-friendly IT system so that end users can understand, quantify, and visualise future multi-risk situations.

The risk from natural hazards can be mitigated, however, through measures related to engineering (e.g. retrofitting of buildings to better withstand earthquake shaking), policy (e.g. better land-use planning to discourage building in areas prone to floods), social sciences (e.g. improving community resilience) and financial measures (e.g. making better use of insurance to reduce the chance of catastrophic financial losses). Application of such mitigation measures, as well as improving the public's comprehension and interpretation of long-term guidance versus short-term warnings, could slow or even stop the forecast increase in losses from disasters in the coming decades. Providing end users (e.g. municipalities, civil protection and asset managers) with the ability to build accurate scenarios accounting for the potential impact of their actions (and those of other actors), based on improved models for forecasting the location and intensity of events considering potential future trends in exposure and vulnerability, remains a key requirement to reduce future risk and enhance community resilience. MEDiate rises to this challenge by providing an assessment framework and web services for a DSS that will be readily adaptable for various end users. The DSS will be validated and verified within the project by means of four testbeds that will be co-developed with project partners who will be end users of the DSS in those testbeds.

Decisions to mitigate risk are often undertaken for an individual hazard rather than considering all hazards that may affect a location (e.g. a location may face threats from earthquakes, floods and extreme winds, each with different recurrence intervals and potential impacts). Mitigating one risk may have side effects for the risk from other natural hazards. These side effects may be beneficial, e.g. a building designed to a seismic design code may also be less vulnerable to extreme winds, but they can also be detrimental, e.g. a seismically-designed building may be more vulnerable to flooding. A narrow-focused single-hazard approach can also lead to increased risks from overlooked hazards (Gill and Malamud, 2016), as part of a failure to account for "asynergies" in disaster risk management (de Ruiter et al., 2021).

The 2010 Haiti earthquake can be used to illustrate this point. Before the earthquake, authorities encouraged people living in informal dwellings built of light materials such as wood and plastic sheeting to move to formal buildings built of masonry/reinforced concrete, because the informal dwellings were more vulnerable to extreme winds (hurricanes are common in Haiti) than buildings made of masonry/reinforced concrete. In the earthquake, however, the light structures performed significantly better than the much heavier structures made from masonry/reinforced concrete, which often collapsed causing many fatalities. Therefore, the mitigation of risk from extreme winds came at the expense of increasing risk from earthquakes.

Making decisions on which risks mitigating against, in which way and how many resources should be spent on each hazard, is often not a rational process. Generally, such decisions are made based on memories of recent damaging events (it is said that we mitigate against the last disaster not the next one), lobbying of a group interested in one hazard or which hazards are the easiest to mitigate against. Research on multi-hazards is well established (Dilley et al., 2005), but there remain many challenges in applying the developments in this field in practice (Kappes et al., 2012) and often assessments focus on a single hazard. Multi-risk mitigation requires extended multi-criteria analysis of potential mitigation strategies.

To overcome the single hazard focus and potential irrationality in the decision-making process, one of the main objectives of MEDiate project is to provide decision makers with a means of visualising the components of disaster risk and resilience, the stakeholders' preferences and the effect of different actions and alternate futures on possible scenarios for an area, considering the multiple hazards that are present and how these (and other risk components) may change with time. This capability of the MEDiate platform will enable end users to answer questions such as:

1) How many resources should be devoted to mitigating floods rather than landslides? The visualisation tools and serious games/simulations developed in the project will provide the decision makers with motivation and justification of the spending of various resources.
2) Should hazard reduction (e.g. raising flood embankments, creating retention basins), vulnerability reduction (e.g. elevating roads or building retrofit) or increasing a community's

resilience through preparedness and outreach (e.g. disaster planning and effective communication) be prioritised and how much effect would each have in terms of social, environmental and economic costs and benefits (each of which may be prioritised differently by the stakeholder)?

3) Which threats are emerging and need to be monitored closely?
4) What is the protection gap that needs to be insured against?

The DSS will be developed using a "plug-and-play" approach to prioritise interoperability, flexibility, and futureproofing (Douglas et al., 2008). The DSS will be developed as a series of loosely coupled and interoperable web services that can be tailored to the end users' needs and combined in different ways to facilitate integration in each testbed through close interactions amongst the project partners, including representative end users from the testbeds.

Within MEDiate a suite of modules will be developed and tailored to the case study needs, but, thanks to the modular, flexible framework of the DSS and the design of the MEDiate platform, future users will be able to develop their own web services and integrate them with the tools developed in this project. This will enable future users to add a module, for example, for a particular hazard or a new risk mitigation action not considered in this project.

6.3 General structure

The Figure 12 shows the structure of the MEDiate platform.

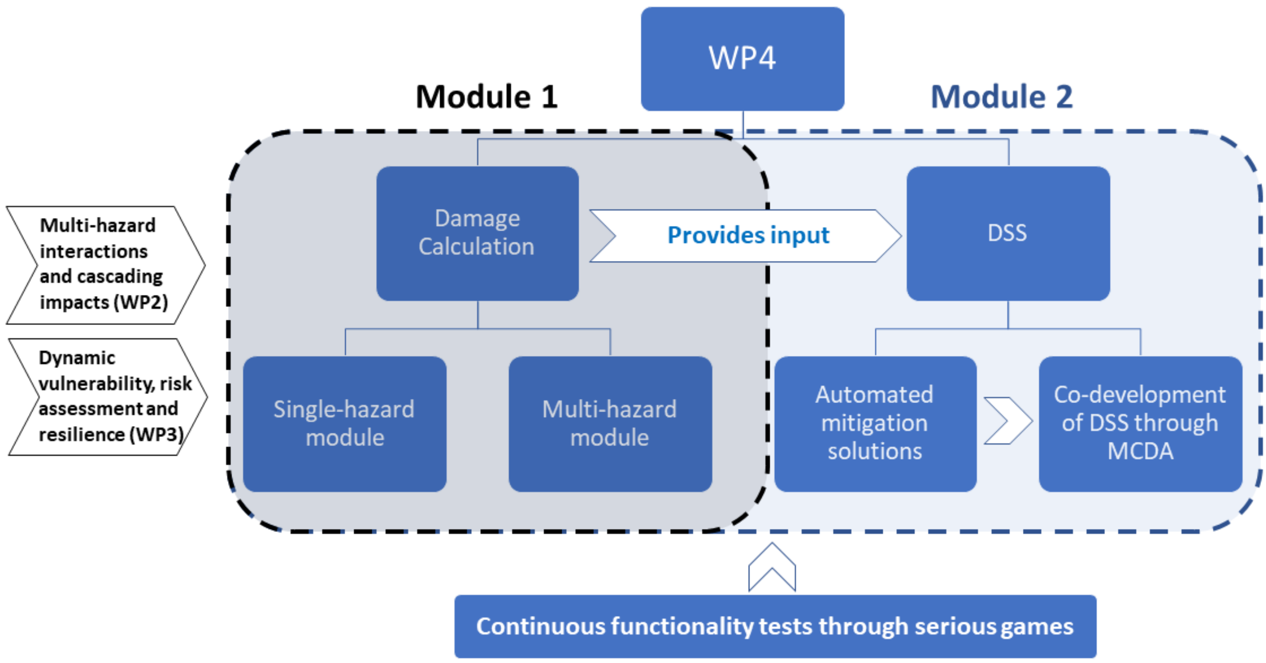

Figure 12: General structure of the MEDiate platform

Through convolving the hazard scenarios with the assessment of the dynamic exposure and physical vulnerability, single-hazard, scenario-based physical loss calculations will be first implemented using the in-house WebGIS platforms[3] (Bozzoni et al., 2018; Borzi et al., 2021, etc.). Once the single hazard module has been implemented, interacting hazard mechanisms and cascading effects will be

[3] https://www.borisproject.eu/web-based-platform/

incorporated into the scenarios. Using novel risk and resilience metrics, a multi-hazard risk assessment will be carried out to identify the most vulnerable proportion of the community for decision making and disaster relief purposes.

Following the scenario-based calculations of the physical and integrated risk, losses and indications of social vulnerability, automatised mitigation options will be generated by using/upgrading the available R-IOSuite prototype[4] which includes an artificial intelligence module.

The scenarios developed using MEDiate's IT system will account for ongoing trends in terms of hazard, demographics, geographic dependencies, and vulnerability to forecast emerging threats, thereby enabling proactive mitigation.

Based on the automated mitigation options, a multi-criteria decision analysis (MCDA) will be followed to set up the DSS. Automated mitigation options will be implemented on the platform once developed. The MCDA module will receive the calculated risk probabilities from the platform for each scenario and mitigation action together with the plug-and play type automated mitigation alternatives developed by the R-IOSuite to create a DSS to elicit the corresponding values/costs for each criterion (or risk/resilience metric).

Furthermore, this module contains a model with a set of stakeholders, where each stakeholder has its priorities among the criteria. Previously mentioned risk calculation results supplied the MCDA module with probabilities and values/costs for each mitigation action under each criterion, stakeholder-specific weights for the criteria, and (if applicable) weights for multiple stakeholders when a multi-stakeholder evaluation is to be performed. The DSS provides the MCDA module with stakeholder weights, probabilities, and utilities/values plus structural information such as a decision tree. Then, the MCDA module delivers different rankings of the mitigation actions to the DSS plus a set of sensitivity analyses to determine the stability of the rankings under (severe) uncertainty. This module is the core of the DSS by providing a trade-off between various risk and/or resilience metrics scales (such as casualties, direct repair cost, and functionality downtime), which will be evaluated later in the four European testbeds.

In order to anchor co-design, co-development, co-implementation and co-validation of the DSS within the project's methodology, MEDiate has partners from four testbeds located in four European countries that all face pressing concerns related to a variety of interacting natural hazards and have specific end users, contexts (e.g. in terms of hazards) and cover different scales in terms of sizes and populations. The variety of hazards, social context, geographical setting, and existing mitigation measures will allow the DSS to be tested for a wide range of situations that are likely to be met in Europe. The development of the DSS will allow for information and exchange of lessons learnt amongst testbeds, thereby demonstrating the flexibility of the project developments and their wide applicability. These specific testbeds will contribute to a wider understanding of interacting hazards in the wider European area in agreement with the global Shared Socioeconomic Pathways (SSPs). For each of the testbeds the project will source Copernicus data from the appropriate national agency.

[4] https://research-gi.mines-albi.fr/display/RIOSUITE/R-IOSuite+Home

6.4 Validation and the next steps

Therefore, the validation of the MEDiate concept showed the need for:

- Creation of a scenario-based web platform to integrate the hazard, exposure, and vulnerability information of physical and social components to compute and visualise physical and social risk.
- Clear visualization of the physical and social interdependencies between the exposed and damaged assets to assist the decision-making process.
- Implementation of automated disaster-mitigation algorithms.
- Co-development of DSS for multi-hazard scenarios in synergy with decision-makers so that end-users may simulate actions and observe their impact on the risk and resilience metrics.

7 COMMUNITY RESILIENCE AND DISASTER RISK REDUCTION FROM THE PERSPECTIVE OF PRACTICIONERS

All four testbeds (Austurbrú, Essex, Nice and Oslo) are experiencing multiple hazards and the table below shows the top five hazards which are prioritized in various testbeds (Figure 13). These hazards have multi-risk features including interacting, compound, interconnected and cascading risks. The examples of interacting hazards were identified in Austurbrú when a primary hazard triggers a secondary hazard (or increases / decreases its probability). In Austurbrú, heavy rainfall can trigger landslides and/or flooding, and heavy snowfall combined with changing temperatures can trigger avalanches. The historical cases of compound risk when extreme events happen simultaneously or successively were identified in Nice. In October 2020, Nice faced storm Alex, the Covid pandemic, and a terrorist attack. Responding to several extreme events simultaneously / in quick succession posed logistical challenges and required a high level of inter-organizational collaboration. In Oslo interconnected risks when interdependencies between systems shape risk were mentioned. In Oslo, power and water supplies are closely connected: both depend mainly on rainfall. Drought affects both systems. In Essex examples of cascading impacts when a disruption in one system triggers a disruption in another (connected) system was provided. In Essex, overwhelmed drainage systems can lead to flooding, which in turn can disrupt transportation systems (rails/roads).

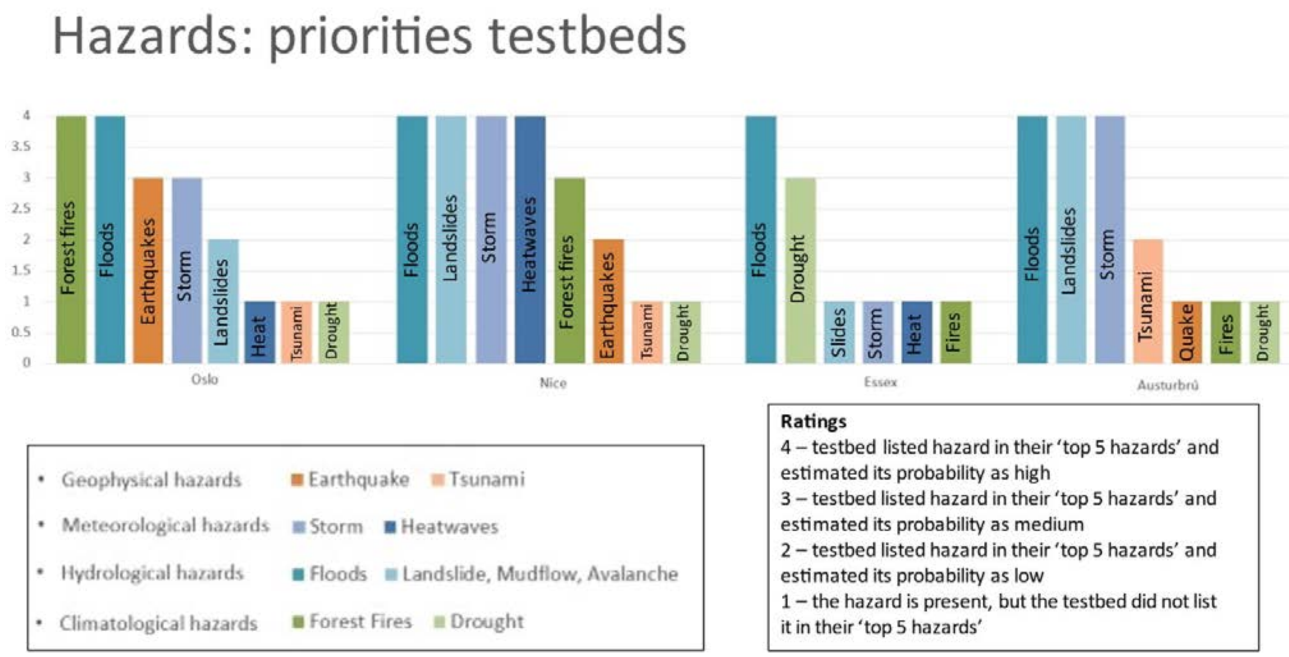

Figure 13: Hazards priorities in testbeds

The size of the coloured bars indicates the probability of the hazards estimated by the testbeds. 'Flooding' includes fluvial, pluvial, coastal, tidal, urban, storm, and other (e.g., sewer flooding). The category 'landslides' includes avalanches, mudflows and ground movements caused by quick clay and liquefaction.

During the validation workshop the differences between the hazards flagged as priorities during discussions / questionnaire to hazards mentioned in the MEDiate concept were identified. For instance, instead of extreme rain and snowfall in Oslo, forest fires were mentioned as second priority. In Nice violent wind, storm and forest fires were added to the hazards mentioned in the MEDiate concept. In Essex drought and water scarcity were added instead of heatwaves. In Austurbrú storm, flood and tsunami were added instead of landslides.

During interviews and based on information collected from questionnaires examples of exposure and vulnerability mentioned in testbeds were identified (Table 3 and Table 4).

Table 3: Exposure in testbeds

Exposed people and assets	Oslo	Nice	Essex	Austurbrú
Housing areas border forests and are at risk of forest fires	X	X		
Housing areas, infrastructure, and transportation are at risk of quick clay, landslides, mudflows and/or avalanches	X	X		X
Entire region is located in a seismic risk area	X	X		X
A significant part of the population lives in a flood zone		X	X	
Coastal areas are at risk of storms		X		X

Table 4: Vulnerability in testbeds

Vulnerable people and assets	Oslo	Nice	Essex	Austurbrú
Older housing in the city is not earthquake resistant	X	X		
Some housing areas at risk of quick clay are low-income and very crowded	X			
More than a fifth of the population is aged 65 and over		X	X	
Some villages completely depend for access on roads that are at risk of landslides		X		X
Some public buildings are not earthquake or flood resistant		X		
Some housing is not designed for extreme heat		X	X	
Forests contain many flammable species of tree		X		
Some buildings have not been designed to withstand avalanches				X
Some areas are located below sea level and have poor drainage systems			X	

The validation with the stakeholders from testbeds identified areas in disaster risk assessment and management where further improvements are necessary. Collaboration and process are areas needing improvement for both risk assessment and risk management. For risk assessment the situation when insights depend on the extent to which agencies collaborate and exchange information should be improved. The delays in formalizing risk documents should be avoided. Measures should be identified to prevent delays in implementing risk preparedness plans and intercommunal safety plans. Following legal requirements, risk management activities undertaken at the local level should be strengthened. Overall level of coordination and cooperation should be improved. Volumes of funding for risk management should be increased and their certainty should be improved.

In addition, operational relevance, and completeness, timeless and details of risk assessment are areas which required further improvement. While speaking about operational relevance, very long-term vision should be included, the situation when deprioritized risks are underfunded and delayed should be improved. While speaking about timeliness, completeness, and details of risk assessment data should be updated more frequently, national maps should show local risks in enough details and go beyond desk-based studies, national and local models should cover key hazard.

During interviews strengths and weaknesses of current tools for disaster risk management were identified. The identified weaknesses include five groups of factors which could be further applied in decision making experiments while identifying preferences of stakeholders for priorities of action. These factors are ease of use, operational relevance, the group of factors including completeness, detail, accuracy and timeliness, facilitation of collaboration and empowerment of local actors (Table 5).

Table 5: Disaster risk management: current tools

Disaster Risk Management: Current Tools		
	Strengths	**Weaknesses**
Ease of use	Easy to digest information for decision-makers and professionals	• Tool does not help create a simple and comprehensive document about a complex event • Some tools require more personnel than is available • Inputs to the tools (analyses) require funding which is not easy to obtain • Tool is prone to malfunctioning • Tool requires that sensors/cameras be installed – when they break the tool becomes 'blind'
Operational relevance	• Proven successful in actual usage • Specifies what risk management measures should be taken at national and local levels • Forecasts extreme events • Shows how the disaster situation unfolds during the response • Helps prepare for landslides • Helps responders direct relief as quickly as possible to the worst affected areas	• Only specifies to a limited extent what measures should be taken • Tools that are rarely used are forgotten about
Completeness, detail, accuracy & timeliness	• Provides information about the number of properties vulnerable to the hazard • Provides information in real time	• Risk information is too high-level • Does not cover all hazards/impacts of interest • Does not cover the entire region that the authority manages • Forecasts have a low level of precision • Tools cannot predict with certainty what the impact will be: sometimes citizens are alerted unnecessarily
Facilitates collaboration	• Defines the responsibilities of every agency – and systematically addresses these • Facilitates a fast response • Tool is widely used • Tool provides an opportunity for participatory feedback	• Municipalities do not always sufficiently engage with national-level tools • The effectiveness of the tool depends on the level of knowledge of the responders on-call during the event.
Empowers local actors	• Empowers local authorities to manage hazards • Informed by local standards • Local actors contribute local knowledge and understandings to risk management	• Local standards are not supported
Long-term view	• Based on a long-term vision • Identifies flood-proof areas for planning and development	
Strategic focus	• Promotes green infrastructure and the protection of natural habitats	

The identified recommendations for future disaster risk management tools can serve as an input for DSS development foreseen in the MEDiate concept (Table 6).

Table 6: Recommendations for future disaster risk management tools

Recommendations for Future Disaster Risk Management Tools	
Facilitate planning	• The outputs should be illustrative maps rather than reports of raw data • Data should be presented in a way that assists interpretation and makes it easy to use. • Tools should improve disaster forecasting, identifying areas that will be most affected. • Tools should help decision-makers prioritize risks in their territory based on how likely they are to occur. • Tools should identify roads that need to be closed during a flood, before the event. • Tools should assess property flood resilience (PFR) and inform natural flood management (NFM).
Facilitate response	• Tools should be dynamic and have real operational value during crisis situations (not remain static/theoretical). • Tools should usefully inform decision-making at an emergency operations post, e.g., by showing cascading and interacting risks. • Tools should facilitate the evacuation of areas that are at risk by suggesting safe routes and places of refuge.
Coordination & awareness	• Tools should facilitate the work of both first responders and central crisis management • Risk tools should facilitate awareness
Long-term view	• Tools should take a very long-term view, informing decision-makers of distant consequences. • Tools should inform future urban development by taking into account all future changes, both in terms of climate and in terms of population.
Comprehensive	• Tools should bring together and systematically process all the important data needed for risk monitoring. The current challenge is that all this data is dispersed.
Accurate	• The data used to model risk should be more accurate than what's used by current tools – local people on the ground should be able to feed into it
Format	• It should be a web-based information management portal

8 DSS MCDA DESIGN BRIEF

8.1 Introduction into DSS Design Brief

This document views the design of the MEDiate DSS from a combined perspective of designing forward from user needs and expectations and designing backward from goals, requirements, and limitations.

The decision-support system is partly built as a traditional DSS where information is retrieved from various sources and displayed in various combinations. The architecture of such a part can be seen in the left part of the figure (adapted from Khanna and Madan, 2015).

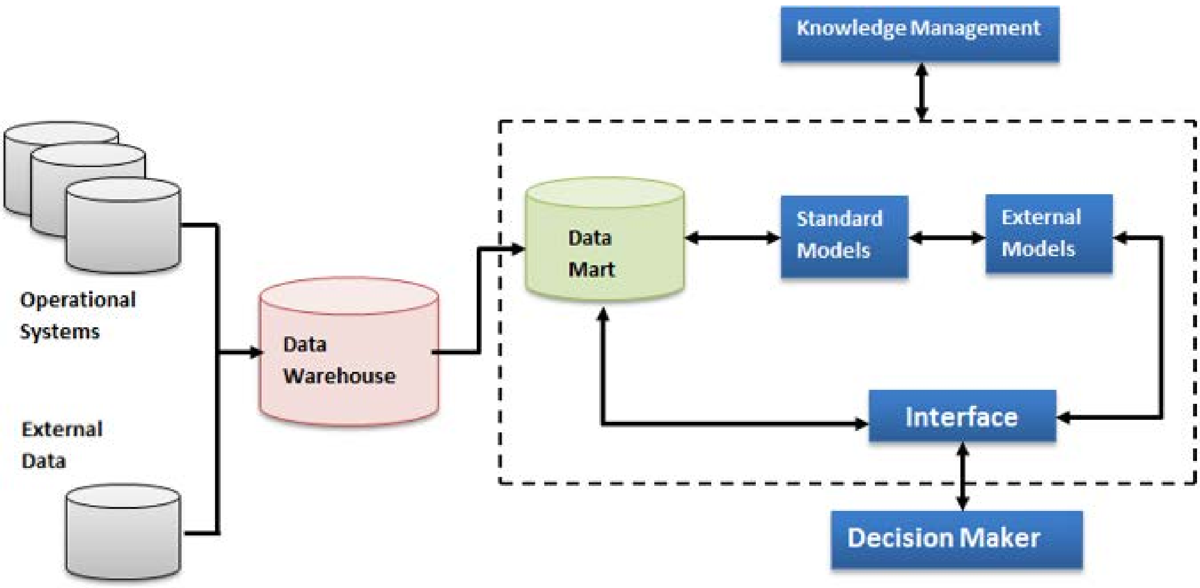

Figure 14: Architecture of standard DSS (adapted from Khanna and Madan, 2015)

The MEDiate DSS consists of a data presentation part, what is traditionally called a decision-support system, and a decision-making part not seen in Figure 14. The decision-making part is an MCDA (multi-criteria decision analysis) module that sits between the traditional interface in the figure and the decision-maker. This is illustrated in Figure 15, where a natural hazard DSS is connected to a decision module, through which the users interact with the data presentations of the system.

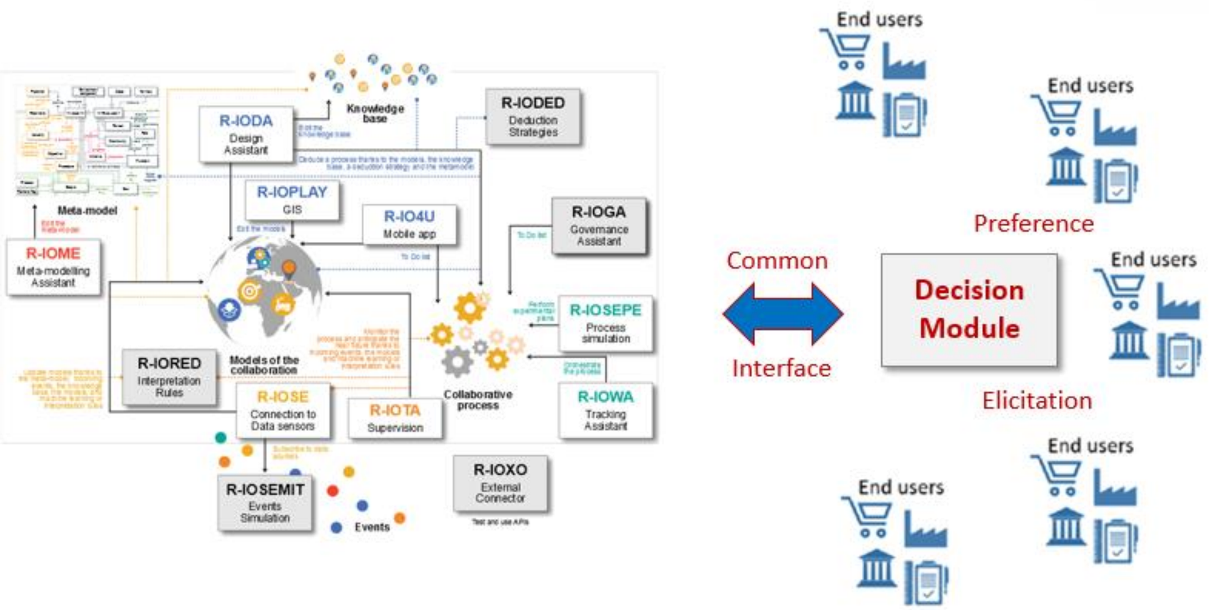

Figure 15: Decision module interface to presentational part of DSS (left part from r-iosuite.com)

This design brief will next present a literature review of the components of the decision module and thereafter discuss the architecture of the implementation of the decision parts of the DSS.

The fact that people often have problems making decisions was early noted in a wide range of areas, and decision-making has been an issue of concern for quite some time. During the last few decades, research has increased significantly and has shown that the cognitive limitations of the human mind make it difficult to process the complex, large amounts of information intrinsic in many decision-making situations. In fact, people seldom talk about possibilities when speaking about decisions to be made, but always use the term decision problem. Much of the work that steers progress within organizations relates to decision-making and problem-solving (Simon et al., 1986), and consequently, there is a great interest in how decisions are made in these settings. Within organization theory (c.f. March and Simon, 1993; Cyert and March, 1963; March and Olsen, 1976), especially strategic management (c.f. Porter, 1980; Hart, 1992), decision-making is central, and the tradition of rationality is especially considered important in systematic approaches to management, such as, e.g., planning and processing. In a broad sense of the term, rational behaviour has to do with reasonable and consistent acts, whereas its meaning in the classical economic literature (cf. von Neumann and Morgenstern, 1947) is to maximize and choose the optimal alternative of all those available to us.

Theoretical developments of decision-making have traditionally been divided into normative and descriptive disciplines. Within the normative discipline, the rational model has been prominent (von Neumann and Morgenstern, 1947; Savage, 1954, Luce and Raiffa, 1957), and models belonging here describe how decision-makers should make choices when considering risk. The rational model of decision-making is essentially based on the notion that managers systematically gather information to objectively analyse it before deciding (Morrow and Hitt, 2000). However, even though rationality is a desirable trait, the rational model has often been criticized over the years in the behavioural literature concerning its inherent assumptions on cognitive and motivational assumptions (Hart, 1992). Therefore, the descriptive discipline (cf., e.g., Simon, 1957; Tversky and Kahneman, 1979) has evolved, where models describing how people make decisions are in focus. Within organizational settings, this has led to the development of other models (Simon, 1945, 1957; March and Simon, 1993; Cyert and March, 1963; March, 1994), where organizational characteristics, like, e.g., context, societal structures, organization, conflicting or unclear goals, and political activities (conflict among stakeholders), cause decision makers in organizations to depart from rational decision-making procedures. However, descriptive models mainly account for actual behaviour and do not provide tools for applied decision-making, and like, e.g., Kirkwood (1997) argues, to make decisions strategically, it is a requirement to adopt a structured decision-making process. Also, although real decision-makers do not behave as the normative models predict, they might still need and want help (Bell et al., 1988). People do not naturally approach problems in a structured fashion, and the amount of information involved in many decision-making situations has increased dramatically in recent years, which complicates matters further. Yet, when it comes to decision-making processes, structured methods are still seldom applied in real settings, and decision-makers often act on rules of thumb, intuition, and experience instead.

During the last several decades, the field of decision analysis (the applied form of decision theory (Raiffa, 1968; Keeney and Raiffa, 1976)) has developed as a structured approach to formally analyse decision problems, and is based on research within several disciplines, such as psychology, mathematics, statistics, and computer science. See, e.g., early work by psychologists Edwards (1954), who introduced Bayesian analyses to psychology, and Ellsberg (1961), and statisticians Wald (1950) and Savage (1954). In economics, Simon (1955), and March and Simon (1993) have had a great deal of influence, and Markowitz (1952) has contributed to decision-theoretic research within finance. Any decision analysis is aimed at helping people make better decisions (Keeney, 2004), and over the years, research on quantitative decision-making has moved from the study of decision theory founded on single criterion decision-making towards decision support for more realistic decision-making situations with multiple, often conflicting, criteria. Multi-Criteria Decision Analysis (MCDA) stands out as a promising category within the decision support methods. MCDA can provide decision-makers with a better understanding of the trade-offs involved in a decision, e.g., between economic, social, and environmental aspects (criteria). After identifying the primary objective(s) or goal(s) of the decision-maker(s) and the different alternatives (the available courses of action), the possible consequences are analysed mathematically based on the provided input data.

Research within the instrumental part of the decision-making process, as well as means to support it, have developed significantly during the last half-century. Still, despite the promising solutions offered today, and a belief in their potential to support complex decision-making, decision analysis tools are infrequently utilized to aid decision-making processes in most organizations (March, 1994; Shapira, 1995; Brown, 2006), and people rarely perform formal analysis to complex problems (Keeney, 2004). The number of MCDA applications has increased during the last decade, but behavioural issues have not received much attention within this field of research, yet the identification of such problems and the call for research on behavioural issues have been recognized for a long time (Wallenius et al., 2008). Moreover, current applications provide good support for decision analytical calculations but lack support for the decision-making process itself (French and Xu, 2005). French and Xu (2005) suggest that this functionality is something that needs to be included in MCDM packages in further developments, and Banville et al. (1998) claim that regardless of the progress made within the instrumental dimension of multiple criteria approaches, the under- or non-utilization problem will continue until parallel research on the socio-political context in which these MCDA methods are to be applied is emphasized.

Brown (1989) states that the low level of attention given to prescriptive decision support research in real settings has contributed to the limited practical impact that formal decision aid has had on decision-making in business and government. The explicit use of quantitative decision models to support and improve decision-making activities remains modest in real settings (Brown, 2006). Thus, theory and tools still differ too much from reality and there is reason to believe that without the involvement of actual decision-makers and research on the process surrounding the developed models, strategies and techniques, the utilization of these tools as a self-evident aid in real decision-making processes will not increase. Another explanation for their limited usage within organizations today is the fact that they are too demanding in terms of required time (especially the first time of usage) and effort. As, e.g., Keeney (2004, p. 194) points out, "we all learn decision-making by doing it", and he states that almost everyone could make better decisions, but we need training (which is something very few people have ever had). Research has shown that people are more likely to deal with information in a controlled fashion when they are motivated and capable to analyse it carefully (Cialdini, 2009). Thus, one conclusion is that there is a need to better communicate the benefits of using decision support tools. Moreover, many decision problems have large outcome spaces, making the representation and elicitation of preferences and beliefs for all outcomes a costly venture in terms of time and cognitive effort. However, even in situations where the outcome space is manageable, there is a need for elicitation methods better adapted for real usage, since part of the attraction of using a decision analysis tool to support the decision process is reliant on the applicability of generated results. Suggested techniques for elicitation are to a great extent a matter of balancing the retrieved quality of the elicitation with the time and cognitive effort demanded on the users for eliciting all the required values. A more prescriptively useful approach to adopt within elicitation would be to allow for greater imprecision, when possible, both to accommodate human capabilities, as well as, to reduce the cognitive effort and time required. Additionally, decision analysis tools deviate too much from current practice within decision-making as their use (if employed) is mainly as an expert tool for analysis at later stages of such processes and not as more complete support for decision-makers throughout the process.

8.2 Multi-criteria decision analysis

While solving problems, people often consider different features of the alternatives by taking different aspects of importance to them into account (choice criteria). Humans have inherent limitations when processing much information at one time, and the more criteria to consider, the more difficult. When solving such problems, we make errors, as well as use simplifying strategies to adapt the problem to our capabilities. As a result, research on quantitative decision-making has moved from the study of single criterion decision-making towards decision support for more realistic decision-making situations involving multiple, often conflicting criteria. Multi-criteria decision analysis or MCDA is a promising category within decision support methods and can provide the decision-makers with a better understanding of the trade-offs involved in a decision, e.g., between economic, social, and environmental aspects (criteria). Current research is mostly concentrated on providing models to support the structuring of the problem to increase understanding and identify possible problematic elements. Furthermore, the output from these models should not be interpreted as the solutions to the problems, but rather give a clearer picture of the potential consequences of selecting a certain course of action. In this context, the decision-maker is assumed to be an agent[5] who chooses one alternative (or a subset of alternatives) from a set of alternatives (typically consisting of collections of choices of moderate size[6]) that are being evaluated based on more than one criterion.

Multi-Attribute Value Theory, MAVT, and Multi-Attribute Utility Theory, MAUT (Keeney and Raiffa, 1976; von Winterfeldt and Edwards, 1986) are the most widely used MCDA methods in practical applications. The relative importance of each criterion is assessed, as well as, value functions characterizing the satisfaction of the alternatives (according to the decision-maker) under each criterion, and thereafter the overall score of each alternative is calculated. The difference between the two is that MAVT is formulated such as to assume that outcomes of the alternatives are known with certainty, whereas MAUT explicitly takes uncertainty (relating to the outcomes) into account (and uses utility functions instead of value functions). However, in many practical situations, it is hard to distinguish between utility and value functions elicited with risky or riskless methods due to factors such as judgmental errors and response mode effects (von Winterfeldt and Edwards, 1986). Moreover, in many applications, using simple value functions in combination with sensitivity analysis provide essentially the same results and insights (Belton and Stewart, 2002). All MAUT methods contain the following five steps, where the procedures for the first and last step are alike:

- Define the alternatives and the relevant attributes (criteria).
- Evaluate each alternative separately on each attribute, i.e., the satisfaction of each alternative under each criterion represented by a value/utility function.
- Assess the relative importance of each criterion, i.e., assign relative weights to the attributes.
- Calculate the overall score of each alternative by aggregating the weights of the attributes and the single-attribute evaluations of alternatives into an overall evaluation of alternatives.
- Perform sensitivity analyses on the model and make recommendations.

Examples of other MCDA methods than the MAVT/MAUT approach are the Analytic Hierarchy Process, AHP (Saaty, 1980), which is like MAVT, but uses pairwise comparisons of alternatives (utilizing semantic scales) with respect to all criteria, or methods like the outranking methods based on a partial ordering of alternatives, where the two main approaches are the ELECTRE family of methods (Roy, 1996), and PROMETHEE (Brans et al., 1986). Moreover, fuzzy set theory (introduced by Zadeh in 1965) is an attempt to model human perceptions and preferences more genuinely but has some practical problems, e.g., with visualizing an operational elicitation process for the required values (Belton and Stewart, 2002). The Measuring Attractiveness by a Categorical Based Evaluation TecHnique, MACBETH (Bana e Costa and Vansnick, 1994), uses pairwise comparisons (like the AHP method) to express the strength of preference (on a semantic scale) for value increments in moving from a performance level to another.

Different software approaches implementing MCDA have been suggested over the years. MAVT techniques have been implemented in, e.g., V.I.S.A (Belton and Vickers, 1988), HiView (Barclay, 1984), which supports the MACBETH pairwise comparison approach to elicitation (Bana e Costa and Vansnick, 1994), DecideIT (Danielson et al., 2003) and GMAA (Jiménez et al., 2006), which both allow the use of interval value and weight statements, The AHP method proposed by Saaty (1980), is implemented in several applications, amongst which EXPERT CHOICE (Expert Choice, 2010) is probably the most widely used. HIPRE 3+ (Hämäläinen and Lauri, 1995) and Logical Decisions are examples of software packages supporting both MAVT and AHP methodologies. Decision Lab 2000 (cf. Geldermann and Zhang, 2001, for a review) is based on outranking methods, such as PROMETHEE (Brans et al., 1986).

[5] The decision making agent can be an individual or a group that agrees to act in uniform according to the equivalent rational decision making process as would be followed by an individual (Wallenius et al., 2008).

[6] This is in contrast to optimization problems where feasible sets of alternatives usually consist of infinitely many alternatives.

8.3 Descriptive models

Over the years, research on decision-making has gone back and forth between theory and observation, and other, more descriptive models of choice behaviour, i.e. models describing how people actually make decisions, have been proposed. Within the psychological discipline, the dominating viewpoint is that people make decisions not only based on how they judge the available information but that they are also influenced by subconscious factors in the interactive process. One of the early critics of the subjective expected utility model of rational choice was Simon (1957), who argued that complete rationality was an unrealistic assumption in terms of human judgment. Instead, he proposed a more realistic approach to rationality, called bounded rationality, which takes the inherent limitations humans have when processing information into account. The principle of satisficing can be applied without highly sophisticated skills in reasoning and evaluation. It proposes that people attempt to find an adequate solution rather than an optimal one and choose the first course of action that is satisfactory on all the important attributes. Simon also coined the terms substantive and procedural rationality, where the former has to do with the rationality of a decision situation, i.e. the rationality of the choice made (which is what economists have focused on), whereas procedural rationality considers the rationality of the procedure used to reach the decision (has been more in focus within psychology).

Prospect theory (Kahneman and Tversky, 1979) is among the most influential of the descriptive models and can be perceived as an attempt to bring psychological aspects of reasoning into economic theory. In prospect theory, utility is replaced by value (of gains and losses) and deviations from a reference point. The value function is S-shaped and passes through the reference point. It is asymmetric (steeper for losses than for gains) and implies that people are loss averse, i.e. the loss of €100 has a higher impact than the gain of €100. Moreover, it suggests that people, in general, are risk averse when it comes to gains and risk-seeking when it comes to losses, and systematically overweight small probabilities and underweight large ones. Prospect theory also expects preferences to depend on the framing of the problem, i.e. how the problem is formulated. People are inclined to simplify complex situations, using heuristics and frames when dealing with information (Kahneman et al. 1982). Regret theory (Loomes and Sugden, 1982; Bell, 1982) has been offered as an alternative to prospect theory. In short, regret theory adds the variable regret to the regular utility function and suggests that people avoid decisions that could result in regret. Other problems with the application of normative theories to decision problems and how people make judgments have been accounted for by, e.g., March and Olsen (1976), who coined the term garbage can decision-making, Slovic et al. (1988), and Shapira (1995). The reality of human decision-making and the difference (from normative models) in how decision rules are used by real decision-makers have resulted in adaptations of original rational choice theories to the introduction of the limited rationality concept (March 1994).

Over the last several decades, numerous models of decision-making within organizational settings have been proposed from several different theoretical perspectives, and Hart (1992, p. 327) describes the result as "a bewildering array of competing or overlapping conceptual models". Decision-making in organisations seldom follows rational decision-making processes. March (1997) states that according to rational theory, decision-making processes are based on four parts, namely:

- Knowledge of alternatives (a set of alternatives exists).
- Knowledge of consequences (probability distributions of the consequences are known).
- Consistent preference order (the decision makers' subjective values of possible consequences are known and are consistent).
- Decision rule (used for selection among the available alternatives based on its consequences for the preferences).

March (1997) also declares that the structure is understandable and that the core ideas are flexible, but that each of these four main parts (and the assumptions made regarding them in the rational model) have problems when applied in organizational settings. Bounded rationality (Simon, 1957) limits the rationality of identifying all possible alternatives, as well as all their consequences. Moreover, when considering a series of choices in order to establish preference consistency, research has shown that this has been notoriously hard to determine (March, 1997).

8.4 Prescriptive decision analysis

Although real decision-makers do not behave as the normative models declare, they might still need and want help (Bell et al., 1988). Thus, if the aim is to act "rational" and comprehensively, a systematic approach for information processing and analysis of some kind is needed, especially when the problem at hand is complex, non-repetitive, and involves uncertainty. The identified gap between normative (cf., e.g., von Neumann and Morgenstern 1947, Luce and Raiffa 1957) and descriptive (cf., e.g., Simon 1957, Kahneman and Tversky, 1979) theories, suggests that a prescriptive approach to a decision-making process would be valuable (cf., e.g., Bell et al. 1988, French and Rios Insua 2000, Keeney 1992).

In 1966, Howard coined the term decision analysis as a formal procedure for the analysis of decision problems. It is the applied form of decision theory and is particularly useful for dealing with complex decision-making involving risk and uncertainty. Major advances within the discipline have been achieved by Raiffa (1968) and extended to include multiple objectives by Keeney and Raiffa (1976). Decision analysis is a structured way of modelling decision situations to explore and increase understanding of the problem and possible problematic elements and improve the outcome of the decision process. After identifying the primary objective(s) or goal(s) of the decision-maker(s) and the different alternatives (the available courses of action), the possible consequences are analysed mathematically based on the provided input data.

The discrepancy between theory and real behaviour is the very heart of prescriptive interventions (Bell et al. 1988), and decision analysts talk of prescriptive decision analysis as a more pragmatic approach than what the normative theories suggest. It can be described as "the application of normative theories, mindful of the descriptive realities, to guide real decision-making" (French and Rios Insua, 2000, p. 5). Prescriptive decision analysis is focused on merging the two main disciplines (the normative and the descriptive) within decision-making into a more practically useful approach for handling decision problems and helping decision-makers solve real decision problems. The prescriptive approach aims at obtaining the required components for analysis in a structured and systematic way with a great deal of human participation and awareness of the descriptive realities (von Winterfeldt and Edwards, 1986). Brown and Vari (1992) state that much of the work within the descriptive discipline is of substantive importance for prescriptive decision-aiding, such as the work on cognitive illusions and human limitations (Kahneman et al., 1982), which can be corrected (or reduced) by decision aids. Moreover, prescriptive analysis can be seen as the application of reason to real-world decision problems, and the employment of an underlying formal model can increase knowledge about the problem at hand and create incentives to acquire as accurate information as possible (Larsson, 2008). In essence, prescriptive decision analysis is about the applicability of decision analysis to real problems in real contexts (and by real decision-makers), and French (1995b, p. 243) brands the term as the usage of "normative models to guide the evolution of the decision makers' perceptions in the direction of an ideal, a consistency, to which they aspire, recognizing the (supposed) limitations of their actual cognitive processes." In the end, the prescriptive approach deals with the tailoring of the decision analysis process for the specific problem, context, and decision-maker(s) at hand, and the theoretical and operational choices made provide how the analyst helps guide the decision-maker(s) through the analysis (Keeney, 1992b). The main criteria for evaluating prescriptive models are usefulness (Keeney, 1992b) and pragmatic value (Bell et al., 1988), and such models should thus provide decision-makers with suitable assistance to improve their decision-making.

Keeney (1992b) stresses that, unlike normative and descriptive theories, the focus of prescriptive decision analysis is to address one decision problem at a time and is not particularly concerned with whether the axioms utilized to support the analysis for the given problem are appropriate for classes of problems (typically the focus of descriptive theories) or all other problems (the focus of normative theories).

Fischer (1989) argues that unless a superior alternative to the EU model is available (and a consensus is established among decision analysts regarding a new alternative), there is a danger in abandoning it since the concept of rationality will lose much of its appeal (if rationality becomes a matter of taste) and the field of decision analysis will no longer be coherent. For many decision problems, the expected utility axioms provide a very good basis for decision analysis (Keeney, 1992b; Howard, 1992; Fischer, 1989), but the tackling of the unique and complex in a decision problem may require the use of complementary rules as well as a wider spectrum of risk attitude modelling.

Complexities about a problem may involve such factors as significant uncertainties, multiple objectives, multiple stakeholders, and multiple decision-makers. The choice of axioms to guide the prescriptive analysis is a problem facing the analyst trying to help the decision-maker(s), where the overall objective is to provide a foundation for quality analysis (Keeney, 1992b). These axioms should be practical in the sense that it is feasible to conduct an analysis based on them, and the information required to implement them must be attainable and possible to assess in a logically sound and consistent manner. An influential approach to successful prescriptive analysis is the value-focused thinking advocated by Keeney (1992a). Keeney argues that the values of the decision-makers should be understood before the formulation of alternatives takes place for the decision-makers to be more creative and think more widely about possible courses of action. This contrasts with alternative-focused thinking where you initially find the available alternatives and thereafter evaluate them. However, Keeney recognizes that the ideal of value-focused thinking is hard to achieve, and many decision problems we face initially arise from a set of alternatives from which we must choose (French, 1995b).

Any decision analysis is essentially a model of a specific decision situation, a simplification of reality that includes significant aspects of the problem and lends insights about these aspects (Keeney, 1992b). Phillips (1984) uses the term requisite model to describe a judgmental model, which is appropriate when neither normative nor descriptive models are sufficient to capture the value judgments and their relative importance. In a requisite model, everything required to solve the problem is represented in the model or can be simulated by it. Such models are construed through the interaction between specialists, who contribute to the form and assist with the encoding of the content to the appropriate form, and problem owners who provide content. The form of the model is decision-theoretic, both in its structure (decision trees, influence diagrams, etc.) and its generic components (events, outcomes, consequences, attributes, etc.). The content of the model (probabilities, utilities, weights, etc.) is a result of the participants' understanding of the problem, which evolves through the course of modelling (Phillips, 1984). Phillips mentions three aspects of simplification in such models: 1) elements of reality that are not expected to contribute significantly to the problem-solving are omitted, 2) complex relationships among elements of the social reality are approximated, and 3) distinctions in either form or content regarding social reality may be blurred in the model, e.g., one may choose not to make distinctions between the present and future worth of a product. The prescriptive decision analysis process is cyclic with iterations through the steps of modelling values, identifying alternatives, evaluating, reflecting, and possibly remodelling of values, modifying or identifying new alternatives, re-evaluating, and so on (French, 1995b). During prescriptive decision analysis, perceptions change and evolve, and the representation of these perceptions should not be static (French and Rios Insua, 2000). The perceptions of the decision-maker(s) evolve because of the analysis, and it is important to see the modelling process involved in representing these perceptions as creative, dynamic, and cyclic (French and Rios Insua, 2000; French, 1995b). Requisite modelling is the term used by Phillips (1984) to describe this approach to modelling and a model is requisite when it is sufficient for the inference or decision faced. This contrasts with the static view, too often taken in decision analysis, where all of the judgments of the decision-maker(s) are taken as fixed and binding from the outset of the analysis (French and Rios Insua, 2000).

The modelling and the selection of the appropriate formal rules are only part of the assumptions necessary to approach the problem prescriptively. An important aspect to consider is how to assess or elicit the required information and values to apply the rules in a prescriptive manner. "The art and science of elicitation of values (about consequences) and judgments (about uncertainties) lies at the heart of prescriptive endeavours" (Bell et al. 1988, p. 24). The techniques and methods used for elicitation must be practicable and should not require too much input from the decision-maker (French and Rios Insua, 2000). Fischer (1989) points at three fundamental problems that need to be confronted when attempting to develop prescriptive science: (1) reference effects (which lead to systematic violations of the independence principle of the EU model), e.g., people's tendency to be risk-averse for gains and risk-seeking for losses, as well as, weigh losses more heavily than gains (Kahneman and Tversky, 1979), (2) framing problems, i.e. that formally equivalent ways of framing (describing) decision problems can highly influence people's choices in reality, and (3) different outcomes resulting from strategically equivalent assessment procedures for eliciting preferences. Prescriptive analysts must, thus, be attentive to the descriptive realities of human behaviour and the common mistakes people make when eliciting decision data as the applicability of generated results often relies on the quality of input data. Prescriptive analysts must learn how to elicit adequate judgments from decision-makers and make sense of them (Bell et al., 1988). Moreover, many decision analysts believe that the insights that can come to light during the elicitation process can be more valuable than what is done with the elicited values after elicitation, and it is thus an important ingredient in a successful prescriptive decision analysis process. The specialist (or analyst) has a dual role, both to facilitate the work and keep the decision-maker(s) task-oriented, as well as, to contribute to the aspects of the task concerned with model form, but not its content (Phillips, 1984).

Conclusively, when decision analysis applications are used to aid prescriptive decision-making processes, additional demands are put on these applications to adapt to the users and context. French and Rios Insua (2000) state that prescriptive methodologies for decision analysis should aim to be satisfactory regarding such aspects as:

- Axiomatic basis. The axiomatic basis should be acceptable to the users, and they should want their decision-making to reflect the ideal behaviour encoded in the set of axioms used for analysis.

- Feasibility. The techniques and methods used must be practicable, which suggests that the elicitation of decision data from the users must be feasible (the number of required inputs from the users should be acceptable) and results must be intelligible to the users. The descriptive realities of human behaviour also add demands on elicitation processes to reduce the cognitive load on decision-makers, as well as, to aim to eliminate biases that have been documented in behavioural research.

- Robustness. The sensitivity to variations in the inputs should be understood, e.g., if the analysis results rely heavily on certain inputs the decision makers should be aware of this and be able to reconsider judgments made.

- Transparency to users. The users must understand the analysis procedure and find it meaningful.

- Compatibility with a wider philosophy. The model used for analysis must agree with the decision-makers' wider view of the context (and the world). The model must be requisite; thus, the application must provide interactivity and cyclic modelling possibilities in order to reach the goal of compatibility.

This concludes the review of different classes of MCDA models. Next, elicitation of user information is reviewed.

8.5 Elicitation

In almost all decision-making situations where decision analysis is used, complete information about the world we seek to depict is unavailable. Any decision analysis situation relies on numerical input of which we are unsure (French, 1995a), and some of the uncertainty relates to judgmental estimates of numerical values, like beliefs or preferences. The models used for computation require probabilistic information to represent uncertainty (in the form of probability distributions) and preferences (in the form of utility functions). In decisions involving multiple objectives, there is also the need to make value trade-offs to indicate the relative desirability of achievement levels on one objective in comparison to the others (represented by criteria weights in MAVT/MAUT methods).

While there has been an increase in research (and an intense debate) on elicitation over the last few decades within several disciplines, such as, e.g., psychology, statistics, and decision and management science, there are still no generally accepted methods and the process of eliciting adequate quantitative information from people is still one of the major challenges facing research within the field of decision analysis (Fox, 2003). Although different research areas have different explanations for elicitation problems, they seem to agree on the fact that in applied contexts we should be concerned not only with what we ask experts to assess but also with how we ask it (Kynn, 2008). Statistical research on elicitation has been greatly influenced by psychological findings on how people represent uncertain information cognitively, and how they respond to queries regarding that information.

The suggested methods for elicitation have distinct features which all can impact their applicability in practice and need to be addressed more explicitly. Also, both procedural and evaluative elicitation aspects are often discussed interchangeably. To study and analyse elicitation more explicitly, there is a need to categorize methods and the following division of elicitation into three conceptual components are therefore suggested:

- Extraction: This component deals with how information (probabilities, utilities, weights) is derived through user input.
- Representation: How to capture the retrieved information in a formal structure, i.e. the internal format used to represent user input.
- Interpretation: Is dependent on the expressive power of the representation used and how to assign meaning to the captured information in the evaluation of the decision model used.

This division will be used here to analyse elicitation methods in order to recognize their characteristics and identify elements that can impact their applicability in practice.

8.6 Probability and utility elicitation

The decision module in MEDiate will contain representation of both probabilities for events to occur and valuations of their utilities when occurring. In the classic decision analytic framework (cf., e.g., von Winterfeldt and Edwards, 1986), numerical probabilities are assigned to the different events in decision tree[7] representations of decision problems. The best alternative is the one with the optimal combination of probabilities and utilities corresponding to the possible outcomes associated with each of the possible alternatives. After the process of identifying what aspects of a problem (what parameters) to elicit, which subjects (information sources) to use and possible training for the subject(s), the most crucial part is then to elicit the necessary values from people. Probability information is most elicited from domain experts, and the expert must express his or her knowledge and beliefs in probabilistic form during the step of extractions. This task often involves a facilitator to assist the expert, as most people are unaccustomed to expressing knowledge in this fashion. Gartwaite et al. (2005) conclude that for an elicitation to be successful, the values may not be “true” in an objectivist sense (and cannot be judged that way) but are an accurate representation of the expert’s knowledge (regardless of the quality of that knowledge). Moreover, they believe that a reasonable goal for elicitation is often to describe the “big message” in the expert’s opinion. The subjectivist outlook on the information required in decision analysis is shared by others, see, e.g., Keeney (2004) who states that the foundation for decision-making must be based on subjective information, although part of the decision analysis

[7] A decision tree is a way of structuring the sequences of possible external events and actions consequent to each external event (von Winterfeldt and Edwards 1986).

discipline still refers to an objective analysis. For a wider discussion concerning objective (classical) and subjective (personal) probabilities, cf., e.g., (de Finetti, 1968; Savage, 1954; Wright and Ayton, 1994). Subjective probability is thus one of the prime numerical inputs, but the meaning of probability depends on the conceptual distinction between single-event probabilities and frequencies. This perception can differ among experts, even among those making assessments regarding the same quantities. The elicitation of probabilities has been quite extensively studied, and recommendations as to how to make such assessments and corresponding problems can be reviewed further in, e.g., (Clemen, 1996; Corner and Corner, 1995; Hogarth, 1975; Morgan and Henrion, 1990; Wallsten and Budescu, 1983).

Methods for utility elicitation have many similarities to probability elicitation processes but are more complex. Probabilities can be elicited from experts (and should remain the same regardless of who makes the assessment), but can also be learned from data, whereas utility functions are to accurately represent decision-makers' individual risk attitudes, and are, thus, required for each user. Utility can be described as the value a decision-maker relates to a certain outcome, and in utility elicitation, different methods are used to give the (abstract) concept of preference an empirical interpretation. The elicitation process itself, regardless of the method employed, has proved to be cognitively demanding for people and error prone. Several techniques for utility elicitation have been proposed and used, and in Johnson and Huber (1977) a categorization of these techniques is provided. The category labelled gamble methods contains the most used techniques, where several variations on question design are being used. A broad categorization of standard-gamble methods is given in (Farquhar 1984) but framing the utility assessment in terms of hypothetical gambles and lotteries may not map people's behaviour in real situations. Some people have a general aversion towards gambling, and people often overweight certain outcomes in comparison to those that are merely probable (Kahneman and Tversky, 1979), which complicates matters further.

Moreover, the classical theory of preference assumes that normatively equivalent procedures for elicitation should give rise to the same preference order, which is an assumption often violated in empirical studies, cf., e.g. (Tversky and Kahneman, 1981; Lenert and Treadwell, 1999). Lichtenstein and Slovic (2006) state that people do have well-articulated preferences regarding certain matters, but in some settings construct our preferences during the process of elicitation, which is the cause for these violations. They suggest that the need for preference construction often occurs in situations where some of the decision elements are unfamiliar and where there are some types of conflicts among our preferences regarding the choices presented to us. Such circumstances make us more susceptible to being influenced by certain factors during the elicitation process, such as, e.g., framing and could thus explain many of the problems related to elicitation.

8.7 Criteria weight elicitation

MEDiate is aimed at a broad range of users, ranging from experts in the fields, over policymakers, to educated laymen. This variety of user categories calls for an elaborated and robust process for collecting criteria preferences. In MCDM, the relative importance of the different criteria is a central concept. In an additive MAVT/MAUT model, the weights reflect the importance of one dimension relative to others. The weight assigned to a criterion is basically a scaling factor, which associates scores on that criterion to scores on all other criteria. Methods for eliciting criteria weights are compensatory, i.e. the extracted information on the weights' relative importance as assigned by decision-makers implicitly determine trade-offs between the number of units on one criterion they are willing to waive to increase the performance on another criterion by one unit. As already mentioned, there are various sources of uncertainty within the application of MCDA methods and regarding criteria, their definition as well as the elicitation of criteria performance values (weights) involve uncertainty.

There are several techniques for deriving weights from preference statements. However, like probability and utility elicitation, the elicitation of weights is a cognitively demanding task (Larichev, 1992; Barron and Barrett, 1996a; Belton and Stewart, 2002) which is subject to different biases (cf., e.g., Borcherding et al.,

1991) and the elicited values can be heavily dependent on the method of assessment (cf., e.g., Pöyhönen and Hämäläinen, 2001). In the literature, there have been several methods suggested for assessing criteria weights, but the suggested methods have distinct features which all can impact their applicability in practice. Weight elicitation methods differ regarding the type of information they preserve from the decision-maker's judgments in the extraction component to the interpretation component. In practice, the actual usefulness of elicitation methods is determined by procedural aspects (Mustajoki et al. 2005), and therefore elicitation methods with relatively simple extraction components are most common in applied settings. Several weighting methods superficially appear to be minor variants of one another, but even small procedural differences have been shown to have important effects on inference and decision-making (Bottomley and Doyle, 2001).

8.7.1 Ratio Weight Procedures

Ratio weight procedures maintain ratio scale properties of the decision-maker's judgments from extraction and use exact values for representation and interpretation. Common to all these methods is that the actual attribute weights used for the representation are derived by normalising the sum of the given points (from the extraction phase) to one. Methods adopting this approach range from quite simple rating procedures, like the frequently used direct rating (DR) and point allocation (PA) methods (for a comparison of the two methods, cf., e.g., Bottomley et al., 2000), to somewhat more advanced procedures, such as the often used SMART (Edwards 1977), SWING (von Winterfeldt and Edwards, 1986) or trade-off (Keeney and Raiffa, 1976) methods.

As already mentioned, these methods all differ in the procedure during the step of extraction. In the DR method, the user is asked to rate each attribute on a scale of 0-100, whereas the user in PA is asked to distribute a total of 100 points among the attributes. Bottomley et al. (2000) conclude that weights derived from DR are more reliable, and perhaps the extra cognitive step of having to keep track of the number of points to distribute in the PA method influences the test-retest reliability.

In SMART, the user is asked to identify the least important criterion, which receives 10 points, and thereafter the user is asked to rate the remaining criteria relative to the least important one by distributing points. Since no upper limit is specified, the rating extracted from the same person can differ quite a bit in the interpretation if the method is applied twice. Consequently, this aspect of the extraction stage of SMART seems like an element that can affect the internal consistency in the interpretational step of the method.

In the SWING family of methods, the decision-maker is asked to consider all criteria at their worst consequence levels and to identify which criterion whose consequence he or she would prefer most to change from its worst to its best level (swing). This criterion will be given the highest number of points, 100. This procedure is repeated on the remaining set of criteria. First, with the criterion next to the most important swing, where this criterion will be given a value relative to the most important one (thus their points denote their relative importance), and so on. Common to all the methods described so far is also that the number of judgments required by the user during extraction is a minimum of N number of judgments, where N is the number of attributes.

In the trade-off method, the criteria are considered in pairs where two hypothetical alternatives are presented to the decision-maker during extraction. These alternatives differ only in the two criteria under consideration, and in the first alternative the performance of the two criteria is set to their worst and best levels respectively and in the second alternative the opposite applies. The decision-maker is asked to choose one of the alternatives and thereby indicates the more important one. Thereafter (s)he is asked to state how much (s)he would be willing to give up on the most important criterion to change the other to its best level, i.e. state the trade-off (s)he is willing to do for certain changes in values between the criteria. The minimum number of judgments is $N-1$, but a consistency check requires considering all possible combinations of criteria, which would result in $N\cdot(N-1)$ comparisons. Consequently, the extraction component of the trade-off method is operationally quite complex and cognitively demanding in practice due to the large number of pairwise comparisons needed when the criteria are more than a few. Moreover, there is a tendency to give greater weight to the most important attribute in comparison to methods like DR and SWING (see, e.g. Fischer, 1995).

Most commonly, the degree of importance of an attribute depends on its spread (the range of the scale of the attribute), and therefore methods like SMART, which do not consider the spread specifically, have been criticized. The SMART and SWING methods were therefore later combined in the SMARTS method (Edwards and Barron, 1994) to explicitly include spread as well during elicitation. Yet, with methods where ranges are explicitly considered during the elicitation of weights, several empirical studies imply that people still do not adjust weight judgments properly when there are changes in the ranges of the attributes (cf., e.g., von Nitzsch and Weber, 1993). In all studies reported in the literature, the range sensitivity principle (measured by the Range Sensitivity Index, RSI, as suggested by von Nitzsch and Weber, 1993) is violated, often significantly (Beattie and Barron, 1991; von Nitzsch and Weber, 1993; Fischer, 1995; Yeung and Soman, 2005). Von Nitzsch and Weber (1993) suggest that during decision-makers' judgment on importance, an intuitive idea of an attribute's importance (experience) functions as an anchor that is thereafter adjusted by the range of the attribute in the current choice context. Fischer (1995) posited that methods that more explicitly focus on what is gained or lost in terms of different objectives result in assessed values that are more sensitive to the ranges of the consequences. As an alternative explanation to violations of the range sensitivity principle, Monat (2009) claims that the use of local scales may be the problem. Instead, global scales that reflect the best and worst values from the decision-maker's view (not the best and worst from the option set) should be remapped to the best and worst values on the scale (ibid.). However, in such a model the problem is instead the difficulty in identifying the extreme values on the global scale. So far, no method has managed to adequately respect the range sensitivity principle in empirical studies.

8.7.2 Imprecise Weight Elicitation

Accurate determinations of attribute weights by using ratio weight procedures are tricky to acquire in practice as assessed weights are always subject to response error (Jia et al., 1998), and some suggest that the attempt of finding precise weights may be an illusion (Barron and Barrett, 1996a). Consequently, suggestions on how to use imprecise weights instead have been proposed. In MCDA, there are different approaches for handling more imprecise preference, mainly outlined as one or more of the following (Belton and Stewart, 2002): (1) Ordinal statements, (2) Classifying outcomes into semantic categories, and (3) Interval assessments of magnitudes using lower and upper bounds.

Rank-order methods belong to the first approach. During the extraction, decision-makers simply rank the different criteria, which are represented by ordinal values. Thereafter, these ordinal values are translated into surrogate (cardinal) weights that are consistent with the supplied rankings in the interpretational step. The conversion from ordinal to cardinal weights is needed to employ the principle of maximizing the expected value or any other numerical decision rule in the evaluation. Thus, in these methods ratios among weights are determined by the conversion of ranks into ratios in the interpretational step. Several proposals on how to convert such rankings to numerical weights exist, e.g., rank sum (RS) weights, rank reciprocal (RR) weights (Stillwell et al., 1981), and centroid (ROC) weights (Barron, 1992). Of the conversion methods suggested, ROC has gained the most recognition. Edwards and Barron (1994) propose the SMARTER (SMART Exploiting Ranks) method to elicit the ordinal information on importance before being converted to numbers using the ROC method.

However, there is often some weak form of cardinality, e.g., people can be quite confident that some differences in importance are greater than others (Jia et al., 1998), which is ignored in rank-order approaches. Thus, although mere ranking alleviates some of the cognitive demands on users, the conversion from ordinal to cardinal weights may produce differences in weights that do not closely reflect what the decision-maker means by his/her ranking.

Methods utilizing semantic scales (e.g. very much more important, much more important, moderately more important, etc.) for stating importance weights and/or values of alternatives during extraction belong to the second category, like in the AHP method (Saaty, 1980). However, the correctness of the conversion in the interpretational step, from the semantic scale to the numeric scale used by Saaty as a measure for preference strength has been questioned, e.g., by Belton and Stewart (2002). Moreover, the use of verbal terms in general during elicitation has been criticised, since words can have very different meanings for different people, and people often assign different numerical probabilities to the same verbal expressions (Merkhofer, 1987; Kirkwood, 1997). Thus, such numerical interpretations of verbally extracted information from people are less common among the imprecise preference methods (except for the AHP method).

In some applications for decision analysis, preferential uncertainties and incomplete information are handled by using intervals (cf., e.g., Walley, 1991; Danielson et al., 2008), where a range of possible values is represented by an interval. Such methods belong to the third approach and are claimed to put fewer demands on the decision-maker as well as being suitable for group decision-making as individual differences in preferences and judgments can be represented by value intervals (Jiménez et al., 2006). When using interval estimates during extraction, the minimum number of judgments is $2 \cdot (N-1)$, since both the upper and lower bounds are needed for the preference relations. In the GMAA system (Jiménez et al., 2003, 2006), there are two procedures for assessing weights. Either the extraction is based on trade-offs among the attributes and here the decision-maker is asked to give an interval such that (s)he is indifferent concerning a lottery and a sure consequence. The authors state that this method is most suitable for low-level criteria, whereas the other extraction approach, direct assignment, is more suitable for upper-level criteria that could be more political. Here, the decision-maker directly assigns a weight interval to the respective criteria. In the interpretational step, the extracted interval values are automatically computed into an average normalized weight (precise) and a normalized weight interval for each attribute. In Mustajoki et al. (2005), the authors propose an Interval SMART/SWING method, in which they generalize the SMART and SWING methods (for point estimates) into a method that allows interval judgements to represent imprecision during extraction. Here, the reference attribute is given a fixed number of points, whereas the decision-maker is allowed to reply with interval assessments to the ratio questions during extraction (to describe possible imprecision in his/her judgments). The extracted weight information is represented by constraints for the attributes' weight ratios, which in addition to the weight normalization constraint determine the feasible region of the weights in the interpretational step.

Looking a bit deeper into design options available for MEDiate to represent the inherent uncertainty in expressed user preferences, there are a lot of suggestions available in the literature. Well-known methods for approaching this problem are based on, e.g., sets of probability measures, upper and lower probabilities as well as interval probabilities and utilities (Coolen and Utkin, 2008), fuzzy measures (Aven and Zio, 2011; Shapiro and Koissi, 2015; Tang et al., 2018) as well as evidence and possibility theory, cf., e.g., (Dubois, 2010; Dutta, 2018; Rohmer and Baudrit, 2010) just to mention a few. Other approaches include second-order methods (Ekenberg et al., 2014; Danielson et al., 2007, 2019) and modifications of classical decision rules, cf., (Ahn and Park, 2008; Sarabando and Dias, 2009; Aguayo et al., 2014; Mateos et al., 2014). Regarding MCDM problems, Salo, Hämäläinen, and others have suggested methods for handling imprecise information, for instance, the PRIME method (Salo and Hämäläinen, 2001) with various implementations thereof, see e.g. (Mustajoki et al., 2005b). Several other models are focussing on preference intensities, such as the MACBETH method (Bana e Costa et al., 2002), a variety of ROC approaches, such as (Sarabando and Dias, 2010), or the Simos's method and variants thereof (Figueira and Roy, 2002). Furthermore, there are smart swaps methods, such as (Mustajoki and Hämäläinen, 2005a). Mixes of the above techniques are also common, as in Jiménez et al. (2006).

A major problem is combining interval and qualitative estimates without introducing evaluation measures like Γ-maximin or (Levi's) E-admissibility, cf., e.g., (Augustin et al., 2014). Greco et al. (2008) suggest a methodology for purposes like MEDiate's. By using an ordinal regression technique, they can form a representation based on a set of pairwise comparisons. This is generalised in Figueira et al. (2009) by introducing cardinalities for obtaining a class of total preference functions compatible with user assessments. However, this is less suitable for MEDiate since it is unclear how interval constraints can be handled in combination with the extracted preference functions without encountering the computational difficulties discussed in, e.g., (Danielson and Ekenberg, 2007). Also, structural constraints should be taken into consideration as discussed already in, e.g., (Ekenberg et al., 2005).

Ordinal methods for generating weights, sometimes with further discrimination mechanism, constitute a quite commonly used approach to handle the difficulties in eliciting precise criteria weights from decision-makers, c.f., e.g., (Stewart, 1993; Arbel and Vargas, 1993; Barron and Barrett, 1996ab; Katsikopoulos and Fasolo, 2006). The decision-maker supplies ordinal information on importance, which subsequently is converted into numerical weights in accordance with the ordinal information. There have in the literature been several suggestions of such methods, e.g., rank sum weights (RS), rank reciprocal weights (RR) (Stillwell et al., 1981), and centroid (ROC) weights (Barron, 1992). Based on simulation experiments, Barron and Barrett (1996b) found ROC weights superior to RS and RR. Danielson and Ekenberg (2014, 2016ab) have suggested extended families of so-called surrogate weights and have applied them in large-scale contexts, such as (Fasth et al., 2020, Komendantova et al., 2018, 2020). They have also proposed a spectrum of similar methods and suggested some that are more robust than earlier suggestions. In these large-scale experiments, surrogate weights as well as “true” reference weights are sampled from some underlying distributions. Then it is investigated how well the surrogate number results match the result of using the “true” results.

8.8 Key points in elicitation

There is a widely discussed contradiction between the ambiguity of human judgment and the exactness (of elicited values) required by most decision analysis models. People have problems judging exact values (see, e.g., Shapira, 1995), which poses a problem when the required values are point estimates, and some of the deviations from the traditional decision theoretical expectations could probably be attributed to this inability. Using a single number to represent an uncertain quantity can also confuse a person’s judgment about uncertainties with the desirability of various outcomes (Kirkwood, 1997). Also, subjects often do not initially reveal consistent preference behaviour in many decision situations (Keeney and Raiffa, 1976; Keeney, 1982; Wehrung et al., 1980), or protect themselves from intelligence by obscuring and managing their preferences (March, 1997). Brunsson (1989) argues that organizations continuously work with a two-faced perspective and logical approach, where the logical rationality of a decision must be legitimized, which in turn results in ambiguous preferences. Moreover, in elicitation methods where a risky alternative is compared to a certain outcome, people often overweight the certain outcome - the so-called certainty effect (Kahneman and Tversky, 1979). In addition, the conditions for procedure invariance are generally not true, people do not have well-defined values and beliefs in many decision situations where decision analysis is used, and choice is instead contingent or context sensitive (Tversky et al., 1988). People are, furthermore, poor intuitive decision-makers in the sense that our judgments are clearly affected by the frame in which information is presented, as well as the context. Decision-makers appear to use only the information that is explicitly presented in the formulation of a problem (Slovic, 1972; Fischoff et al., 1978), and implicit information that must be deduced from the display seems to be ignored. The framing (formulation) of the problem strongly affects human reasoning and preferences, even though the objective information remains unchanged (Tversky and Kahneman, 1981, 1986).

The heuristics and biases programme initiated by Tversky and Kahneman (1974) illustrates many of the systematic deviations from traditional theoretical expectations inherent in our ways of reasoning, making judgments and in our memory, which cause problems for elicitation processes. We have, e.g., a tendency to be overconfident in our judgments, overestimate desirable outcomes and seek confirmation of our preconceptions. Tversky and Kahneman (1974) argued that the processes of human judgment were totally different than what rational models required and identified a set of general-purpose heuristics that underlie judgment under uncertainty. These heuristics (originally three – availability, representativeness, and anchoring and adjustment) were shown to result in systematic errors (biases), such as the conjunction fallacy and base rate neglect. Over the years, many more such heuristics and biases have been identified. These can be both motivational (due to overconfidence) and cognitive (due to human thought processes). Studies where methods for elicitation have been compared in practice are often inconsistent (cf., e.g., Wang et al., 2002, regarding probabilities; Lenert et al., 2001, concerning preferences; and Pöyhönen and Hämäläinen, 2001, regarding weights), and there is no general agreement on the underlying cognitive processes involved in these assessments. Behavioural concerns are highly relevant to prescriptive decision-aiding, especially in identifying where the improvable deficiencies in current practices are, as well as, in fitting the design of decision aids to the reality of human abilities (Brown and Vari, 1992).

An additional problem in measuring method preciseness for preference elicitation methods occurs due to the subjective nature of the elicited values. Even though most people now agree on the fact that assessed probabilities are subjective in nature, they are to represent facts and if experts' values disagree, different methods can be used for combining multiple assessments to improve the quality of the final probabilities (in the belief that a set of experts can provide more information than one). When combining assessments, the main approaches for doing this are by mathematical aggregations of individual assessments or by obtaining group consensus (Clemen and Winkler, 1999). When it comes to preference elicitation, it is more difficult to determine that the elicited values correctly represent the preferences held by the decision-maker. Thus, there is a bigger problem with validation in this realm.

There is a great deal of uncertainty involved in elicitation and the many reports of the difficulties with eliciting precise values (probabilities, utilities, and weights) from people, suggest that current procedures need to be better adapted to real settings to be more practically useful. The human brain is not inherently numeric, and we are not introspective by nature. Elicitation is an iterative process, where the elicited values may have to be adjusted, due to deviations from theoretical expectations or an increased understanding of the problem and the context by the expert/decision-maker. Coherence in elicited values has to do with how well the values fit together, and models for coherence are mainly focused on probability theory and compensating for the fact that it often falls short as a model of subjective probability (Kynn, 2008). For example, Tversky and Kahneman have raised the question of whether probability theory should be thought of as the calculus of human uncertainty in the first place, and Fox (1994, p. 80) states that "mathematical probability has been developed as a tool for people to use; a body of concepts and techniques which helps to analyse uncertainty and make predictions in the face of it", but that a more liberal attitude would allow for a better understanding of human judgment under uncertainty and the development of more sophisticated technologies for aiding such judgment. Prescriptive analysts must learn how to elicit judgments from decision-makers and make sense of them (Bell et al., 1988).

Prescriptive decision analysis is an attempt to narrow the gap between research within the normative and descriptive disciplines. It is a more practically useful approach for handling decision problems, still employing a formal model for analysis but better adapted to real decision problems. If we are to adopt the prescriptive approach there is a need for processes, methods, and tools that can handle the inherent uncertainty of the decision-maker more explicitly and are coherent. In essence, prescription involves making it all more realistically useful, and for tools to provide the good support they are intended to, there is a need to use them realistically. We can support decision-makers in their decision-making, but we cannot change them. Brown and Vari (1992), among others, assert that behavioural (descriptive) realities are very important to design more prescriptive decision aids.

In the literature on elicitation of the inputs required for decision analysis (probabilities, utilities, weights), there is no consensus to be found regarding:

- the exact nature of the identified gap between ideal and real behaviour,
- how to avoid the observed phenomena, and
- how to evaluate whether a method has produced accurate input data.

However, while reaching a consensus on all aspects within the decision analysis community is difficult, instead, as e.g. Pöyhönen (1997) suggests, research could focus on how methods are used in practice instead of searching for a superior theoretical base for methods. By dividing elicitation into the three components Extraction, Representation, and Interpretation, the applicability of methods in practice can be addressed more explicitly. In practice, we should strive for finding methods that are less cognitively demanding and less sensitive to noisy input within each component.

The extraction component appears like the most error-prone of the three suggested as it concerns the procedural design of the method, which is cognitively demanding during user interaction. Especially behavioural research has concentrated on the extraction aspect of elicitation, most commonly how different biases occur when people interact with elicitation methods. Within this realm, the interpretational component is mostly discussed during validation as a means for measurement (e.g. illustrating procedure invariance).

To reduce the gap between theoretical research and practical needs, there are several aspects of the extraction component that need to be considered. Behavioural aspects, like the heuristics and corresponding biases people use during extraction (cf., e.g., Kahneman et al., 1982), are important to be observant of to reduce such effects. Increased awareness of how presentation formats affect people's choices is suggested to reduce the framing problems (cf., e.g., Tversky and Kahneman, 1981) are often discussed as a hindrance to sufficient elicitation, e.g., such as being aware of people's aversion to losses, a tendency to overestimate certain outcomes, etc. Moreover, relaxation of the precise statements that are commonly required in the extraction component of elicitation methods seems like an advantageous approach to adopt.

Examples of approaches for eliciting the required information in a less precise fashion are methods based on visual aids or verbal expressions. For example, the probability wheel (Spetzler and Staël von Holstein, 1975) is a popular visual method for eliciting probabilities (the user indicates his/her belief in probability size on a circle by sizing a pie wedge to match the assessment on that probability). Such methods often use a combinatorial extraction approach, where the user can modify the input both visually and numerically. The representation of visually extracted input is most commonly an exact number, which is then also used in the interpretation. The use of verbal terms during extraction is supposedly more in line with the generally imprecise semantics of people's expressions of preferences and beliefs but have as already mentioned been criticised for their vagueness, which can cause problems in the interpretational step where the verbal expressions are represented by numbers. Words can have different meanings for different people and people often assign different numerical probabilities to the same verbal expressions (Merkhofer, 1987; Kirkwood, 1997).

Another way of handling preferential uncertainties and incomplete information in a less precise way is by using intervals (cf., e.g., Danielson et al. 2009; Jiménez et al. 2006; Park, 2004), where a range of possible values is represented by an interval. Declared benefits of the interval approach are, e.g., that such representations are more realistic interpretations of people's knowledge, beliefs, and preferences since these elements are not stored with preciseness in our minds. One can also conduct a first analysis of the problem given imprecise statements and test whether the input is sufficient for the final evaluation of alternatives. If not, one can identify the input that needs to be further specified. Other advantages are that methods based on more approximate preferences can lead to a more interactive decision support process as the evolution of the decision-maker's priorities can be computed throughout the process, which in turn could lead to improved decision quality (Salo, 1995). In addition, such methods are especially suitable for group decision-making processes as individual preferences can be represented by a union of the group's judgments (ibid.). In the latter case, group members can seek consensus by trying to reduce the width of the intervals and compromise on their individual judgments if needed.

For the elicitation of weights, ranking methods using surrogate weights (e.g., ROC weights, Barron, 1992; Barron and Barrett, 1996b) in the interpretational step have been alleged to be less cognitively demanding and advantageous for group consensus (as groups are more likely to agree on ranks than precise weights, Barron and Barrett, 1996a). The input retrieved from the extraction step of elicitation methods adopting this approach is a ranking order of the criteria in question, and thus, the representation is merely ordinal information. The interpretation is the surrogate weights (exact numbers) resulting from the conversion method used.

Looking at weight elicitation, methods differ regarding the type of information they preserve from the decision-maker's judgments in the extraction component to the interpretation component. The two extremes within weight elicitation approaches are to use either exact values or mere ranking during extraction. In the representational system proposed for MEDiate, both extremes, as well as intermediate methods, will be allowed for collecting user criteria preferences.

Important for the practical applicability of MCDA methods is the easiness of the method (see, e.g., Stewart, 1992), and simpler tools are easier to use and therefore more likely to be useful. The CROC method for eliciting weights was implemented and tested in practice as part of an MCDA process model used to aid a decision-making process (Danielson et al., 2010), where it was shown useful. In this real-life case, elicitation was more explicitly emphasized throughout the decision process. Moreover, more direct elicitation methods are easier and less likely to produce elicitation errors (Edwards and Barron, 1994). Some even claim that simpler, fast, and frugal methods can produce results that are almost or as good as results attributed to those obtained by more extensive analysis, cf., e.g. (Katsikopoulus and Fasolo, 2006). Larichev et al. (1995), among others, suggest that the exactness of results must not be the main aim of decision analysis and that different situations call for different levels of exactness depending on decision-makers' abilities to provide exact judgments. Consequently, simpler approaches, less reliant on great precision from people, are allegedly a better way of accommodating decision-makers in real settings.

In recent years, the research frontier when it comes to realistic representation of decision problems (i.e. those that allow for imprecision and knowledge gaps which invariably occur in real-life decision situations) has moved in three directions. The first one concerns more elaborated and deeper formal models of decision situations. A representative example is the recurring ISIPTA (International Symposium on Imprecise Probabilities: Theories and Applications) conferences arranged by the Society for Imprecise Probabilities[8] which advances the mathematical modelling further. The second direction is more focused on the descriptive parts of research in order to describe how people currently make decisions in the face of uncertainty. While this is important research, it does not currently aid substantially in the design of a real-world DSS. The third direction, that of finding representations and methods of evaluations for the input that decision-makers are actually able to produce in decision situations are of more interest to this project and are exemplified by (Danielson et al., 2019; Danielson and Ekenberg, 2016; Dutta, 2018; Fasth et al., 2020; Komendantova et al., 2018, 2020; and Tang et al., 2018). The latter approach seems to be the most feasible and fruitful for MEDiate to explore when designing and implementing a decision-analytic module in its DSS.

8.9 Handling elicitation in software

Elicitation is highly important to prescriptive endeavours and to decision-making processes. From behavioural research, the need for decision support systems (based on decision analysis) that are easier for people to understand, and use has been highlighted, although their application will still require some form of training before usage and/or a facilitator to assist during the decision-making process. Many of the current decision analysis tool deficiencies would be alleviated if elicitation of inputs were effective (Brown, 2006). Decision analysis applications should also agree with and support the different steps of the decision-making process in a more complete fashion (French and Xu, 2005), and offer more flexibility by being adaptable to different user needs.

[8] https://sipta.org/

Adopting a prescriptive approach to make decision-making processes, supported by decision analysis applications, more practically useful is now more or less an agreement within the decision analysis community. However, there is still a great need to focus on the elicitation of information to use for analysis as the axioms of decision analysis advise us how to analyse decision problems, but do not indicate where the information used for analysis comes from. Within elicitation, a central question is how to elicit knowledge in probabilistic form and to represent people's individual preferences adequately.

In the following, suggestions on measures to reduce some of the problems with elicitation and things to consider when designing decision analysis tools are described. The intended context is for application in a decision analysis tool used to support a decision-making process. In practice, we should aim for methods that are less cognitively demanding and less sensitive to noisy input.

The extraction component of elicitation methods appears like the most error-prone of the three elicitation components as it concerns the procedural design of the elicitation method. This can be cognitively demanding during the step of extraction, and therefore, there is a need to incorporate support for users during the extraction step of the elicitation method in decision analysis applications. This procedure should preferably be interactive to reduce incoherence in values by assisting the expert/decision-maker during extraction in a cyclic fashion until coherence is achieved and satisfaction is reached.

Moreover, the extraction should allow for more imprecision in the decision input data required from users, especially such input that is subjective and/ or is not naturally processed numerically by people during assessments, like beliefs and preferences. Also, sometimes users are unable to provide all the needed input with the exactness required by many current applications. In any case, the preciseness in such fixed assessments is not certain enough and presents a false impression of accuracy. von Winterfeldt and Edwards (1986) call the precision of numbers an illusion. Allowing for more imprecision during extraction could be achieved by using imprecise procedures, where user statements are quantified to imprecise statements in the interpretational step of the approach. Imprecise extraction can also be achieved by having the user state an imprecise value, e.g., an interval (as in software such as PRIME Decisions (Gustafsson et al., 2001), GMAA (Jiménez et al., 2006) and DecideIT (Danielson et al., 2003)). In applications supporting an interval approach, the user normally enters an interval in the interface of the extraction part of the elicitation method, which is later used in the interpretation.

When designing elicitation methods, there is a need to understand psychological traps within elicitation, such as framing and heuristics that produce biased assessments in order to apply measures to lessen their effect on the method design. Using clear terminology is important, such as e.g., explaining the meaning of certain terms in the specific context, thoroughly considering the phrasing of questions, being explicit on whether the required probabilities are single-event probabilities or frequencies (and explaining the difference to people unaware of the difference).

It is important to understand that the use of formal training can help make people more familiar with the concepts of decision analysis and the value of using this approach (Keeney, 2004). For example, within weather forecasting experts have been shown to make better judgements with training and experience. However, in many situations where one would benefit from the use of decision analysis, the values to elicit are one-time events (and thus frequencies cannot be used) or the situation is new, but training in decision analysis and probabilistic thinking could probably still improve assessments made in situations new to us, especially probability assessments. Moreover, motivation to use decision analysis (if we understand its value) could increase the usage of decision analysis applications to support decision-making processes.

Suggested practical techniques for elicitation are to a great extent a matter of balancing the retrieved quality of the elicitation with the time available and the cognitive effort demanded from the users for eliciting all the required values. Sensitivity analysis could be used to study the consequential variations in the input provided and identify the information most critical for the results, which may need to be considered and specified more thoroughly. This could save users both time and effort, by making the elicitation step of the decision process simpler and faster, as well as reducing the cognitive load.

MEDiate will base its MCDM DSS calculation algorithms on the above results, but the methods must be further developed to fit the demanding modelling requirements of MEDiate that call for being able to combine stakeholders, criteria, event trees, and chains of sub-decisions into a unified decision-supporting framework. The resulting DSS will thus have a number of features never seen before in a DSS, not least when it comes to handling imprecise real-life decision data which is why the state-of-the-art will be reached and surpassed.

8.10 DSS design process

The MEDiate DSS is where the information and scenarios generated in MEDiate meet the decision preferences of the stakeholders in testbeds. For this system to be useful in the end, it should be designed from both ends – i.e. both data-driven as well as preference-driven, see Figure 16.

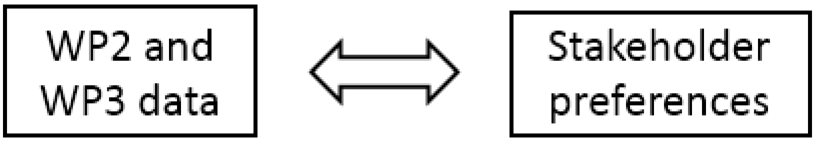

Figure 16: Bi-directional design between work packages

There is at the same time another trade-off that preferably should be addressed by a bi-directional design, i.e., the relation between user needs and wants on the one hand and the DSS capabilities on the other hand, see Figure 17. This was discussed during the validation workshop in early March 2023.

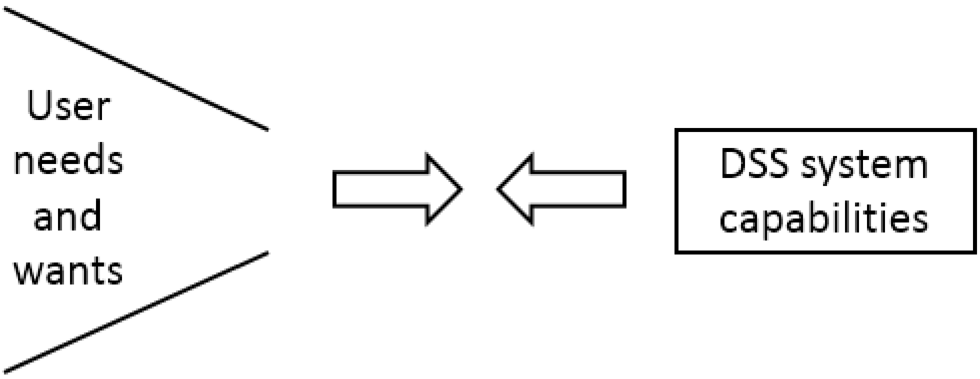

Figure 17: Bi-directional design for MCDA

There is the MCDA calculation module, capable of evaluating decision situations under severe uncertainty. This calculation module for decision problems (selecting one alternative mitigation out of a set) will be described below.

8.11 Data architecture and flow

The data presented to the user for decision-making are of various kinds. In this design brief, the numerical and non-numerical representations of the underlying probabilities, utilities, criteria weights, and stakeholder weights are discussed. Together with structural information (such as event trees), they form the basis for the decision-making support capabilities of MEDiate (Figure 18).

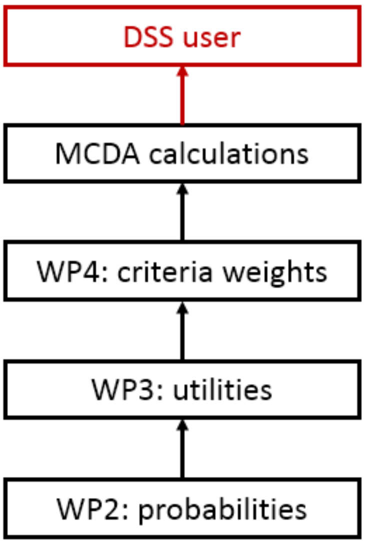

Figure 18: MCDA input/output data hierarchy

More formally, the decisions to be supported are between different mitigations (intervention options) to specific risk problems. For each problem, there is a set of mitigation actions A = {A1, A2, …, An}. This set is mutually exclusive and exhaustive, i.e. the decision problem is to select exactly one mitigation action Ai. Of course, one of the actions can be "do nothing". This set is valued along a set of criteria C = {C1, C2, …, Cm} such as casualties, direct repair cost, and functionality downtime as well as socioeconomic factors. There is no practical limit to the number of criteria, even though above 30 criteria the problem probably becomes hard to handle cognitively. The criteria can be arranged in a criteria hierarchy (in a tree format) rather than having all criteria at the same level.

Probabilities

WP2 and WP3 will generate probability estimates to be fed into MEDiate DSS for the calculation of an expected value $E(A_i)$ per scenario and mitigation action with probabilities expressed in any of the formats 1A-1E. This represents the case where there is more than one possible outcome following an alternative (course of action). In that case, the possible outcomes should be assigned probabilities in order for them to be assessed by a decision-maker. Those probabilities stem from hazard and disaster models as well as social risk models in WP2 and WP3. By this representation, a less likely outcome with larger cost can therefore be efficiently compared to a more likely outcome with a smaller cost. This adds much flexibility to the scenario handling in the DSS.

1A. Fixed numbers: $p_1 = 0.3$, $p2 = 0.5$, …
1B. Imprecision – intervals: $p_1 \in [0.15, 0.35]$, $p_2 = \in [0.2, 0.4]$, …
1C. Imprecision – intervals & midpoint: $p_1 \in [0.15, 0.27, 0.35]$, $p_2 = \in [0.2, 0.35, 0.4]$, …
1D. Ordinal ranking: $p_2 > p_5 > p_1 > \ldots$
1E. Cardinal ranking: $p_2 >> p_5 = p_1 > \ldots$

For each mitigation action in the set A, the output from MEDiate is one probability expression per action (mitigation). The MCDA has no notion of how the probabilities are arrived at. The DSS receives probabilities from MEDiate applicable to each scenario and mitigation action.

Utilities/values

Primarily from WP3, the DSS collects the corresponding values (utilities), expressed in the formats 2A-2E.
2A. Fixed numbers: $v_1 = 30$, $v_2 = 50$, …

2B. Imprecision – intervals: $v_1 \in [15, 35]$, $v_2 = \in [20, 40]$, …
2C. Imprecision – intervals & midpoint: $v_1 \in [15, 27, 35]$, $v_2 = \in [20, 35, 40]$, …
2D. Ordinal ranking: $v_2 > v_5 > v_1 >$ …
2E. Cardinal ranking: $v_2 >> v_5 = v_1 >$ …

Criteria weights

For each criterion in the set $C = \{C_1, C_2, …, C_m\}$ of criteria (or aspects), there is a corresponding criterion weight that denotes the relative importance that the decision-maker attributes to that criterion in the current decision situation. They are expressed using formats 3A-3E.
3A. Fixed numbers: $w_1 = 0.3$, $w_2 = 0.5$, …
3B. Imprecision – intervals: $w_1 \in [0.15, 0.35]$, $w_2 = \in [0.2, 0.4]$, …
3C. Imprecision – intervals & midpoint: $w_1 \in [0.15, 0.27, 0.35]$, $w_2 = \in [0.2, 0.35, 0.4]$, …
3D. Ordinal ranking: $w_2 > w_5 > w_1 >$ …
3E. Cardinal ranking: $w_2 >> w_5 = wy >$ …

Stakeholder weights

Furthermore, the DSS can have an internal model with a set $S = \{S_1, S_2, …, S_j\}$ of stakeholders, either in a tree format or on the same level. Again, the relative importance of the different stakeholders can be expressed symmetrically to all other sets of MCDA input information in the form of formats 4A-4E.
4A. Fixed numbers: $s_1 = 0.3$, $s_2 = 0.5$, …
4B. Imprecision – intervals: $s_1 \in [0.15, 0.35]$, $s_2 = \in [0.2, 0.4]$, …
4C. Imprecision – intervals & midpoint: $s_1 \in [0.15, 0.27, 0.35]$, $s_2 = \in [0.2, 0.35, 0.4]$, …
4D. Ordinal ranking: $s_2 > s_5 > s_1 >$ …
4E. Cardinal ranking: $s_2 >> s_5 = s_1 >$ …

MCDA Decision-Making Calculations

The DSS UI supplies the MCDA module with probabilities on formats 1A-1E and values/utilities on formats 2A-2E for the criteria, weights for the criteria on formats 3A-3E, and – if applicable – weights for the stakeholders on formats 4A-4E if a multi-stakeholder evaluation is to be performed (optional). The DSS UI calls the MCDA module with stakeholder weights, criteria weights, probabilities and utilities/values plus structural information such as tree formats. The MCDA module delivers different rankings of the mitigation actions plus a set of sensitivity analyses to determine the stability of the rankings under (severe) uncertainty. The MCDA module can also assist the DSS UI in the trade-off between scales (such as, e.g., casualties, direct repair cost, and functionality downtime) which must be done for each stakeholder in a user interface dialogue.

Each data layer can consist of a single flat structure (as in Figure 19) or several levels arranged in a tree format. The figure displays a hierarchy in which *j* stakeholders assess a decision situation. The situation contains *n* alternative courses of action which are assessed under *m* criteria. There is one consequence associated with each alternative, thus there are *n* consequences. In a more elaborated model, several consequences could be associated with an alternative, and those would then be additionally described by their respective probabilities to occur.

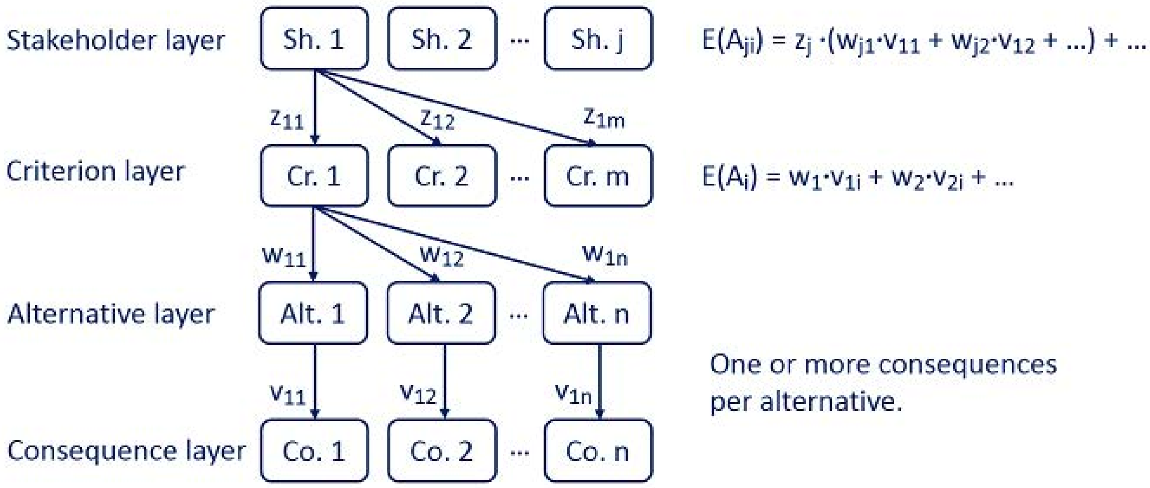

Figure 19: Data structure layers

The event (probability) structures can be of a one level format (left), have several levels in a tree format (middle), or even contain several decisions in a sequence (right), see Figure 20. Next, a decision analysis for a stakeholder is described.

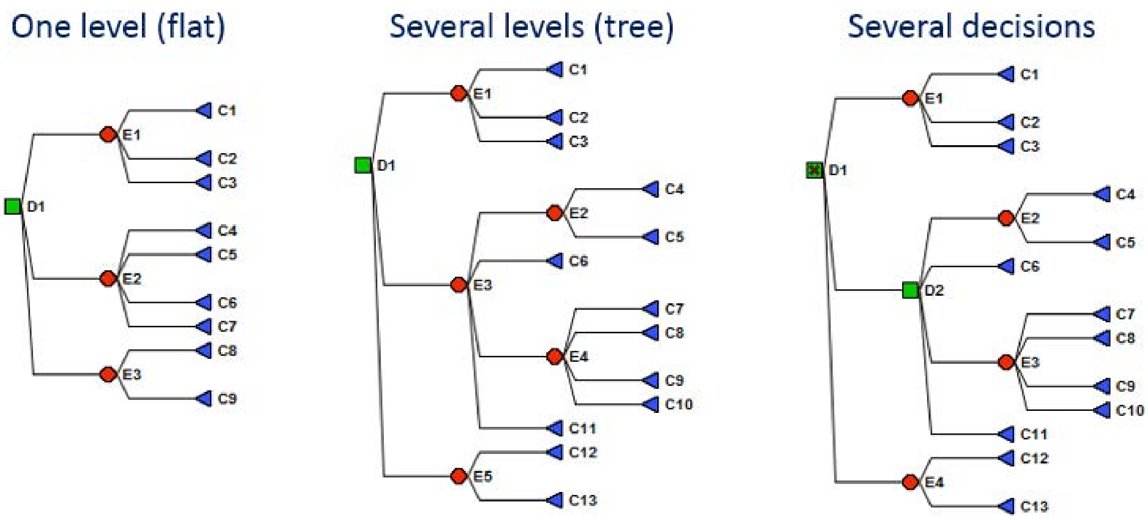

Figure 20: Format of event trees

A decision analysis seen from the MCDA perspective consists of 5 steps that are carried out in sequence. If a user returns to an earlier step, the succeeding steps must be revisited in order to be able to evaluate (Step 4) and analyse (Step 5) the decision problem being worked with. In the case where several stakeholders simultaneously make analyses, and there is a desire to concatenate them into a unified analysis, the third step is extended with an analogous process in which the stakeholders are weighted.

Step 1: Set up decision problem
Step 2: Valuate alternatives
Step 3: Criteria trade-off
Step 4: Evaluate problem
Step 5: Analyse results

STEP 1

The core data of the MCDA problem is a set of data structures where the data is stored. There could be one or more sets of structures, but one will always be the active one. The simplest data structure is a 2-dimensional matrix. Schematically, a decision matrix is a matrix with the alternatives of action that are being considered as rows. Each alternative, defined by the user, occupies one row or column depending on the design. For each criterion, each alternative can have 1-3 numbers associated with it representing the minimum, most likely, and maximum values (utilities) for that alternative under the specific criterion. See Figure 21 for a simple example of a decision matrix.

	Crit 1			Crit 2			Crit 3			Crit 4			Crit 5			Crit 6		
	Min	Mid	Max	Min	Mid	Max	Min	Mid	Max	Min	Mid	Max	Min	Mid	Max	Min	Mid	Max
Alt 1	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00
Alt 2	12,60		89,00	12,60		89,00	12,60		89,00	12,60		89,00	12,60		89,00	12,60		89,00
Alt 3		15,33			15,33			15,33			15,33			15,33			15,33	
Alt 4	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00
Alt 5	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00
Alt 6	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00

Figure 21: Decision matrix with 6 alternatives under 6 different criteria

Each criterion is then (in Step 3) assigning an importance weight in such a manner that the weights sum to 1 (100%). The weights are also expressed in a minimum, most likely, and maximum format, see Figure 22.

	Min	Mid	Max	Min	Mid	Max	Min	Mid	Max	Min	Mid	Max	Min	Mid	Max	Min	Mid	Max
Weights	20%	25%	40%	10%	15%	25%	10%	15%	25%	10%	15%	25%	10%	15%	25%	10%	15%	25%
	Crit 1			Crit 2			Crit 3			Crit 4			Crit 5			Crit 6		
	Min	Mid	Max	Min	Mid	Max	Min	Mid	Max	Min	Mid	Max	Min	Mid	Max	Min	Mid	Max
Alt 1	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00
Alt 2	12,60		89,00	12,60		89,00	12,60		89,00	12,60		89,00	12,60		89,00	12,60		89,00
Alt 3		15,33			15,33			15,33			15,33			15,33			15,33	
Alt 4	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00
Alt 5	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00
Alt 6	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00	12,60	15,33	89,00

Figure 22: Decision matrix like Figure 19 but with criteria weights added on top

In MEDiate, more complex data structures will be used. The above one is for illustrational purposes since it is easy to follow.

Once the data structures are created, they are filled in and the decision is then analysed in a series of steps. Note that all steps follow each other in a chain and the user can only follow it by moving back and forth between steps in a predetermined sequence with no possibility to jump oversteps. This is not a formal requirement of the MCDA module but makes implementation easier from a UI standpoint.

Note that all figures below are only mock-ups – nothing exists yet or is even designed to any level of detail. But they serve to visualise the necessary steps for arriving at a decision using the DSS.

STEP 2

In Step 2, each alternative is valued (the utilities are filled in) under each criterion by either a) entering 1-3 numbers representing a quantitative assessment of the alternative, or b) entering a ranking of the alternatives under that criterion without using numbers (qualitative assessment – where one alternative is equal to or slightly better, clearly better, much better than another).

For Step 2a, by choosing input options for each alternative and criterion, 1-3 numbers can be entered. One number if only the midpoint (most likely value) is known, two if only the lowest and highest values are known, and otherwise.

In case of Step 2b, rankings are entered instead of numbers. These rankings are converted to numbers internally in the MCDM module and the conversion is not a task for the UI, see Figure 23. The number of allowed steps between alternatives is a minimum of 0 and a maximum of 3. In the example, the names are “Str.1”, “Str.2”, and so on but the real names of the mitigation alternatives should be displayed.

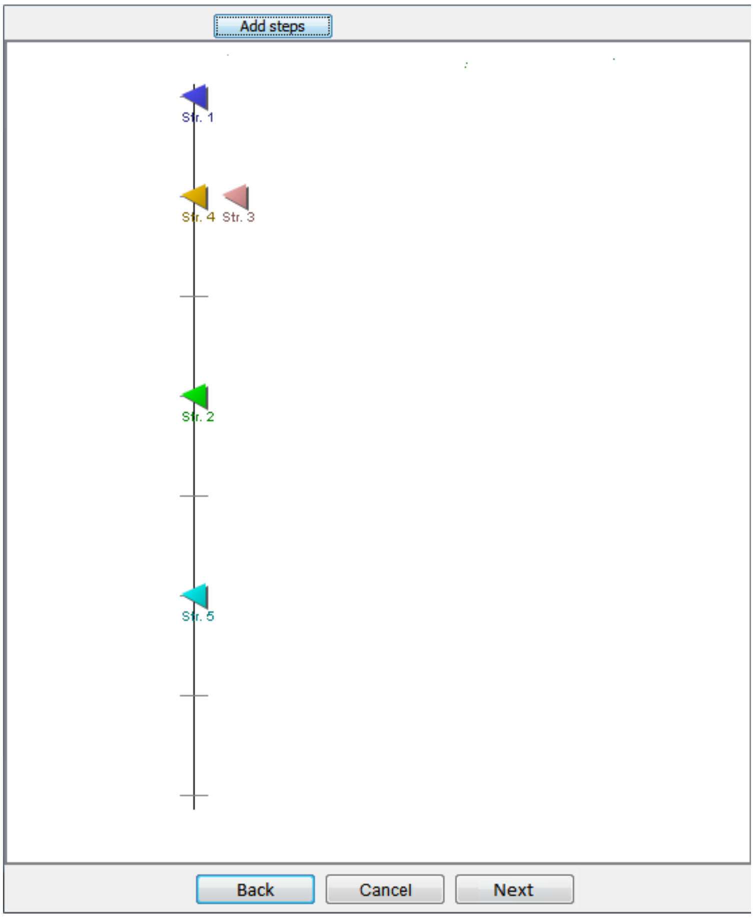

Figure 23: Entering values as rankings

When Step 2 is completed for all criteria (i.e. there is one dialogue for each criterion and they are in the same sequence as they were defined), the dialogue moves on to Step 3 in which the criteria weights are entered.

STEP 3

This is the criteria trade-off step which data entry-wise is similar to Step 2, the only major difference being that the highest and lowest values of the input scale are shown for each criterion. This is in accordance with the so-called Swing technique for calibrating the trade-offs between the criteria.

As with Step 2, Step 3 could also be entered in the form of a ranking ladder. The main difference is that the minimum and maximum values of each criterion are shown. If it is a Ranking criterion (emanating from Step 2b), the highest and lowest ranked alternatives are shown instead, see Figure 24.

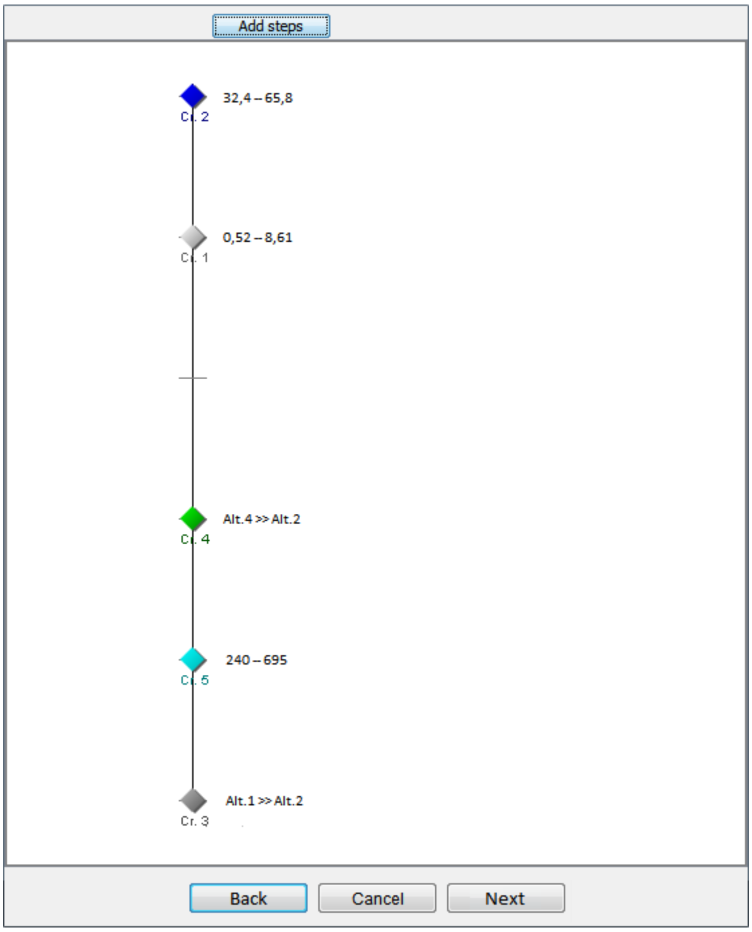

Figure 24: Entering weights as rankings

At any time the user can click Back and return to previous steps. When Step 3 has been completed, the guided dialogue moves to Step 4 which is the evaluation of the decision situation.

STEP 4

In Step 4, there are two ways of displaying the evaluation results. Either as a) a comparison between the alternatives, or b) as a pie chart.

The final displays from Steps 4a (Figure 25) and 4b (Figure 26) could look like the following:

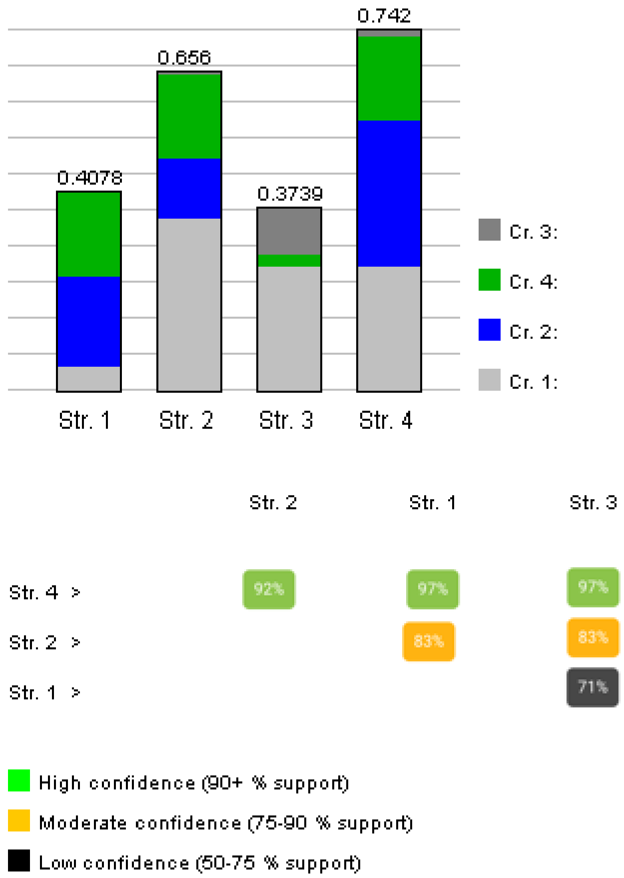

Figure 25: Output result diagram of type 1

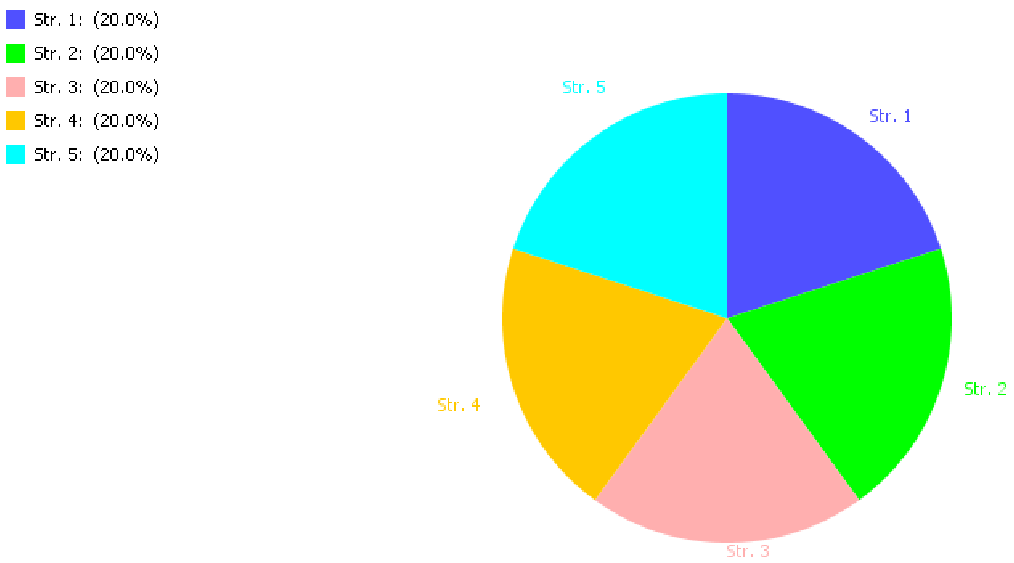

Figure 26: Output result diagram of type 2

STEP 5

The user can then move on to the next step, Step 5, which is sensitivity analyses. In this step, the DSS can point out which information has the most impact on the end results in the preceding step. This is displayed in so-called tornado diagrams, whose numbers are in the same manner retrieved from the calculation library and not computed by the UI. The UI merely displays the results of the calculations. A tornado can look like Figure 27.

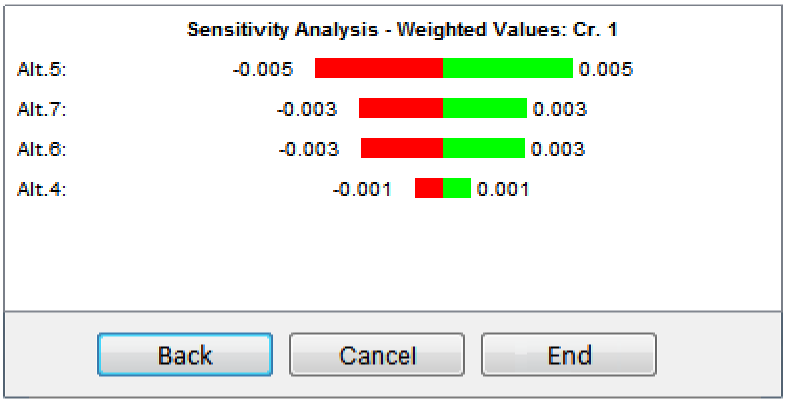

Figure 27: Sensitivity analysis diagram

Further, the user can then move on to the last part of the step, which is S-curves. In this part, the UI can show the exact distributions of belief based on the user input. This is displayed in so-called S-curves, where the coordinates for the curves are obtained from the calculation library and not computed by the UI. The UI merely displays the curve results of the calculations. A pair of S-curves can look like Figure 28.

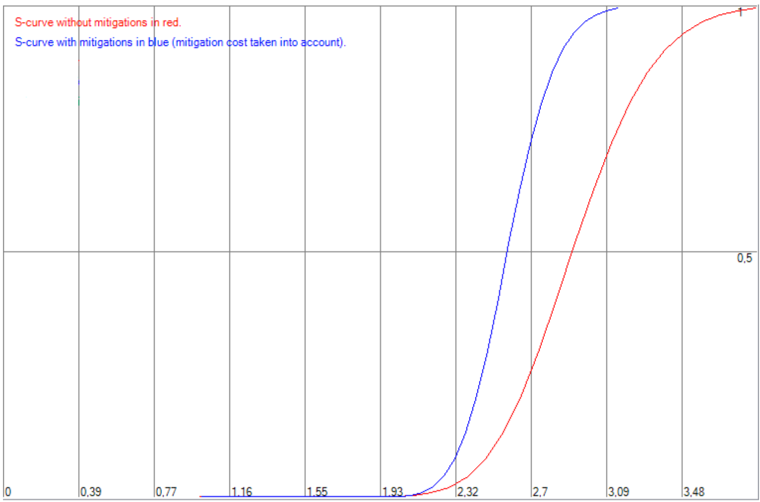

Figure 28: S-curve diagram for two alternatives

This proposed DSS structure goes well beyond what can be found today in decision support systems, both in terms of the rich set of possible input data and in the decision evaluations and sensitivity analyses possible.

9 CONCLUSIONS

The background knowledge on the state of the art in community resilience and disaster risk reduction presented in the present report informs each of the work packages in MEDiate and paves the way towards meeting the project objectives: to improve multi-hazard assessments and highlight potential trends due to climate change, to improve the modelling of risk assessments taking into account interactions and trends in their components, to advance beyond the state-of-the art in multi-hazard and risk approaches and, last but not least, to provide end users with the means to visualize potential scenarios and model the impact of mitigation solutions.

In what concerns the translation of existing conceptualizations, frameworks and applications of community resilience into co-designing an innovative framework and decision-support system for multi-hazard risks, we have elicited end-user stakeholder input across the four project testbeds (see Annexes 1, 2, 3 and 4) for a baseline on the relevant aspects that have been identified in the literature reviews in the following areas: (a) Hazards, exposure, vulnerability and risk, (b) Disaster risk assessment and (c) Disaster risk management and governance. The first cycle of the Participatory Action Research (PAR) involved designing a questionnaire and collecting data in an ethically and legally abiding manner as well by paying attention to any societally sensitive issues. The questionnaires see resilience as intrinsically linked to hazard likelihood and impact, to future effects of climate change, to existing interacting and compound risks, to present and future vulnerability of people, infrastructure, institutions, housing, business and nature, as well as to the presence of assets and human livelihoods in the areas under study, as all these aspects have been shown in the scientific fields covered in the report to play an important role in positively or negatively affecting disaster resilience. Identifying current actors in charge with and approaches to disaster risk assessment, management, and decision-making further builds upon the existing knowledge on risk analysis associated with future multi-hazards (see Chapter 3), community and organizational resilience (Chapters 1 and 5, respectively). Based on both the reviews of current best practices and the questionnaire responses from the stakeholders, decision-making in disaster risk management is not sufficiently informed by tools and even the existing ones that are used, for instance, in disaster response planning or shoreline management planning, do not manage to adequately support stakeholder participation in knowledge exchange or evaluation of mitigation strategies based on current and future scenarios.

The gap MEDiate proposes to address is the lack of an analytical framework for complete end-to-end risk quantification, that can integrate multi-hazard impact analysis, conceptualization of future pathways, and the evaluation of strategies and policies in mitigating risks in the regions and communities where natural hazards might occur. The project provides, moreover, end-users the ability to build accurate scenarios through an IT system that supports single and multi-hazard scenarios and risk assessments, as well as multi-criteria, multi-stakeholder decision analyses that will be used in disaster risk management and governance.

Regarding the validation of the MEDiate concept, the first thing to keep in mind is that any software endeavour of the size of this MEDiate DSS is too large and too complex to specify or even envision in any detail this early in the design process. Fallacies to recognise this was a core of the so-called software crisis in the early-to-mid 1990s in which almost all larger software systems invariably failed in one way or another – from never becoming operational at all to albeit being operational never meeting even a reasonable subset of the original goals. This fact is grounded in the observation that while the largest industrial projects, be it bridges, buildings, cars, or airplanes, are physical objects which can be pictured in drawings and assessed by the “naked eye” (not literally, but progress can be reasonably estimated by inspection). Software, on the other hand, is notoriously hard to specify beforehand and even harder to measure its level of progress or success. The successful software methods since the 1990s are highly iterative, which a large portion of continuous end-user involvement in each phase, including specification and testing, not only at well-defined checkpoints.

The MEDiate project heeds these facts and have taken an approach in which initial user involvement is being used almost from day one to shape the project and most notably the DSS which is a key outcome. In what is called the first PAR cycle, the four testbeds have been involved extensively in trying to understand which detailed directions to take and which the largest hurdles might be, from a general DSS standpoint as well as from a specific resilience standpoint. Judging from the results from the testbed involvement, the MEDiate project seems to be on a good trajectory as can be seen in Chapters 1-7. In parallel, a first design sketch of the decision-making core of the DSS has been made, see Chapter 8. The overall design process will progress from both directions, the user needs and the product, both within the DSS work package as well as between work packages.

It would rather have been a warning sign than an accomplishment if detailed DSS specifications would have been completed this early in the project. It has been verified through testbed interactions that there are a large set of valid user needs that this project will strive to meet. At the other end, the DSS MCDA module has started its work by studying those needs and by participating in the discussions around model building from various angles of requirement of resilience. The validation workshop as well as PAR cycle interactions showed that no real red flags have been raised at either end of the overall design process which is a good sign in such a complex project as MEDiate. At the same time, the discussion on interoperability of various requirements of resilience to be addressed by DSS is already ongoing, combatting the possible risk of an intra-work package silo effect. In summary, the validation workshop showed that partners dealing with various aspects of resilience as well as partners from testbeds are well connected and aware of each other's results and next steps. This first deliverable stands as a testament for the promising progress so far in MEDiate. The progress should continue with analysis of further data collected during PAR cycle interactions in the follow-up deliverables.

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ANNEX 1: DATA STRUCTURE INPUT FORMATS

In all formats, midpoints (most likely numbers) are allowed but not required. Intervals could be derived from estimates, standard deviations, etc.

Probabilities
1A. Fixed numbers: $p_1 = 0.3$, $p_2 = 0.5$, …
1B. Imprecision – intervals: $p_1 \in [0.15, 0.35]$, $p_2 = \in [0.2, 0.4]$, …
1C. Imprecision – intervals & midpoint: $p_1 \in [0.15, 0.27, 0.35]$,
$p_2 = \in [0.2, 0.35, 0.4]$, …
1D. Ordinal ranking: $p_2 > p_5 > p_1 >$ …
1E. Cardinal ranking: $p_2 >> p_5 = p_1 >$ …

Utilities/values
2A. Fixed numbers: $v_1 = 30$, $v_2 = 50$, …
2B. Imprecision – intervals: $v_1 \in [15, 35]$, $v_2 = \in [20, 40]$, …
2C. Imprecision – intervals & midpoint: $v_1 \in [15, 27, 35]$,
$v_2 = \in [20, 35, 40]$, …
2D. Ordinal ranking: $v_2 > v_5 > v_1 >$ …
2E. Cardinal ranking: $v_2 >> v_5 = v_1 >$ …

Criteria weights
3A. Fixed numbers: $w_1 = 0.3$, $w_2 = 0.5$, …
3B. Imprecision – intervals: $w_1 \in [0.15, 0.35]$, $w_2 = \in [0.2, 0.4]$, …
3C. Imprecision – intervals & midpoint: $w_1 \in [0.15, 0.27, 0.35]$,
$w_2 = \in [0.2, 0.35, 0.4]$, …
3D. Ordinal ranking: $w_2 > w_5 > w_1 >$ …
3E. Cardinal ranking: $w_2 >> w_5 = w_1 >$ …

Stakeholder weights
4A. Fixed numbers: $s_1 = 0.3$, $s_2 = 0.5$, …
4B. Imprecision – intervals: $s_1 \in [0.15, 0.35]$, $s_2 = \in [0.2, 0.4]$, …
4C. Imprecision – intervals & midpoint: $s_1 \in [0.15, 0.27, 0.35]$,
$s_2 = \in [0.2, 0.35, 0.4]$, …
4D. Ordinal ranking: $s_2 > s_5 > s_1 >$ …
4E. Cardinal ranking: $s_2 >> s_5 = s_1 >$ …

ANNEX 2: FOUR TESTBEDS PAR TEAMS

Testbed 1: Oslo	
Organisation	People
PAR lead: Oslo Kommune	Osman Mohammad Ibrahim & Ian Gjetrang
Representative WP1&4: IIASA	Nadejda Komendantova
Representative WP2&6: RINA-C	Fabio Bolletta & Clemente Fuggini
Representative WP3: NOR	Chen Huang & Ivan van Bever
Representative WP3&4: EUC	Barbara Borzi
Representative WP5&6: ARU	Femke Mulder

Testbed 2: Nice	
Organisation	People
PAR lead: Metropole Nice Cote d'Azur	Yannick Revel & Romain Gitenet
Representative WP1&4: IIASA	Nadejda Komendantova
Representative WP2: IUSS	Marcello Arosio
Representatives WP3: BRGM & UCL	Samuel Auclair & Dina D'Ayala
Representative WP4: IMT	Aurelie Montarnal
Representative WP5&6: ARU	Femke Mulder
Representative WP7: R2M	Cecile Barrere

Testbed 3: Essex	
Organisation	People
PAR lead: Essex County Council	Marc Inman
Representative WP1&4: IIASA	Nadejda Komendantova
Representative WP2: USTR & DEL	John Douglas (until postdocs are recruited) & Frederiek Sperna Weiland
Representatives WP3: UCL	Catalina Gonzalez Duenas (Carmine Garlasso)
Representative WP5&6:	Femke Mulder & Keith Jones & Mara Morga

Testbed 4: Austurbru	
Organisation	People
PAR lead: Austurbru SES	Erna Rakel Baldvinsdóttir & Tinna Halldorsdottir
Representative WP1&4: IIASA	Nadejda Komendantova
Representative WP2: IMO	Esther Hlíðar Jensen (Tinna Þórarinsdóttir & Matthew James Roberts)
Representatives WP3: UIce	Solveig Thorvaldsdottir (Benedikt Halldórsson)
Representative WP5&6: ARU	Femke Mulder

ANNEX 3: QUESTIONNAIRE AUSTURBRÚ

PART A: HAZARDS, EXPOSURE, VULNERABILITY AND RISK

Section 1: Hazards

Definition of hazard: a process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation. (Source: UNDRR).

Question 1.1: What natural hazards does this testbed face? Please list the top 5. How likely are they? How severe would their impact be?

	Natural Hazard	Likelihood (low, medium, high)	Impact (low, medium, high)
1	Mudflow	High	High
2	Avalanche	High	High
3	Storm	High	High
4	Flood	Medium	Medium
5	Tsunami	Low	Low

Question 1.2: How would climate change affect the likelihood and impact of these hazards?

	Natural Hazard	Likelihood (low, medium, high)	Impact (low, medium, high)
1	Mudflow	High	High
2	Avalanche	Medium	High
3	Storm	High	Medium
4	Flood	High	Low
5	Tsunami	Low	Low

Mudflow:
https://www.ruv.is/frett/2021/10/18/sifreri-i-strandartindi-ognar-atvinnusvaedi-baejarins

Section 2: Exposure

Definition of exposure: the situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas (Source: UNDRR).

Question 2.1: In this testbed, are people and assets currently located in hazard-prone areas? If so, please give examples.

Physical and human assets	Currently located in a hazard-prone area
People	People in their homes and workplaces in hazard-prone area
Infrastructure	Electrical boxes, submarine cables, roads, light poles, sewage systems
Institutions	First-aid responders/rescue squad, municipality offices, Technical museum, LungA school, Port house, outdoor scale for cars and cargo
Housing	Houses located in hazards zone C (hazards zones by Icelandic regulations classified into groups: A, B and C https://statics.teams.cdn.office.net/evergreen-assets/safelinks/1/atp-safelinks.html)
Business	Austurbrú, Síldarvinnslan, Guesthouse, garage, atelier, storages for multiple businesses, offices, workshop
Nature	Water reservoir
Other (please specify)	Outdoor art installation

Question 2.2: In this testbed, are people and assets located in areas that are currently safe, but likely to become hazard prone in the future? (for example, as a result of climate change). If so, please give examples.

Physical and human assets	Located in an area that is currently safe, but likely to become hazard-prone in the future
People	*The hazard zone does not change*
Infrastructure	*The hazard zone does not change*
Institutions	*The hazard zone does not change*
Housing	*The hazard zone does not change*
Business	*The hazard zone does not change*
Nature	*The hazard zone does not change*
Other (please specify)	

Section 3: Vulnerability

Definition of vulnerability: the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards (Source: UNDRR).

Question 3.1: In this testbed, are some people and assets currently highly susceptible to the impact of the hazards they face? If so, please give examples.

Physical and human assets	Currently highly susceptible to the impact of hazards.
People	People in their homes and workplaces in hazard-prone area
Infrastructure	Electrical boxes, submarine cables, roads, light poles, sewage systems
Institutions	First-aid responders/rescue squad, municipality offices, Technical museum, LungA school, Port house, outdoor scale for cars and cargo
Housing	Houses located in hazards zone C (hazards zones by Icelandic regulations classified into groups: A, B and C https://statics.teams.cdn.office.net/evergreen-assets/safelinks/1/atp-safelinks.html)
Business	Austurbrú, Síldarvinnslan, Guesthouse, garage, atelier, storages for multiple businesses, offices, workshop
Nature	Water reservoir
Other (please specify)	Outdoor art installation

Question 3.2: In this testbed, are some people and assets currently not vulnerable, but likely to become vulnerable in the future? (for example, as a result of climate change). If so, please give examples.

Physical and human assets	Currently not vulnerable, but likely to become vulnerable in the future
People	Possibly more
Infrastructure	*No*
Institutions	Possibly more
Housing	Possibly more housing
Business	Possibly more
Nature	*No*
Other (please specify)	

Section 4: Disaster Risk (interacting, interconnected, compound and cascading risk)

Definition Disaster Risk: The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity (Source: UNDRR).

Question 4.1: In this testbed, how have different risks historically affected each other? Please give examples.

Different ways in which risks affect each other	Historic example (if available)
Interacting risks - how did different hazards trigger with each other? For example, when heavy rainfall triggers landslides	heavy rainfall triggers landslides heavy snowfalls with different temperatures trigger avalanches Big storms and rainfall can cause flooding
Interconnected risks - how did interdependencies between human, natural and technological systems shape risk? For example, when a drought puts food production at risk	roads closed do to bad weather while at the same time having avalanche risk
Compound risk – how did simultaneous or successive extreme events affect risk? For example, when an earthquake occurs during a period of severe flooding	tsunami damages the harbour
Cascading risk - how did a disruption of closely interconnected systems affect risk? For example, when collapsed buildings and bridges disrupted the supply chain of key businesses	the clean up in the harbour area had a negative affect on harbour activities

Part B: Disaster Risk Assessment

Section 5: Disaster Risk Assessment

Definition Disaster Risk Assessment: A qualitative or quantitative approach to determine the nature and extent of disaster risk by analysing potential hazards and evaluating existing conditions of exposure and vulnerability that together could harm people, property, services, livelihoods and the environment on which they depend (Source: UNDRR).

Question 5.1: Which authorities (or departments) are responsible for the assessment of hazards, exposure, vulnerability, capacity, resilience, and risk in your testbed? Where available, please provide links or references to their procedures.

Funded by the European Union

<table>
<tr><td rowspan="5">Top 5 natural hazards (listed in question 1.1)

Landslide
Snow Avalanche
Storm
Flood
Tsunami</td><td>1</td><td>IMO Landslides: Veðurstofan sér um hættumat en Almannavarnanefndir á svæðinu sem á að óska eftir hættumati.</td></tr>
<tr><td>2</td><td>IMO Snow Avalanches: Veðurstofan sér um hættumat en Almannavarnanefndir á svæðinu sem á að óska eftir hættumati.</td></tr>
<tr><td>3</td><td>[Femke, based on discussion: IMO is responsible for storm forecasting and real time monitoring and issue warnings. The community is responsible for asking for assessments].</td></tr>
<tr><td>4</td><td>[Femke, based on discussion: IMO also assesses floods, but there are no formal rules/procedures for doing this yet, so this work is preliminary]</td></tr>
<tr><td>5</td><td>[Femke, based on discussion: IMO are currently not assessing tsunamis. They are looking to recruit someone for this].</td></tr>
<tr><td>Exposure</td><td colspan="2">[Femke, based on discussion: IMO primarily assesses hazards. They don’t conduct a risk assessment as such, by looking at exposure or vulnerability. They look at the impact on all people in an affected area (without differentiating). The only risk that is assessed is whether a generic child living in a generic house would survive the impact of the hazard on a given locality.]</td></tr>
<tr><td>Vulnerability</td><td colspan="2"></td></tr>
<tr><td rowspan="5">Capacities / Resilience (see section 7 for explanations and examples)</td><td>Urban development</td><td>Write your answer, or insert a reference / link.
Law – strict building code

[Femke, based on discussion: buildings legally have to be able to withstand earthquakes and wind, but not snow avalanches. Houses have been built that can withstand them, but they are not common].</td></tr>
<tr><td>Infrastructure</td><td>The Icelandic Road and Coastal Administration (IRCA): https://www.road.is/</td></tr>
<tr><td>Natural buffers</td><td>Write your answer, or insert a reference / link.

[Femke, based on discussion: national level institutions issue permits and are responsible for monitoring national level environmental issues, whereas municipalities are responsible for some local issues (e.g., rivers). Note, respondents were not 100% sure about local vs national mandates].</td></tr>
<tr><td>Institutional capacity</td><td>Write your answer, or insert a reference / link.

[Femke, based on discussion: capacity building for
the police was run by national government
the fire brigade was run by municipality
Volunteer responders have their own training programs and fund themselves. The department of civil protection organizes a lot of this training.
The international airport has regular exercises (ever 3-4 years)
Combined exercises between police, fire brigade etc. are held but not routinely.</td></tr>
<tr><td>Societal capacity</td><td>[Femke, based on discussion: it appears that policy and mandates are unclear when it comes to building societal capacity (e.g., training civilians). The remit of the civil protection committee is unclear and they lack resources].

[Femke: it is not clear that this information is in the public domain. Deliverable 1.1 can only include information that is publicly available]</td></tr>
</table>

<table>
<tr><td></td><td>Economic capacity</td><td>Write your answer, or insert a reference / link.

[Femke, based on discussion: civil protection department, which plays a role similar to FEMA]</td></tr>
<tr><td rowspan="4">Risk
(see section 4 for explanations and examples)</td><td>Interacting risks</td><td rowspan="4">Civil Protection committees:
https://www.government.is/publications/legislation/lex/2017/12/21/Civil-Protection-Act-No.-82-2008

IMO:
https://www.reglugerd.is/reglugerdir/allar/nr/505-2000

[Femke, based on discussion: these authorities are responsible for analysing risk – not specifically for analysing how risks are interacting, interconnected, compound and/or cascading…]</td></tr>
<tr><td>Interconnected risks</td></tr>
<tr><td>Compound risk</td></tr>
<tr><td>Cascading risk</td></tr>
</table>

Question 5.2: Which authorities are responsible for the assessment of future risk resulting from climate change in your testbed?

Same as above and the ministry of environment.

Question 5.3: Do the authorities responsible for assessing disaster risk in your testbed use scenarios? If so, are those scenarios developed at national or local level (or both)? Please tick all that apply.

No, they don't use scenarios	
Yes, they use locally developed scenarios	
Yes, they use nationally developed scenarios	Yes.

Question 5.4: What are the strengths and weaknesses of the approaches that are currently used in your testbed to assess risk?

Strengths	*IMO procedures for avalanches and landslides. Strong relationship between scientists and the Civil Protection.*
Weaknesses	*Unclear policy. Resulting in policy not being implemented* [Femke, based on discussion: unclear and overlapping mandates]

Part C: Disaster Risk Management and Governance

Section 6: Disaster Risk Management and Governance

Definition of Disaster Risk Management: DRM is the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses (Source: UNDRR).

Question 6.1: Which authorities (or departments) are responsible for developing disaster risk management plans for this testbed - and what procedures do they follow? (For example, do local plans need to be approved by national authorities?)

Department of Civil Protection and Emergency Management and Icelandic Police/local police - Civil Protection responsibilities at the national level are delegated to the National Commissioner of the Icelandic Police (NCIP). The NCIP runs a Department of Civil Protection and Emergency Management which is responsible for daily administration of Civil Protection matters, maintains a national co-ordination/command centre which can be activated at any time and is in charge of the centre in emergency situations. The NCIP is also responsible for monitoring and supporting research and studies related to risk factors and natural catastrophes, and co-ordination and support measures aimed at reducing risks of bodily harm.

https://www.almannavarnir.is/english/

IMO – disaster risk plans, hazard zoning, evacuation maps for towns in collaboration with civil protection departments. Those are all based on a regulation from the government regarding *Regulation on flood risk assessment, classification and utilization of risk areas and preliminary risk assessment.*

https://en.vedur.is/avalanches/imo/
https://www.reglugerd.is/reglugerdir/eftir-raduneytum/umhverfis--og-audlindaraduneyti/nr/4428

Municipality - Local governments prepare preventive measures and contingency plans. In times of danger, an authority or organization takes care of rescue work in its area of responsibility, and all responders coordinate their work with emergency response assistance so that equipment and manpower are used efficiently. [Natural hazards] may mean that other parties such as the police, the National Radiation Protection Authority or the Coast Guard also have a role. Here, the municipality has a significant role as a partner to solve common challenges within the boundaries of the municipality. It is the municipality's task to maintain the socially important projects and services for which it is responsible and at the same time take care of the residents' need for safety and security.

It is also the municipalities responsibility to assess and prepare for natural hazards and they should have plans and entities as first responders such as fire squad, local civil department committee.

https://www.almannavarnir.is/wp-content/uploads/2021/12/Lei-sveitarf.html#_Toc87000111

The National Institute of Health Austurland – A contingency plan intended to dictate the organization and management of operations within the National Institute of Health Austurland (HSA) following an incident that calls for an increased response from the organization's employees. An incident can be caused by an accident, natural disaster, disease outbreak, poison, pollution or by unknown origin. The preparation of the plan is based on the Act on Health Services no. 40/2007, Civil Defense Act no.82/2008 and Act on quarantine no. 19/1997, also regulation no. 817/2012 regarding quarantine measures. In addition, the program supports the International Health Regulations (IHR-2005) and the Strategic framework for Emergency preparedness, WHO-2017.

https://hsa.is/images/Skjol_a_vef/vibragstlun-HSA__26022020_1.pdf

Question 6.2: What are local authorities' official and legal obligations when it comes to disaster risk management?

To make risk management plans according to civil protection law and work with all entities and parties that are part of such assessment, prevention and response teams or plans.

Question 6.3 Which authorities (or departments) are responsible for communicating local disaster risk management plans to community groups - and what procedures do they follow?

Municipality Múlaþing – is responsible for communicating to the inhabitants of Seyðisfjörður all relevant information regarding natural hazards in Seyðisfjörður. This information can be relayed from other authorities. **IMO** – responsible for communicating hazards risk assessments to the inhabitants and the municipalities. https://www.sfk.is/is/moya/news/endurskodad-haettumat-fyrir-seydisfjord-og-haettumat-fyrir-vestdalseyri Also responsible for monitoring the situation regarding the natural hazard risk in Seyðisfjörður. https://statics.teams.cdn.office.net/evergreen-assets/safelinks/1/atp-safelinks.html **Natural catastrophe insurance** https://island.is/seydisfjordur

Question 6.4 What mechanisms have been set up to ensure that local authorities and emergency responders coordinate effectively during a disaster event - and what procedures do they follow?

There is no mechanism other than the law that ensures that these procedures are done.

Question 6.5 Which authorities (or departments) are responsible for developing economic recovery plans after a disaster in the testbed - and what procedures do they follow?

Municipalities but little focus has been placed on this.

Question 6.6. What are the strengths and weaknesses of the ways in which disaster risks are currently managed in this testbed?

Strengths	Hazard monitoring, relationship between scientists and municipalities.
Weaknesses	Lack of activities by the municipalities despite the law.

Section 7: Managing Resilience & Capacities

Definition of capacity: the combination of all the strengths, attributes and resources available within an organisation, community or society to manage and reduce disaster risks and strengthen resilience (Source: UNDRR). **Definition community resilience**: The ability of a community to prevent, prepare for, respond to, and recover from disasters.

Question 7.1: Please answer for each item in the table below, which authorities (or departments) are responsible for the governance and management of capacities and resilience in this testbed. Where available, please provide links or references to their procedures.

Urban development	Example: use of hazard scenarios	Municipality, authorities
Infrastructure Housing, transport, power, water, communications, etc.	Example: adherence to the building code	Rarik, Míla, The Icelandinc Road and Coastal Administration (IRCA/Vegagerðin), Municipalities
Natural buffers	Example: environmental protection legislation	Ofanflóðasjóður
Institutional capacity Local authorities, first responders	Example: training in disaster management	Local police First aid responders (Björgunarsveitin) Municipality
Societal capacity	Example: public awareness campaigns about hazards	Municipality
Economic capacity	Example: support to business organisations	Nobody

Section 8: Decision Making Tools for Disaster Risk Managemen

Question 8.1 What tools does this testbed currently have to inform decision making in disaster risk management? Do these tools focus on the short-term, the medium-term or the long-term? What are their strengths and weaknesses?

Current tools	Focus short-term, medium-term, or long-term	Strengths	Weaknesses
Disaster response plan	Medium-term	Have proofed successful	Are not used, can be forgotten

National civil protection system	Long-term	High response time	Not enough involvement from the municipalities
IMO measuring tools	Short-term	Have proofed successful	Lack of manpower

Question 8.2 What recommendations do you have for future disaster risk management tools to be developed?

Web based information management portal

Section 9 Evaluations of Disaster Risk Management Plans

Question 9.1. Please insert links or references to publicly available formal assessments of this testbed's disaster risk management plans (in any language).

https://www.almannavarnir.is/utgefid-efni/?wpdmc=vidbragdsaaetlanir-seraaetlanir

https://www.vedur.is/ofanflod/haettumat/seydisfjordur/

https://www.mulathing.is/static/files/skipulag/Hamfarir_Seydisfirdi/Vedurstofa/20210222_ibuafundur_magni.pdf

Question 9.2. Does this testbed use any participatory approaches to evaluate disaster risk management plans? (for example, through serious games).

No

ANNEX 4: QUESTIONNAIRE ESSEX

Part A: Hazards, Exposure, Vulnerability and Risk

Section 1: Hazards

Definition of hazard: a process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation. (Source: UNDRR).

Question 1.1: What natural hazards does this testbed face? Please list the top 5. How likely are they? How severe would their impact be?

	Natural Hazard	Likelihood (low, medium, high)	Impact (low, medium, high)
1	Pluvial Flooding	1:30 year storm event Medium to High	High
2	Fluvial Flooding	1:30 storm event Medium to High	High
3	Coastal and Tidal Flooding	1:30 year storm event Medium to High	High
4	Other sources of flooding eg sewer flooding	1:30 year storm event Medium to High	High
5	Drought /Water sacristy	Low - Medium	Medium - high

Question 1.2: How would climate change affect the likelihood and impact of these hazards?

	Natural Hazard	Likelihood (low, medium, high)	Impact (low, medium, high)
1	Pluvial Flooding	high	Very high
2	Fluvial Flooding	high	Very high
3	Coastal and Tidal Flooding	high	high
4	Other sources of flooding eg sewer flooding	high	high
5	Water sacristy	Medium to high	high

Section 2: Exposure

Definition of exposure: the situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas (Source: UNDRR).

Question 2.1: In this testbed, are people and assets currently located in hazard-prone areas? If so, please give examples.

Physical and human assets	Currently located in a hazard-prone area
People	Preliminary Flood Risk Assessment (PFRA) provides information on a county scale and was last updated by ECC in 2017. The PFRA identifies Flood Risk Areas (FRAs), which are local areas where the risk of flooding is likely to be significant for people, the economy or the environment and consider all sources of flood risk (i.e. Coastal, River, Surface Water etc.). The latest PFRA (2017) identified 5 FRAs within Essex, as follows: ▪ South Essex ▪ Canvey Island ▪ Harlow ▪ Colchester ▪ Chelmsford Preliminary Flood Risk Assessment (PFRA) https://www.rochford.gov.uk/sites/default/files/evibase_98eb49.pdf https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/698238/PFRA_Essex_County_Council_2017.pdf The Risk of Flooding from Surface Water Map (RoFfSW), last updated in 2013 provides information on a national scale and is used as an evidence base for the PFRA. The EA produced the RoFfSW map as part of their strategic overview role in England. https://check-long-term-flood-risk.service.gov.uk/map?easting=569329.82&northing=209333.06&map=SurfaceWater The map provides information on flood extent, depth, velocity, and hazard in a range of events. These maps provide an indication of areas (not individual properties) that are at highest risk from surface water flooding, Rivers, and Sea. The Surface Water Management Plans (SWMP's) are a further development on this and provide more detailed information at a district scale. https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/ Surface water management plans (SWMPs) have identified the properties and infrastructure which is at risk of flooding from Surface water based on EA methodology which considers the depth of flood water against the percentage of the building perimeter that has been flooded. https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/ Further the SWMPS have identified the number of residential properties, non-residential and critical services at risk based on determination of Critical Drainage Area (CDA). CDAs are hydraulic catchment within the SWMP Study Area where multiple or interlinked sources of flood risk cause flooding during a severe rainfall event thereby affecting people, property, or local infrastructure. https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/chelmsford/ **Essex Green Infrastructure (GI) Strategy** The Green Essex Story Map provides a visual and interactive tool, and it is evidence of the Essex Green Infrastructure Strategy Green Essex | Place Services **GI - Principle 3: Multifunctional Outcomes**

	Integration of flood and water management as part of green space, highways and other provision - Flooding remains one of the most frequent natural hazards in Essex and is predicted to experience an increase in flooding, extreme weather events and summer droughts through climate change. GI provides significant opportunities to deliver space for water and natural options for flood alleviation and water management. Development should include biodiversity and open space provision, which will provide aesthetic and amenity value, and safe public access as well as managing flood risk. The importance of this is highlighted within the Essex SuDS Design Guide. For further details, please visit Essex Green Infrastructure Strategy (2020) **Planning Policy Statement 25: Development and Flood Risk Practice Guide - Updated December 2009** Planning shapes the places where people live and work and the country we live in. It plays a key role in supporting the Government's wider economic, social and environmental objectives and for sustainable communities https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/7772/pps25guideupdate.pdf **South Essex Level 1 Strategic Flood Risk assessment © 2018 AECOM** The South Essex study area is located in the east of England and comprises the administrative areas of Local Planning Authorities (LPA): Basildon Borough Council, Castle Point Borough Council, Rochford District Council and Southend-On-Sea Borough Council https://localplan.southend.gov.uk/sites/localplan.southend/files/2019-02/South%20Essex%20Strategic%20Flood%20Risk%20Assessment%20Level%201.pdf Historic Flood risk Records, **Basildon** (South Essex SFRA 2018) Table 4-4 Summary of past flood events in Basildon (pages 26-27) There are three Environment Agency Flood Warning Areas in Basildon; one for tidal flooding, one for the Thames Estuary and one for fluvial flooding from the River Crouch. These are identified in Appendix A Figure 4.6, as follows: 1. River Crouch from Noak Bridge to Runwell, including Wickford; 2. Canvey Island North; and 3. Shellhaven to Grays including Tilbury. Designated emergency rest centres for Basildon Borough are mapped in Appendix A Figure 4.6 Historic Flood Records, **Castle Point** (South Essex SFRA 2018) Table 5-3 Summary of past flood events in Castle Point (page 34) Appendix A Figure 5.6 identifies three Environment Agency Flood Warning Areas in Castle Point, for tidal flood risk: 1. Canvey Island North; 2. Canvey Island South; and 3. Leigh on Sea frontage from Chalkwell to Hadleigh Marshes including Two Tree Island. Designated emergency rest centres for the Castle Point Borough are mapped in Appendix A Figure 5.6 and summarised in Table 5-3 (page 32) There are five Environment Agency Flood Warning Areas in the **Rochford** District relating to tidal flooding. These are identified in Appendix A Figure 6.6, and are listed below: 1. Wallasea and Foulness Islands; 2. Paglesham, Rochford, The Wakerings and Potton Island; 3. Eastwood Brook from downstream of Rayleigh Weir and the Prittlewell Brook to Southend Airport; 4. Tidal River Crouch from Creeksea to Battlesbridge; and, 5. Hullbridge waterside properties. Designated emergency rest centres for the Rochford District are mapped in Appendix A Figure 6.6 and summarised in Table 6-2 (Page 38).

	The Environment Agency Historic Flood Map indicates areas that have been previously flooded but not show the source of the flood. The map (Appendix A Figure 6.3) shows areas to the north of the district along the River Crouch and to the east of the district along the course of the River Roach that have previously been flooded. There is also an area to the south of Rochford along the course of Prittle Brook has also been previously flooded. Table 6-3 Summary of past flood events in Rochford (Page 40, 41) Historic Records - **Southend-On-Sea** (South Essex SFRA 2018) The Environment Agency Historic Flood Map indicates areas that have been previously flooded but does not show the source of the flood. The map (Appendix A Figure 7.3) shows that the areas along the Southend town seafront and Willigale Brook have previously flooded, as well as areas to the south east and north east of the Borough. Table 7-3 Summary of past flood events in Southend-On-Sea (Page 47) Flood Warning Areas (page 43) **Recent significant flood events include**; (page 45) • 24th August 2013; • 11th October 2013; • 20th July 2014; and, • 19th September 2014 There are five Environment Agency Flood Warning Areas in the Southend-On-Sea Borough; three for tidal flooding from the Thames Estuary, one for the Tidal River Crouch and one for the Roach, Prittle Brook, Eastwood Brook. These are identified in Appendix A Figure 7.6, and are listed below: 1. Paglesham, Rochford, The Wakerings and Potton Island; 2. Shoeburyness to Southend Pier including Southchurch Park; 3. Southend Sea Front from the Pier to Chalkwell; 4. Leigh On Sea frontage from Chalkwell to Hadleigh Marshes including Two tree Island; and 5. Eastwood Brook from downstream of Rayleigh Weir and the Prittlewell Brook to Southend Airport. Designated emergency rest centres for the Southend-On-Sea Borough are mapped in Appendix A Figure 7.6 and summarised in Table 7-2 (Page 45)
Infrastructure	**Brentwood** Infrastructure Delivery Plan (IDP) provides a schedule of infrastructure requirements to help support new development growth planned within Brentwood Borough Council's Local Plan in the period up to 2033. https://document.brentwood.gov.uk/pdf/04022019161832000000.pdf **Braintree Infrastructure** Delivery Plan (IDP) 2021 https://www.braintree.gov.uk/downloads/file/3260/bdc058-infrastructure-delivery-plan-update-june-2021 **Chelmsford** Infrastructure Delivery Plan (IDP) 2018 https://www.chelmsford.gov.uk/media/03lkqt3t/eb-018a-chelmsford-infrastructure-delivery-plan-january-2018.pdf **Colchester** Infrastructure Delivery Plan (IDP) 2021. https://cbccrmdata.blob.core.windows.net/noteattachment/CBC-Colchester-Local-Plan-Evidence-Base---Emerging-Local-Plan-2017-2033---infrastructure-EBC%205.13%20Colchester%20Infrastructure%20Delivery%20Plan.pdf **Harlow and Gilston Garden Town Infrastructure** Delivery Plan (IDP) 2019. https://www.efdclocalplan.org/wp-content/uploads/2019/04/ED34-and-EB1418-Harlow-and-Gilston-Garden-Town-Infrastructure-Delivery-Plan-HDH-Planning-Development-and-Arup-April-2019.pdf **Uttlesford Local Plan Infrastructure** Delivery Plan (IDP) 2017 https://www.uttlesford.gov.uk/media/7053/Infrastructure-Development-Plan-Troy-Planning-May-2017/pdf/2017.05.25_Draft_2.1_LOW_RES.pdf?m=636360834146400000

	Essex Surface water management plan (SWMPs) have identified human used areas at risk of surface water flooding. https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/. Unfortunately, there is no classification found in Essex planning documents for exposure categories as indicated in this exposure question The documents listed in above section under (people) can also be used to get the information about infrastructure.
Institutions	Please see all the documents listed under People https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/
Housing	Please see all the documents listed under People And specific housing location with different risk scenarios can be seen by SWMPs https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/
Business	Please see all the documents listed under People https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/
Nature	Essex Green Infrastructure Strategy (2020) NPPF 2021 - 13. Protecting Green Belt land (pages 41- 44) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005759/NPPF_July_2021.pdf
Other (please specify)	

Question 2.2: In this testbed, are people and assets located in areas that are currently safe, but likely to become hazard prone in the future? (for example, as a result of climate change). If so, please give examples.

Physical and human assets	Located in an area that is currently safe, but likely to become hazard-prone in the future
People	*SWMPs* https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/ Essex Green Infrastructure Strategy (2020) Essex SWMP has identified the hazard prone areas where people are at risk of surface water flooding. The plan shows the location and number of properties affected by 1 in 30 year storm event, 1 in 100 year Storm Event and 1 in 100 year plus climate change storm event. The SWMP did not differentiated between infrastructure, business and institutions rather classifying the flood risk across study area by residential and non-residential properties, the critical services.
Infrastructure	*SWMPs* https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/ Essex Green Infrastructure Strategy (2020) Essex SWMP has identified the hazard prone areas where people are at risk of surface water flooding. The plan shows the location and number of properties affected by 1 in 30 year storm event, 1 in 100 year Storm Event and 1 in 100 year plus climate change storm event. The SWMP did not differentiated between infrastructure, business and institutions rather classifying the flood risk across study area by residential and non-residential properties, the critical services. South Essex Outline Water Cycle Study Technical Report 2011

	https://www.basildon.gov.uk/media/4062/Basildon-Borough-Council-Scott-Wilson-South-Essex-WCS-2011/pdf/Basildon_Borough_Council_-_Scott_Wilson_-_South_Essex_WCS_2011.pdf?m=634770102469070000
Institutions	*SWMPs* https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/ Essex Green Infrastructure Strategy (2020) Essex SWMP has identified the hazard prone areas where people are at risk of surface water flooding. The plan shows the location and number of properties affected by 1 in 30 year storm event, 1 in 100 year Storm Event and 1 in 100 year plus climate change storm event. The SWMP did not differentiated between infrastructure, business and institutions rather classifying the flood risk across study area by residential and non-residential properties, the critical services.
Housing	*SWMPs* https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/ Essex Green Infrastructure Strategy (2020) Essex SWMP has identified the hazard prone areas where people are at risk of surface water flooding. The plan shows the location and number of properties affected by 1 in 30 year storm event, 1 in 100 year Storm Event and 1 in 100 year plus climate change storm event. The SWMP did not differentiated between infrastructure, business and institutions rather classifying the flood risk across study area by residential and non-residential properties, the critical services.
Business	*SWMPs* https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/ Essex Green Infrastructure Strategy (2020) Essex SWMP has identified the hazard prone areas where people are at risk of surface water flooding. The plan shows the location and number of properties affected by 1 in 30 year storm event, 1 in 100 year Storm Event and 1 in 100 year plus climate change storm event. The SWMP did not differentiated between infrastructure, business and institutions rather classifying the flood risk across study area by residential and non-residential properties, the critical services.
Nature	Essex Green Infrastructure Strategy (2020) NPPF 2021 - 13. Protecting Green Belt land (pages 41- 44) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005759/NPPF_July_2021.pdf

Section 3: Vulnerability

Definition of vulnerability: the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards (Source: UNDRR).

Question 3.1: In this testbed, are some people and assets currently highly susceptible to the impact of the hazards they face? If so, please give examples.

Physical and human assets	Currently highly susceptible to the impact of hazards.
People	Elderly Children Hospitals Proximity to watercourses See SWMP map for People vulnerability

	https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/chelmsford/ Canvey Island – different drainage system heavily connected to each other, location is below sea leave. Integrated urban design studies Preliminary Flood Risk Assessment (PFRA) provides information on a county scale and was last updated by ECC in 2017. The PFRA identifies Flood Risk Areas (FRAs), which are local areas where the risk of flooding is likely to be significant for people, the economy or the environment and consider all sources of flood risk (i.e. Coastal, River, Surface Water etc.). The latest PFRA (2017) identified 5 FRAs within Essex, as follows: ▪ South Essex ▪ Canvey Island ▪ Harlow ▪ Colchester ▪ Chelmsford Preliminary Flood Risk Assessment (PFRA) https://www.rochford.gov.uk/sites/default/files/evibase_98eb49.pdf https://www.rochford.gov.uk/sites/default/files/evibase_98eb49.pdf **Community Risk Register For Essex** - The Community Risk Register provides information on the emergencies that may happen in Essex. There is also an assessment of how likely they are to happen and the impacts if they do. This includes the impacts to people, property, the environment and local businesses. http://www.essexprepared.co.uk/upload/documents/Essex_CRR_Public_Information_592fe6379ae7c.pdf **The Essex Profile** Some risks are more significant in Essex, because of its location, social, economic and geographical factors. These factors also influence how we can prepare for and manage emergencies across the County. Essex is located in the East of England and lies to the north east of London and is a large County covering 3,670sq km. Essex has a population of around 1.78 million). It shares borders with the county authorities of Hertfordshire, Cambridgeshire, Suffolk and Kent; the unitary authorities of Southend-on-Sea and Thurrock; and the London Boroughs of Enfield, Waltham Forest, Redbridge and Havering. The eastern boundary of Essex is formed by the North Sea. Much of the boundary with Suffolk is also formed by water; • The River Stour divides Essex and Suffolk, each having a major Port on the Stour Estuary. • The River Thames provides much of the southern boundary, endorsing the Essex relationship with tidal waters. • The western boundary runs with or close to two motorways, the M25 and the M11. Essex being largely rural and has a population density that is almost 60% higher than the national average. Density is focused on the higher populated urban districts and towns. Essex is the driest county in the UK, on average receiving less than 600mm of rain per year **Environment** Essex has over 500km of coastline which is one of the longest biologically and economically important coastlines in England. The coastline is generally low lying; however flood defences in Essex are of a high standard. There are a number of Rivers in Essex which are vulnerable to flooding due to a combination of factors including prolonged or intense rainfall, or rapid thaw of heavy snow.

	Please follow the community register web link for further detail. http://www.essexprepared.co.uk/upload/documents/Essex_CRR_Public_Information_592fe6379ae7c.pdf
Infrastructure	**Greater Essex Growth And Infrastructure Framework 2016-2036 (February, 2017)** Greater Essex is home to 1.8 million people, with a further 300,000 forecast to live in the area within 20 years. To better understand the scale of the infrastructure challenge, all of the local authorities in Essex commissioned AECOM to prepare a Growth and Infrastructure Framework (GIF) for the county and two unitary authorities. The framework presents an overview of growth patterns to 2036, evidences the infrastructure required, and estimates likely costs and funding gaps. 4.8 FLOODING & DRAINAGE (Pages 100 - 103) https://www.activeessex.org/wp-content/uploads/2021/04/The-Final-GIF-document-Feb-2017-print-version.pdf Vol. 1: South Essex Strategic Green And Blue Infrastructure Study Resilient By Nature https://ca1-jsp.edcdn.com/downloads/South-Essex-Strategic-Green-and-Blue-Infrastructure-Study.pdf
Institutions	Essex SWMP has identified the hazard prone areas where people are at risk of surface water flooding. The plan shows the location and number of properties affected by 1 in 30 year storm event, 1 in 100 year Storm Event and 1 in 100 year plus climate change storm event. The SWMP did not differentiated between infrastructure, business and institutions rather classifying the flood risk across study area by residential and non-residential properties, the critical services. *SWMPs* https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/
Housing	Essex SWMP has identified the hazard prone areas where people are at risk of surface water flooding. The plan shows the location and number of properties affected by 1 in 30 year storm event, 1 in 100 year Storm Event and 1 in 100 year plus climate change storm event. The SWMP did not differentiated between infrastructure, business and institutions rather classifying the flood risk across study area by residential and non-residential properties, the critical services. *SWMPs* https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/
Business	**Everyone's Essex: our plan for levelling up the county 2021 to 2025** **https://www.essex.gov.uk/everyones-essex-our-plan-for-essex-2021-2025/our-20-commitments**
Nature	**Essex Local Nature Partnership (LNP)** Local Nature Partnerships (LNPs) bring together local organisations, businesses and people who want to improve their local natural environment. The Local Nature Partnership Board and Essex County Council coordinate the LNP across the county. Together, with our partners, we will strengthen the impact of local action for nature recovery. https://www.essexclimate.org.uk/essex-local-nature-partnership **Net Zero: Making Essex Carbon Neutral report** The initial purpose of the Essex Climate Action Commission was to set out recommendations on tackling the climate crisis. This included devising a roadmap to get Essex to net zero by 2050. These recommendations were set out in the commission's report Net Zero: Making Essex Carbon Neutral report (PDF, 5.33MB), published in July 2021. The report put forwards a comprehensive plan to: • reduce the county's greenhouse gas emissions to net zero by 2050, in line with UK statutory commitments, • make Essex more resilient to climate impacts such as flooding, water shortages and overheating

Question 3.2: In this testbed, are some people and assets currently not vulnerable, but likely to become vulnerable in the future? (for example, as a result of climate change). If so, please give examples.

Physical and human assets	Currently not vulnerable, but likely to become vulnerable in the future
People	https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/ Essex SWMP has identified the hazard prone areas where people are at risk of surface water flooding. The plan shows the location and number of properties affected by 1 in 30 year storm event, 1 in 100 year Storm Event and 1 in 100 year plus climate change storm event.
Infrastructure	Essex County Council Flood Investigation Report Helions Bumpstead (Jan 2022) https://helionsbumpsteadparishcouncil.gov.uk/wp-content/uploads/simple-file-list/Flood-Investigation-Helions-Bumpstead-V1_4.pdf
Institutions	https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/ Essex SWMP has identified the hazard prone areas where people are at risk of surface water flooding. The plan shows the location and number of properties affected by 1 in 30 year storm event, 1 in 100 year Storm Event and 1 in 100 year plus climate change storm event.
Housing	https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/ Essex SWMP has identified the hazard prone areas where people are at risk of surface water flooding. The plan shows the location and number of properties affected by 1 in 30 year storm event, 1 in 100 year Storm Event and 1 in 100 year plus climate change storm event.
Business	https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/ Essex SWMP has identified the hazard prone areas where people are at risk of surface water flooding. The plan shows the location and number of properties affected by 1 in 30 year storm event, 1 in 100 year Storm Event and 1 in 100 year plus climate change storm event.
Nature	https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/ Essex SWMP has identified the hazard prone areas where people are at risk of surface water flooding. The plan shows the location and number of properties affected by 1 in 30 year storm event, 1 in 100 year Storm Event and 1 in 100 year plus climate change storm event.
Other (please specify)	

Section 4: Disaster Risk (interacting, interconnected, compound and cascading risk)

Definition Disaster Risk: The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity (Source: UNDRR).

Question 4.1: In this testbed, how have different risks historically affected each other? Please give examples.

Different ways in which risks affect each other	Historic example (if available)
Interacting risks - how did different hazards trigger with each other? *For example, when heavy rainfall triggers landslides*	Climate change is known phenomenon to trigger multiple hazards. Essex is facing number of risks ranging from record high temperature during summer and prolonged intense storm events during winter. These whether patterns result in hotter summer days with less rainfall, which causes drought conditions in many areas and cussing water scarcity issue. Flash flooding is one of the outcomes of these climate extreme events due to increased and prolonged rainfall during winter. which impacts people, property and infrastructure. Essex town are mostly urbanized with limited capacity of drainage and have old drainage system in existing populated areas where such storm events couple with sewer flooding due to lack of capacity within the existing system and makes the flooding situation difficult to manage. South Essex Level 1 strategic Flood Risk Assessment (SFRA) 2018 - Table 5-3 Summary of past flood events in Castle Point (page 34). Tidal and fluvial flooding poses the most significant flood risk to the Castle Point Borough, in particular Canvey Island and Hadleigh Marshes. The topography and location of watercourses on Canvey Island means that the whole island is at risk from tidal and fluvial flooding. Although much of the Island is protected by the presence of defences, the island is still at residual risk of flooding if the defences were to fail or to be overtopped. https://localplan.southend.gov.uk/sites/localplan.southend/files/2019-02/South%20Essex%20Strategic%20Flood%20Risk%20Assessment%20Level%201.pdf
Interconnected risks - how did interdependencies between human, natural and technological systems shape risk? *For example, when a drought puts food production at risk*	Essex became a popular place for people to live, work and commute to neighbouring cities due to its geographical location. With the passage of time the demand for housing, infrastructure, educational institute, commercial development and National significant infrastructure has been increased. This led to influence the natural environment or ecosystem services which are vital to keep the balance between resources and healthy environment. Water scarcity is one of the examples of overconsumption of existing resource and it intensifies manifolds where no measures are put in place to replenish the depleted aquifer. Further causes the drought conditions within different areas across the county. This issue is not only interconnected to overconsumption but heavily dependent on human activities in terms of increased impermeable areas for new developments and associated infrastructure which alters the natural ways of water interception into the ground and replenish aquifer. **Essex water shortage prediction "terrifying"** The East of England will be short of water by up to 1.6billion litres per day by the 2050s, a new report has warned. https://www.essexlive.news/news/essex-news/essex-water-shortage-prediction-terrifying-4734287 **Essex Climate Action Commission** https://www.essex.gov.uk/news/increases-in-flooded-homes-heat-related-deaths-and-water-shortages-what **Areas of water stress: final classification report by Environment Agency** https://www.iow.gov.uk/azservices/documents/2782-FE1-Areas-of-Water-Stress.pdf

	Research Article- Ajia, F.O., Wagstaff, T. and Sharp, L. (2021) ***Mobilising the public to reduce household water use in Essex and Suffolk Water.*** In: Morris-Iveson, L. and Day, S.J., (eds.) Resilience of Water Supply in Practice: Experiences from the Frontline. IWA Publishing , pp. 59-80. ISBN 9781789061611 https://eprints.whiterose.ac.uk/184920/ Essex as Lead Local Flood Authority on the other hand using national policies and local guideline to manage our resources; SuDS Design Guide https://www.essexdesignguide.co.uk/suds and Essex Green Infrastructure Strategy (2020) are key documents to help understand the incorporation of integrated system to manage surface water runoff and use of multifunctional space to enhance local and neighbourhood values for people to live and communicate with the aim to provide better planning proposal and development outcomes for people and property. Further the unmanaged rainwater will initiate overland flow rotes from densely populated areas and causses flash flooding.
Compound risk – how did simultaneous or successive extreme events affect risk? *For example, when an earthquake occurs during a period of severe flooding*	Essex have recorded data where number of properties are flooded due to heavy rainfall for couple of hours which generate high volume of water, in densely populated areas with insufficient sewer capacity or sometime lack of ordinary watercourse management. Compound risk also evident in low lying areas closer to coastline. Section 19 Flood Investigation Report for Castle Point https://www.rebeccaharris.org/sites/www.rebeccaharris.org/files/2022-11/S19_%20CastlePointFloodIncident%20REPORT.pdf Essex County Council Flood Investigation Report Helions Bumpstead (Jan 2022) https://helionsbumpsteadparishcouncil.gov.uk/wp-content/uploads/simple-file-list/Flood-Investigation-Helions-Bumpstead-V1_4.pdf Essex County Council Flood Investigation Report Roydon Essex (Dec 2021) https://roydonessex.org.uk/wp-content/uploads/2022/06/Flood-Report-on-25-July-2021-event.pdf
Cascading risk - how did a disruption of closely interconnected systems affect risk? *For example, when collapsed buildings and bridges disrupted the supply chain of key businesses*	Essex may not have records of collapse building during flash flooding, but flooding and Heat wave does impact the daily services as both have significant impact on the roads/trains which disrupt the transportation. Heatwaves: adapting to climate change, Ninth Report of Session 2017–19 (Pages 37 – 42) https://publications.parliament.uk/pa/cm201719/cmselect/cmenvaud/826/826.pdf Flooding – Transport disruption https://www.networkrail.co.uk/running-the-railway/looking-after-the-railway/delays-explained/flooding/ Essex Highway - Drainage and flooding (introductory page) https://www.essexhighways.org/roads-and-pavements/drainage-and-flooding

Part B: Disaster Risk Assessment

Section 5: Disaster Risk Assessment

Definition Disaster Risk Assessment: A qualitative or quantitative approach to determine the nature and extent of disaster risk by analysing potential hazards and evaluating existing conditions of exposure and vulnerability that together could harm people, property, services, livelihoods and the environment on which they depend (Source: UNDRR).

Question 5.1: Which **authorities (or departments) are responsible** for the assessment of hazards, exposure, vulnerability, capacity, resilience and risk in your testbed? Where available, please provide links or references to their procedures.

Top 5 natural hazards (listed in question 1.1)	1	**Pluvial Flooding** Essex County Council as Lead Local Flood Authority is responsible for managing risk from Surface water, ground water and ordinary watercourses. Local Flood Risk Management Strategy https://flood.essex.gov.uk/media/1293/essex-local-flood-risk-management-strategy.pdf Flood Strategy Appendix B- useful links and documents https://flood.essex.gov.uk/media/1292/flood-strategy-appendix-b.pdf Strategic Environmental Assessment (SEA) https://flood.essex.gov.uk/media/1291/flood-strategy-appendix-sea-d.pdf SWMP - https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/
	2	Fluvial Flooding Environment Agency is responsible to manage flood risk from River, Sea and Coasts. Managing flood risk • Lead Local Flood Authorities • District and Borough Councils • Coast protection authorities • Water and sewerage companies • Internal Drainage Boards • Highways authorities. Further information can be found on below link https://www.local.gov.uk/topics/severe-weather/flooding/local-flood-risk-management/managing-flood-risk-roles-and Flood map for planning to view the flood risk zone based on fluvial flooding, any water storage areas. *https://flood-map-for-planning.service.gov.uk/location* Check the long term flood risk for an area in England – provide flood risk around your areas from surface water and river and sea https://www.gov.uk/check-long-term-flood-risk
	3	Coastal Erosion / Tidal flooding East Anglia Coastal Group | Shoreline Management Plan (SMP 8)

		The SMP covers some 440 km of coast between Landguard Point in Felixstowe and Two Tree Island in the Thames Estuary. This SMP includes an intricate mix of islands and estuaries including polices for the Stour and Orwell estuary, Hamford Water, the Colne estuary, the Blackwater estuary and the Crouch and Roach estuary. Shoreline Management Plans (SMPs) are non-statutory plans for coastal defence management planning. The aim of an SMP is to provide a strategy for managing flood and erosion risk for a particular stretch of coastline. The SMPs provide estimates of how the coast is likely to change over the next 100 years, taking into account the future implementation of coastal policies, geology, likely impacts of climate change and the existing condition of the coast including coastal defences. https://www.eastangliacoastalgroup.org/smp-8 The national flood and coastal erosion risk management strategy for England Flood and coastal erosion risk in England is expected to increase due to climate change and development in areas at risk. It is not possible to prevent all flooding or coastal erosion, but there are actions that can be taken to manage these risks and reduce the impacts on communities. The Strategy provides a framework for guiding the operational activities and decision making of practitioners supporting the direction set by government policy. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/920944/023_15482_Environment_agency_digitalAW_Strategy.pdf National flood and coastal erosion risk management strategy for England Annex A- Outline of existing roles and responsibilities in relation to flood and coastal risk management activities https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/917641/15482_Environment_agency_digital_AnnexA_PDFA.pdf Regional Flood and Coastal Committee (RFCC) Each Regional Flood & Coastal Committee (RFCC) is a committee established by the Environment Agency under the Flood & Water Management Act 2010. The Environment Agency must consult with RFCCs about flood and coastal risk management (FCRM) work in their region and take their comments into consideration. RFCCs approve the annual programme of FCRM work in their region and set the local levy that funds FCRM activities within the region that are a local priority. Regional Flood and Coastal Committee Map https://www.ada.org.uk/our-members/regional-flood-coastal-committees/ Anglian (Eastern) Regional Flood and Coastal Committee (RFCC) https://www.norfolkalc.gov.uk/news/2019/02/anglian-eastern-regional-flood-and-coastal-committee-rfcc
	4	**Other sources of flooding eg sewer flooding** Water Companies (Anglian Water and Thames Water) are responsible to manage flooding from Sewer. Anglian Water Flood Reporting Tool

		https://www.anglianwater.co.uk/services/sewers-and-drains/flooding/ Anglian Water Flooding in your home https://www.anglianwater.co.uk/help-and-advice/flooding-guidance/flooding-in-your-home/ Thames Water flood reporting tool https://www.thameswater.co.uk/help/emergencies/flooding Highway Authorities are managing flooding from Highway drainage system. https://www.essexhighways.org/tell-us
	5	**Water Scarcity** South Essex Outline Water Cycle Study Technical Report 2011 https://www.basildon.gov.uk/media/4062/Basildon-Borough-Council-Scott-Wilson-South-Essex-WCS-2011/pdf/Basildon_Borough_Council_-_Scott_Wilson_-_South_Essex_WCS_2011.pdf?m=634770102469070000 **Thames: groundwater situation 24 January 2023 Policy Paper Updated 24 January 2023** *https://www.gov.uk/government/publications/thames-west-area-groundwater-situation/thames-groundwater-situation-10-january-2023* SWMPs https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/ Essex Green Infrastructure Strategy (2020)
Exposure	People	National Planning Policy Framework https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005759/NPPF_July_2021.pdf Department for Environment Food & Rural Affairs (DEFRA) https://www.gov.uk/government/organisations/department-for-environment-food-rural-affairs Essex County Council – Essex Flood and Water Management https://flood.essex.gov.uk/ **Local Planning Authority** https://www.essex.gov.uk/our-role-planning/local-planning ***SWMPs*** https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/ **Environment Agency** https://www.gov.uk/government/organisations/environment-agency
	Infrastructure	**Highway Authorities** are managing flooding from Highway drainage system. https://www.essexhighways.org/tell-us **Environment Agency** https://www.gov.uk/government/organisations/environment-agency **Local Planning Authority** https://www.essex.gov.uk/our-role-planning/local-planning

		Highway England https://www.gov.uk/government/organisations/highways-england **National Planning Policy Framework** (NFFP) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005759/NPPF_July_2021.pdf **National Rail** https://www.nationalrail.co.uk/service_disruptions/81155.aspx
	Institutions	**Essex County Council** **https://www.essex.gov.uk/** **Highway Authorities** are managing flooding from Highway drainage system. https://www.essexhighways.org/tell-us **Environment Agency** https://www.gov.uk/government/organisations/environment-agency **Local Planning Authority** https://www.essex.gov.uk/our-role-planning/local-planning **National Planning Policy Framework** (NFFP) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005759/NPPF_July_2021.pdf
	Housing	**Essex County Council** **https://www.essex.gov.uk/topic/planning-land-recycling** **Environment Agency** https://www.gov.uk/government/organisations/environment-agency **Local Planning Authority** https://www.essex.gov.uk/our-role-planning/local-planning **National Planning Policy Framework** (NFFP) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005759/NPPF_July_2021.pdf
	Business	**Essex County Council** **https://www.essex.gov.uk/topic/business** **Environment Agency** https://www.gov.uk/government/organisations/environment-agency **Local Planning Authority** https://www.essex.gov.uk/our-role-planning/local-planning **National Planning Policy Framework** (NFFP) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005759/NPPF_July_2021.pdf
	Nature	**Essex County Council** **https://www.essex.gov.uk/leisure-culture-local-heritage**

		Environment Agency https://www.gov.uk/government/organisations/environment-agency **Local Planning Authority** https://www.essex.gov.uk/our-role-planning/local-planning **National Planning Policy Framework** (NFFP) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005759/NPPF_July_2021.pdf **Environment Bill – September 2021: Nature and Conservation covenants (Parts 6 and 7) (policy paper)** *https://www.gov.uk/government/publications/environment-bill-2020/10-march-2020-nature-and-conservation-covenants-parts-6-and-7* **Environment Act 2021** Environment Act 2021 (legislation.gov.uk) https://www.legislation.gov.uk/ukpga/2021/30/contents/enacted
Vulnerability	People	EA – Risk of Flooding from Surface water (RoFSW) https://check-long-term-flood-risk.service.gov.uk/risk ECC – SWMP https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/ LPA – **Local Planning Authority** https://www.essex.gov.uk/our-role-planning/local-planning **SFRAs** –please see section A (people) for South Essex Strategic Flood Risk Assessment, and district wise SFRAs. Please refer to sequential test and exception tests. **National Planning Policy Framework** (NFFP) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005759/NPPF_July_2021.pdf
	Infrastructure	Essex Highway https://www.essex.gov.uk/roads-streets-and-transport **Essex Transportation Strategy**: the local transport plan for Essex June 2011 Essex County Council has prepared this plan to best respond to the needs of everyone who lives or works in Essex. This is a long-term plan covering 15 years which sets out our aspirations for improving travel in the county, demonstrating the importance of our transport network to achieving sustainable long-term economic growth and enriching the lives of our residents. https://www.essexhighways.org/uploads/downloads/essex_ltp.pdf **Essex County Council** **https://www.essex.gov.uk/topic/schools-and-learning** **Environment Agency** What is the Risk of Flooding from Surface Water map? Report version 2.0 April 2019 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/842485/What-is-the-Risk-of-Flooding-from-Surface-Water-Map.pdf

		Local Planning Authority https://www.essex.gov.uk/our-role-planning/local-planning **National Planning Policy Framework** (NFFP) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005759/NPPF_July_2021.pdf **ECC SWMP** https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/ LPA – **Local Planning Authority** https://www.essex.gov.uk/our-role-planning/local-planning **SFRAs** –please see section A (people) for South Essex Strategic Flood Risk Assessment, and district wise SFRAs. Please refer to sequential test and exception tests. **National Planning Policy Framework** (NFFP) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005759/NPPF_July_2021.pdf East - National Highways Highways England
	Institutions	Essex Highway https://www.essex.gov.uk/roads-streets-and-transport **Essex Transportation Strategy**: the local transport plan for Essex June 2011 Essex County Council has prepared this plan to best respond to the needs of everyone who lives or works in Essex. This is a long-term plan covering 15 years which sets out our aspirations for improving travel in the county, demonstrating the importance of our transport network to achieving sustainable long-term economic growth and enriching the lives of our residents. https://www.essexhighways.org/uploads/downloads/essex_ltp.pdf **Essex County Council** **https://www.essex.gov.uk/topic/schools-and-learning** **Environment Agency** What is the Risk of Flooding from Surface Water map? Report version 2.0 April 2019 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/842485/What-is-the-Risk-of-Flooding-from-Surface-Water-Map.pdf **Local Planning Authority** https://www.essex.gov.uk/our-role-planning/local-planning **National Planning Policy Framework** (NFFP) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005759/NPPF_July_2021.pdf **ECC SWMP** https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/

		LPA – **Local Planning Authority** https://www.essex.gov.uk/our-role-planning/local-planning **SFRAs** –please see section A (people) for South Essex Strategic Flood Risk Assessment, and district wise SFRAs. Please refer to sequential test and exception tests. **National Planning Policy Framework** (NFFP) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005759/NPPF_July_2021.pdf East - National Highways Highways England
	Housing	Essex Highway https://www.essex.gov.uk/roads-streets-and-transport **Essex Transportation Strategy**: the local transport plan for Essex June 2011 Essex County Council has prepared this plan to best respond to the needs of everyone who lives or works in Essex. This is a long-term plan covering 15 years which sets out our aspirations for improving travel in the county, demonstrating the importance of our transport network to achieving sustainable long-term economic growth and enriching the lives of our residents. https://www.essexhighways.org/uploads/downloads/essex_ltp.pdf **Essex County Council** **https://www.essex.gov.uk/housing** **Environment Agency** What is the Risk of Flooding from Surface Water map? Report version 2.0 April 2019 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/842485/What-is-the-Risk-of-Flooding-from-Surface-Water-Map.pdf **Local Planning Authority** https://www.essex.gov.uk/our-role-planning/local-planning **National Planning Policy Framework** (NFFP) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005759/NPPF_July_2021.pdf **ECC SWMP** https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/ LPA – **Local Planning Authority** https://www.essex.gov.uk/our-role-planning/local-planning **SFRAs** –please see section A (people) for South Essex Strategic Flood Risk Assessment, and district wise SFRAs. Please refer to sequential test and exception tests. **National Planning Policy Framework** (NFFP) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005759/NPPF_July_2021.pdf

		[East - National Highways](#) Highways England
	Business	*Write your answer, or insert a reference / link.* Essex Highway https://www.essex.gov.uk/roads-streets-and-transport **Essex Transportation Strategy**: the local transport plan for Essex June 2011 Essex County Council has prepared this plan to best respond to the needs of everyone who lives or works in Essex. This is a long-term plan covering 15 years which sets out our aspirations for improving travel in the county, demonstrating the importance of our transport network to achieving sustainable long-term economic growth and enriching the lives of our residents. https://www.essexhighways.org/uploads/downloads/essex_ltp.pdf **Essex County Council** **https://www.essex.gov.uk/topic/business** **Environment Agency** What is the Risk of Flooding from Surface Water map? Report version 2.0 April 2019 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/842485/What-is-the-Risk-of-Flooding-from-Surface-Water-Map.pdf **Local Planning Authority** https://www.essex.gov.uk/our-role-planning/local-planning **National Planning Policy Framework** (NFFP) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005759/NPPF_July_2021.pdf **ECC SWMP** https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/ LPA – **Local Planning Authority** https://www.essex.gov.uk/our-role-planning/local-planning **SFRAs** –please see section A (people) for South Essex Strategic Flood Risk Assessment, and district wise SFRAs. Please refer to sequential test and exception tests. **National Planning Policy Framework** (NFFP) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005759/NPPF_July_2021.pdf East - National Highways Highways England
	Nature	**Magic Maps** Magic Map Application (defra.gov.uk) **Environment Agency - Working with Nature ()July 2022** *https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1094162/Working_with_nature_-_report.pdf* *ECC -* Essex Green Infrastructure Strategy (2020)

		NPPF 2021 - 13. Protecting Green Belt land (pages 41- 44) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005759/NPPF_July_2021.pdf LPA – **Local Planning Authority** https://www.essex.gov.uk/our-role-planning/local-planning **SFRAs** –please see section A (people) for South Essex Strategic Flood Risk Assessment, and district wise SFRAs **National Planning Policy Framework** (NFFP) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005759/NPPF_July_2021.pdf **Environment Act 2021** Environment Act 2021 (legislation.gov.uk) https://www.legislation.gov.uk/ukpga/2021/30/contents/enacted **ECC – Place services** *https://www.placeservices.co.uk/*
Capacities / Resilience *(see section 7 for explanations and examples)*	Urban development	Essex County Council have been involved to deliver flood resilience schemes to manage flood risk. the below website will represent the previous schemes. https://flood.essex.gov.uk/our-work-1/ https://www.facebook.com/essexFWM/ https://www.essexdesignguide.co.uk/suds/further-guidance/case-studies/ **ECC Capital Schemes** The Essex Flood Prevention Capital Programme was instigated to reduce the level of surface water flood risk to properties. The programme has been running for seven years, and the team have protected over 1600 properties by the end of 2021/22. Some of the schemes have included: The award winning flood protection scheme for 38 homes in the **Kingsmoor area** of Harlow whereby a series of 'leaky dams' were installed in Parndon and Risden Woods, where timber and woody debris were positioned across water channels to slow down water flow during periods of heavy rainfall. Leaky dams were chosen for this scheme as they minimised disruption in the woodland area and enabled the preservation of natural habitats. They have a much lower carbon footprint than conventional flood projects as they are a natural way to reduce flooding and installed using heavy horses. The project was led by ECC's Flood Team working in partnership with Harlow District Council, Place Services, Jacobs and the Environment Agency. By using the leaky dam method, it's estimated we saved approximately £38,000 and 95 tonnes of Co2 equivalent when compared to an earth bund alternative. https://flood.essex.gov.uk/our-work-1/harlow-leaky-dams-project/ **Brentwood Ursuline School Scheme**, which benefitted 20 properties from flooding. This project involved reinforcing the existing ponds embankment and lowering the outfall by 0.5m which as a result increased the amount of available storage within the pond. **Bradford Street, Braintree**, which benefitted protected 46 properties and benefitted over 100 properties. This project created a surface water flood attenuation basin in a local area of open space. The scheme has been made by moving soil around the site, reducing the environmental impact compared to building walls or concrete structures. Doing so also allows the scheme to blend

		into the landscape and for it to continue to be used and enjoyed as an open space. This basin during normal dry periods remains open and usable making the scheme a multifunctional feature. As part of the **SPONGE project**, Essex County Council is worked with Basildon and Thurrock University Hospitals to retrofit the Essex Cardiothoracic Centre courtyard with Sustainable Urban Drainage System (SuDS). Funded by Interreg 2 Seas, the project increases resilience against surface water flooding whilst simultaneously improving the communal space in Basildon Hospital for both patients and members of staff. SuDS manage precipitation in a similar fashion to nature itself in order to minimise the effects of excessive rainfall. This can help to reduce water pollution and reduce surface water runoff. SuDS also create green spaces and habitats that encourage and improve biodiversity. https://flood.essex.gov.uk/our-work-1/sponge/
	Infrastructure	Essex Highways *https://www.essexhighways.org/roads-and-pavements/drainage-and-flooding/surface-water-alleviation-schemes* ECC – SUDS Design Guide *https://www.essexdesignguide.co.uk/suds* AW – planning and development services *https://www.anglianwater.co.uk/developing/planning--capacity/planning-services/* Sewers and drains (anglianwater.co.uk) Thames Water – planning and development services https://www.thameswater.co.uk/developers/larger-scale-developments/planning-your-development The Essex Design Guide *https://www.essexdesignguide.co.uk/about/the-growth-and-infrastructure-framework-gif-and-the-edg/*
	Natural buffers	Magic Map Application (defra.gov.uk) Essex Green Infrastructure Strategy (2020) Essex-Green-Infrastructure-Standards https://www.essexdesignguide.co.uk/supplementary-guidance/essex-green-infrastructure-standards/ NPPF 2021 - 13. Protecting Green Belt land (pages 41- 44) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005759/NPPF_July_2021.pdf ECC Place services https://www.placeservices.co.uk/ *Essex Local Authorities* *Essex is made up of 15 Local Planning Authorities including City, District, Borough, Unitary and County Councils.* *https://www.essexdesignguide.co.uk/essex-local-authorities/* The Local Nature Recovery Strategy (LNRS) Introduced in the Environment Act 2021, The Local Nature Recovery Strategy (LNRS), is a statutory requirement, and a new mandatory England-wide system

		of spatial strategies that will establish priorities and map proposals for specific actions to drive natures recovery. The Environment Act 2021 lays the foundation for a single Nature Recovery Network (NRN). The LNRSs' across England will underpin the NRN, with each county / responsible authority, joining up their strategies and acknowledging the overlap in spaces for nature. The LNRS will be a shared creation, working with the Essex Local Nature Partnership to deliver a strategy that will provide the best outcomes for nature in Essex. The Essex LNRS covers Greater Essex, working in partnership with Thurrock and Southend to deliver the strategy. Expected date for further LNRS guidance from DEFRA is April 2023.
	Institutional capacity	*Write your answer or insert a reference / link.* ECC – schools – GI delivery at schools, tree planting Schools - Essex County Council ECC project into Basildon Hospital SPONG project https://flood.essex.gov.uk/our-work-1/sponge/
	Societal capacity	Local Plans Local plans are prepared by the Local Planning Authority (LPA), usually the Council or the national park authority for the area. The National Planning Policy Framework (NPPF) states that the planning system should be genuinely plan-led. Succinct and up-to-date plans should provide a positive vision for the future of each area and a framework for addressing housing needs and other economic, social and environmental priorities. Environment Agency - Check your flood risk https://www.gov.uk/check-flooding https://www.gov.uk/sign-up-for-flood-warnings The Blue Pages http://bluepages.org.uk/ ECC -Surface water management plans (SWMP) *https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/* BRIC project – with Thames 2021 Thames21 is empowering communities in Canvey Island, Essex, to co-create solutions to flooding with public authorities as part of an exciting two-year pilot project funded by the European Union. Building Resilience in Communities (BRIC) is a €3.4 million initiative led by Plymouth City Council. Building Resilience in Communities (BRIC) project | PLYMOUTH.GOV.UK Rain Gardens, created for first time in Essex, to reduce flooding and improve the environment in a Canvey Road *https://www.essex.gov.uk/news/rain-gardens-created-for-first-time-in-essex-to-reduce-flooding-and-improve*

		Heatwave plan for England Protecting health and reducing harm from severe heat and heatwaves. The Heatwave Plan for England is a guide to protect the population from heat-related harm to health. The aims of the plan are to prepare, alert and prevent the major avoidable effects on health during periods of severe heat in England. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1096593/heatwave-plan-for-England-2022-5-August-2022.pdf
	Economic capacity	Central govt money funded project, all the risk management authorities then apply for grant to carry on works. Essex County Council Highway Authorities Anglian Water Environment Agency DEFRA funding Charity Organizations as Woodland Trust - *https://www.woodlandtrust.org.uk/* **Natural England** - *https://www.gov.uk/government/organisations/natural-england* **Essex Forest Initiative** https://www.essex.gov.uk/the-essex-forest-initiative New tree planting dates continue the climate work of the Essex Forest Initiative https://www.essex.gov.uk/news/new-tree-planting-dates-continue-the-climate-work-of-the-essex-forest ECC project into Basildon Hospital SPONG project https://flood.essex.gov.uk/our-work-1/sponge/ **Interreg** *https://www.interregeurope.eu/*
Risk *(see section 4 for explanations and examples)*	Interacting risks	**ECC as Lead local flood authority is a statutory consultee on major planning application.** https://flood.essex.gov.uk/our-strategies-and-responsibilities/our-duties-as-a-lead-local-flood-authority-llfa/ Manging flash flood and water scarcity with the use of Sustainable drainage principles for all major developments across Essex. Limiting discharge rates to sewer or open water feature. Maintain water quality, introducing multifunctional green spaces to enhance biodiversity and landscape for people living around. Promote to discharge by means of infiltration to increase groundwater recharge. https://www.essexdesignguide.co.uk/suds **AW – SUDS adoption and design** https://www.anglianwater.co.uk/siteassets/developers/aw_suds_manual_aw_fp_web.pdf **Southend City Council** **Our Flood Strategies and Responsibilities**

		Under this legislation, Southend-on-Sea City Council is designated as a Lead Local Flood Authority (LLFA) and has the duty to take the lead in the management of local flood risk in the area. We also have the responsibility to work closely with relevant flood Risk Management Authorities (RMA's). The act also confers powers on the LLFA to enforce flood management policies in the city for riparian owners. Responsibility for the management of flood risk from the sea, main rivers and reservoirs remains with the Environment Agency. https://www.southend.gov.uk/homepage/458/flood-and-water-management **Thurrock Flood Risk Management** Our local flood risk management strategy deals with flooding from sewers, drains and groundwater, and the runoff from land, watercourses and ditches, that can follow heavy rainfall. We have looked at how flooding can affect properties, businesses and infrastructure. Areas that are most at risk are called Areas of Critical Drainage (AoCD). These include the areas: • at risk of flooding • that can affect the extent of flooding **Epping Forest – Flooding** Our Environmental Protection & Drainage Team work closely with Essex County Council, the surrounding town and parish councils and the Environment agency to ensure our district is prepared in case of a flooding risk. https://www.eppingforestdc.gov.uk/environment/flooding/
	Interconnected risks how did interdependencies between human, natural and technological systems shape risk?	**The Essex Climate Action Commission** (ECAC) was set up to advise Essex County Council about tackling climate change. The commission has over 30 members. They include a Lord, local councillors, academics, business people and 2 members of the Young Essex Assembly. Find out more about the commissioners from their biographies. The commission will run for 2 years initially and make recommendations about how we can improve the environment and the economy of Essex. The Essex Climate Action Commission will: Identify ways where we can mitigate the effects of climate change, improve air quality, reduce waste across Essex and increase the amount of green infrastructure and biodiversity in the county Explore how we attract investment in natural capital and low carbon growth They will do this by drawing on in-house expertise, commissioning research and forming new external partnerships. The Cabinet will consider all recommendations put forward by the commission with both the cost and benefits of implementing recommendations in mind. https://www.essex.gov.uk/climate-action **The Essex Advice Pack** https://ealc.gov.uk/wp-content/uploads/2022/06/ECAC_Resident_Advice_Pack.pdf **Climate Focus Area Creation Programme (Recommendation of the ECAC)** The Land Use and Green Infrastructure SIG of the Essex Climate Action Commission are proposing the concept of a Climate Focus Area (CFA), as a demonstration site for best practice in sustainable land use management. Targeting a designated area within the county allows for more focused,

ambitious and intensive action within shorter time frames where learning and acquired new knowledge of positive impacts can quickly be disseminated across the county. In order to implement this, we have chosen a representative area of Essex, the catchments of the Blackwater and Colne rivers, where a focused effort can be made to combat climate change, leading the way for the rest of Essex to follow.

The Objectives of the Climate Focus Area:
The principal objective of the CFA is to become net zero carbon.
The secondary objective of the CFA is to become more Climate Change resilient by:

- implementing biodiversity net gain
- Improving soil health
- improving air pollution,
- reducing flooding,
- reducing the urban heat island effect,
- lowering the energy for communities,
- improving the amenity and liveability of Essex communities

Features of the CFA:
A large, interconnected area that would include a mixed urban and rural landscape running from inland Essex to the sea.
A learning place for sustainable development.
A site for testing interdisciplinary approaches to understanding and managing changes and interactions between social and ecological systems, including conflict prevention and management of biodiversity.
The CFA represents environmental sustainability for 27% of the inland and coastal landscapes of Essex
The CFA will be river catchment-based, including rural, urban and coastal areas.
The CFA comprises the Blackwater and Colne estuaries, an area of 930 sq km or 27% of the area of Essex.

Design principles and criteria for the CFA:
The CFA is necessary to promote intactness of ecosystems; connectivity and effective integrated management planning.
The CFA should represent close-to-ideal objectives and practices, including biodiversity net gain, carbon net zero, water conservation and re-use, sustainable land stewardship practices including: regenerative agriculture; agro-forestry, organic farming and climate friendly farming etc.
The CFA should also represent best practice in socio-economic systems, promoting sustainable living in the built environment, innovative transport systems, modal shift and non-carbon transport infrastructure and zero-to-minimum plastic waste and 100% renewable energy.

Urban Greening (Recommendation of the ECAC)
The LU&GI SIG recommended that the urban areas match the rural areas in 30% Natural green Infrastructure by 2050, this is a longer deadline, recognising this restricted nature of the urban context. It suggested this could be done by

1. greening the public realm
2. developing sustainable drainage systems (SuDS)
3. increased greenspace creation,
4. naturalising existing green space,

Greening the public realm is within the gift of ECC as the Highways Authority.

		Developing sustainable drainage systems (SuDS) is also an area where ECC has led as the Lead Local Flood Authority. Increasing greenspace creation, is a longer term ambition often relating to new development and planning. While naturalising existing green space principally falls to the districts and boroughs who are the major owners of green spaces in urban areas. In terms of short or medium term projects, this paper focuses on greening the public realm and developing Sustainable Drainage Systems. There has been increased collaboration between Essex Highways and Climate Adaptation and Mitigation (CAM) over the issue of greening the public realm. These are: In recent months CAM have bid successfully for £300,000 for planting 5,595 trees in the urban area via the Local Authority Treescape Fund. However, the issue has always been these trees are then a financial burden for the Highways Authority. We have successfully bid for £1.925 million Green Infrastructure Reserve to fund the medium term maintenance from 2022 onwards. Further discussions are taking place with Essex Highways to create a project whereby citizens can more easily adopt part of the Highway to adopt a tree or create Green Infrastructure. This was in the past been hampered by onerous insurance issues and now we are re-visiting the whole scheme. https://www.essexclimate.org.uk/sites/default/files/LUGI%20Technical%20Annex%20_0.pdf https://assets.ctfassets.net/knkzaf64jx5x/I9s2K8YmSWTjxDOU7qjSz/e1a2c27e79661f691c8af5687c34d70e/Net-Zero-Report-Making-Essex-Carbon-Neutral.pdf **Environment Act 2021** Environment Act 2021 (legislation.gov.uk) https://www.legislation.gov.uk/ukpga/2021/30/contents/enacted **Environment Bill – September 2021: Nature and Conservation covenants (Parts 6 and 7) (policy paper)** *https://www.gov.uk/government/publications/environment-bill-2020/10-march-2020-nature-and-conservation-covenants-parts-6-and-7* **National Planning Policy Framework** (NFFP) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005759/NPPF_July_2021.pdf Essex Green Infrastructure Strategy (2020) Biodiversity Net Gain for local authorities This is the front page of a set of resources PAS is developing to support local authorities moving towards the introduction of mandatory biodiversity net gain. It provides an overview of biodiversity net gain and why it is important. Links to further content are at the bottom of the page and more will be coming soon to add to these. https://www.local.gov.uk/pas/topics/environment/biodiversity-net-gain-local-authorities#:~:text=Resources-,What%20is%20biodiversity%20net%20gain%3F,state%20than%20it%20was%20beforehand.

		Department for Environment Food & Rural Affairs (DEFRA) https://www.gov.uk/government/organisations/department-for-environment-food-rural-affairs Environment Agency – Coastal and Tidal risk (please see section 5 hazard category coastal and tidal for further information)
	Compound risk how did simultaneous or successive extreme events affect risk? *For example, when an earthquake occurs during a period of severe flooding*	EA- flood gates closure, flood assets to manage *https://consult.environment-agency.gov.uk/engagement/bostonbarriertwao/results/appendix-8---nra-leaflet-on-colne-barrier.pdf* Chelmsford Gates Sluice Monitoring Station *https://riverlevels.uk/essex-chelmsford-gates-sluice* **Essex Culver Policy** *https://flood.essex.gov.uk/media/1263/essex_county_council_culvert_policy.pdf* Ordinary Watercourse Consent – The Land Drainage Act 1991 https://www.essexdesignguide.co.uk/suds/further-guidance/ordinary-watercourse-consent/ Ordinary Watercourse maintenance https://flood.essex.gov.uk/media/1320/essex-county-council-ordinary-watercourse-maintenance-guide-1.pdf Essex Highway - Drainage and flooding *https://www.essexhighways.org/roads-and-pavements/drainage-and-flooding* **National Rail** https://www.nationalrail.co.uk/service_disruptions/81155.aspx **Property resilience fund** – ECC Help protect your property against flooding with a Property Flood Resilience (PFR) grant worth up to £8,000 *https://flood.essex.gov.uk/get-a-grant-to-protect-your-home-from-flooding/*
	Cascading risk how did a disruption of closely interconnected systems affect risk? *For example, when collapsed buildings and bridges disrupted the supply chain of key businesses*	Essex Highway - Drainage and flooding *https://www.essexhighways.org/roads-and-pavements/drainage-and-flooding* **EA – flooding from river , managing their assets to reduce flooding** https://www.gov.uk/government/publications/river-and-coastal-maintenance-programme **Property resilience fund** – ECC Help protect your property against flooding with a Property Flood Resilience (PFR) grant worth up to £8,000 *https://flood.essex.gov.uk/get-a-grant-to-protect-your-home-from-flooding/* **National Rail** https://www.nationalrail.co.uk/service_disruptions/81155.aspx ECC – SuDS - New development and new motorways schemes used sustainable drainage principles to manage surface water runoff from impermeable surfaces. More capacity building by introducing green suds features, tree line street and Green infrastructure. https://www.essexdesignguide.co.uk/suds Essex Green Infrastructure Strategy (2020)

Question 5.2: Which authorities are responsible for the assessment of future risk resulting from climate change in your testbed?

National Planning Policy Framework (NFFP) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005759/NPPF_July_2021.pdf Essex County Council as Lead Local Flood Authority - https://flood.essex.gov.uk/ **Environment Agency** - https://www.gov.uk/guidance/adapting-to-climate-change-risk-assessment-for-your-environmental-permit **Internal drainage board (IDB)** An Internal Drainage Board (IDB) is a local public authority that manages water levels. They are an integral part of managing flood risk and land drainage within areas of special drainage need in England and Wales. https://www.ada.org.uk/downloads/publications/IDBs-An-Introduction-web.pdf **ADA Representing drainage water level and flood risk management authority** ADA represents over 230 members nationally, including **internal drainage boards**, **regional flood & coastal committees**, **local authorities** and **national agencies**, as well our **Associate Members** who are contractors, consultants and suppliers to the industry. https://www.ada.org.uk/ Sewerage companies - https://www.anglianwater.co.uk/services/sewers-and-drains/ Local Authorities - https://www.essexdesignguide.co.uk/essex-local-authorities/ National Rail- https://www.nationalrail.co.uk/service_disruptions/81155.aspx ECC Place services https://www.placeservices.co.uk/ **Essex Transportation Strategy**: the local transport plan for Essex June 2011 Essex County Council has prepared this plan to best respond to the needs of everyone who lives or works in Essex. This is a long-term plan covering 15 years which sets out our aspirations for improving travel in the county, demonstrating the importance of our transport network to achieving sustainable long-term economic growth and enriching the lives of our residents. https://www.essexhighways.org/uploads/downloads/essex_ltp.pdf Department for Environment Food & Rural Affairs (DEFRA) https://www.gov.uk/government/organisations/department-for-environment-food-rural-affairs Natural England - *https://www.gov.uk/government/organisations/natural-england* Essex Climate Action Commission https://www.essex.gov.uk/climate-action

Question 5.3: Do the authorities responsible for assessing disaster risk in your testbed use scenarios? If so, are those scenarios developed at national or local level (or both)? Please tick all that apply.

No, they don't use scenarios	
Yes, they use locally developed scenarios	Yes

Yes, they use nationally developed scenarios	Yes

Question 5.4: What are the strengths and weaknesses of the approaches that are currently used in your testbed to assess risk?

Strengths	Local Models - Local up to date information to provide accuracy to hydraulic modelling! SWMPs, SFRA modelling, those informed other docs to manage risk for example sequential and exception testing. Local and national information reinforces the information presented in models EA hold funding but requires application submission and have no guarantee of success
Weaknesses	Data needs to be update; data become outdated (SWMP update every 6 years) National scale maps are based on desk base studies. And are not very detailed to present the local risk on across the county/ test bed Available funding to update at regular bases, There is nothing for water scarcity at national and local models. No legislation doc related to water scarcity

Part C: Disaster Risk Management and Governance

Section 6: Disaster Risk Management and Governance

Definition of Disaster Risk Management: DRM is the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses (Source: UNDRR).

Question 6.1: Which authorities (or departments) are responsible for developing disaster risk management plans for this testbed - and what procedures do they follow? (For example, do local plans need to be approved by national authorities?)

Department for Environment Food & Rural Affairs (DEFRA) https://www.gov.uk/government/organisations/department-for-environment-food-rural-affairs Local plans for districts – Each of the 12 borough, district or city councils in Essex is a Local Planning Authority. They're responsible for producing a Local Plan to shape development of their area. https://www.essex.gov.uk/our-role-planning/local-planning Neighbourhood plans for parishes - https://www.eastcambs.gov.uk/sites/default/files/Briefing%20note%20-%20Relationship%20between%20LP%20%20NPs%20-%20Jan%202016.pdf

RTPI Royal Town Planning Institute https://www.rtpi.org.uk/planning-advice/neighbourhood-planning/ Community Risk Register For Essex http://www.essexprepared.co.uk/upload/documents/Essex_CRR_Public_Information_592fe6379ae7c.pdf

Question 6.2: What are local authorities' official and legal obligations when it comes to disaster risk management?

Please see the above links for all local authorities to manage risk. DEFRA - Department for Environment Food and Rural Affairs Essex County Council as Lead Loal Flood Authority - https://flood.essex.gov.uk/ Environment Agency Sewerage companies Local Authorities District councils LPA Internal drainage board

Question 6.3 Which authorities (or departments) are responsible for communicating local disaster risk management plans to community groups - and what procedures do they follow?

Please see the above links for all local authorities to communicate risk. Essex County Council as Lead Local Flood Authority - https://flood.essex.gov.uk/ Environment Agency Sewerage companies (Water scarcity, water preservation) Local Authorities - SFRAs

Question 6.4 What mechanisms have been set up to ensure that local authorities and emergency responders coordinate effectively during a disaster event - and what procedures do they follow?

Acting on online event reporting/incident https://flood.essex.gov.uk/what-to-do-about-flooding/report-a-flood/ **ECC Emergency planning team,** Essex police, team are ready to respond. Met office https://www.essex.gov.uk/floods-emergency-planning Essex Police

https://www.essex.police.uk/foi-ai/essex-police/our-policies-and-procedures/d/d0503-procedure---responding-to-incidents/

National emergency response and recovery guidance
https://www.gov.uk/guidance/emergency-response-and-recovery
Latest Essex Weather Warnings
http://www.essexprepared.co.uk/about-us/weather-warnings

Flood Warnings
http://www.essexprepared.co.uk/about-us/flood-warnings
Emergency Response Plan for Braintree District Council
https://www.braintree.gov.uk/downloads/file/3090/emergency-plan-for-the-district

Emergency Response Plan Uttlesford District Council
https://www.uttlesford.gov.uk/media/1376/Uttlesford-District-Council-Emergency-Response-Plan/pdf/UDC_Emergency_Response_Plan_2020_unrestricted_v1.1-A.pdf?m=637491827308930000

EMERGENCY PLANNING AT COLCHESTER BOROUGH COUNCIL
https://www.colchester.gov.uk/info/cbc-article/?catid=emergencies&id=KA-01776

Property resilience fund – ECC Help protect your property against flooding with a Property Flood Resilience (PFR) grant worth up to £8,000/-
https://flood.essex.gov.uk/get-a-grant-to-protect-your-home-from-flooding/

Question 6.5 Which authorities (or departments) are responsible for developing economic recovery plans after a disaster in the testbed - and what procedures do they follow?

PFR – Environment Agency grant to deliver locally
Property resilience fund – ECC Help protect your property against flooding with a Property Flood Resilience (PFR) grant worth up to £8,000/-
https://flood.essex.gov.uk/get-a-grant-to-protect-your-home-from-flooding/

Insurance company
https://www.floodre.co.uk/
https://www.total-insurance.co.uk/home-insurance/flood-risk/?medium=PPC2&gclid=EAIaIQobChMI5p2myJTl_AIVk4BQBh2h0wB4EAAYAiAAEgLFLfD_BwE

Essex Town of Essex Business Partners Disaster Preparedness and Business Continuity Guide
https://www.essex.ca/en/live/resources/Town_of_Essex_Business_Continuity_Guide_acc.pdf
Economic plan for prevention of the disaster as opposed to the recovery

Economic plan for Essex
Our Economic plan for Essex (PDF, 1.3MB) shows how we intend to support economic growth across the county in the period 2017 to 2021.
https://www.essex.gov.uk/plans-and-strategies/economic-plan-for-essex

Question 6.6. What are the strengths and weaknesses of the ways in which disaster risks are currently managed in this testbed?

Strengths	Essex County Council has the ambition to deliver Capital schemes across access in an areas prioritised as a results of Surface water management plans (SWMPs) specifically properties fall with Critical drainage areas (CDA). ECC delivers, flood alleviation scheme, Natural Flood Management Schemes, Property Flood Resilience, Incorporation of Sustainable drainage System (SuDS) and Green Infrastructure to tackle climate change impacts at local scales and contribute toward achieve resilient community. Wider Env benefits **Net Zero: Making Essex Carbon Neutral report** The initial purpose of the Essex Climate Action Commission was to set out recommendations on tackling the climate crisis. This included devising a roadmap to get Essex to net zero by 2050. These recommendations were set out in the commission's report Net Zero: Making Essex Carbon Neutral report (PDF, 5.33MB), published in July 2021. The report put forwards a comprehensive plan to: • reduce the county's greenhouse gas emissions to net zero by 2050, in line with UK statutory commitments, • make Essex more resilient to climate impacts such as flooding, water shortages and overheating **Essex Forest Initiative** https://www.essex.gov.uk/the-essex-forest-initiative New tree planting dates continue the climate work of the Essex Forest Initiative https://www.essex.gov.uk/news/new-tree-planting-dates-continue-the-climate-work-of-the-essex-forest Essex Green Infrastructure Strategy **ESSEX GREEN INFRASTRUCTURE STRATEGY (2020)** Essex Green Infrastructure Standards https://www.essexdesignguide.co.uk/supplementary-guidance/essex-green-infrastructure-standards/ Levelling Up Essex https://www.essex.gov.uk/news/levelling-up-essex **Essex Local Nature Partnership (LNP)** *(This website is going to be updated soon, if you experience any difficulty to access, please contact to us, there are section above which says, Local nature recovery partnership (LNRP). Once the updated LNP website will be live it will include separate section of LNRP to get information). these comments should be considered wherever LNRP Or LNP is discussed in questionnaire.* Local Nature Partnerships (LNPs) bring together local organisations, businesses and people who want to improve their local natural environment. The Local Nature Partnership Board and Essex County Council coordinate the LNP across the county. Together, with our partners, we will strengthen the impact of local action for nature recovery. https://www.essexclimate.org.uk/essex-local-nature-partnership

Weaknesses	Limited funding schemes, weighted capacity from central gov, acceptance or cooperation from Business and developers, landowners, farmers, results are uncertain to win funding

Section 7: Managing Resilience & Capacities

Definition of capacity: the combination of all the strengths, attributes and resources available within an organisation, community or society to manage and reduce disaster risks and strengthen resilience (Source: UNDRR).

Definition community resilience: The ability of a community to prevent, prepare for, respond to, and recover from disasters.

Question 7.1: Please answer for each item in the table below, which authorities (or departments) are responsible for the governance and management of capacities and resilience in this testbed. Where available, please provide links or references to their procedures.

Urban development	Example: use of hazard scenarios	LLFA in response to property flooding from surface water ground water and ordinary watercourses. https://flood.essex.gov.uk/media/1293/essex-local-flood-risk-management-strategy.pdf
Infrastructure Housing, transport, power, water, communications, etc.	Example: adherence to the building code	I guess local authorities, Essex Highway, Essex transportation and Communication, Anglian Water, Thames Water. Web links are provided on above sections for these authorities.
Natural buffers	Example: environmental protection legislation	**National Planning Policy Framework** (NFFP) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005759/NPPF_July_2021.pdf **Environment Act 2021** Environment Act 2021 (legislation.gov.uk) https://www.legislation.gov.uk/ukpga/2021/30/contents/enacted **Environment Bill – September 2021: Nature and Conservation covenants (Parts 6 and 7) (policy paper)** *https://www.gov.uk/government/publications/environment-bill-2020/10-march-2020-nature-and-conservation-covenants-parts-6-and-7* *Essex Climate Action Commission* Essex Climate Action Commission - Essex County Council ***Essex Net Zero*** **4.2. Net Zero: Making Essex Carbon Neutral report** The initial purpose of the Essex Climate Action Commission was to set out recommendations on tackling the climate crisis. This included devising a roadmap to get Essex to net zero by 2050.

		These recommendations were set out in the commission's report Net Zero: Making Essex Carbon Neutral report (PDF, 5.33MB), published in July 2021. The report put forwards a comprehensive plan to: • reduce the county's greenhouse gas emissions to net zero by 2050, in line with UK statutory commitments • make Essex more resilient to climate impacts such as flooding, water shortages and overheating **The Local Nature Recovery Strategy (LNRS)** Introduced in the Environment Act 2021, The Local Nature Recovery Strategy (LNRS), is a statutory requirement, and a new mandatory England-wide system of spatial strategies that will establish priorities and map proposals for specific actions to drive natures recovery. The Environment Act 2021 lays the foundation for a single Nature Recovery Network (NRN). The LNRSs' across England will underpin the NRN, with each county / responsible authority, joining up their strategies and acknowledging the overlap in spaces for nature. The LNRS will be a shared creation, working with the Essex Local Nature Partnership to deliver a strategy that will provide the best outcomes for nature in Essex. The Essex LNRS covers Greater Essex, working in partnership with Thurrock and Southend to deliver the strategy. Expected date for further LNRS guidance from DEFRA is April 2023 *Essex GI strategy* Essex Green Infrastructure Strategy (2020) *Land Drainge Act 1991- https://www.legislation.gov.uk/ukpga/1991/59/contents* *Flood AND WATER MANAGEMNET ACT 2010* *https://www.legislation.gov.uk/ukpga/2010/29/contents* *Green Belts* NPPF 2021 - 13. Protecting Green Belt land (pages 41- 44) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005759/NPPF_July_2021.pdf
Institutional capacity Local authorities, first responders	Example: training in disaster management	Environment Agency https://www.gov.uk/government/organisations/environment-agency Essex County Council Flood website https://flood.essex.gov.uk/ Department for Environment Food & Rural Affairs (DEFRA) https://www.gov.uk/government/organisations/department-for-environment-food-rural-affairs
Societal capacity	Example: public awareness campaigns about hazards	Essex County Council – LLFA Environment Agency Water companies Educational Institutes Volunteer groups Charity organizations
Economic capacity	Example: support to	EA – proving funding for to enable us to deliver schemes or projects, or sometime projects are delivered in partnership with European funding organizations

	business organisations	https://flood.essex.gov.uk/our-work-1/ **Rain Gardens, created for first time in Essex, to reduce flooding and improve the environment in a Canvey road** Park Avenue, Canvey, is the first road in Essex to have new rain gardens installed, a £260k joint project between Essex County Council and Anglian Water aiming to reduce local flood risk and improve the environment. https://www.essex.gov.uk/news/rain-gardens-created-for-first-time-in-essex-to-reduce-flooding-and-improve ECC – LLFA Green infrastructure projects in School

Section 8: Decision Making Tools for Disaster Risk Management

Question 8.1 What tools does this testbed currently have to inform decision making in disaster risk management? Do these tools focus on the short-term, the medium-term or the long-term? What are their strengths and weaknesses?

Current tools	Focus short-term, medium-term, or long-term	Strengths	Weaknesses
Write your answer, or insert a reference / link	Flood risk Management Plan https://www.gov.uk/government/collections/flood-risk-management-plans-2021-to-2027 Flood risk management plans for England to cover the period from 2021 - 2027.	Strategic Plans explain the objectives and the measures (actions) needed to manage flood risk at a national and local level.	Strategic and overarching overview of flood risk
Write your answer, or insert a reference / link	Surface water Management Plan https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/ long terms plan – updated every 5- 6 years	Based on urbanised areas where the risks are high. Gave information regarding property number, which are susceptible to different storm scenarios including climate change allowances	Difficult to manage funding to undertake detailed analysis.
Write your answer, or insert a reference / link	Local Plan – long term plan updated every 5 years IDPs – Infrastructure delivery plan	Opportunity to feedback and assess the allocated sites with respect to surface water	Sometime does not address the issues of flooding. The information including on

		flooding and proposed mitigations.	flooding and drainage is very high level
	Strategic Flood Risk Management Plan (SFRA) -Medium term 6 years update	Identify the flood prove areas to prevent development. Planning decisions, design measures for planning development	Difficult to manage funding to undertake detailed analysis.
	Shoreline management plan Shoreline management plans are developed by Coastal Groups with members mainly from local councils and the Environment Agency. They identify the most sustainable approach to managing the flood and coastal erosion risks to the coastline in the: • short-term (0 to 20 years) • medium term (20 to 50 years) • long term (50 to 100 years)	Participatory and collective knowledge exchange, better understanding due to local partners contributing local knowledge and understanding to manage risk.	Difficult to manage funding to undertake detailed analysis.
	Risk of flooding from Surface WATER management	Widely used maps to understand risk from surface water, river and sea.	
	Essex SuDS Design Guide	Local standards For new development within Essex	Local standards are not fully supported by NPPF
	Essex Green Infrastructure Strategy and Essex Green Infrastructure Standards	Strategy helps to promote Green infrastructure through Essex and conservation of natural habitat	
	Land Drainage Act 1990	Legislations to empower Local authorities to deal with Water management issues	Long term plan
	Flood water management plan to produce local flood risk management strategy (LFRMS)	Defines role and responsibility of	

	This strategy sets out our aims and actions to reduce the impact of local flooding to your community. 'Local' flooding in Essex means the risk of water from man-made drainage systems, small watercourses and rainfall off the land.	different authorities, communicated the services provided by LLFA.	

Question 8.2 What recommendations do you have for future disaster risk management tools to be developed?

Greater accuracy of data to model risk Data - Local people on the ground Better presentable raw data to assist interpretation and easy to make use of it. Record hazard into model Output maps illustrative maps rather than reports of raw data Inclusion of historic flood teamwork in terms property Flood Resilience (PFR), Natural Flood Management (NFM)

Section 9 Evaluations of Disaster Risk Management Plans

Question 9.1. Please insert links or references to publicly available formal assessments of this testbed's disaster risk management plans (in any language).

Flood Risk Management Plan https://www.gov.uk/government/collections/flood-risk-management-plans-2021-to-2027 Surface water Management Plan https://www.essexdesignguide.co.uk/suds/surface-water-management-plans/ long terms plan – updated every 5- 6 years https://flood.essex.gov.uk/media/1292/flood-strategy-appendix-b.pdf **Check if you're at risk of flooding** https://flood.essex.gov.uk/know-your-flood-risk/check-if-you-re-at-risk-of-flooding/ SuDS Design Guide https://www.essexdesignguide.co.uk/suds/planning-advice/suds-planning-advice/ Ordinary Watercourse Consent **HTTPS://WWW.ESSEXDESIGNGUIDE.CO.UK/SUDS/FURTHER-GUIDANCE/ORDINARY-WATERCOURSE-CONSENT/** **National Planning Policy Framework** (NFFP) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005759/NPPF_July_2021.pdf

Question 9.2. Does this testbed use any participatory approaches to evaluate disaster risk management plans? (for example, through serious games).

Community flood groups Consultation – production of report No formal means of evaluation. All the plans and policies are consulted to partner services and Risk management authorities to feedback and make the plan sound and effective for its use. In terms of floor risk maps or surface water management plans the updated version does the assessment of previous version to monitor the gaps in existing plans and to better inform the public and authorities about risk patterns, its exposure and vulnerabilities.

ANNEX 5: QUESTIONNAIRE NICE

Part A: Hazards, Exposure, Vulnerability and Risk

Section 1: Hazards

Definition of hazard: a process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption, or environmental degradation. (Source: UNDRR).

Question 1.1: What natural hazards does this testbed face? Please list the top 5. How likely are they? How severe would their impact be?

	Natural Hazard	Likelihood (low, medium, high)	Impact (low, medium, high)
1	Inondation (débordement de cours d'eau + submersion marine)	Elevé → Ex : depuis 1982 et jusqu'à juin 2020, la ville de Nice a été concernée par plus de 40 arrêtés de catastrophe naturel de type inondation.	Elevé → Ex : impact dans les Alpes-Maritimes lié aux inondations consécutives à la tempête Alex : 10 morts et 8 disparus. Des millions d'euros de dommages financiers, des centaines de bâtiments détuits ou endommagés omme l'usine hydroélectrique de Roquebillière.
2	Mouvement de terrain (+ retrait gonflement des argiles)	Elevé (Ex : En fin d'anné 2019, plus de 80 glissements de terrain ont été recensés à Nice)	Elevé
3	Episode climatique extrême (vent violent, tempête, épisode méditerranéen)	Elevé : entre 2010 et 2021 on ne dénombre pas moins de 30 événements pluvieux extrêmes (pour les Alpes-Maritimes) parmi ces événements on peut notamment citer la tempête Alex. Inondations catastrophiques sur les Alpes-Maritimes - pluies extrêmes en France métropolitaine (meteo.fr)	Elevé → Ex : tempête Alex : épisodes méditerranéens ayant engendré des inondations d'une ampleur très importante (cf. inondation). Avec des cumuls de pluies sans précédent, plus de 500,2 mm sur la commune de Saint-Martin- Vésubie en 24h.
4	Vague de chaleur	Elevé	Elevé : conséquences sanitaires importantes notamment sur les plus fragiles (personnes âgées et jeunes enfants).
5	Feux de forêt	Moyen Ex : 2003 →234 hectares brulés à Cagnes-sur-Mer mais aussi 260 en 2016 à Belvédère.	Elevé → Ex : 2003, 234 hectares brûlés à Cagnes-sur- Mer mais aussi 260 en 2016 à Belvédère.
6	Séisme	Faible	Elevé → Ex : 1887 - région ligure : 600 morts en Italie, 10 morts dans le pays

			niçois (à priori le séisme le plus fort jamais ressenti en France métropolitaine).

Question 1.2: How would climate change affect the likelihood and impact of these hazards?

	Natural Hazard	Likelihood (low, medium, high)	Impact (low, medium, high)
1	Inondation (débordement de cours d'eau + submersion marine)	Elevé	Elevé
2	Mouvement de terrain	Elevé	Elevé
3	Episode climatique extrême (vent violent, tempête, épisode méditerranéen)	Elevé	Elevé
4	Vague de chaleur	Elevé	Elevé
5	Feux de forêt	Elevé	Elevé
6	Séisme	Nul	Nul

Section 2: Exposure

Definition of exposure: the situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas (Source: UNDRR).

Question 2.1: In this testbed, are people and assets currently located in hazard-prone areas? If so, please give examples.

Physical and human assets	Currently located in a hazard-prone area
People	Oui - Exemples : - L'ensemble de la population mét opolitaine se situe dans une zone à risque sismique moyenne (4/5). - Toutes les communes de la Métropole NCA sont concernées par le risque inondation. Une partie non négligeable de la population se situe donc en zone inondable. - Toutes les communes de la Métropole NCA sont concernées par les mouvements de terrain. Une grande partie du territoire est également concernée par le risque de retrait (gonflement des argiles). - Le risque incendie sur le territoire de la Métropole NCA : aux vues de la surface forestière importante présente sur notre territoire ainsi que du nombre très important d'interfaces habitat/forêt la population est exposé fortement à ce risque.

	*Pour observer les zones à risques vous pouvez vous rendre sur le site suivant : [Carte interactive | Géorisques - Ministère de la transition écologique (georisques.gouv.fr)] *Source : DDRM à télécharger par partie / Dossier Départemental sur les risques majeurs - Edition 2021 / Les risques naturels et technologiques / Environnement, risques naturels et technologiques / Politiques publiques / Accueil - Les services de l'État dans les Alpes-Maritimes*
Infrastructure	Oui ➔ Concernant le risque sismique, la mission du CGEDD a notamment identifié en 2019 trois points sensibles : - Parmi les trois ouvrages de franchissement routier du fleuve Var, deux sont vulné ables : l'A8 et le pont Napolé n III, celui-ci étant en outre le seul point de franchissement ferroviaire. - La plateforme aéroportuaire est construite en remblai sur le plateau continental. - Le résea d'alimentation éle trique. ***Source : 012485-01_rapport-publie.pdf;jsessionid=825B8EE87BD634FDB3768F2A9CD69D6D (developpement-durable.gouv.fr)*** - Un certain nombre de lignes de transports routière et ferroviaire se trouve dans des zones à risques, notamment des voies de circulation situées en bord de mer ou encore en zone montagneuse. Il existe également des lignes de transports qui sont exposées aux risques inondations ou encore aux mouvements de terrain. - Le réseau électrique est exposé aux risques de tempête et vents violents. Etc.
Institutions	Oui - Donnez 1 exemple : Préfecture (risque sismique et inondation) - Mairie de Nice (sismique). Source : 012485-01_rapport-publie.pdf;jsessionid=825B8EE87BD634FDB3768F2A9CD69D6D (developpement-durable.gouv.fr)
Housing	*Oui* - Vieux-Nice (aléa sismique) bâti ancien → le Vieux-Nice est très sensible à ce risque mais il ne s'agit pas de la seule zone bâtie à risque sur le territoire métropolitain. - De nombreux logements ne sont pas bien isolés, ce qui entraîne en été une chaleur très importante dans les logements et une utilisation importante de la climatisation. - Logement proche des massifs forestiers (risque d'incendie) le territoire métropolitain dispose de nombreuses interfaces bâti/forêt.
Business	Oui - Zone industrielle de Carros (risque inondation)
Nature	Oui - Les massifs forestiers sont soumis à un stress hydrique important et à une sècheresse de plus en plus forte. Ils sont susceptibles de s'enflammer très facilement. En particulier, avec la proportion importante d'espèces pyrophiles présentes sur notre territoire.

Other (please specify)	/

Question 2.2: In this testbed, are people and assets located in areas that are currently safe, but likely to become hazard prone in the future? (for example, as a result of climate change). If so, please give examples.

Physical and human assets	Located in an area that is currently safe, but likely to become hazard-prone in the future
People	Oui - L'arrière-pays pourrait connaître des vagues de chaleurs à l'avenir. Les populations âgées habitant dans ces villages pourraient donc en être impactées l'avenir. - Une partie de la population pourrait connaître à l'avenir dans certaines localités des pénuries d'eau.
Infrastructure	Oui - Les infrastructures seront menacé s par l'élévation du niveau de la mer.
Institutions	Oui - Certaines institutions seront également menacé s par l'élévation du niveau de la mer.
Housing	Oui - Le retrait gonflement des argiles : étant donné que le facteur principal des déclenchements de ce phénomène étant relié aux événements climatiques extrêmes, sa fré uence risque indubitablement de s'accroître ces prochaines dé ennies et donc d'impacter des logements qui étaient jusque-là plutôt épargnés par ce phénomène.
Business	Oui - En ce qui concerne les quartiers d'affaire, le quartier de l'Aré as situé à proximité du bord de mer pourrait être impacté par l'élévation du niveau de la mer. - En ce qui concerne l'é onomie mét opolitain, le changement climatique va probablement bouleverser le tourisme sur le territoire. Il se peut que les fortes chaleurs de l'été dét urnent les touristes de notre territoire, les chutes de neige se faisant de plus en plus rares, les stations de ski pourront-elles survivre sans manteau neigeux suffisant ? Dans un territoire qui repose en grande partie sur ce secteur d'activité, le changement climatique risque de poser de nombreux problèmes à l'avenir.
Nature	Oui - Le dépérissement progressif des massifs forestiers entraîne une baisse de la productivité et une augmentation de la matière combustible et donc une augmentation des zones très sensibles aux risques incendie. - Une disparition progressive des lacs de montagne est attendue, à cause du changement climatique et de la diminution de la recharge de ces zones humides montagneuses.
Other (please specify)	/

Section 3: Vulnerability

Definition of vulnerability: the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards (Source: UNDRR).

Question 3.1: In this testbed, are some people and assets currently highly susceptible to the impact of the hazards they face? If so, please give examples.

Physical and human assets	Currently highly susceptible to the impact of hazards.
People	*Oui* - Une population vieillissante qui sera d'autant plus sensible à l'augmentation de la tempé ature, de l'intensité et de la durée des épisodes caniculaires ainsi que de la multiplication du nombre de nuits tropicales. Plus d'un cinquième de la population est âgé de 65 ans ou plus en 2010, et d'ici 2030 pour cette même tranche d'âge, les projections montrent une hausse de 29 000 habitants de 65 ans et plus (INSEE).
Infrastructure	*Oui* - Infrastructures routières particulièrement sensibles aux mouvements de terrain notamment dans l'arrière-pays niçois. Cette vulnérabilité est accentué par le changement climatique et ses effets sur l'augmentation des pé iodes de sècheresse et l'augmentation des épisodes de pluies extrêmes. Il ne pleut pas forcément moins mais cela se fait plus ponctuellement (en quelques heures peuvent s'abattre des mois de pluies). Certains villages dépendent en grande partie de ces voies d'accès parfois uniques. La résilience est donc fragile pour ces villages face à ces phénomènes.
Institutions	Oui - Un certain nombre de bâtiments publics sont très sensibles aux risques de survenue d'un séism ainsi qu'aux risques d'inondations.
Housing	Oui - De nombreux logements subissent très fortement les fortes chaleurs car leur isolation n'est pas adaptée à ces chaleurs extrêmes. Cela est visible par l'augmentation très importante du nombre de climatiseurs. Mais dans un contexte de crise énergétique, certains ménages ne pourront plus se permettre d'utiliser autant ces sources de fraicheur et vont donc subir d'autant plus les fortes chaleurs.
Business	Oui - La zone industrielle de Carros sensible en cas d'une crue importante du Var. - Le quartier d'affaire de l'Arénas très sensible aux ruissellements urbains lors des épisodes de fortes pluies.
Nature	Oui

	- Espaces forestiers de la Métropole NCA très sensibles face à la sécheresse et aux incendies. Cela est notamment dû à des espèces très facilement inflammables.
Other (please specify)	/

Question 3.2: In this testbed, are some people and assets currently not vulnerable, but likely to become vulnerable in the future? (for example, as a result of climate change). If so, please give examples.

Physical and human assets	Currently not vulnerable, but likely to become vulnerable in the future
People	Oui, - L'augmentation des températures attendue pour la fin du siècle n'impactera plus de manière importante uniquement les personnes fragiles. C'est l'ensemble de la population qui sera touché par ces températures extrêmes. Il faut cependant rappeler que la morphologie de notre territoire avec la présence de la mer Méditerranée et des massifs montagneux dans l'arrière-pays épargne « pour l'instant » le territoire des températures « très extrêmes » qui touchent d'autres ré ions. Cependant cela ne nous protège pas des infernales nuits tropicales que nous subissons de plus en plus fréquemment.
Infrastructure Institutions Housing Business	Oui 1. Nous pouvons nous interroger sur l'impact des fortes tempé atures attendu pour la fin du siècle sur les réseaux, infrastructures, bâtiments publics, logements, etc. 2. Les tempé atures extrêmes, entrecoupé s d'épisodes pluvieux de plus en plus intenses, vont indubitablement augmenter le risque de retrait gonflement des argiles et donc **la vulnérabilité du bâti**. (Il faut savoir que ce risque à déjà été revu à la hausse sur une partie du territoire métropolitain). 3. L'augmentation de la tempé ature va entraîner des épisodes cé enols de plus en plus importants. La cause principale étant : une mer Méditerranée de plus en chaude. Cela impactera certainement de manière plus importante le territoire et donc augmentera de fait la vulné abilité des infrastructures, bâtiments, quartiers d'affaire, etc. 4. L'aéroport et les zones touristiques du bord de mer vont certainement subir l'augmentation du niveau de la mer et la modification du trait de côte. Cela est valable aussi pour la voie ferrée et les routes du bord de mer. Leurs vulnérabilités vont augmenter fortement.
Nature	Oui - Le changement climatique menace la survie des arbres, nous pourrions connaître à l'avenir une perte de biodiversité importante. La hausse des températures pourrait également entraîner l'arrivé d'agents biotiques (insectes, ravageurs, pathogènes). Nous pouvons nous attendre à une détérioration des essences sensibles en réponse aux changements de tempé ature et de pré ipitations à l'horizon 2100.
Other (please specify)	/

Section 4: Disaster Risk (interacting, interconnected, compound and cascading risk)

Definition Disaster Risk: The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity (Source: UNDRR).

Question 4.1: In this testbed, how have different risks historically affected each other? Please give examples.

Different ways in which risks affect each other	Historic example (if available)
Interacting risks - how did different hazards trigger with each other? *For example, when heavy rainfall triggers landslides*	La tempête Alex : un flux maritime chargé en air chaud et humide a provoqué des pluies intenses et orageuses dans les Alpes-Maritimes. Ces fortes pluies ont provoqué une rapide augmentation des dé its des principaux cours d'eau prése ts sur la zone. Les pics de crues ont été atteints en quelques heures seulement. Cela a entraîné des mouvements de terrain importants, accompagnés de la destruction des infrastructures routière et bâtimentaire. Les milliers de débris charriés par les crues ont créés au niveau des ponts des embâcles très importants, provoquant des inondations beaucoup plus importantes au niveau de ces zones. Ces débris ont également provoqué sur leur passage de nombreux dégâts. Enfin, la houle importante ce jour-là a créé au niveau de l'embouchure des fleuves un sur-aléa en empêchant le bon écoulement des eaux et des débris, avec des inondations et des milliers de tonnes de débris refoulés sur les côtes.
Interconnected risks - how did interdependencies between human, natural and technological systems shape risk? *For example, when a drought puts food production at risk*	Le retrait gonflement des argiles va influencer très fortement le marché de l'immobilier à l'avenir avec une dé aluation importante de la valeur de certains biens. Durant la tempête Alex, certains villages se sont retrouvés coupés u monde, car leur unique route d'accès avait été coupé . C'est donc toute l'activité de ces villages qui a été à l'arrêt.
Compound risk – how did simultaneous or successive extreme events affect risk? *For example, when an earthquake occurs during a period of severe flooding*	Le mois d'octobre 2020 a vu le territoire de la Métropole Nice Côte d'Azur subir plusieurs crises importantes à commencer par la crise du Covid qui touchait à ce moment-là la Métropole depuis plusieurs mois, la tempête Alex a ensuite frappé le territoire les 2 et 3 octobre. Enfin, la ville de Nice a été touchée par un attentat terroriste le 29 octobre 2020. L'organisation de la réponse à ces diffé entes crises a demandé une logistique et une mobilisation très importante. De nombreux agents ont été mobilisés sur ces crises successives. De plus la Métropole a montré durant cette pé iode (en termes d'organisation territoriale) son importance puisque l'ensemble des communes a participé à cet effort collectif.

Cascading risk - how did a disruption of closely interconnected systems affect risk? *For example, when collapsed buildings and bridges disrupted the supply chain of key businesses*	La tempête Alex a perturbé le système économique et social des vallées de l'arrière-pays niçois, ramenant quasiment à l'âge de pierre certains territoires enclavés. Sans la mise en place d'un pont aérien très important, tant en terme logistique, qu'en terme financier, les habitants n'auraient pas survécu très longtemps dans les zones impactées.

Part B: Disaster Risk Assessment

Section 5: Disaster Risk Assessment

Definition Disaster Risk Assessment: A qualitative or quantitative approach to determine the nature and extent of disaster risk by analysing potential hazards and evaluating existing conditions of exposure and vulnerability that together could harm people, property, services, livelihoods and the environment on which they depend (Source: UNDRR).

Question 5.1: Which authorities (or departments) are responsible for the assessment of hazards, exposure, vulnerability, capacity, resilience, and risk in your testbed? Where available, please provide links or references to their procedures.

Interne :
Externe : (Notamment département, région, état, etc..)
Acteurs du risque, présent sur notre territoir[redacted] (liste non exhaustive)

Top 5 natural hazards (listed in question 1.1)	1	Inondation (débordement de cours d'eau + submersion marine)
	2	Mouvement de terrain
	3	Episode climatique extrême (vent violent, tempête, épisode méditerranéen)
	4	Vague de chaleur
	5	Feux de forêt
	6	Séisme
Exposure	People Infrastructure Institutions Housing Business	Agence de Sécurité Sanitaire environnementale et de gestion des risques – DPGR – GEMAPI – Service transition écologique. Préfecture des Alpes-Maritimes (service interministériel de défense et de protection civile) – Préfecture zonale (région PACA) – SMIAGE – Préfecture de bassin (inondation) – DDTM – DREAL - Ministère de la transition Ecologique et de la cohésion des territoires – CD 06 Météo France – BRGM – CEREMA – SDIS
	Nature	Agence de Sécurité Sanitaire environnementale et de gestion des risques – DPGR – GEMAPI -Service transition écologique (DIRECTION DELEGUEE A LA NATURE, A LA MER, ET A L'ENVIRONNEMENT) – Observatoire du développement durable

		Préfecture des Alpes-Maritimes - Ministère de la transition Ecologique et de la cohésion des territoires – DREAL – SMIAGE – DDTM – ARBE région SUD ONF
Vulnerability	People	Agence de Sécurité Sanitaire environnementale et de gestion des risques – DPGR – GEMAPI Préfecture des Alpes-Maritimes (service interministériel de défense et de protection civile) – Préfecture zonale (région PACA) - SMIAGE - Préfecture de bassin (inondation) -DDTM – DREAL – Ministère de la transition écologique et de la cohésion des territoires – CD06 Météo France – BRGM – CEREMA – SDIS
	Infrastructure	
	Institutions	
	Housing	
	Business	
	Nature	Agence de Sécurité Sanitaire environnementale et de gestion des risques – DPGR – GEMAPI - Service transition Ecologique - Observatoire du développement durable Préfecture des Alpes-Maritimes - Ministère de la transition écologique et de la cohésion des territoires - DREAL – SMIAGE-DDTM – ARBE Région SUD ONF
Capacities / Resilience *(see section 7 for explanations and examples)*	Urban development	/
	Infrastructure	MNCA - Agence de Sécurité Sanitaire environnementale et de gestion des risques – DPGR – Ré ie Eau d'Azur – DSI ENEDIS - Opérateurs TELECOM – Opé ateurs de Gaz et d'Eau – Service pré ectoraux et de l'é at – Service d'autoroute.
	Natural buffers	Agence de Sécurité Sanitaire environnementale et de gestion des risques – DPGR – GEMAPI - Service transition écologique – Mission climat Préfecture des Alpes-Maritimes - Ministère de la transition écologique et de la cohésion des territoires - DREAL – SMIAGE-DDTM – ARBE Région SUD ARBE Region SUD ONF
	Institutional capacity	Préfecture : service interministériel de défense et de protection civile. Service interministériel de défense et de protection civile / Direction des sécurités / Le Cabinet du préfet / La Préfecture des Alpes-Maritimes / Préfecture et sous-préfectures / Services de l'Etat / Accueil - Les services de l'État dans les Alpes-Maritimes
	Societal capacity	Agence de Sécurité Sanitaire environnementale et de gestion des risques – DPGR Préfecture : service interministériel de défense et de protection civile.

	Economic capacity	/
Risk *(see section 4 for explanations and examples)*	Interacting risks	Agence de Sécurité Sanitaire environnementale et de gestion des risques – DPGR – DPGR
	Interconnected risks	Préfecture des Alpes-Maritimes (service interministériel de défense et de protection civile) – Préfecture zonale (région PACA) - SMIAGE - Préfecture de bassin (inondation) – DDTM – DREAL - Ministère de la transition écologique et de la cohésion des territoires.
	Compound risk	
	Cascading risk	Météo France – BRGM – CEREMA – SDIS

Question 5.2: Which authorities are responsible for the assessment of future risk resulting from climate change in your testbed?

Au niveau de la Métropole NCA, cette mission a été confiée à l'Agence de Sécurité Sanitaire, Environnementale et de gestion des risques, qui collabore avec la DPGR ainsi qu'avec le service « Transition écologique et sa mission climat ».

La Métropole Nice Côte d'azur a voté la création d'un haut conseil pour le climat. Il a vocation à renforcer le conseil scientifique et à conseiller sur les orientations et les décisions stratégiques à prendre dans tous les domaines de l'adaptation et de la transition. Ces experts de haut niveau, choisis pour leurs travaux et leurs expertises, se réuniront deux fois par an. Ce conseil est une déclinaison du Haut Conseil pour le Climat auprès du Gouvernement, il travaillera sur les mesures locales à mettre en œuvre.

Question 5.3: Do the authorities responsible for assessing disaster risk in your testbed use scenarios? If so, are those scenarios developed at national or local level (or both)? Please tick all that apply.

No, they don't use scenarios	
Yes, they use locally developed scenarios	X
Yes, they use nationally developed scenarios	X

Question 5.4: What are the strengths and weaknesses of the approaches that are currently used in your testbed to assess risk?

Strengths	1. Une Agence unique en France avec la particularité de réunir le volet opérationnel et prospectif ; 2. Une bonne connaissance des risques, une solide culture du risque (au niveau des acteurs) ; 3. Une bonne collaboration avec la Prefecture.
Weaknesses	1. Retard dans la formalisation de certains documents lié aux risques, le changement climatique est en avance sur nos documents. 2. Beaucoup de risques à traiter, avec une priorisation et donc du retard sur d'autre risque. 3. Manque de coordination. Beaucoup d'acteurs travaillant sur les mêmes domaines et des initiatives prises sans concertation préalable.

	4. Manque de moyens car priorisation des dépenses obligatoires dans un contexte de crise. 5. Manque d’une vision très long terme.

Part C: Disaster Risk Management and Governance

Section 6: Disaster Risk Management and Governance

Definition of Disaster Risk Management: DRM is the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses (Source: UNDRR).

Question 6.1: Which authorities (or departments) are responsible for developing disaster risk management plans for this testbed - and what procedures do they follow? (For example, do local plans need to be approved by national authorities?)

Il existe plusieurs plans de gestion des risques de catastrophe qui s’appliquent pour le territoire de la Métropole Nice Côte d’Azur.

1) La responsabilité de la Préfecture dans l’éla oration et la mise à jour des plans :

A) Le plan ORSEC :

Le dispositif ORSEC (pour Organisation de la Ré onse de Séc rité Civile) est un programme d’organisation des secours à l’é helon dé artemental (en ce qui concerne les Alpes-Maritimes). En cas de catastrophe, ce dispositif a pour objectif la mise en œuvre rapide et efficace de tous les moyens né essaires sous l’autorité du pré et.

Ce plan permet de faire face à tous types d’urgence (pour des risques liés a x infrastructures et aux transports, des risques naturels, sanitaires, vétérinaires et séc ritaires), qu’ils soient pré isibles ou non. Le pré et prend la main, soit quand la catastrophe touche plusieurs communes, soit quand son ampleur est très grande et qu'il juge que le Maire de la commune concernée ne pourra pas y répondre seul.
Ce plan permet de ré nir l’organisation des secours (Sapeurs-Pompiers, SAMU, forces de l’ordre, etc.) et les moyens, publics et privés (Etats, collectivités, opérateurs de réseaux, etc.) susceptibles d’être mis en œuvre.
Le dispositif ORSEC **est placé sous la direction unique du préfet de département,** sauf lorsque l’é énement a lieu à plus grande échelle : le plan est alors déployé au niveau maritime et zonal (regroupant plusieurs régions), et coordonné par le préfet de zone (préfet des Bouches-du-Rhône pour la région SUD). Le préfet de département restant directeur des opérations.
Liens ou références utiles :
Planification et exercices de Sécurité civile / Documentation technique / Sécurité civile / Le ministère - Ministère de l'Intérieur (interieur.gouv.fr)
Plaquette ORSEC.pdf - Ministère de l'Intérieur
ORSEC méthode générale.pdf - Ministère de l'Intérieur
DGv3 – Articulation entre le dispositif ORSEC et l’organisation propre des acteurs : POI, PPMS, PCS… – Mémento du maire et des élus locaux (mementodumaire.net)
Présentation du dispositif ORSEC
Articulation entre le dispositif ORSEC et l’organisation propre des acteurs
Risques naturels | Ministères Écologie Énergie Territoires (ecologie.gouv.fr)

B) Le PPRN :

En 1995, les Plans de Prévention des Risques Naturels prévisibles (PPRN) ont remplacé les PSS et PER, se substituant également à tout autre plan ou dispositif approuvé par les préfets (ex : périmètre de risques délimité par l'article R111-3 du Code de l'urbanisme, Plan de Surfaces Submersibles (PSS), Plans de Zones Sensibles aux Incendies de Forêt (PZSIF). La loi Barnier vise à renforcer et à unifier l'action de pré ention. Elle pré ise, en outre, que les procédures déjà approuvées valent PPR.
La mise en œuvre de cette politique de pré ention relève d'une compét nce partagé , impliquant les services dé oncentrés de l'Etat, les collectivité territoriales, plusieurs ministères mais aussi les citoyens, chacun intervenant dans son domaine.

Le Plan de Prévention des Risques Naturels, approuvé par le préfet, est annexé après enquête publique et approbation au Plan Local d'Urbanisme (PLU) en tant que servitude d'utilité publique. Ses dispositions priment sur toute autre considération.

Les PPRN dé inissent les zones d'exposition aux phé omènes naturels prévisibles, directs ou indirects, et caractérisent l'intensité possible de ces phénomènes.

A l'inté ieur de ces zones dites « d'alé », les PPRN ré lementent l'utilisation des sols, la façon de construire, l'usage et la gestion des zones à risques dans une approche globale du risque. Les réglementations s'appliquent tant aux futures constructions qu'aux constructions existantes dans le but de maîtriser et ré uire leur vulné abilité

Même en l'absence de Plan de Prévention des Risques (naturels, technologiques ou miniers), le Plan Local d'Urbanisme (PLU) peut dé inir les zones à risques et les règles spé ifiques à respecter. Le Code de l'urbanisme dans son article L110 pose la prévention des risques naturels et technologiques dans ses principes. L'article L122-1 impose aux Schémas de COhérence Territoriale (SCOT) de prendre en compte la prévention des risques dans leur élaboration.

Liens ou références utiles :

Prévention des risques naturels | Ministères Écologie Énergie Territoires (ecologie.gouv.fr)
Prevention des inondations | Ministères Écologie Énergie Territoires (ecologie.gouv.fr)

2) La responsabilité du Maire dans l'élaboration et la mise à jour des plans, dans le cadre de ses pouvoirs de police administrative

A) Le PCS :

Le Plan Communal de Sauvegarde (PCS) est l'outil opé ationnel à la disposition du Maire pour l'exercice de son pouvoir de police en cas d'é énement de sé urité civile. Dispositif élémentaire de la solidarité entre les habitants, il organise la continuité des missions que la commune doit obligatoirement assurer en situation d'urgence.
Il est obligatoire dans les communes identifiées comme soumises à un risque majeur, c'est-à-dire celles concernées par un Plan de Prévention des Risques Naturels prévisibles approuvé (PPRN), un Plan de Prévention des Risques Miniers approuvé (PPRM), ou un Plan Particulier d'Intervention (PPI). Il est par ailleurs conseillé à toutes les communes de se doter d'un PCS car aucune n'est à l'abri de :

- Phénomènes climatiques extrêmes (tempête, orage, neige, canicule, etc.) ;
- Perturbations de la vie collective (interruption durable de l'alimentation en eau potable ou en é ergie, etc.) ;
- Problèmes sanitaires (épidémie, canicule, etc.) ;
- Accidents de toute nature (transport, incendie, etc.) ;
- etc.

L'objectif du PCS est triple :

1. Sauvegarder les personnes, les biens et l'environnement,
2. Limiter les consé uences d'un accident, d'un sinistre, d'une catastrophe,
3. Organiser les secours communaux.

Tout au long du projet, la commune peut faire appel à diffé ents services de l'Etat. Etant donné le nombre de communes concerné s par l'obligation de mise en place d'un PCS dans chaque département, il est probable que les services étatiques n'aient pas la capacité d'être présents dans toutes les étapes de réalisation du plan.
En schématisant, on peut estimer les rôles de chaque partenaire institutionnel tout au long du projet, de la manière suivante :
■ durant le projet, sous rése ve de leurs capacité internes et de leurs disponibilités, certains services peuvent éventuellement apporter un soutien méthodologique ou des conseils : SIDPC (ou SIRACEDPC), SDIS, etc.
■ ponctuellement, des questions techniques peuvent se poser. Plusieurs services de l'Etat peuvent alors être sollicités pour obtenir des réponses techniques (DDE, DIREN, DRIRE, DDASS, etc.).
Par ailleurs, dans le cadre de l'éla oration de certaines dispositions spé ifiques du plan ORSEC (PPI notamment), les SIDPC (ou SIRACEDPC) associent régulièrement les mairies. Ce travail en commun permet un échange de culture entre les diffé ents niveaux d'intervention. Les communes doivent profiter de ces occasions pour valider un maximum d'informations et échanger le plus possible avec les services pré ectoraux.
Certaines collectivités territoriales tels les Etablissements Publics de Coopération Intercommunale (EPCI) à fiscalité propre (communauté de communes, d'agglomérations, urbaine…), les conseils dé artementaux ou ré ionaux peuvent proposer des soutiens particuliers selon leurs ressources : soutien financier (permettant de faciliter la sous-traitance), technique (si la collectivité est dotée de la compétence en interne), etc.
L'article 4 du dé ret n°2005-1156 du 13 septembre 2005 relatif au PCS : " Le Plan Communal de Sauvegarde est élaboré à l'initiative du maire de la commune. Il informe le conseil municipal du début des travaux d'élaboration du plan. A l'issue de son élaboration ou d'une révision, le PCS fait l'objet d'un arrêté pris par le Maire de la commune et, à Paris, par le préfet de police. Il est transmis par le Maire au préfet du département."

Liens ou références utiles :
Plan communal de sauvegarde - le guide - Format pdf (5,2Mo) / Files / Sécurité civile - Ministère de l'Intérieur (interieur.gouv.fr)
Le plan communal de sauvegarde / Sécurité civile et gestion de crise / Sécurité et protection de la population / Politiques publiques / Accueil - Les services de l'État dans les Alpes-Maritimes
Memento (alpes-maritimes.gouv.fr)
Memento (alpes-maritimes.gouv.fr)
Plan communal de sauvegarde (PCS)
Synthèse du PCS.pdf → Nice

B) Le PICS : La Métropole NCA devrait voir prochainement apparaitre un Plan InterCommunal de Sauvegarde ou PICS

La loi Matras du 25/11/2021 instaure un cadre juridique pour les Plans InterCommunaux de Sauvegarde (PICS). Ceux-ci ont vocation à organiser la ré onse mutualisé aux situations de crise à l'é helle intercommunale et à compléter les plans communaux de sauvegarde. Le PICS est obligatoire pour les EPCI à fiscalité propre comptant au moins parmi leurs membres une commune elle-même soumise à l'obligation d'éla orer un PCS.
La loi 2004-811 du 13 août 2004 relative à la modernisation de la sé urité civile pré ise qu'un PICS peut être éta li dans les établissements publics de coopération intercommunale (EPCI) à fiscalité propre. Ce dernier est arrêté par le prési ent de l'EPCI et par chacun des Maires des communes concerné s. Il est à noter que la mise en œuvre de ce document relève de chaque Maire sur le territoire de sa commune. Il comprend les mêmes éléments que le PCS, il définit une organisation de gestion des évènements pour chaque commune et une pour l'intercommunalité Il faut rappeler que la direction des opérations de secours ne peut être assurée que par le Maire ou le préfet : ne peut donc en aucun cas, être transfé é à un prési ent d'intercommunalité.
Cette disposition devrait laisser s'exprimer la volonté politique de solidarité des élus communautaires dans le cadre de la gestion de crise par la mutualisation des moyens né essaires (humains, maté iels, structures d'hébergement, assistance post crise…).
Liens ou références utiles :
R8 – Plan communal de sauvegarde (PCS) et Plan Intercommunal de Sauvegarde (PICS) – Mémento du maire et des élus locaux (mementodumaire.net)

Les communes de la Métropole NCA peuvent également si elles le souhaitent solliciter la DPGR (Direction de la Prévention et de la Gestion des Risques) pour assistance dans la rédaction et l'élaboration des différents plans liés aux risques.

Question 6.2: What are local authorities' official and legal obligations when it comes to disaster risk management?

1) L'organisation générale de la sécurité civile

Trois autorités sont traditionnellement responsables de la police administrative générale en France et exercent cette compétence en fonction de l'ampleur des problèmes à traiter :

- Le Premier ministre ;
- Le préfet de département ;
- Le Maire dans sa commune.

A) En qualité de chef du gouvernement, le Premier Ministre prépare et coordonne l'action des pouvoirs publics en cas de crise majeure (article L.111-3 du Code de la défense)

En ce qui concerne, plus précisément, la préparation et l'exécution des politiques de sécurité intérieure et de sécurité civile qui concourent à la défense et à la sécurité nationale, **celles-ci relèvent du ministre de l'Intérieur, sous l'autorité du Premier ministre.**
A ce titre, il est, sur le territoire de la République, responsable de l'ordre public, de la protection des personnes et des biens ainsi que de la sauvegarde des installations et ressources d'intérêt général.
En complément des échelons, communal, départemental, et national, la zone de défense et de sécurité s'intercale dans des missions d'appui, de planification, de gestion de moyens, de synthèse.
Ce dispositif constitue le fondement de l'organisation de la sécurité civile et plus largement de la gestion de crise en France.
Il est complété par le Code de la sécurité intérieure, qui dispose dans son article L112-1 que « la sécurité civile, dont l'organisation est définie au livre VII, a pour objet la prévention des risques de toute nature, l'information et l'alerte des populations ainsi que la protection des personnes, des animaux, des biens et de l'environnement contre les accidents, les sinistres et les catastrophes par la préparation et la mise en œuvre de mesures et de moyens appropriés relevant de l'Etat, des collectivités territoriales et des autres personnes publiques ou privées. »
État, collectivités territoriales et des autres personnes publiques ou privées : chacun a donc vocation à apporter une réponse dans ses domaines de responsabilité.

B) Le Maire, premier échelon de la réponse de sécurité civile

La compétence de police générale du Maire constitue un élément à la fois historique et essentiel du dispositif français de sécurité civile, qui remonte à la législation de 1789/1790 et à la loi d'organisation municipale d'avril 1884. Ses grands principes sont aujourd'hui repris dans les articles L.2211-1, L.2212-2, L.2214-4 et L.2215-1 du Code général des collectivités territoriales. Il s'agit d'une compétence obligatoire, **que le Maire est tenu d'exercer pleinement et en permanence, et d'une compétence propre, qui lui est directement attribuée par la loi.**
Le Code de la sécurité intérieure confirme les prérogatives du Maire en matière de sécurité civile ainsi que les bases juridiques du partage de compétence entre le Maire et le préfet pour la Direction des Opérations (DO).
De manière générale, le Maire assure la DO dans la limite de sa commune jusqu'à ce que, si nécessaire, le préfet assume cette responsabilité.
Les missions principales qui relèvent du Maire sont les suivantes :

- L'alerte et l'information des populations ;
- L'appui aux services d'urgence ;
- **La sauvegarde et le soutien des populations** (hébergement, ravitaillement, etc.) ;
- L'information des autorités.

Liens ou références utiles :
Traitement au niveau local de la vigilance et de l'alerte
Pour apporter une réponse de proximité à la crise, et en complément de l'intervention des services de secours et du dispositif opérationnel ORSEC, le Code de la sécurité intérieure prévoit l'élaboration des Plans Communaux ou InterCommunaux de Sauvegarde (PCS / PCIS) et la Réserve Communale de Sécurité Civile (RCSC).
Pour aller plus loin consulter la fiche : Réserves communales de sécurité civile
Focus sur l'organisation du Poste de Commandement Communal (PCC) de la ville de Nice :

<u>Le Poste de Commandement Communal à l'Hôtel de Ville</u>
Une salle dé iée à la gestion de crise é uipé d'outils performants a été amé agé en 2009 afin de :

1. Permettre en concertation, de prendre les dispositions les mieux adaptées
2. Coordonner efficacement les moyens, ainsi que les partenaires présents, sur le terrain

Les outils modernes mis en place au sein du PCC vont permettre de :

1. Visualiser en temps réel les **images de vidéo protection** (+ de 1300 caméras) pour faire des points de situation
2. Consulter les **cartographies opérationnelles** et informatives à partir du système d'information géographique sur les différents risques répertoriés et les enjeux associés
3. Communiquer avec les principales autorités publiques (**visioconférence, téléphone satellitaire** en cas de rupture du réseau de communication terrestre) en période de crise
4. Orienter les agents de terrain dans leurs rôles de fermeture des routes/accès aux plages, déblaiements des routes... (PM, agents de la voirie, RCSC, etc.)
5. Utiliser une **main courante** informatisé de manière à suivre en temps ré l l'é énement et de disposer d'une chronologie des actions engagées.

Ces outils sont indispensables à l'efficacité et la réactivité des cellules de crise mises en place : Cellules Evaluation, Logistiques technique et sociale, Communication, Transmissions, Juridiques et Finances, services extérieurs.

Le DICRIM :

Dès lors qu'une commune est exposé à au moins un risque majeur, elle doit en informer ses administrés en élaborant et mettant à leur disposition un Document d'Information Communal sur les Risques Majeurs (DICRIM). Cet outil d'information pré entive est indispensable pour pré arer la population à bien ré gir en cas de crise.
Inscrite dans le Code de l'environnement, la ré lisation du DICRIM est une obligation réglementaire pour toutes les communes exposé s à au moins un risque majeur. L'objectif est d'informer la population (administrés, touristes, etc.) de l'existence de ce(s) risque(s) et des mesures de prévention, de protection et de sauvegarde mises en place. Il contribue ainsi à responsabiliser chaque citoyen pour sa propre mise en sé urité renforç nt l'efficacité des mesures mises en œuvre par la collectivité dans le cadre de son plan communal de sauvegarde (PCS).
Le Maire fait connaître le DICRIM au public par tout moyen approprié (sites internet, événements municipaux, distribution de plaquettes, etc.).
Que doit contenir un DICRIM ?
Le DICRIM reprend les informations transmises par le préfet dans le cadre du dossier départemental des risques majeurs (DDRM), notamment :

- La liste des risques majeurs auxquels la commune est exposée ;
- La description de chacun de ces risques et de leurs conséquences prévisibles pour les personnes, les biens et l'environnement ;
- Les mesures de prévention, de protection et de sauvegarde pour chacun de ces risques ;
- Les consignes de sécurité individuelle à mettre en œuvre.

C) Le préfet de département, directeur des opérations en cas de crise majeure

Le cas é hé nt, l'Etat, par l'interme iaire du pré et, prend la direction **des opérations de secours**, lorsque :

- Le Maire ne maîtrise plus les é é ements, ou lorsqu'il fait appel au represe tant de l'Etat ;
- Le Maire s'éta t abstenu de prendre les mesures nécessaires, le préfet se substitue à lui, après mise en demeure et après que celle-ci soit restée sans résultat ;
- Le problème concerne plusieurs communes du département ;
- La gravité de l'é ènement tend à dé asser les capacité locales d'intervention.

Lorsque le préfet prend la direction des opérations, le maire assume toujours, sur le territoire de sa commune, la responsabilité de la mise en œuvre des mesures de sauvegarde vis-à-vis de ses administrés (alerte,

évacuation, etc.) ou des missions que le préfet peut être amené à lui confier (accueil de personnes évacuées, etc.).
Dans l'exercice de ses pouvoirs de police, le pré et mobilise l'ensemble des moyens publics et privés Police, Gendarmerie, Sapeurs-Pompiers, SAMU, conseil départementale, opé ateurs, etc.) pour la mise en œuvre des mesures directes et indirectes né essaires à la protection gé é ale des personnes, des biens et de l'environnement contre les accidents, les sinistres, les catastrophes ou tout autre événement présentant un risque immédiat ou imminent.
Autorité de police administrative générale, le Préfet est de facto un « directeur général des opérations », englobant dans ce périmètre la direction de toutes les opérations précitées, relatives à la sécurité, à la protection et la sauvegarde des populations.
Le pré et assure l'approche globale de la situation et donne ainsi son unité à la gestion de crise. Il coordonne l'action de tous les intervenants (services de l'Etat, des collectivité territoriales, des établissements publics, des opérateurs, etc.) en s'appuyant sur le dispositif d'Organisation de la Ré onse de SEcurité Civile (ORSEC).
Dans le cas des opérations de secours relevant du domaine de compétence des Sapeurs-Pompiers, le Préfet prend formellement la « Direction des Opérations de Secours » (DOS) en remplacement du Maire, qui est le premier DOS. Il est épaulé dans ce cadre par un Commandant des Opérations de Secours (COS).
Le DDRM :
En application de l'article L 125-2 du code de l'environnement, **les citoyens disposent du droit à l'information sur les risques majeurs** auxquels ils sont soumis dans certaines zones du territoire et sur les mesures de sauvegarde qui les concernent. Ce droit s'applique aux **risques technologiques et aux risques naturels** prévisibles. L'information donnée au public est consignée dans un Dossier Départemental des Risques Majeurs (DDRM), élaboré par le préfet, et dans un Dossier d'Information Communal sur les Risques Majeurs (DICRIM), établi à l'initiative du Maire.

D) Le Préfet de zone de défense et de sécurité conforté dans son rôle de coordination

Si les consé uences d'un é é ement dé assent les limites ou les capacité d'un département, le represé tant de l'Etat dans le département du siège de la zone de défense et de sécurité intervient dans la conduite des opérations lorsque c'est né essaire.
La zone de défense et de sécurité, occupe une position de plus en plus importante. Elle constitue au premier chef un é helon de la chaîne dé isionnelle dé ié à l'appui (pourvoyeur de moyens en renfort, etc.) et à la coordination opérationnelle supra-départementale (par exemple, la gestion de crise des réseaux routiers nationaux, etc.). De plus, elle constitue un niveau d'agrégation de métie s dé ié au soutien (expertise, localisation de ressources inexistantes au niveau départemental, etc.).
Bien qu'il ne détie ne pas de pouvoir de police administrative gé é ale, le Préfet de zone bé é icie aujourd'hui de compétences élargies qui lui permettent de :

- Prendre les mesures de coordination, né essaires lorsqu'une situation de crise intervient ou que des é ènements d'une particulière gravité se produisent dépassant, ou susceptibles de dé asser, le cadre d'un département ;
- Faire appel aux moyens privé à l'é helon de la zone et les réquisitionner si besoin ;
- Mettre à la disposition d'un ou plusieurs Préfets de département de la zone, les moyens publics existant dans la zone ;
- Assurer la ré artition des moyens exté ieurs alloués ar le ministère de l'Inté ieur ;
- Mettre en œuvre les mesures opé ationnelles dé idé s par le ministère de l'Inté ieur pour les moyens de sécurité civile extérieurs à sa zone de compétence ;
- Dét rminer les priorité dans le réta lissement des liaisons gouvernementales sur l'ensemble de sa zone ;
- Coordonner la communication de l'État pour les crises dé assant le cadre du dé artement ;
- Coordonner l'action des Pré ets des dé artements de la zone pour pré enir les é ènements troublant l'ordre public ou y faire face, lorsque ces évènements intéressent au moins deux départements ;
- Procéder à la répartition des unités mobiles de police et de gendarmerie implantées sur la zone ;
- Mettre à disposition pour une mission et une durée déterminée, des effectifs et des moyens de police et de gendarmerie relevant d'un autre dé artement de la zone de dé ense et de sé urité

Le Préfet de zone peut dés rmais, en complé entarité de l'action des Pré ets de département, prendre, en situation de crise majeure, des mesures de police administrative qui devraient ainsi l'autoriser, par exemple, à interdire la circulation sur un axe routier traversant plusieurs départements dans sa zone de défense.

Enfin, en cas d’accident majeur ayant son origine en mer et né essitant le dé lenchement simultané du plan ORSEC maritime (pour lequel le Préfet maritime est directeur des opé ations de secours) et d’un ORSEC dé artemental ou de zone, le Préfet de zone territoriale, compétent, « s’assure de la cohé ence » des actions terrestre et maritime.
Afin de lui permettre d’assumer pleinement ses nouvelles compétences, le Préfet de zone dispose maintenant, en complément du Centre Opérationnel Zonal (COZ) permanent, d’un Etat-Major Interministériel de Zone de Défense et de Sécurité (EMIZDS), dont les compétences ont été étendues à l’ensemble des missions relevant de la sécurité nationale (article R.1311-26 du Code de la défense), et qui doit désormais bénéficier de la mise à disposition de personnels des principaux ministères (Intérieur, Défense, Santé, Economie, Industrie, Budget, Agriculture, Transport, Environnement, Energie, Aménagement du territoire).

E) Les autres acteurs de la sécurité civile

Si la direction et la coordination sont assurées par les administrations précitées, la gestion des événements de sécurité civile nécessite de recourir de manière souvent concomitante à des compétences différentes dans le cadre d’une opé ation unique, mais à multiples facettes : services de secours, forces de police ou de gendarmerie, autres services de l’Etat, techniciens ou experts dans des domaines particuliers, collectivités locales, associations agréées de sécurité civile, opérateurs publics ou privés, Procureurs de la République, etc.
La doctrine ORSEC est aujourd’hui le seul dispositif interservices de portée ré lementaire, au niveau territorial, permettant de garantir une réponse coordonné de l’ensemble des acteurs publics et privés

Question 6.3 Which authorities (or departments) are responsible for communicating local disaster risk management plans to community groups - and what procedures do they follow?

Chacune des autorités en charge de la réalisation des plans évoqués précédemment a la charge de les communiquer aux autres autorité . Les PCS sont communiqués ar les Maires au pré et ainsi qu’à la DPGR pour la mét opole NCA, les plans ORSEC et les PPR sont en consultation à la Préfecture ainsi que sur le site internet de la Préfecture pour les PPR.

[Les plans de prévention des risques (PPR) approuvés et l'Information Acquéreurs-Locataires (IAL) / Les risques naturels et technologiques / Environnement, risques naturels et technologiques / Politiques publiques / Accueil - Les services de l'État dans les Alpes-Maritimes]

Le site GEORISQUES permet également de consulter une grande partie des documents locaux de gestion des risques. Il est à destination des particuliers, des collectivités et des experts du risques :

[Accueil - Particulier | Géorisques - Ministère de la transition écologique (georisques.gouv.fr)]

Question 6.4 What mechanisms have been set up to ensure that local authorities and emergency responders coordinate effectively during a disaster event - and what procedures do they follow?

Organisation de la chaîne opérationnelle de gestion de crise sur le territoire national :
Chaque niveau territorial dispose de sa structure de commandement permettant aux autorités ’être informé s et d’exercer les fonctions qui leur sont dé olues en temps de crise (direction des opé ations ou coordination).

1) Au niveau communal, le Maire met en place un Poste de Commandement Communal (PCC), activé en fonction des évé ements en tant que structure d’aide à la dé ision du Maire, d’é hange et de synthèse de l’information.
2) Au niveau du département, le dispositif opé ationnel de l’autorité pré ectorale s’articule autour de deux types de structures de commandement :
    - Le Centre Opérationnel Départemental (COD) à la Préfecture, organisé autour du Service Chargé de la Défense et de la Protection Civile (SIDPC ou SIRACEDPC),

- Le Poste de Commandement Opérationnel (PCO) au plus près des lieux d’actions mais hors de la zone à risques. Il est chargé de coordonner les différents acteurs agissant sur le terrain.

Si l’é é ement dépasse les capacité de ré onse d’un dé artement, la zone de défense par l’interme iaire du Centre Opérationnel de Zone (COZ) fournit les moyens de renforts et coordonne les actions. En cas de besoin, le niveau national, par l’intermédiaire du Centre Opérationnel de Gestion Interministériel de Crise (COGIC), appuie le dispositif déjà en place.

3) Enfin, dans le cas de crises majeures intersectorielles de portée nationale, le Premier ministre peut décider d’activer une Cellule interministérielle de crise (CIC) qui ré nit l’ensemble des ministères concernés par l’é é ement. Il peut dé ider de coordonner lui-même l’action gouvernementale ou bien de la confier à un Ministre en fonction de la nature de l’évé ement. Dans le cas d’une crise majeure sur le territoire national, c’est le ministre de l’Inte ieur qui assure en principe la coordination gouvernementale au sein de cette cellule.

<u>Schéma de la chaîne opérationnelle de gestion des crises sur le territoire :</u>

Liens ou références utiles :

<u>DGv1 – Organisation de la sécurité civile – Mémento du maire et des élus locaux (mementodumaire.net)</u>
<u>DGv2 – Présentation du dispositif ORSEC – Mémento du maire et des élus locaux (mementodumaire.net)</u>
<u>DGv3 – Articulation entre le dispositif ORSEC et l’organisation propre des acteurs : POI, PPMS, PCS… – Mémento du maire et des élus locaux (mementodumaire.net)</u>

Question 6.5 Which authorities (or departments) are responsible for developing economic recovery plans after a disaster in the testbed - and what procedures do they follow?

Question 6.6. What are the strengths and weaknesses of the ways in which disaster risks are currently managed in this testbed?

Strengths	1) La cré tion et la mise en place de l’Agence de Séc rité Sanitaire Environnementale et de gestion des Risques, dont la structure et l’organisation fait d’elle une agence pionnière et unique en France.

	L'Agence de Séc rité Sanitaire Environnementale et de gestion des Risques de la mét opole Nice Côte d'Azur est chargé de coordonner, de conseiller et d'apporter une expertise straté ique au niveau de la Métropole, en cas de crise sanitaire, environnementale ou sécuritaire. Son but est de mettre en place une organisation à la fois adaptée aux nouveaux besoins de protection des populations et du cadre de vie de l'ensemble de la Métropole Nice Côte d'Azur, tout en éta t flexible pour passer en mode « urgence » lors de la gestion de crise. 2) Une Préfecture, active et réactive, et également sensibilisée aux risques majeurs. 3) Une prise de conscience collective après les terribles événements que nous avons connus.
Weaknesses	1) Difficulté pour l'articulation du rôle de chacune des parties prenantes, car la Métropole NCA possède une force de frappe et une volonté d'agir, même lorsque le préfet prend en main le rôle du DOS. La Métropole porte donc également secours dans le même temps à la population. Il y a par moment des chevauchements sur les mêmes activités d'assistance et de secours. 2) Retards dans la mise en place des plans de préparation aux risques sismiques. 3) Lenteur dans la mise en place du PICS. (Plan Intercommunal de Sauvegarde)

Section 7: Managing Resilience & Capacities

Definition of capacity: the combination of all the strengths, attributes and resources available within an organisation, community or society to manage and reduce disaster risks and strengthen resilience (Source: UNDRR).

Definition community resilience: The ability of a community to prevent, prepare for, respond to, and recover from disasters.

Question 7.1: Please answer for each item in the table below, which authorities (or departments) are responsible for the governance and management of capacities and resilience in this testbed. Where available, please provide links or references to their procedures.

Urban development	Example: use of hazard scenarios	/
Infrastructure Housing, transport, power, water, communications, etc.	Example: adherence to the building code	Voiries : depuis le transfert de compétence des voies communales de 2009 et des routes départementales de 2012, la Métropole NCA (MNCA) est seul gestionnaire de l'ensemble des voiries (hors A8) sur son territoire. Pour cette gestion, 5 directions se répartissent le territoire avec une direction support. Eau potable : compét nce gé ée par la Ré ie Eau d'Azur depuis 2013, établissement public à caractère industriel et commercial. Assainissement : compétence intégrée depuis le 1er janvier 2022 à la Régie Eau d'Azur, qui gère ainsi la totalité de la gestion du cycle de l'eau. Eaux pluviales et GeMAPI : gestion MNCA en régie.

		Résea d’é lairage public : gestion MNCA en régie. ENEDIS (Electricité) : contrat de concession depuis 2018 entre ENEDIS et MNCA portant sur l’ensemble du territoire métropolitain. Opérateurs TELECOM : opérateurs privés comme ORANGE, BOUYGUES TELECOM, SFR, etc. + SICTIAM (fibré) piloté par la Direction des Services Informatiques (DSI) de MNCA.
Natural buffers	Example: environmental protection legislation	/
Institutional capacity Local authorities, first responders	Example: training in disaster management	Préfecture : service interministériel de défense et de protection civile. - Service interministériel de défense et de protection civile / Direction des sécurités / Le Cabinet du préfet / La Préfecture des Alpes-Maritimes / Préfecture et sous-préfectures / Services de l'Etat / Accueil - Les services de l'État dans les Alpes-Maritimes
Societal capacity	Example: public awareness campaigns about hazards	Cela dépend du pouvoir de police du Maire sur son territoire avec une obligation de sensibiliser aux risques avec notamment la ré lisation d’un DICRIM. Cet outil d’information préventive est indispensable pour préparer la population à bien réagir en cas de crise. Le Maire fait connaître le DICRIM au public par tout moyen approprié (sites internet, événements municipaux, distribution de plaquettes, etc.). Des services ont également la charge de la sensibilisation du public face aux risques majeurs : - L’Agence de Séc rité Sanitaire Environnementale et de Gestion des Risques qui a notamment organisé en 2022 deux conférences à destination du public (Risques sismiques et Risque de pénurie énergétique), avec également la Réserve Communale de Sécurité Civile pour la sensibilisation dans les écoles. La DPGR
Economic capacity	Example: support to business organisations	/

Section 8: Decision Making Tools for Disaster Risk Management

Question 8.1 What tools does this testbed currently have to inform decision making in disaster risk management? Do these tools focus on the short-term, the medium-term or the long-term? What are their strengths and weaknesses?

Current tools	Focus short-term, medium-term, or long-term	Strengths	Weaknesses
Monitoring des cours d'eau principaux de la métropole NCA. Capteurs et débitmètres, pluviomètres et caméras de lever de doutes. (Poursuite des installations en cours)	Court terme	Informations en temps réel	Peut casser ou dysfonctionner Délais importants pour l'installation des capteurs/caméras Incapacité pour l'heure à estimer l'impact du reflux en cas de houle/vagues submersion qui viendrait gêner l'ecoulement.
Alertes de la Préfecture	Court terme	Information sur les événements en approche : tsunamis, fortes dépressions, épisodes de grand froid, canicules, etc.	On ne sait jamais vraiment à l'avance si l'on va être impacté et à quelle force, donc on peut parfois alerter la population pour rien. Plus il y a de personnes à qui envoyer des SMS plus l'envoi est long et certains SMS peuvent arriver après la survenue de l'incident.
<u>(PROJET EN COURS) A venir, livraison début d'année 2023 :</u> création d'un outil permettant une estimation rapide des dommages à la suite d'un séisme.[1]	Court, moyen et long terme (En effet il sera possible également de faire des simulations grâce à l'outil, pour anticiper à moyen et long terme et préparer le territoire)	Possibilité d'orienter au plus vite les secours dans la zone la plus impactée par le séisme.	Si destruction des capteurs à la suite d'un séisme très important, l'outil est aveugle et ne peut donc pas nous donner d'indication.
<u>(PROJET A VENIR) Lancement en 2023 :</u> volonté de création, en partenariat avec le BRGM, d'un outil permettant d'obtenir des alertes précoces sur les mouvements gravitaires.[2]	Court, moyen et long terme (En effet il sera possible également de faire des simulations grâce à l'outil, pour anticiper à moyen et long terme et préparer le territoire.)	Anticiper les glissements de terrain	Nous ne pourrons pas quadriller tout le territoire et le degré de précision ne sera pas très fort. Il s'agira d'isoler des zones assez larges.

PCC avec astreinte spécifique (expertise sur l’événement)	Court terme	Anticiper les événements extrêmes et obtenir lors du PCC des informations sur l’é olution de la situation.	Difficulté organisationnelle notamment due à des niveaux de connaissance et de préparation inégale suivant les participants d’astreinte au moment de l’é é ement.
Retex	Moyen et long terme	Retour participatif sur l’é ènement permettant d’améli rer la réponse pour les crises futures.	Difficulté de réaliser un document simple et synthétique sur un événement complexe.
Agence de Sécurité Sanitaire, Environnementale et de Gestion des Risques (partie Prospective)	Court, moyen et long terme	Une agence unique en France regroupant l’Opé ationnel et la Prospective. Celle-ci ayant une orientation à moyen et long terme pour anticiper au mieux les futures crises et préparer les territoires.	En cours de création et de développement.
Création d’une cellule de coordination des subdivisions métropolitaines.	Court terme	Permet de piloter les interventions sur l’ensemble du territoire.	/
Création du haut conseil pour le climat ***Liens ou références utiles :*** https://info.nice.fr/environnement/la-metropole-se-dote-dun-haut-conseil-pour-le-climat/	Moyen et long terme	En cours de création	En cours de création

1) ***Ce projet d'étude doit nous permettre d'obtenir un outil clé en main visant à :***

- *Evaluer l'intensité des secousses sous la forme d'une cartographie dite « Shakemap » ;*
- *Estimer le nombre de bâtiments affectés par niveau d'intensité et classes de vulnérabilité ;*
- *Et à estimer les dommages et les pertes humaines.*

L'outil opérationnel prévu pour la métropole NCA sera le suivant : déclinaison de l'outil sur le territoire métropolitain

- *Définition d'indicateurs d'impacts adaptés ;*
- *Prototypage d'un communiqué NCA ;*
- *Automatisation de communiqués.*

Plateforme utilisateur (demande de l'Agence)

- *Pouvoir utiliser l'outil en mode temps-réel ou en mode scénario ;*
- *Pouvoir accéder en ligne aux communiqués et aux archives ;*
- *Pouvoir réaliser des tests d'envoi ;*
- *Pouvoir gérer l'annuaire des destinataires.*

2) L'objectif est de rendre opérationnel la chaîne de traitement automatique pluie-glissement établie dans le cadre du programme AD-VITAM à l'aide du modèle ALICE sur la métropole NCA afin d'anticiper la formation de glissements de terrain et les actions de prévention.

Question 8.2 What recommendations do you have for future disaster risk management tools to be developed?

L'outil devra :

- Permettre d'améli rer la prévision des catastrophes et également de mieux localiser les zones qui seront les plus impactées ;
- L'outil devra permettre d'é lairer au mieux les dé isions lors d'un PCC en se basant par exemple sur les donné s météorologiques de l'é é ement en cours (risque de dé ordement à venir ou de sur-aléas avec la survenue d'un glissement de terrain) ; Il devra avoir un vé itable usage opérationnel lorsqu'une alerte est en cours et ne pas rester simplement à l'état thé rique.
- L'outil devra permettre aussi de prioriser les risques en fonction des plus grandes probabilités e survenue. De manière à pouvoir travailler plus et en priorité sur des risques plus importants sur notre territoire.
- L'outil devrait permettre également de faciliter l'évacuation des zones à risques avec la proposition d'itiné aire sûr et/ou de lieu refuge ;
- Une problématique importante se pose sur notre territoire lors d'é é ement pouvant faire craindre une inondation : celui de la fermeture des routes. Les moyens humains ne sont pas suffisants pour effectuer ce travail assez rapidement ;
- L'outil doit permettre d'é lairer nos choix pour le futur en termes d'amé agement, en tenant compte de toutes les é olutions à venir, qu'elles soient climatiques mais é alement socié les (augmentation de la température, vieillissement de la population, etc.) ;
- L'outil doit avoir une vision à très long terme. Prenons l'exemple de la hausse du niveau des mers : quels impacts va-t-elle avoir sur le comportement des cours d'eau et cela notamment lors des crues ? L'outil doit donc aussi pouvoir alerter sur des consé uences lointaines pour permettre aux dé ideurs d'agir.

- Cette fonction d’alerte est indispensable pour les dé ideurs, compte tenu du nombre de donné s très importantes qui compose la surveillance des risques. Un outil permettant d’être alerte lorsque des donné s (températures, sècheresse des sols, précipitations, etc.) serait très intéressant. La difficulté réside dans le fait que toutes les données sont dispersées.

Section 9 Evaluations of Disaster Risk Management Plans

Question 9.1. Please insert links or references to publicly available formal assessments of this testbed’s disaster risk management plans (in any language).

Aucune information n’est publiquement disponible.

Question 9.2. Does this testbed use any participatory approaches to evaluate disaster risk management plans? (for example, through serious games).

L’approche participative est en place pour les RETEX et é alement pour la cré tion et la mise à jour des plans de gestion des risques.

ANNEX 6: QUESTIONNAIRE OSLO

Part A: Hazards, Exposure, Vulnerability and Risk

Section 1: Hazards

Definition of hazard: a process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation. (Source: UNDRR).

Question 1.1: What natural hazards does this testbed face? Please list the top 5. How likely are they? How severe would their impact be?

	Natural Hazard	Likelihood (low, medium, high)	Impact (low, medium, high)
1	Forest fire	High	Medium
2	Urban flood	High	Low
3	Earth quake	Medium	High
4	Storm flood	Medium	Medium
5	Quick clay landslide	Low	Medium

Question 1.2: How would climate change affect the likelihood and impact of these hazards?

[Femke, based on discussion:]

Drought
- Drought would increase the risk of forest fires.
- It would also pose challenges to Oslo's water and electricity supply. Oslo depends on rain for both water consumption and power production. As such, a lack of rain would affect Oslo severely. In that case, Oslo might need to implement rationing. Cascading impacts would be likely.

Floods
- Urban floods would be more likely.
- A large part of Oslo consists of marine clay. The ground might get soaked to such an extent that landslides would be more likely.

Section 2: Exposure

Definition of exposure: the situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas (Source: UNDRR).

Question 2.1: In this testbed, are people and assets currently located in hazard-prone areas? If so, please give examples.

[Femke, based on discussion:]

There are 11 rivers in Oslo that all have potential to get clogged and flood. This is a recurring threat. Rivers flood every few years. The drainage system cannot necessarily cope. The Akerselva river runs through Olso city centre into the fjord. Businesses and institutions in the city centre are at risk, as are train tunnels. Flooding can affect power, transportation and trigger small landslides in Oslo.

Section 3: Vulnerability

Definition of vulnerability: the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards (Source: UNDRR).

Question 3.1: In this testbed, are some people and assets currently highly susceptible to the impact of the hazards they face? If so, please give examples.

[Femke, based on discussion:]

Earthquakes
Older housing in Oslo (built between 1800s and 1920s) is structurally not as safe (able to withstand earthquakes) as newer housing. Modern buildings are built on pillars: a fair number of older houses in downtown Oslo are not built on pillars.

Quick clay
Part of the Alna area of Oslo is at risk from quick clay. Quick clay poses a risk to downstream housing areas: infrastructure and transportation would be affected, as would the water supply (there would be pressure losses and disconnects) – waste water would also be affected.
Alna contains some poorer neighbourhoods where lots of lower income people live cramped together, increasing their vulnerability (to quick clay). Housing strategies were developed without this in mind.

Forest fires:
The municipality of Oslo includes two green areas, including forest areas. In summer, these areas are at risk of forest fires.
The impact of the fire hazard on people is very low (mainly toxic air) but some fires are close to the city. The parts of the city bordering the forest areas are mainly housing areas. When the fire cannot be controlled, these areas need to be evacuated.
Oslo's main water supply is located in the forest areas, so forest fires put this at risk as well.

Section 4: Disaster Risk (interacting, interconnected, compound and cascading risk)

Definition Disaster Risk: The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity (Source: UNDRR).

Question 4.1: In this testbed, how have different risks historically affected each other? Please give examples.

Different ways in which risks affect each other	Historic example (if available)
Interacting risks - how did different hazards trigger with each other? *For example, when heavy rainfall triggers landslides*	[Femke, based on discussion:] The largest quick clay/landslide disaster (1953) in Norway was triggered by digging/construction works.
Interconnected risks - how did interdependencies between human, natural and technological systems shape risk? *For example, when a drought puts food production at risk*	[Femke, based on discussion:] The above mentioned disaster destroyed 100 meters of the main highway and tore out rail track foundations, forcing trains to stop. A bus and some cars were taken by the landslide. 88 people were affected and 5 people died.
Compound risk – how did simultaneous or successive extreme events affect risk? *For example, when an earthquake occurs during a period of severe flooding*	[Femke, based on discussion:] The COVID pandemic coincided with a drought, which meant that Oslo had to introduce measures to ration water consumption. Power (which is generated mainly through rainfall) became more expensive. Oslo had to reduce power consumption and rely more heavily on EU systems.
Cascading risk - how did a disruption of closely interconnected systems affect risk? *For example, when collapsed buildings and bridges disrupted the supply chain of key businesses*	[Femke, based on discussion:] In Oslo, the power and water supplies are closely connected: both depend mainly on rainfall.

Part B: Disaster Risk Assessment

Section 5: Disaster Risk Assessment

Definition Disaster Risk Assessment: A qualitative or quantitative approach to determine the nature and extent of disaster risk by analysing potential hazards and evaluating existing conditions of exposure and vulnerability that together could harm people, property, services, livelihoods and the environment on which they depend (Source: UNDRR).

Question 5.1: Which authorities (or departments) are responsible for the assessment of hazards, exposure, vulnerability, capacity, resilience and risk in your testbed? Where available, please provide links or references to their procedures.

Top 5 natural hazards (listed in question 1.1)	1	Agency for Fire and Rescue Services
	2	Agency for Planning and Building Services
	3	Agency for Planning and Building Services
	4	Agency for Planning and Building Services
	5	Agency for Planning and Building Services
Exposure	People	Agency for Health
	Infrastructure	Agency for Planning and Building Services / Agency for Water and Wastewater Management
	Institutions	Agency for Health / Nursing Home Agency
	Housing	Agency for Planning and Building Services
	Business	Department of Business Development and Public Ownership
	Nature	Agency for Urban Environment/ Cultural Heritage Management Office
Vulnerability	People	Agency for Health
	Infrastructure	Agency for Planning and Building Services / Agency for Water and Wastewater Management
	Institutions	Agency for Health / Nursing Home Agency
	Housing	Agency for Planning and Building Services
	Business	Department of Business Development and Public Ownership
	Nature	Agency for Urban Environment / Cultural Heritage Management Office
Capacities / Resilience *(see section 7 for explanations and examples)*	Urban development	Agency for Urban Improvement and Development / Cultural Heritage Management Office / Agency for Planning and Building Services / Agency for Climate
	Infrastructure	Agency for Planning and Building Services / Agency for Water and Wastewater Management
	Natural buffers	Agency for climate / Agency for Planning and Building Services
	Institutional capacity	Agency for Emergency Planning / Agency for Fire and Rescue Services / Agency for Health

	Societal capacity	Agency for Emergency Planning / Agency for Fire and Rescue Services
	Economic capacity	Department of Finance / City of Oslo Collection Agency
Risk *(see section 4 for explanations and examples)*	Interacting risks	Agency of Emergency Planning
	Interconnected risks	Agency of Emergency Planning
	Compound risk	Agency of Emergency Planning
	Cascading risk	Agency of Emergency Planning

Question 5.2: Which authorities are responsible for the assessment of future risk resulting from climate change in your testbed?

Write your answer, or insert a reference / link. Agency for Climate / Agency of Emergency Planning https://www.oslo.kommune.no/getfile.php/13433175-1642068044/Tjenester%20og%20tilbud/Politikk%20og%20administrasjon/Egenberedskap/BER_Kommunalt%20Risikobilde%202021_Kortversjon_030122.pdf

Question 5.3: Do the authorities responsible for assessing disaster risk in your testbed use scenarios? If so, are those scenarios developed at national or local level (or both)? Please tick all that apply.

No, they don't use scenarios	
Yes, they use locally developed scenarios	X
Yes, they use nationally developed scenarios	X

Question 5.4: What are the strengths and weaknesses of the approaches that are currently used in your testbed to assess risk?

Strengths	Dimensioning scenarios with focus on impact past normal emergency response resources Focus on impact on vital societal functions and the fundamental needs of citizens
Weaknesses	Results may vary Results depend on what level each actor collaborate

Part C: Disaster Risk Management and Governance

Section 6: Disaster Risk Management and Governance

Definition of Disaster Risk Management: DRM is the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses (Source: UNDRR).

Question 6.1: Which authorities (or departments) are responsible for developing disaster risk management plans for this testbed - and what procedures do they follow? (For example, do local plans need to be approved by national authorities?)

Agency of emergency preparation is responsible to develop holistic risk assessments and overall preparedness systems in according with legislation of municipal emergency preparedness. The agency is also responsible for auditing all municipal enterprises complies with legislation and the requirements set by the municipal preparedness system.

Every agency and department have an independent responsibility to develop preparedness for their identified risks. They are also independently responsible to handle incidents, but may be coordinated by higher crisis management levels if it is escalated in the overall preparedness system. The levels are as follow: level 1 – agency, level 2 – sector, level 3 – central crisis management.

Local plans does not in general need approval by national authorities. However, many areas will have legislation that mandates minimum requirements to preparedness. However, when it comes to rescue, the police will be in charge due to Police Act §27. More information is in Question 6.4.

Question 6.2: What are local authorities' official and legal obligations when it comes to disaster risk management?

Local legislation in Norway maintain this in several approaches, however directly address municipalities with the act of civil protection. The act demands every municipality in Norway to create overall and holistic risk assessments and preparedness plans where, amongst other, disaster risks must be addressed.

In specific subject matters, i.e. fire and rescue services there are specific capability requirements in addition. Most agencies will have legislation directly addressing various preparedness requirements within their domains.

Question 6.3 Which authorities (or departments) are responsible for communicating local disaster risk management plans to community groups - and what procedures do they follow?

Agency of emergency preparedness is responsible for alerting the citizens and use cell phone messages. All agencies however may have an interest in sending information depending on the situation and may be given access to this.

If the information is more general it depends on the community subject to the outreach. Primary agencies in reaching the citizens will often be Agency of Health, the Education agency and City districts.

In disaster situations, communication will be coordinated by central crisis management.

Question 6.4 What mechanisms have been set up to ensure that local authorities and emergency responders coordinate effectively during a disaster event - and what procedures do they follow?

The Police act §27 mandates the police as the responsible actor in disaster situation, however that all parties that is involved participate through rescue management. The rescue management have two levels, national and regional. The Chief of Police in the region (two of the regions are designated as national rescue management) is also leader of the rescue management. The rescue management is the arena of coordination and information sharing between the involved actors of the incident, such as civil defence, military, coast guard, volunteers, regional authorities

Question 6.5 Which authorities (or departments) are responsible for developing economic recovery plans after a disaster in the testbed - and what procedures do they follow?

The procedure is that the independent enterprises of the municipality will address their needs to their sectors, which will address it to the city government where a political decision will be made. At a national level it is similar where the government will usually create finance packages for municipalities affected, based in needs proposed.

Question 6.6. What are the strengths and weaknesses of the ways in which disaster risks are currently managed in this testbed?

Strengths	Every agency has better understanding and awareness of their own responsibilities and capabilities in incidents as risk owners. This provides opportunity to better utilize all resources available in a crisis.
Weaknesses	Requires higher degree of coordination and cooperation

Section 7: Managing Resilience & Capacities

Definition of capacity: the combination of all the strengths, attributes and resources available within an organisation, community or society to manage and reduce disaster risks and strengthen resilience (Source: UNDRR). **Definition community resilience**: The ability of a community to prevent, prepare for, respond to, and recover from disasters.

Question 7.1: Please answer for each item in the table below, which authorities (or departments) are responsible for the governance and management of capacities and resilience in this testbed. Where available, please provide links or references to their procedures.

Urban development	Example: use of hazard scenarios	Write your answer, or insert a reference / link. Planning and building act The municipal plan, area part - https://www.oslo.kommune.no/politikk/kommuneplan/kommuneplanens-arealdel/ Planning and building agency
Infrastructure Housing, transport, power, water, communications, etc.	Example: adherence to the building code	Write your answer, or insert a reference / link. Planning and building act The municipal plan, area part - https://www.oslo.kommune.no/politikk/kommuneplan/kommuneplanens-arealdel/ Planning and building agency
Natural buffers	Example: environmental protection legislation	Write your answer, or insert a reference / link. Planning and building act The municipal plan, area part - https://www.oslo.kommune.no/politikk/kommuneplan/kommuneplanens-arealdel/ Planning and building agency
Institutional capacity Local authorities, first responders	Example: training in disaster management	Write your answer, or insert a reference / link. Agency of emergency preparedness Overall municipal risk assessment https://www.oslo.kommune.no/egenberedskap/kommunens-arbeid-med-samfunnssikkerhet-og-beredskap/
Societal capacity	Example: public awareness campaigns about hazards	Write your answer, or insert a reference / link. Agency of emergency preparedness Citizen preparedness campaign – yearly basis https://www.oslo.kommune.no/egenberedskap/
Economic capacity	Example: support to business organisations	Write your answer, or insert a reference / link. All municipal enterprises analyse their needs and propose to the City Government who address to City Council what kind of effort and extent is needed.

Section 8: Decision Making Tools for Disaster Risk Management

Question 8.1 What tools does this testbed currently have to inform decision making in disaster risk management? Do these tools focus on the short-term, the medium-term or the long-term? What are their strengths and weaknesses?

Current tools	Focus short-term, medium-term, or long-term	Strengths	Weaknesses
Write your answer, or insert a reference / link	Overall municipal risk assessment Long term – governance tool Short term – knowledge sharing	Overall digestible information for decision makers and professionals	Does to a very low degree specify measures
Write your answer, or insert a reference / link	Oslo municipal preparedness system Long term – Governance tool Short term – Incident handling tool	Address every agency and responsibilities systematically	
Write your answer, or insert a reference / link			

Question 8.2 What recommendations do you have for future disaster risk management tools to be developed?

Dynamic risk tools that creates awareness and enable handling for responders as well as central crisis management.

Section 9 Evaluations of Disaster Risk Management Plans

Question 9.1. Please insert links or references to publicly available formal assessments of this testbed's disaster risk management plans (in any language).

Not available.

Please look at the overall municipal risk assessment (short version public)

https://www.oslo.kommune.no/getfile.php/13433175-1642068044/Tjenester%20og%20tilbud/Politikk%20og%20administrasjon/Egenberedskap/BER_Kommunalt%20Risikobilde%202021_Kortversjon_030122.pdf

Please find evaluation reports from covid-19 crisis management here:

https://www.oslo.kommune.no/koronavirus/evaluering/

Evaluation report from all agencies, districts, departments, municipal undertakings and a summary report

Question 9.2. Does this testbed use any participatory approaches to evaluate disaster risk management plans? (for example, through serious games).

Write your answer, or insert a reference / link The municipality have adopted the national preparedness principles into their governing documents. Principle 4 demands cooperation between actors with stakes and/or capacities in incidents. The principle extends beyond response, such as planning, mitigation and consequence. Every agency should work in cooperative approach at all times in DRM. Agency of emergency preparedness audits all municipal enterprises where preparedness plans is subject to possible audit. Development of overall risk assessments and overall preparedness system will be subject to hearings where all municipal enterprises and relevant cooperating external actors can provide input for revisions.