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CORE

sCience and human factOr for Resilient sociEty

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Authoring & Approval

Authors of the document	
Name/Beneficiary	Position/Title
Dilanthi Amaratunga (HUD)	Work Package Lead
Richard HaigH (HUD)	Work Package Lead
Malith Senevirathne (HUD)	Research Assistant
Adriano de Acutis (INFC)	Task 3.2 contributor
Vittoria Nacarlo (INFC)	Task 3.2 contributor
Stefano Zanut (INFC)	Task 3.2 leader
Sofia Karma (ISSNOVA)	Task 3.2 contributor
Consuelo Agnesi (ISSNOVA)	Task 3.2 contributor
Giovanni Gugg (ISSNOVA)	Task 3.2 contributor
Gabriella Duca (ISSNOVA)	Task 3.2 contributor

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Approved for submission - Representatives of beneficiaries involved in the project		
Name/Beneficiary	Position/Title	Date
Paolo Capuano	Project coordinator	28/02/2023
Monica Crisan (CRI)	Reviewer	28/02/2023
Nadejda Komendatova (IIASA)	Reviewer	28/02/2023

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Executive summary

The complexity of disaster risk assessment processes makes the planning for disaster risk reduction more challenging in multiple dimensions. Such dimensions rely on the diversity of hazards, vulnerability, risk awareness, safety culture, and social and scientific trust. At the European scale, the risk characteristics are driven by interdependent urban-rural systems and environmental inter-linkages. Further, the vulnerable categories are compounded by risks such as climate change, terrorism, pandemics, industrial accidents, and cyber-attacks. The lessons learned by the COVID-19 and civil disputes in Europe explain that risk is systemic, and the effects of crises are cascading. Disasters can trigger more disasters in related areas while jeopardizing human lives in vulnerable categories. Therefore, the need to strengthen disaster resilience is widely recognised at the level of European municipalities, member states and agencies, which must consider the diversity of European society, and the variability of human factors. This requires transdisciplinary research conducted in relevant case studies involving the social and scientific communities. Under this viewpoint, this report aims to illustrate the analysis of past disasters via the identified case studies (listed in the methodology section) on their disaster preparedness strategies. The methodological approach consists of a scope of scientific knowledge, case studies from an earthquake, tsunami, flood, terrorist attacks, industrial accidents, COVID-19, and institutional and social trust including a variety of personal and cultural variables. The task analyses in depth procedures and protocols adopted in all the past cases by policy makers on preparedness planning, and first responders' perspective during the emergency to understand population response. Cases analysed will be in the following countries: Italy, Germany, Israel, Japan. There is much that can be learned from these specific case studies that were carefully selected with a high level of risk of natural hazards, including Japan with high levels of risks of earthquakes, volcanic events, and tsunamis) and where risk awareness is high. The outcome of the research can support the human, social, societal, and organisational aspects of environmental and anthropogenic risks.

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Acronyms

AI - Artificial Intelligence

Apps - Applications

ADA - The Americans with Disabilities Act

BGI – Blue-Green Infrastructure

CBRN - Chemical, Biological, Radiological and Nuclear

CCA – Climate change adaptation

CORDIS - Community Research and Development Information Service

CRPD - Convention on the Rights of Persons with Disabilities

CVI - Critical Vulnerability indicator

DRR - Disaster Risk Reduction

DG-ECHO - Directorate-General for European Civil Protection and Humanitarian Aid Operation

DT – Digital twin

EM - Emergency Management

EU - European Union

ICF - International Classification of Functioning, Disability and Health

iDMS - The Internal Displacement Monitoring Centre

IDR - Integrated disaster resilience

Mw - Moment magnitude

Natech - Natural Hazards Triggering Technological Accidents

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NbS – Nature based solutions

NGOs - Non-Governmental Organizations

PT – Physical Twin

PPE - Personal Protective Equipment

RBPA – Risk-Based Planning Approach

rescEU - The European Commission upgraded the EU Civil Protection Mechanism and created rescEU to protect citizens from disasters and manage emerging risks

RDT – Risk-informed digital twin

SFDRR – Sendai framework for disaster risk reduction

UAVs - Unmanned Aerial Vehicles

UGVs - Unmanned Ground Vehicles

UNDRR – United nation's office for disaster risk reduction

UNISDR – The United Nations (UN) International Strategy for Disaster Reduction Secretariat

UNHCR - The United Nations Refugee Agency

VS - Versus

WIN DRR - Women's International Network for Disaster Risk Reduction

WUI - Wildland Urban Interface

WP – Work package

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1 Introduction

1.1 CORE Project - 'sCience and human factOr for Resilient sociEty

The CORE project funded by the Horizon 2020 program investigates such complex characteristics in the EU countries and the transversal social groups, to develop a harmonized resilience approach for strengthening the crisis management capacities of EU countries via the involvement of transdisciplinary social and scientific communities. Under the CORE approach, this research aims to develop a comprehensive methodology to review and evaluate the diversity in risk perception, and past preparedness and risk governance strategies within and outside Europe to develop a comprehensive community resilience strategy.

1.2 Work package number 3 - Community resilience in selected past crisis (WP3).

The work package (WP) has the main objective to develop a community resilience strategy. The WP will compare plans and procedures associated with past disaster events of different countries (Italy, Germany, Israel, Japan) to understand people response and identify possible protocols pitfalls. An inclusive approach will be used, taking particular care of typical vulnerable categories. Using the previously identified (in WP2) case studies from previous natural and manmade disasters, to conduct a thorough and in-depth analysis to extract lessons learnt from the perspective of community resilience, this WP3 will have the following objectives:

- Better understanding and implementation of new technologies, media and tools, and their capacity to raise disaster risk awareness, to improve citizen understanding of risks, and thereby to build a culture of risks in society for different disaster scenarios (natural hazards, industrial disasters, terrorist threats) involving different actors, including first responders, city authorities and citizens, in the identified cases.
- To explore the cultural diversity, tangible and intangible cultural heritage, traditional know-how, land use, construction technologies, and other local knowledge as a valuable source of information for the local communities that can help prevent the creation of new risks, to reduce existing risks, to prepare for and to respond to disasters and to build back better.
- To understand how governments and civil society organisations implement policies for mitigating risks, preparing for, reacting to, overcoming, and learning from disasters at the community level.
- To propose new approaches and strategies for community awareness, for leadership, and for disaster readiness and management with a particular emphasis on the use of new technologies.

1.2.1 Underlying tasks in the Work Package No 3

- Task 3.1 Past events and preparedness strategy

Analysis of past disasters via the identified case studies (listed in the methodology section) on their disaster preparedness strategies. The task will analyse in depth procedures and protocols adopted in all the past cases by policy makers on preparedness planning, and first responders' perspective during the emergency to understand population response. Cases analysed will be in the following countries: Italy, Germany, Israel, Japan. There is much that can be learned from these specific case studies that were carefully selected with a high level of risk of natural hazards, including Japan with high levels of risks of earthquakes, volcanic events, and tsunamis) and where risk awareness is high.

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- Task 3.2 Disaster risk reduction & vulnerable categories

Analysis of vulnerable categories based on the experiences of past cases will be performed. The analysis will be made in the following countries: Italy, Germany, Israel & Japan and the risk perception of those categories and their level of preparedness will be analysed. Furthermore, a framework for vulnerable social groups mapping will be created to be used by the social department of the interested municipality.

- Task 3.3 Cultural Heritage

We will study tangible and intangible cultural heritage, traditional know-how, land use, construction technologies, and other local knowledge which is a valuable source of information for the local communities that can help prevent the creation of new risks, to reduce existing risks, to prepare for and to respond to disasters and to build back better, in all the identified/ selected cases. Accordingly, this task is concerned with improving the understanding of human-environment interactions using historical data, inherent vulnerabilities, tipping points and critical thresholds. Accordingly, community knowledge will be captured using narratives in addition to exploring natural hazard histories from communities (oral histories) with close practical collaboration with poor and marginalised populations at risk. Moreover, this task is also concerned with comprehending indigenous knowledge on early warnings, relationships across technology, livelihoods, social and cultural relations in relation to formal and informal risk-reduction activities.

- Task 3.4 Risk governance strategy

The resilience of societies heavily depends on how governments and civil society organisations design and implement policies for mitigating risks, preparing for, reacting to, overcoming, and learning from disasters. Accordingly, this task will investigate the existing governance structures associated with the interface of identified hazards within the identified case scenarios, and how the information is shared, and decisions are coordinated from national to local level (vertically), and across local governance level (horizontally). Accordingly, gaps in the governance of mitigating risks, preparing for, reacting to, overcoming, and learning from disasters will be identified and the factors on how local governments can be empowered, and governance can be reformed to ensure successful implementation at the local level. A risk governance strategy with the aim to engage all society will then be developed. The task will provide direct input towards enhancing preparedness for possible future disasters taking particular attention to the decision-making to be inclusive and risk-informed for potential affected populations.

- Task 3.5 Community resilience strategy

To enable an effective response from affected populations, to improve functional organisation in most fragile and vulnerable environments, and to increase the resilience of health services, social services, education, and governance, in line with target (d) of the Sendai Framework on critical infrastructure and disruption of basic services, a community resilience strategy will be developed. resilience strategy. Accordingly, a resilience building up approach will be developed, a disaster will be simulated, and all phases of the disaster cycle will be considered. Role of participants.

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1.3 Deliverable No: 3.1 Critical analysis of past disasters

The aim of this deliverable is to identify the preparedness strategies of the identified past events/case studies and their reference to the Sendai Framework priority targets. D 3.1 can be identified as the first out of four deliverables in the WP3.

The analysis of past disasters via the identified case studies on their disaster preparedness strategies includes the key lessons learned from the case studies mapped against the state-of-the art in the multi-hazard preparedness strategies and the SFDRR priorities for actions which was used as the underlying basis for deriving state-of-the art elements. The section also includes an analysis of vulnerable categories behaviour studies in the identified cases. The task analyses in depth procedures and protocols adopted in all the past cases by policy makers on preparedness planning, and first responder's perspective during the emergency to understand population response.

2 Analysis on Vulnerable Categories

Partner responsible for this section (Analysis on Vulnerable Categories 2): MINISTERO DELL'INTERNO, National Fire Corp. Department of fire-fighters, public rescue and civil defence, Italy (INFC)

2.1 Vulnerability taxonomy

2.1.1 Introduction

Based on the SENDAI framework and its priorities for action to prevent new and reduce existing disaster risks, it appears that one of the main goals towards this direction is to reduce exposure and vulnerability.

It should be noticed that disasters are not natural; this means that natural hazards such as floods, droughts and heatwaves become disasters because of vulnerability; we must acknowledge the human-made components of both vulnerability and hazard and emphasize human agency to proactively reduce disaster impacts [Raju, E., Boyd, E. & Otto, F., 2022].

According to UNDRR, vulnerability[1] is one of the defining components of disaster risk (Figure 1) [UNDRR, Vulnerability].

Figure 1: Vulnerability is one of the defining components of disaster risk (UNDRR)

[1] Vulnerability is defined in the Hyogo Framework for Action as: "The conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards". [SENDAI Framework 2015-2030]

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In that context, this work strives to provide with vulnerability taxonomy in the prospect of better understanding which factors may perform as precursors or inhibitors of vulnerability, but also contribute to manage it during a disaster or emergency situations. As a next step towards increasing communities' coping capacity, mitigation of the identified vulnerability precursors and reinforcement of available vulnerability inhibitors maybe used as a basis for effective disaster planning, management, and resilience policies.

According to the above, a Vulnerability Roadmap was prepared, where Critical Vulnerability Indicators (CVIs)-Vulnerability Drivers are indicated. The CVIs considered were categorized as follows:

- BACKGROUND: Inherent weaknesses/Default conditions, as well as Social & Economic status/Biases
- HUMAN: Environment interaction
- GOVERNANCE MODEL: Disaster Risk Management Policies and Approaches
- INSTRUMENTS/MEANS: Application of new Technologies and Modelling tools

Each of the above CVIs was analysed, as shown in the roadmap presented in Table 1. The CVI entitled "BACKGROUND: Inherent weaknesses/Default conditions" was subdivided into two different categories: "Personal factors/Communities" and "Environmental factors/Ecosystems", since interaction among communities and ecosystems is critical for assessing vulnerability.

Also, the CVI entitled "GOVERNANCE MODEL: Disaster Risk Management" was subdivided into two different categories: "Policies" and "Approaches".

In this roadmap, the interdependencies among all the CVIs are illustrated with the respective coloured arrows. It seems that the CVI entitled "INSTRUMENTS/MEANS: Application of new Technologies and Modelling tools" feeds the CVI entitled "GOVERNANCE MODEL: Disaster Risk Management".

The CVIs entitled "BACKGROUND: Inherent weaknesses/Default conditions" and "BACKGROUND: Social & Economic status/Biases" are considered as Vulnerability Precursors, whilst "GOVERNANCE MODEL: Disaster Risk Management Policies and Approaches" and "INSTRUMENTS/MEANS: Application of new Technologies and Modelling tools" as Vulnerability Inhibitors; grouping this knowledge may help policy makers first of all to take into consideration existing conditions that facilitate vulnerabilities, as well as methods and procedures to mitigate them.

In any case, the main issue to deal with vulnerability based on the interdependencies shown in Table 1 is to pay attention to the human interaction with the environment as already mentioned above and this is explained via the CVI entitled "HUMAN-ENVIRONMENT INTERACTION".

To address different aspects of vulnerability and vulnerable groups, the WHO ICF (International Classification of Functioning, Disability and Health)[2] framework for measuring health and

[2] ICF proposes a "bio-psycho-social" approach to disability to provide a coherent perspective of the different dimensions of health at the biological, individual, and social levels. The medical perspective is visible in the upper part of the diagram, the social one in the lower part relating to the environment and the central area is the result of the relationship between

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disability at both individual and population levels was used as a reference; ICF provides a standard language and a conceptual basis for the definition and measurement of health and disability, as well as interaction with environment [ICF].

Figure 2, shows the interactions between the components of the ICF (WHO 2001:18). According to ICF, there is several environmental factors, meaning the physical, social, and attitudinal environment in which people live and conduct their lives, that can function either as barriers to or facilitators of the person's functioning. In our work this conceptual model was utilized, trying to be aligned with the international classification provided by the WHO. In that concept, the CVI entitled "BACKGROUND: Inherent weaknesses/Default conditions" indicated at the forthcoming roadmap, was subdivided into the two categories of "Personal factors/Communities" and "Environmental factors/Ecosystems".

Based on the Roadmap presented in Table 1 and the respective CVIs, there was an effort to tackle vulnerability Before-During-After a disaster as a further step, to identify possible limitations and gaps in disaster preparedness and response of different groups of people that may bring them in the position of being considered as "vulnerable groups" (see Table 2).

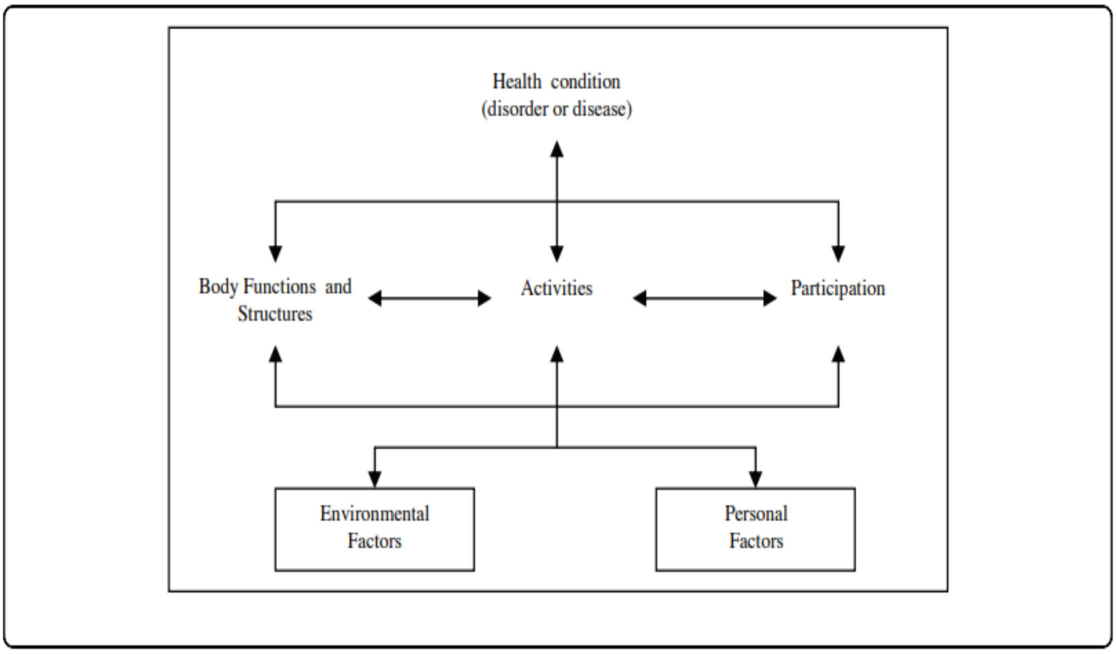

Figure 2: Interactions between the components of the ICF (WHO 2001:18)

health conditions and the environment. From this perspective disability is no longer an intrinsic characteristic of the individual, but a social condition imposed on some individuals than others, when the company in terms of facilities, tools and services is accomplished without keeping in mind the abilities of all individuals but only those of some considered "normal" and therefore "regulatory". The ICF propose a political and social reading of the disadvantage caused to persons with disabilities due to lack of resources, opportunities, or adaptations of the environment, provides the starting point for providing scientific validity to these concepts. It demonstrates when and with which entities the environment may cause restrictions in full participation of a person and what kind of environmental modification is needed to increase participation (remove obstacles/provide opportunities). From this point of view the function of the environmental factors which interact with the person and can, depending on the dimensional and qualitative characteristics, facilitate or not the performance.

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In that prospect, 10 basic vulnerability types that are under the umbrella of the CVIs of Table 1, entitled "BACKGROUND: "Inherent weaknesses/ Default Conditions - Personal factors/ Communities" and "Social & Economic status/ Biases", are thoroughly explained.

The idea was to investigate the default conditions (BACKROUND) since they are considered vulnerability precursors, providing the current situation in terms of response "Before-During-After a disaster" for the considered "vulnerable groups" and tackle which exactly conditions make these people vulnerable. It must be mentioned that the other two CVIs, namely the "GOVERNANCE MODEL: Disaster Risk Management Policies and Approaches" and "Application of new Technologies and Modelling tools" run horizontally all the ten categories, affecting the "HUMAN-INTERACTION with environment", based on the CVIs interdependencies shown in the vulnerability roadmap (Table 1).

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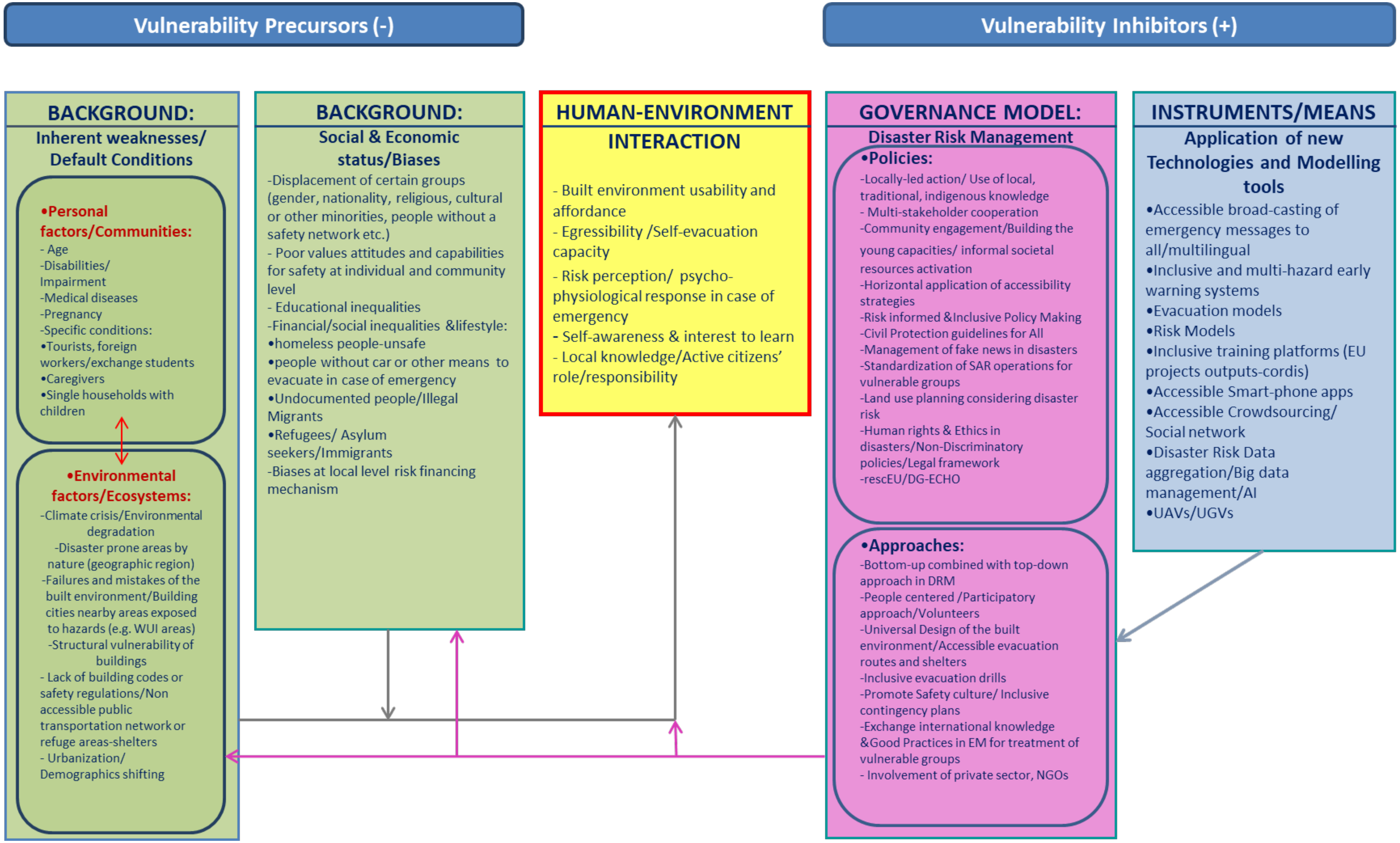
Table 1: VULNERABILITY ROADMAP

Critical Vulnerability Indicators (CVIs)-Vulnerability Drivers



2.2 Vulnerability Before-During-After: Methodology

2.2.1 General perspective

Having as a basis the Vulnerability Roadmap that provides with an overview of the so- called vulnerability drivers (vulnerability precursors and vulnerability inhibitors) presented in Table 1, there was an effort to explain why certain groups of people defined as "vulnerable groups" can be indeed vulnerable in case of a disaster, in the three phases: Before-During-After a disaster. The idea of answering this question per phase of a disaster was to be aligned with the concept of the Disaster Management Cycle (Figure 3).

Figure 3: Disaster Management Cycle

Table 2: Interconnection of Vulnerability "Before-During-After" a disaster with the CVIs presented in the Vulnerability Roadmap (Table 1) and the Disaster Management Cycle

DISASTER PHASES	BEFORE	DURING	AFTER
VULNERABILITY DRIVERS	Vulnerability Precursors and Inhibitors	Vulnerability Precursors and Inhibitors	Vulnerability Precursors and Inhibitors
	Human-Environment Interaction		
DISASTER MANAGEMENT CYCLE	**Preparedness-Prevention**	**Response**	**Recovery**
COPING CAPACITY/RESILIENCE	Governance Model/Instruments &Means		

Trying to answer the question "why these people can be considered vulnerable?" per disaster phase, can provide with valuable information for mitigating the vulnerability enablers and promoting the vulnerability barriers towards an effective Disaster Risk Management; vulnerability is the result of the decisions to make, so the CVI of Table 1 entitled "Governance Model "plays a major role in achieving disaster resilience.

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In the following paragraph there will be a thorough description of the Vulnerability analysis "Before-During-After" a disaster that will be presented in Table 3.

2.2.2 Explanation of the Vulnerability analysis "Before-During-After" a disaster

Under the perspective of creating a vulnerability taxonomy and with the vision to potentially be used by the relevant interested parties, like policy or decision makers, Table 3 shows the vulnerability analysis Before-During-After a disaster for selected "vulnerable groups". These groups are based on the different vulnerability types according to the so called "BACKGROUND" CVI, presented in the Vulnerability RoadMap (Table 1); specifically, the vulnerability types that will be analysed in Table 3 are under the "Inherent weaknesses/Default conditions" or the "Social & Economic status/Biases" of Table 1.

It has to be mentioned that the other two CVIs presented in the Vulnerability RoadMap (Table 1), namely the "GOVERNANCE MODEL: Disaster Risk Management Policies and Approaches" and the "Application of new Technologies and Modelling tools" (vulnerability inhibitors) run horizontally all the ten categories of vulnerability types, affecting the "HUMAN-INTERACTION with environment", based on the CVIs interdependencies shown in the vulnerability roadmap (Table 1). Moreover, the CVI "BACKGROUND"- "Environmental factors/Ecosystems" and "Social & Economic status/Biases" (vulnerability precursors), (Table 1) also run horizontally the ten vulnerability types; the idea is how to use the vulnerability inhibitors against the vulnerability precursors, namely the GOVERNANCE MODEL/INSTRUMENTS &MEANS vs the BACKGROUND (see Table 3) to minimize vulnerabilities.

Furthermore, it should be highlighted that in many cases the vulnerability might not be only of one type; it can be a combination of vulnerability types which may result to a synergistic effect in terms of the total disaster impact that should be taken into consideration in the disaster management cycle, e.g., disability and age. The ten vulnerability types selected are explained in the following:

2.2.2.1 Vulnerability per age

Age is indeed a factor that affects vulnerability and there is a need to be included in disaster risk reduction. Based on a recent study by the HelpAge International [Age Inclusive Disaster Risk Reduction– A toolkit], the Disaster Risk and Age Index foresees an increased frequency and intensity of disasters, in the context of a rapid process of population ageing; by 2050, there will be over two billion older people globally. Based to another study Grech, S. (2022) children and older adults with disabilities are often more vulnerable, may encounter barriers in evacuation, and require a set of support mechanisms in recovery.

In that context, in Table 3 we have identified different age groups and for each group we have described the reasons why they are considered vulnerable Before-During-After a disaster. Specifically, the groups created were:

a. (0-5 years old)

This category includes:

- Newborn (ages 0-4 week)
- Infant (ages 4 week - 1 year)
- Toddler (ages 1-3 years)

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- Preschooler (ages 3-5 years)

b. (6-18 years old)

This category includes:

- School aged child (ages 6-13 years)
- Adolescent (ages 14-18 years)

c. (19-29 years old)
- Young adult
- 1.4 (30-64 years old)
- Adult

d. (>65 years old)

This category includes:

- Youngest-old (ages 65-74 years)
- Middle-old (ages 75-84 years)
- Oldest-old (ages more than 85 years)

It has to be stated that the above categorization of the age groups was done to serve the needs of our work, which was to tackle the vulnerability factors Before-During-After a disaster and record the possible reactions of the different groups per disaster phase. Based on our research in the literature it seems that there is not a standard categorization of age groups.

For example, according to the Sendai Framework Monitor (SFM) 2021, the age groups are divided as: Children (0 – 14 years); Adults (15 – 64 years); and Seniors (65 years and older).According to Sasser (2005) children's reactions to disasters depend on their age and maturity and the proposed categorization is as that: Infant to 6 years old, ages 7-10, preteen and teen. Based to another study [ATM, 2016], childhood is structured in the following phases: New-born (up to 28 days of life -4 weeks), Infancy: (small child-1 to 24 months of age), Second childhood: (from 2 to 6 years), Third childhood: (from 6 years to the beginning of puberty), Puberty and Adolescence (from the onset of sexual characteristics up to approximately 22 years of age). The main issue is that these age groups are all linked to the presence of an adult because there is no autonomy of the child; childhood vulnerability needs to be considered carefully, especially 'after the disaster', to assess the possible impact on them. Generally, disasters affect children differently than they do adults; children are more likely to get sick or severely injured, either to lose too much body heat [CDC, 2020; Betty S. Lai and Annette La Greca, 2020].

Regarding the older people, based on the HelpAge International [Age Inclusive Disaster risk Reduction– A toolkit] the categorization is as that: young old: 60-69 years; Old: 70-79; Older old: 80 years and above. According to the same source, four key factors increasing the vulnerability of older people are: 1. Physical decline; 2. Age discrimination; 3. Inadequate services for older people; and 4. Poverty.

As already mentioned, vulnerability can be a complex issue when different vulnerability types exist at the same time, e.g., children with special healthcare needs (e.g., disabilities) or older

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people with disabilities. Age is linked to increasing difficulties in functioning; as populations age, the prevalence of disability will increase; by the age of 60, the major burdens of disability and death arise from age-related losses in hearing, seeing and moving, and non-communicable diseases; 43.6 per cent of older people have a disability with vision, mobility and hearing [Age Inclusive Disaster Risk Reduction– A toolkit].

As far as referred to the children, they have unique needs in emergencies, but care for children with special healthcare needs is often more complicated because of their various health conditions and extra care requirements. They may have a hard time moving from one place to another, as well as urgent or constant medical needs, difficulties in communicating etc. [CDC, 2021]. A disaster can have long-term effects on the mental and emotional health of all children; though, coping with a disaster can be particularly difficult for children with disabilities e.g., children who have serious emotional and behavioural problems are at high risk for severe stress after a disaster or traumatic event [Lai, B.S. et al, 2016]. As it is mentioned in Table 3, regular and on-going support by child psychologists is needed in the post disaster phase. More details regarding the vulnerability per type of disability is provided in the next paragraph.

2.2.2.2 Vulnerability per type of Disability/Impairment or Other diseases

Disability is considered a major vulnerability factor in disasters. Persons with disabilities are often disproportionally affected by disasters and have different and uneven levels of resilience and capacity to recover; due to inaccessible disaster preparedness plans, systemic discrimination, and widespread poverty, persons with disabilities are often left behind in relief and response efforts [UNDRR, Disability Inclusion in Disaster Risk Reduction]

For the needs of this work, the ICF framework explained in paragraph 1 was used as a basis to describe the vulnerability per Disability type, Impairment or Other diseases that will be showcased in Table 3. However, it should be mentioned that people with disabilities are not a homogeneous group and experience disability as well as disasters differently [Twigg et al., 2018; Grech, 2015]. For example, people with intellectual disabilities, people who are deaf or those with visual impairments, confront a different set of barriers and demands. Even people with similar disabilities can experience different sets of obstacles [Grech, S., 2022]. So, the heterogeneity of disability forced us to study thoroughly the vulnerability factors per different disability type and per phase of a disaster, Before-During-After, as shown in Table 3.

For this reason, it is important to take into account the complexity represented by human variability/diversity and all its nuances by having as a reference the spectrum of functioning: specific needs, different demands and capacities to respond to a critical situation, in relation to the context. And finally, consider all the variables encountered in the environment, devices and procedures that may hinder and/or facilitate individual performance and by, consequence, the collective response of the participants. And finally, considering human diversity in this key allows one not to make the mistake of reducing people with disabilities to standard representations even in disability: person with motor disability with wheelchair, person with visual disability with total blindness, and so on.

With reference to the emergency scenario, the table thus structured, helps to assess the difficulties in relation not only to disability but also to any other pathologies that may be associated and not only that, but the possibility also that individual capabilities may vary in the same person throughout the day as a result, for example, of an oncological condition. A deaf

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caregiver, a heart patient with other related critical issues, and so on. In this way all possibilities can be evaluated in the prevention and planning of all criticalities in relation emergency scenario before-after and during the emergency.

Finally, communication before-after-during the emergency plays an important role for all types of disabilities and beyond. Not perceiving the alarm or not understanding the content of the message itself, increase the vulnerability of deaf people, people with intellectual and/or cognitive disabilities, and more generally for all people. In reference to communication itself, a separate chapter should be made.

Communication before- during and after the emergency is a neglected aspect even though, there are clear data in relation to aspects of emergency communication and access to information channels and specific services, especially for people with sensory disabilities.

There are several situations, cases and contexts in which people with sensory disabilities are more vulnerable, such as when deaf people cannot perceive the messaging associated with the emergency because it is predominantly conveyed verbally or people with visual disabilities do not have access to escape routes or information because it is in paper format (as in the case of shelters) so much so that in a climate disaster situation, they are the people with the highest mortality rate (Fuji, 2015).

Therefore, all aspects related to the issue of pre-during and post-emergency communication are a cross-cutting element within the Table, as for one aspect or another, it makes more categories/types of people vulnerable. Just think, for example, of a child with intellectual disability or autism or more generally, of people who do not pay attention to the content of the message/alert or the caregiver who during the rescue, fails to interact with the rescuers. Finally, in the post-disaster period, when services are still lacking, new channels of communication and interaction must be developed to assist all people who become vulnerable because of the emergency.

Therefore, we have chosen to consider communication a cross-cutting element because at each stage, it plays a key role and proper planning of solutions can reverse the outcome, reducing vulnerability, as well as the duty to reach as many people as possible.

For example, in reference to considering communication in different modalities: deaf people were affected by the earthquake more than others, reporting a higher mortality rate (Fuji 2015). Here, deaf people could not perceive the messaging associated with the emergency because it was predominantly conveyed verbally. Or again, during the pandemic, all instructions and directions related to the management of the health emergency in the media, were not accessible through the Sign Language interpreter and/or subtitling and communication was in presence, entirely conveyed by masks that prevented lip-reading. Not only for deaf people but also for an elderly person and/or a child with cognitive disabilities who needs to communicate through body language and facial expressions. To meet the specific needs of human variability, communication must be declined in multiple modalities: multisensory, multichannel, and multimodal.

Devices, tools and whatever else can be developed to enable access to communication in all its forms to as many people as possible. Such as providing PECS to a child with autism to learn the steps of evacuation in an emergency, or a sound/visual and vibration alarm for a person who is

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deaf or deaf-blind, or even the dissemination of emergency-related content in multiple languages, such as Sign Language or that can be explored through touch.

Specifically, we have addressed the following Disability/Impairment types:

a. People with movement disability, e.g., lower, or upper limps impairment and/or body disability:
- Wheelchair users
- Users of walkers or canes

b. People with sensorial disability
- Deaf, Blind
- Deafblind

c. People with cognitive disabilities/Neurodevelopmental Disorders, e.g.:
- Intellectual Disabilities,
- Communication Disorders
- Autism spectrum disorder
- Learning disorder
- Down syndrome (Neurogenetic disorder) etc.

d. People with Schizophrenia and Other Phychotic Disorders, e.g.:
- Depressive disorder
- Bipolar disorder
- Anxiety disorder
- Epilepsy, etc.

e. People with Neurodegenerative disorders or neurological problems, e.g.:
- Alzheimer disease (dementia)
- Parkinson's disease
- Multiple sclerosis
- Fibromialgia etc.

f. Substance-Related and Addictive Disorders, e.g.
- Alcohol use disorder
- Drug addiction etc.

g. People with other diseases, like:
- COVID-19
- Hidden disabilities (i.e. early stage illness such as dementia, SLA, of chemo-therapy patients)
- Chronic disease e.g., respiratory problems (asthma), high blood pressure disorders, diabetes, allergies etc.

It has to be noticed that service dogs can also be seen as part of emergency plans for people/children with disabilities or older people; service dogs are generally trained to assist individuals with disabilities so that they are more able to participate into their daily activities. Moreover, it has to be highlighted that emergency shelters need to be completely accessible to people with service animals so they should not refuse to allow their assisting dogs [ADA, Service Animals in Emergency Situations].

Finally, the communication of an emergency is strategic for the activation of a right response by people involved, whether these are in open or circumscribed environments (schools, cinemas, workplaces, etc.). The signal must be effective perceived and interpreted correctly by any person

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and it must produce the expected response. This topic is dealt also the Convention on the Rights of Persons with Disabilities (CRPD).

Effective mean that some parameters have to be considered with attention:

- The first one is certainly the timeliness, to have the ability to alert the people involved in emergency from its inception, that is before the development of environmental conditions forbidding for people; this timeliness, designed as technological performance, is synergistically related to other factors:
- all have to be reached by communication, for example through multi-channel means (messaging, internet, loudhailer, etc.).
- according to individual needs, all have to be appropriately reached by multisensorial communication (sound signals, vocal or text messages, other means able to arrive to people with specific needs such as deaf, blind or partially sighted people, dyslexics, persons with cognitive deficits).
- all have to understand the content of communication (accessible information).

Communication, especially of the alarm, is not only a multi-sensory issue. The matter is that, according to required performances, some survey parameters - based on specific needs - can be set to measure the effectiveness of system, to find any critical issues and to propose alternative and/or supplementary solutions.

The contents (language) of sender's message and the medium of communication (means and devices) must be analysed, but a receiver/person with a specific need has to be considered as an "input unit" and as a "feedback screening indicator", instead of a "standard unit" without specific needs.

These themes are also found in the "emergency communication", as for the way of relationship established between who manages a critical situation (i.e. the first responders as firefighting workers and then the fire brigade rescuers) and who needs to be helped. The specific needs of any individual must be carefully considered in the training programs and in the operative procedures of rescuers [Romano, A. Porcu, L. Manselli, M. Battaglia, S. Zanut, 2019].

h. People after surgery or accidents
- Temporary disability (movement, sensorial, etc.)
- Permanent disability (movement, sensorial, etc.)

The above categories, namely c, d, e, and f are under the umbrella of mental disorders [DSM-5-TR, 2022]; DSM-5-TR, the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition, Text Revision, is the most comprehensive, current, and critical resource for clinical practice available to today's mental health clinicians and researchers.

Tackling different types of disabilities or impairments is quite important especially for the post disaster treatment; For example, they might be different needs for assistive devices and this fact has serious implications in planning (e.g. of evacuation and shelters), as well as budget and resources to make sure they are available [Grech, S., 2022].

Mapping health care and medication requirements per type of disability/impairment and integrating them in the response mechanisms may reduce the exposure of those people and at

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the same time increase their ability to recover-Build-Back-Better from a disaster. Also, geographical location of shelters and their accessibility is crucial to reduce vulnerability for people with disabilities/impairments and this can be achieved through the correct Governance Model for Disaster Risk Management, as shown in the Vulnerability Roadmap presented in Table 1 (Disaster Risk Management Approaches: Universal Design of the built environment/Accessible evacuation routes and shelters).

2.2.2.3 Vulnerability due to Pregnancy

Another type of vulnerability which is included in Table 3 is that due to pregnancy. Pregnant women are particularly vulnerable to disasters; they're often an afterthought in disaster preparedness, but them and their babies can be exposed to serious consequences after a catastrophic event; children born from mothers who experienced such an event, may have a different cognitive, neurobehavioral, psychosocial, and physiological profile; they can be more reactive, anxious, fearful, or likely to be aggressive [Meyers, 2019]. Based on another study, pregnant and postpartum women seem especially vulnerable after a Typhoon because they suffer from increased risk of physical and mental issues including pregnant related problems [Sato et al, 2016].

According to Meyers, 2019, combination of poor conditions and the extraordinary stress that pregnant women go through in a disaster affects them and their babies' vulnerability. Also, economic and social circumstances can play a substantial role in the final disaster impact, especially when poor pregnant women live in disaster-prone areas (see Table 1, Vulnerability Roadmap, CVI "Background- Environmental factors/Ecosystems").

Moreover, pregnant women usually have more sensitive immune system making them more vulnerable to diseases and they have demanding nutritional needs [Meyers, 2019]; these two factors should be taken into consideration especially during the post disaster treatment in the shelters. Also, the shelters should be accessible (by car or wheelchair) since many pregnant women encounter mobility difficulties. The need of an assistant during evacuation should also be considered. More information on caregivers or carers is given in the next paragraph.

2.2.2.4 Vulnerability of caregivers/carers

Before analyzing the vulnerability of caregivers/carers it is helpful to provide with the relevant definition:

A caregiver or carer is a paid or unpaid member of a person's social network who helps them with activities of daily living [Van Den Berg ET AL.2004]. Examples include children, the elderly, or patients who have chronic illnesses or are disabled [NIH].

According to ABS (2018), older people (>65 years old) in Australia were most likely to need assistance with health care (22.5%), property maintenance (20.0%), household chores (16.0%). Based on the same study, in 2018, primary carers most commonly provided care to spouse or partner (36.6%), their child (27.1%), a parent (26.2%); half of all primary carers said assisted or supervised the main person they cared for with the following core activities: mobility tasks (74.0%), self-care (56.5%), communication (54.1%).

It seems that caregivers should to be trained differently per need/type of disability of the person they assist. Focusing on disasters, the capabilities, preparedness and support needs of carers are crucial for their own vulnerability. Carers carry the load of supporting the persons in need that

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they take care of and in case of an emergency they need to decide effectively and act promptly not only for themselves but also for their assistants. Also, they are responsible not to abandon their assistant in case of a disaster Before-During-After and the need for evacuation, ensuring safety for both of them, though this cannot always be possible. All these factors make them vulnerable, e.g., according to Patton et al., carers of people with disability (especially if they are parents of children with intellectual disability) experience higher levels of stress and mental ill health, such as anxiety and depression during and following a disaster.

Caregivers can generally play a critical role in disaster risk reduction and should not be overlooked; they can be disproportionally affected by disasters like the persons they take care of, e.g., people with disabilities. Inclusive training per type of disaster, evacuation drills and inclusive contingency plans can be used as an effective Disaster Risk Management Approach (See Table 1, CVI “Governance Model”).

2.2.2.5 Vulnerability of tourists, foreign workers/exchange students

Tourists or foreign workers are considered vulnerable in case of a disaster mainly because they don’t speak the local language. This may result to limited understanding of the emergency messages in a foreign country, as well as of the emergency signs, labels, escape plans; as a result, they may be not able to reach a safe refuge area in due time. Based on a study by E.Rindrasih et al., 2018 lack of awareness and understanding of the actions that they need to take in such circumstances make tourists vulnerable. According to the same study, tourists are not a homogeneous group, but they can be considered a complex, diverse, and dynamic body of stakeholders; the focus of disaster management planning should shift from a single rationale to a poly rational methodology and hence, disaster managers need to consider all the above aspects in the context of preparedness.

According to the above, risk communication in terms of accessibility of the broadcasted emergency messages (multilingual), as well as Inclusive and multi-hazard early warning systems are vital to reduce vulnerability (see Table 1, the CVI entitled “INSTRUMENTS &MEANS/Application of new Technologies and Modelling tools”). Based on a recent study dedicated to the wildfire event that occurred in the Rhodes Island, Greece in summer 2021 and specifically nearby the popular touristic destination of the “Valley of Butterflies”, the tourists or foreign visitors of the “Butterflies Valley” could be considered as a vulnerable group in case that early warning and understandable messages were not sent on-time to guide them during the evacuation [S.Karma et al , 2021].

Moreover, the language restriction is the main reason of limited communication capacity with the rescuers during the response phase. Concerning the post disaster phase foreign people may need to contact with relatives abroad, and embassies of home countries.

2.2.2.6 Vulnerability of homeless people

Homelessness is a growing problem, with perhaps greater than a 150 million homeless people globally, also including families with children; the global community has prioritized the problem as one of the United Nation’s sustainability goals of 2030 [Morris, S., 2020].

Homeless people are often the first and most severely affected group during disasters [Gin, June L., 2022]. Based on the same study this group was the one encountered major problems during COVID-19, but also in case of hurricanes, and wildfires; this is mostly because their limited

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resources, social isolation, lack of access to housing and other material needs, and a high prevalence of disabilities, chronic physical conditions, and behavioral health needs. All the above obstruct them from undertaking individual disaster preparedness measures or to shelter in place during and after a disaster.

Incorporating homeless populations into disaster preparedness, planning, and response have been recently tackled in order to develop tools and strategies for communities to include homeless people in disaster planning [Gin, June L., 2022]. According to the same study, the result was “A toolkit—Disaster Preparedness to Promote Community Resilience”; the Homeless Toolkit is divided into 3 sections: section 1—creating an inclusive emergency management system; section 2—guidance for homeless service providers: planning for service continuity; and section 3—guidance for health care providers.

Vulnerability factors for homeless people Before-During-After a disaster are provided in Table 3. It has to be mentioned that in the post disaster phase, psychological recovery of homeless people can be influenced by pre-existing mental illness, substance abuse disorders, and poor physical health that may arise from the experience of homelessness and inadequate systems of care [Ramin & Svoboda 2009]. Based on a review article on “Can homeless people afford resilience?” it seems that there is limited research to build evidence-based programs and it is recommended that further research be conducted on disaster management inclusion of homeless people that building resilience through ongoing social and economic inclusion [Every D. and Thompson K.,2014].

2.2.2.7 Vulnerability of discriminated people

Discrimination in disasters, e.g., due to gender, sexual identity, nationality etc. can be a critical vulnerability factor. This is especially true when we are talking about combined vulnerability types, e.g., gender and disability. For example, women with disabilities may encounter a number of barriers on the basis of their disability and their gender, including problems in evacuation, accessing health care in disaster response, etc. [Emmett and Alant, 2007].

The most important thing is that due to social drawbacks towards these groups that are considered minorities, they are usually excluded from training on early warning systems. However, women for example can play a critical role in DRR; it is important to remember that the majority of caregivers (see previous paragraph for the vulnerability of caregivers) for people with disabilities are in fact women and who may themselves encounter barriers to fast evacuation and accessing other disaster response and relief services [Ryan and Runswick-Cole, 2007]. Nowadays, the Women’s International Network for Disaster Risk Reduction (WIN DRR) aims to empower women and enhance their role in decision-making in disaster risk reduction in the Asia-Pacific region by promoting and supporting women’s leadership; WIN DRR is supported by UNDRR and the Government of Australia [WIN DRR].

2.2.2.8 Vulnerability of people without a social safety network/Internally displaced people

People without a social safety network or internally displaced people are considered quite vulnerable in disasters, as shown in Table 3Table 3.

First of all, “Internally Displaced Persons” are defined as: “people or groups of people who have been forced or obliged to flee or to leave their homes or places of habitual residence, in particular as a result of armed conflict, or to avoid the effects of armed conflict, situations of generalized

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violence, violations of human rights, or natural or human-made disasters and who have not crossed an international border" [The Internal Displacement Monitoring Centre].

According to the same source, "New Displacement" refers to the number of new cases or incidents of displacement recorded over the specified year, rather than the number of people displaced. This is done because people may have been displaced more than once.

Based on the IDMC's Global Report on Internal Displacement 2022, special focus is given on internally displaced children and youth [GRID 2022]. It seems that disasters hit areas already affected by violence and displacement, leaving millions of people to cope with acute food shortages and creating a domino effect of vulnerability and displacement [OCHA, 2022]

According to a recent good practice review [S. Barrett, D. Steinbach and S. Addison, 2021], climate-related disasters that are becoming more frequent and intense the recent years, such as heatwaves and wildfires, flashfloods etc. put millions of people at risk of displacement. Based on the same study social vulnerability is a key displacement risk factor that needs to be well integrated into assessment tools; local-level resilience measuring methods can be used to analyze displacement risk, such as collecting relevant data and integrate them into risk models (see Table 1, CVI "INSTRUMENTS/MEANS- Application of new Technologies and Modelling tools).

2.2.2.9 Vulnerability of Undocumented people/Illegal Migrant

As already mentioned, the climate crisis has forced the communities into adapting to the increased threat of certain hazards like wildfires, drought, heatwaves, and infectious diseases that may cause disasters which are expected to become more frequent and severe in the future. This fact amplifies existing social or economic inequalities and increases vulnerability of groups like the undocumented people/illegal migrants, as shown in Table 3Table 3Table 3.

According to the terminology, Illegal immigrant is someone who lives or works in another country when they do not have the legal right to do this; this term is considered offensive by many people, so the term undocumented immigrant or undocumented person can be used instead. Migrant = temporary movement, Immigrant = permanent residency [Oxford Dictionary].

It is important to mention that one of the main differences between this group of people compared to the legal migrants or immigrants is that it is difficult to be identified during the search and rescue process because they are undocumented (they do not exist at any data-bases). Based on a recent study, undocumented Latino/a, and indigenous immigrants are considered significantly vulnerable to disasters because they are disproportionately affected by racial discrimination, exploitation, etc. in their everyday lives before the disaster [Méndez M, 2020]. Special consideration in disaster planning Before-During-After a disaster is needed to protect the most vulnerable and stigmatized populations, e.g., record their needs, protect their rights, and access to emergency information, since there is the language drawback. Locally led action to engage these people into disaster management cycle and the use of local, traditional, indigenous knowledge can be a significant asset for strengthening disaster resilience (see Table 1, CVI GOVERNANCE MODEL: Disaster Risk Management Policies).

2.2.2.10 Vulnerability of Refugees/ Asylum seekers/Migrants

Migrants, asylum seekers and refugees constitute a significant and growing proportion of the general population of the European Countries. More than 60 million people in a global basis, including refugees and internally displaced persons, are forcibly displaced by conflict, violence,

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disasters, and human rights violations [CoE, Migrants]. Here are the terminologies based on the United Nations Refugee Agency:

Refugee: A person who meets the eligibility criteria under the applicable refugee definition, as provided for by international or regional instruments, under UNHCR's mandate, and/or in national legislation

Aslyum keeper.:An individual who is seeking international protection. In countries with individualized procedures, an asylum-seeker is someone whose claim has not yet been finally decided on by the country in which the claim is submitted. Not every asylum-seeker will ultimately be recognized as a refugee, but every refugee was initially an asylum-seeker.

Migrants: Persons who leave their countries purely for economic reasons unrelated to the refugee definition, or in order to seek material improvements in their livelihood. Economic migrants do not fall within the criteria for refugee status and are therefore not entitled to benefit from international protection.

The above groups are considered more vulnerable in disasters first due to their limited access to information (see Table 3). Usually, they don't understand the language of the country where they are displaced, and hence they cannot be aware of risks familiar to locals. Their vulnerability is increased in case their living conditions are below average (e.g. refugee camps, marginal settings nearby hazard-prone areas) or if, as a consequence of their situation, they have poor health, relatively low education, etc. [CoE, Migrants].

Based on the priorities of the Sendai Framework for Disaster Risk Reduction 2015-2030, EUR-OPA Major Hazards Agreement, is promoting improvements in emergency planning, disaster response and risk mitigation for migrants, refugees and asylum seekers; specifically, by recommending strategies to reduce migrants' vulnerability and exposure to risks; by improving co-ordination between civil protection and other agencies to support these groups; by exchanging good practices for enhancing young people engagement in civil society and in all phases of the disaster risk management cycle, as well as actions for engaging with migrants and using their skills and capacities for disaster risk reduction [CoE, Migrants; B.Pauvert, J.Twigg, S.Sagramola, 2016]. Aligned with this concept, "Horizontal application of accessibility strategies", "Risk informed &Inclusive Policy Making", "Civil Protection guidelines for All" etc. are some of the suggested disaster risk management methods based on Table 1 (CVI, "GOVERNANCE MODEL") to combat such vulnerabilities.

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Table 3: Vulnerability analysis Before-During-After a disaster

N.	Vulnerability Types	BEFORE A DISASTER	DURING A DISASTER	AFTER A DISASTER
		Why certain groups are considered vulnerable in disasters?		
1	**Vulnerability per age:** BACKGROUND: Inherent weaknesses/Default Conditions-Personal factors/Communities"			
	1.1 (0-5 years old)	▪ They are depended on their parents, relatives, babysitters, or any other helpers. ▪ They are not aware of risks. ▪ Limited interaction with environment ▪ Non or inadequate training of their supportive members in emergency preparedness/response	▪ None or limited understanding of the emergency risk /alarms ▪ None or limited evacuation capability on their own ▪ Inability or difficulty to reach safe places on their own	▪ Demanding recovery from disaster after-shock ▪ Regular and on-going support by child psychologists ▪ Medical support in case of injury ▪ Financial support needs ▪ Safe Shelter: food suitable for 0-5 years /water needs
	1.2 (6-18 years old)	▪ None or limited safety culture by their family or school environment ▪ Lack of training in emergency situations	▪ Limited risk perception due to lack of safety culture ▪ Lack of knowledge on how to react in emergencies/wrong decision making. ▪ Difficulty to evacuate or reach safe places. ▪ Difficulty into following guidelines by authorities/ cooperate with rescuers	▪ Regular and on-going support by child psychologists to recover from post- traumatic stress. ▪ Support by sociologists/social workers ▪ Medical support in case of injury ▪ Need to continue education, catch up with missing education program (relevant to longer time disasters). ▪ Financial support needs ▪ Safe Shelter: food /water needs
	1.3 (19-29 years old)	▪ Lack or limited risk awareness and safety culture due to inadequate education during their school life. ▪ Lack of training in emergency situations ▪ Feeling superficial/misjudgement	▪ Limited risk perception ▪ Lack of knowledge on how to react in emergencies/wrong decision making. ▪ Difficulty to evacuate or reach safe places. ▪ Difficulty into following guidelines by authorities/cooperate with rescuers	▪ Regular and on-going support by psychologists/sociologists ▪ Medical support in case of injury ▪ Social adaptation difficulties/affordance ▪ Working place adaptation difficulties/affordance ▪ Financial support needs ▪ Safe Shelter: food /water needs
	1.4 (30-64 years old)	▪ Lack or limited risk awareness. ▪ Lack of training in emergency situations	▪ Limited risk perception ▪ Lack of knowledge on how to react in emergencies/wrong decision	▪ On-going support by psychologists/sociologists ▪ Medical support in case of injury

		▪ Difficulty in gaining safety culture if not already trained like that in their school age	making. ▪ Difficulty or inability to evacuate and reach safe places. ▪ Difficulty into following guidelines by authorities/cooperate with the rescuers	▪ Working place adaptation difficulties/affordance ▪ Financial support needs ▪ Safe Shelter/food /water needs/access to medicine
1.5 (> 65 years old)		▪ Impairments/Difficulties: - Mental - Physical - Sensory - Mobility - Communication - Perception ▪ Physical decline ▪ Age discrimination ▪ Inadequate services for older people ▪ Poverty	▪ Limited risk perception ▪ Low accessibility/understandability of emergency messages ▪ Lack of knowledge on how to react in emergencies/wrong decision making. ▪ Difficulty or inability to evacuate and reach accessible safe places by themselves/possibly need help. ▪ Difficulty into following guidelines by authorities/cooperate with the rescuers	▪ On-going support by psychologists/psychiatrists ▪ Medical support in case of injury/ Difficult health recovery ▪ Financial support needs ▪ Safe Shelter/food /water needs/access to medicine
2.	**Vulnerability per type of Disability/Impairment or Other diseases:** BACKGROUND: Inherent weaknesses/Default conditions -Personal factors/Communities"			
2.1	People with movement disability	▪ Limited mobility capacity ▪ Inaccessible disaster preparedness plans ▪ Systemic discrimination ▪ Poverty	▪ Difficulty or inability to evacuate by themselves and reach accessible shelters	▪ On-going support by psychologists/sociologists ▪ Medical support in case of injury/ Paramedics and doctors are needed based on the specific type of impairment. ▪ Working place adaptation difficulties for those that work/affordance. ▪ Financial support needs ▪ Safe Shelter: food /water needs/access to medicine
2.2	People with sensorial disability (deafness, blindness, deafblind)	▪ Limited sensory capacity ▪ Inaccessible disaster preparedness plans	▪ Difficulty to perceive the emergency messages/alarms. ▪ Difficulty or inability to evacuate	▪ On-going support by psychologists/sociologists ▪ Medical support in case of injury/

		▪ Systemic discrimination ▪ Poverty	by themselves and reach accessible shelters. ▪ Difficulty to communicate and interact with the rescuers	Trained paramedics and doctors are needed based on the specific type of impairment. ▪ Working place adaptation difficulties for those that work /affordance. ▪ Financial support needs ▪ Safe Shelter: food /water needs/access to medicine
Mental Disorders 2.3	People with cognitive disabilities/Neurodevelopmental Disorders e.g.: - Intellectual Disabilities, - Communication Disorders - Autism spectrum disorder - Learning disorder - Down syndrome (Neurogenetic disorder) etc.	▪ Low risk perception ▪ Limited interaction with environment / communication ▪ Limited understanding of disaster risks ▪ Lack of awareness ▪ Inaccessible disaster preparedness plans ▪ Systemic discrimination ▪ Poverty	▪ Difficulty to perceive or comprehend the severity of an emergency or the need for evacuation. ▪ Difficulty to perceive or comprehend the emergency messages/alarms/signs. ▪ Difficulty or inability to evacuate by themselves and reach accessible shelters/Wrong decision making in case of emergency. ▪ Difficulty to follow authorities' guidelines and communicate/interact with the rescuers	▪ On-going support by psychiatrists/special treatment experts ▪ Medical support in case of injury/ Trained paramedics and doctors are needed based on the specific type of impairment. ▪ Financial support needs ▪ Difficulty in mental health recovery ▪ Working place or School adaptation difficulties/ affordance ▪ Safe Shelter: food /water needs/access to medicine
2.4	People with Schizophrenia and Other Phychotic Disorders (e.g., dipressive disorders or bipolar disorders, anxiety disorders, epilepsy, etc.)	▪ Limited interaction with environment / communication (hallucinations, delusions, and disordered forms of thinking) ▪ Seizures (functional neurological disorder) ▪ Problems in social adaptation ▪ Inaccessible disaster preparedness plans ▪ Systemic discrimination ▪ Poverty	▪ Difficulty to perceive or comprehend the severity of an emergency or the need for evacuation. ▪ Difficulty to perceive or comprehend the emergency messages/alarms. ▪ Limited interaction with environment ▪ Problems in communication with the rescuers	▪ On-going support by psychiatrists/neurologists ▪ Medical support in case of injury/ Difficult health recovery/special medical treatment ▪ Financial support needs ▪ Safe Shelter: food /water needs/access to medicine

			▪ Difficulties in movement in case of emergency evacuation	
Mental Disorders 2.5	People with Neurodegenerative disorders or neurological problems, e.g., Alzheimer disease (dementia), Parkinson's disease, Multiple sclerosis, fibromialgia etc.	▪ Cognitive impairment ▪ Difficulty in movement, bradykinesia, rigidity, resting tremor and posture instability. ▪ Problems in social adaptation ▪ Inaccessible disaster preparedness plans ▪ Systemic discrimination ▪ Poverty	▪ Difficulty to perceive or comprehend the severity of an emergency or the need for evacuation. ▪ Difficulty to perceive or comprehend the emergency messages/alarms. ▪ Difficulty or inability to evacuate by themselves and reach accessible shelters. ▪ Limited interaction with environment ▪ Difficulty to follow authorities' guidelines and communicate/interact with the rescuers	▪ On-going support by psychiatrists/neurologists ▪ Medical support in case of injury/ Difficult health recovery/special medical treatment ▪ Financial support needs ▪ Safe Shelter: food /water needs/access to medicine
2.6	Substance-Related and Addictive Disorders e.g., Alcohol use disorder, Drug addiction etc.	▪ Cognitive impairment (decreased coordination, difficulty in concentrating or remembering) ▪ Limited interaction with environment / communication (hallucinations, delusions, and disordered forms of thinking) ▪ Problems in social adaptation ▪ Inaccessible disaster preparedness plans ▪ Systemic discrimination ▪ Poverty	▪ Difficulty to perceive or comprehend the severity of an emergency situation or the need for evacuation ▪ Difficulty to perceive or comprehend the emergency messages/alarms. ▪ Difficulty or inability to evacuate by themselves and reach accessible shelters. ▪ Limited interaction with environment ▪ Difficulty to follow authorities' guidelines and communicate/interact with the rescuers	▪ On-going support by psychiatrists/psychologists/sociologists ▪ Medical support in case of injury ▪ Financial support needs ▪ Working place adaptation difficulties/ affordance ▪ Safe Shelter: food /water needs/access to medicine
2.7	People with other diseases, like COVID-19 or hidden disabilities, e.g., respiratory problems (asthma), high	▪ Limited mobility capacity ▪ Limited sensory capacity ▪ Medical treatment	▪ Difficulty or inability to evacuate by themselves and reach accessible shelters.	▪ On-going support by psychologists/sociologists ▪ Financial support needs

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	blood pressure disorders, diabetes, cancer, allergies etc.	▪ Inaccessible disaster preparedness plans ▪ Systemic discrimination ▪ Poverty	▪ Difficulty to communicate and interact with the rescuers	▪ Safe Shelter: food /water needs/access to medicine
2.8	People after surgery or accidents	▪ Temporary or permanent: - Limited mobility capacity - Limited sensory capacity - Limited interaction with environment / communication ▪ Inaccessible disaster preparedness plans ▪ Poverty	▪ Difficulty to comprehend the emergency messages/alarms. ▪ Difficulty or inability to evacuate by themselves and reach accessible shelters. ▪ Difficulty to communicate and interact with the rescuers	▪ On-going support by psychologists/sociologists ▪ Medical support in case of injury/Difficulty to recover from the surgery or accident. ▪ Working place adaptation difficulties after recovery/affordance ▪ Financial support needs ▪ Safe Shelter: food /water needs/access to medicine.
3.	**Vulnerability due to Pregnancy:** BACKGROUND: Inherent weaknesses/Default Conditions-Personal factors/Communities”			
	Pregnant women	▪ Limited mobility capacity ▪ Sensitive immune system ▪ Significant nutrition needs ▪ Not involved in disaster preparedness ▪ Poverty	▪ Difficulty or inability to evacuate by themselves and reach accessible shelters/Helper might be needed. ▪ Lack of knowledge or experience on how to react in emergencies/wrong decision making. ▪ Wheelchair or car might be needed to evacuate and reach the shelter.	▪ Post disaster stress/On-going support by psychologists/sociologists ▪ Medical support in case of injury or early birth by gynaecologists etc. ▪ Financial support needs ▪ Safe Shelter: food /water needs/access to medicine. ▪ Safe space for pregnancy and post-partum care for mother and child ▪ After-birth treatment for mother and baby
4	**Vulnerability of Caregivers/Carers:** BACKGROUND: Inherent weaknesses/Default Conditions-Personal factors/Communities”			
	Caregivers/Carers	▪ Lack of training on the specific type of need for the people they assist (e.g., infants, old people, or people with disabilities) ▪ Responsibility of taking care	▪ Lack of knowledge on how to react in emergencies and support the people they assist/wrong decision making. ▪ Engagement with the person	▪ On-going support by psychologists/sociologists ▪ Medical support in case of injury ▪ Working place adaptation difficulties after

		other people ▪ Depended on the people that they support	that they assist. ▪ Inability to help the rescuers	recovery/affordance ▪ Financial support needs ▪ Safe Shelter: food /water needs/access to medicine
5	**Vulnerability of tourists, foreign workers/exchange students:** BACKGROUND: Inherent weaknesses/Default Conditions-Personal factors/Communities"			
	Tourists, foreign workers /Exchange students	▪ Limited understanding of disaster risks in a foreign country ▪ Limited communication capacity due to language ▪ Limited or no understanding of signs, labels, escape plans due to language	▪ Limited understanding emergency messages in a foreign country ▪ Limited communication capacity due to language in case of emergency ▪ Limited interaction with the rescuers due to language or cultural specificities ▪ Limited or no understanding of emergency signs, labels, escape plans due to language that obstruct them from reaching a safe refuge area	▪ On-going support by psychologists/sociologists ▪ Medical support in case of i ▪ Financial support needs in cooperation with their Cou ▪ Safe Shelter: food /water needs/free access to medicine. ▪ Need to contact with relatives abroad, embassies of home countries
6.	**Vulnerability of homeless people:** BACKGROUND: Social & Economic status/Biases			
	Homeless people	▪ Directly exposed to environmental hazards ▪ Poor lifestyle ▪ Lack of safety culture ▪ Limited resources ▪ Social isolation ▪ Lack of access to housing and other material needs. ▪ Disabilities, chronic physical conditions, and behavioural health needs	▪ Lack of home/shelter that can be protected. ▪ Low accessibility to information and early warning ▪ Lack of knowledge on how to react in emergencies/wrong decision making. ▪ Difficulty or inability to evacuate by themselves and reach safe places. ▪ Difficulty to communicate and interact with the rescuers	▪ On-going support by psychologists/sociologists ▪ Medical support in case of injury ▪ Financial support needs/ difficulty to find a safe place to recover. ▪ Legal/therapy support if needed to re-integrate them back to society. ▪ Safe Shelter: food /water needs/access to medicine
7.	**Vulnerability of discriminated people, e.g., due to gender, nationality etc.:** BACKGROUND: Social & Economic status/Biases			
		▪ Gender and sexual identity social drawbacks ▪ Nationality based discrimination in education or training/ Lack of	▪ Lack of knowledge or experience on how to react in emergencies/wrong decision making.	▪ On-going support by psychologists/sociologists ▪ Medical support in case of injury ▪ Difficulties in

		safety culture. ▪ Limited engagement in disaster risk management	▪ Difficulties to interact with the rescuers	adaptation/Affordance ▪ Financial support needs ▪ Safe Shelter: food /water needs/access to medicine
8.	**Vulnerability of people without a social safety network/ Internally displaced people:** BACKGROUND: Social & Economic status/Biases			
	People without a social safety network/ Internally displaced people	▪ Exposure to certain risks ▪ Limited affordance	▪ Difficulty to perceive or comprehend the emergency messages/alarms. ▪ Difficulty or inability to evacuate by themselves and reach accessible shelters/need helpers. ▪ Difficulty to communicate and interact with the rescuers	▪ On-going support by psychologists/ sociologists ▪ No support by relatives, friends, or other people ▪ Medical support in case of injury/ Difficult health recovery ▪ Financial support needs ▪ Safe Shelter: food /water needs/access to medicine
9.	**Vulnerability of Undocumented people/Illegal Migrant:** BACKGROUND: Social & Economic status/Biases			
	Undocumented people/Illegal Migrants	▪ Relatively low education ▪ Lack or limited safety culture. ▪ Limited understanding of disaster risks ▪ Limited communication capacity ▪ Poor lifestyle/ Structural vulnerability of the dwellings they live/Poor health. ▪ Racial discrimination ▪ Exploitation	▪ Difficulty to perceive or comprehend the emergency messages/alarms because they don't understand the language. ▪ Difficulty or inability to evacuate by themselves and reach accessible shelters/need helpers. ▪ Difficulty to follow authorities' guidelines and communicate/ interact with the rescuers. ▪ Difficult to be identified during the search and rescue process because they are undocumented (no exist at databases)	▪ On-going support by psychologists/sociologists ▪ Medical support in case of injury ▪ Financial support needs/ difficulty to find a safe place to recover. ▪ Social welfare required. ▪ Legal support to get valid documents for social integration. ▪ Safe Shelter: food /water needs/access to medicine
10.	**Vulnerability of Refugees/ Asylum seekers/Immigrants:** BACKGROUND: Social & Economic status/Biases			
	Refugees/ Asylum seekers/Immigrants	▪ Relatively low education ▪ Lack or limited safety culture. ▪ Limited understanding of disaster risks ▪ Limited communication capacity	▪ Difficulty to perceive or comprehend the emergency messages/alarms because they don't understand the language.	▪ On-going support by psychologists/sociologists ▪ Medical support in case of injury ▪ Financial support needs/ difficulty to find a safe place to recover.

	▪ Racial discrimination ▪ Poor lifestyle (e.g., living at refugee camps, marginal settings nearby hazard-prone areas) ▪ Poor health	▪ -Difficulty or inability to evacuate by themselves and reach accessible shelters/need helpers ▪ Difficulty to follow authorities' guidelines and communicate/interact with the rescuers.	▪ Social welfare required. ▪ Safe Shelter: food /water needs/access to medicine/healthcare

3 Understanding disaster risk in line with global frameworks and case study analysis

The Sendai Framework for Disaster Risk Reduction 2015-2030 (SFDRR) is the first global policy framework of the United nation's post 2015 agenda. The SFDRR represents the direction of global policy coherence explicitly refereeing the health, building resilience, disaster risk reduction and climate change (Aitsi-Selmi et al., 2015). The SFDRR provides an evolved understanding of the systemic nature of disaster risk in the twenty first century. The resent research in disaster risk reduction (DRR) indicates the importance of understanding the systemic nature of disaster risk that could occur by multiple hazards while emphasising on the vulnerability, exposure, and ability of the population to anticipate, respond to, and recover from its effects. Therefore, a shift from the hazard-based response to the assessment and ranking of vulnerabilities and risks is a critical need in the current DRR decision making (Richard Eiser et al., 2012). This shift should consider the social determinants of risk that shape the local development and future trajectories with the assistance of science and technology. In this light, Ten Essentials for making cities resilient by UNDRR (2019) provides a comprehensive way forward by deepening the thinking around understanding and ability to influence disaster prevention and risk mitigation. The 10 essentials enable a comprehensive approach to address local risk governance, urban risk, and resilience via promoting awareness raising and commitment towards sustainable development practices. The essentials provide the foundation for understanding disaster resilience at the local level, based on the Hyogo Framework for Action.

With the launch of SFDRR in 2015 the Ten Essentials for Making Cities Resilient were modified and aligned to the priority actions provided by the Sendai Framework (Amaratunga et al., 2019). Pilot tests for the new Ten Essentials were conducted in 20 cities, and the Essentials were revised based on the feedback. The Ten Essentials are grouped under the four priorities of SFDRR for better understanding the linkage of city resilience needs with the DRR actions. All Essentials are related to each other to achieve disaster resilient cities. Also, to address the growing systemic risk of natural hazards understanding the novelties in DRR is a crucial need as current DRR strategies proven to be challenging when addressing the current state of the risk of natural disasters specifically focusing the COVID-19 emergency. Therefore, by conducting a literature review on recent publications, related state-of-the-art for achieving SFDRR priority actions were identified focusing the ten essentials. Using the Google Scholar search engine, the publication published after 2015 were identified using the following keywords.

Keywords: current and future risk scenarios, resilient urban development, enhance eco system protection, strengthen institutional capacity, infrastructure resilience, effective disaster response, effective build back better, state-of-the-art for achieving SFDRR priority actions.

Accordingly, 54 articles were distinguished for the search which were browsed through abstracts, and body of content to synthesise the state-of-the-art under SFDRR focusing the ten essentials for making cities resilience. Accordingly, as identified in the Figure 4 the SFDRR and Ten Essentials from UNDRR are considered to carry out the literature review in identifying the state of the art of disaster research and distinguish synergies and novelties for achieving SFDRR priority actions. The underlying ten essentials were used as the basis for aligning state of the art with SFDRR. The identified state-of-the-art were carefully examined against the lessons learned from the 7 case studies identified in the CORE project agreement.

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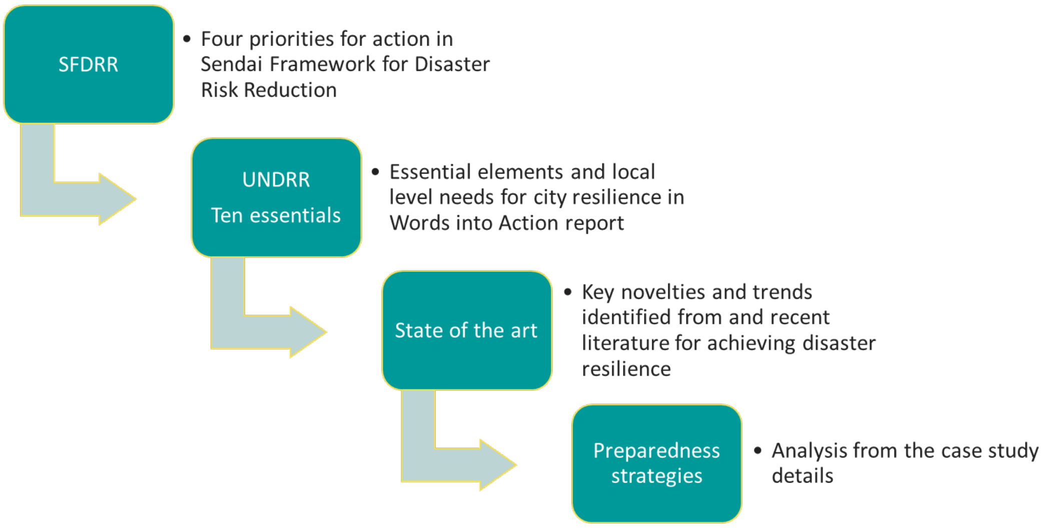

Figure 4: Analysis model of the report

3.1 The Sendai Framework on Disaster Risk Reduction (SFDRR) 2015–2030

The Sendai Framework on Disaster Risk Reduction (SFDRR) 2015–2030 (Sendai Framework) (Figure 5) focuses on the adoption of measures that address all dimensions of disaster risk – hazard, exposure, vulnerability and coping capacity – to prevent the creation of new risk, reduce existing risk and increase resilience (UNDRR, 2015). The Sendai framework enables the implementation of integrated and inclusive economic, structural, legal, social, health, cultural, educational, environmental, technological, political, and institutional measures that prevent and reduce hazard exposure and vulnerability to disaster, increase preparedness for response and recovery, and thus strengthen resilience. The following four priority areas have been identified in the framework which is also considered in this study as the basis of studying the implementation of preparedness strategies in the local level.

- Priority 1: Understanding disaster risk.
- Priority 2: Strengthening disaster risk governance to manage disaster risk.
- Priority 3: Investing in disaster risk reduction for resilience.
- Priority 4: Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation, and reconstruction.

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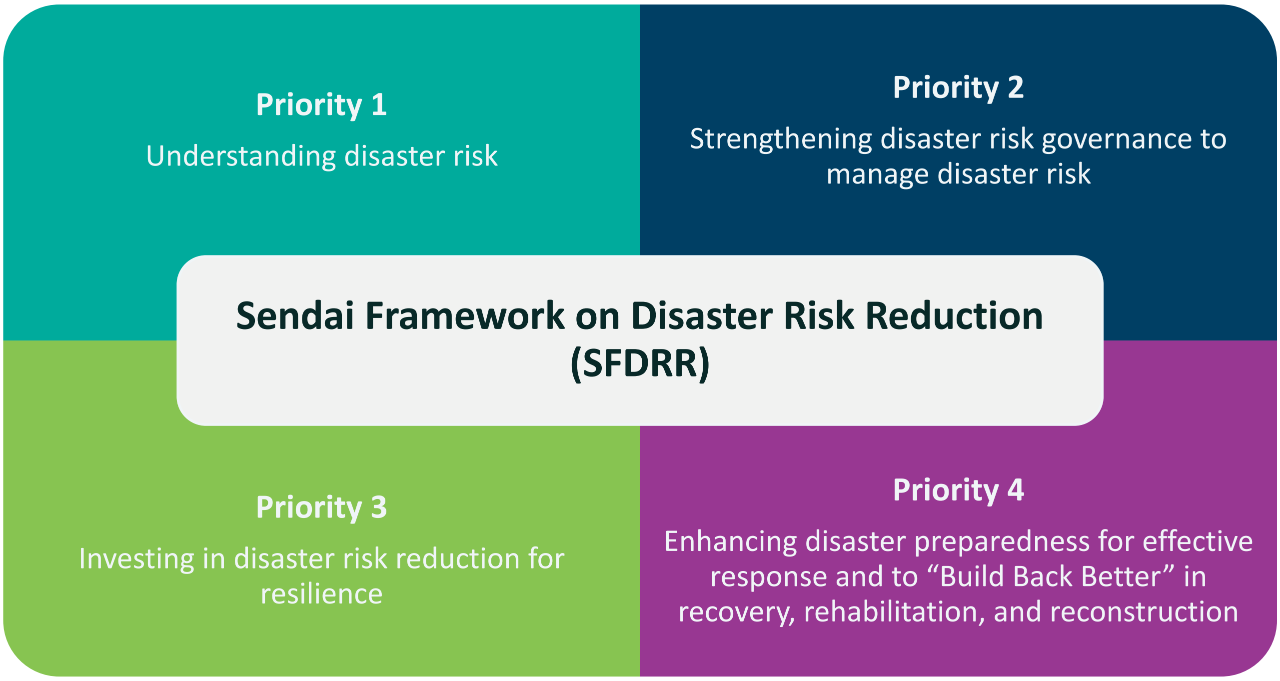

Figure 5: Sendai Framework on Disaster Risk Reduction (SFDRR) 2015–2030 (UNDRR, 2015)

3.2 Ten Essentials for Making Cities Resilient

The Ten Essentials for Making Cities Resilient is a key tool allowing local governments to track progress against a checklist of activities and to evaluate their commitment towards building resilience (UNDRR, 2019). The Ten Essentials aim to assist local governments in establishing DRR and resilience strategies that also consider future risks and uncertainties and in highlighting areas of strength and key challenges. The essentials promote a set of principles for DRR that makes sense for local development and addresses issues that are important for local governments and urban residents. According to the UNDRR (2019) the Ten Essentials can be mapped against the Sendai priorities as mentioned below (Table 4). In this study the preparedness strategies from different studies and their state of the art have been explored alongside of these essentials.

Table 4: Ten Essentials for Making Cities Resilient (UNDRR, 2019)

Sendai priorities for action	Ten essentials and local level needs
Priority for action 1. Understanding disaster risk	Essential 2 – Identify, understand, and use current and future risk scenarios. Essential 4 – Pursue resilient urban development and design. Essential 5 – Safeguard natural buffers to enhance ecosystems' protective functions.
Priority for action 2. Strengthening governance to manage disaster risk	Essential 1 – Organize for disaster resilience. Essential 4 – Pursue resilient urban development and design. Essential 5 – Safeguard natural buffers to enhance ecosystems' protective functions.

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	Essential 6 – Strengthen institutional capacity for resilience. Essential 7 – understand and strengthen societal capacity for resilience. Essential 8 – Increase infrastructure resilience.
Priority for action 3. Investing in disaster risk reduction for resilience	Essential 3 – Strengthen financial capacity for resilience.
Priority for action 4. Enhancing disaster preparedness for effective response, and to 'build back better' in recovery, rehabilitation, and reconstruction	Essential 9 – Ensure effective disaster response. Essential 10 – Expedite recovery and 'build back better'.

3.3 Exploring state of the art in multi-hazard preparedness for systemic risks

Disasters especially in the current urban context are increasingly becoming common and unexpected while making hard to manage due to the concurrent rapid environmental and socioeconomic changes occurring at several levels. These contexts often result in systemic risks marked by complexity, uncertainty, ambiguity, and cross-border consequences as currently experienced with the continuing worldwide COVID-19 pandemic (Jared et al., 2020). According to Jared et al. (2020) these systemic risks outperform the conventional risk management practices while occurring new and challenging policy and governance issues. Therefore, the research into these aspects require to identify key innovation points to assess the origins of systemic risk particularly in relation to disaster risks. In this purview, a state-of-the-art approach is required to harness the areas of opportunity in the governance of such risks by formulating a holistic management system of disaster-related systemic risks and coordinate policy response. Accordingly, this report has identified key state of the art features in systemic risk management in the field of disaster management by building on existing research and conducting a qualitative review of state-of-the-art literature published by academia, industry, and governments Table 5. To strengthen the holistic management of disaster-related systemic risks and coordinate an effective policy response, this research has integrated the SFDRR priorities for action and related 10 essentials of local needs. The findings from the above-mentioned case studies are integrated in respective sections to derive lessons learnt considering the areas for improvement and key recommendations.

Table 5: State-of-the-art identified in the recent literature about achieving the SFDRR priority actions.

CORE D 3.1 - Critical analysis of past disasters - Analysis Matrix			
SENDAI priorities for action	**Ten essentials**	**Local level development needs**	**State of the art**

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Priority for action 1. Understanding disaster risk	**Identify, understand, and use current and future risk scenarios (Essential 2)**	• Have up-to-date information on extensive and intensive risks, small and largescale disasters, and slow and rapid onset disasters. Understand how they (may) change in relation to development trajectories, demographic trends, urbanization, and climate change. Understand the timescales over which risks change and impacts occur. • Have updated information of the main hazards in your region, how they change over time and how multiple hazards may combine. • Consolidate up-to-date information about exposure, vulnerability and coping capacities of people, assets, and activities. Integrate scientific and lay knowledge (i.e., consider the latest available climate data and scenarios, seismic information, census data, etc. but also participatory mapping, enumerations, perception surveys, etc.). • Have updated information of critical infrastructure and services, the potential impact of hazardous events and cascading effects. • Develop mechanisms to update data and to generate local disaster risk knowledge, enabling local actors to access and exchange risk-related information. • Make sure that risk information is widely communicated and available to all stakeholders, in easy language and a usable format, so that risk information is factored in all decision-making processes.	**Carrying out a comprehensive risk diagnosis** Hazard risk diagnosis of past experiences based on the lessons learned in applying risk assessment tools (Zharikova et al., 2021). Mainly identifying the disposition of the set of valuable objects at critical risk, the set of active disasters, and the set of manpower and resources for response operations. **Identifying the systemic nature of risks** Emerging approaches to assessing systemic risk in the era of networked risk (Renn, 2021). Navigating the risk management through the new normalities of COVID-19 requires the understanding of integrative risk concept including evaluation criteria, cascading effects, different risk classes and corresponding management strategies for the handling of systemic risks. **Understanding the dynamic drivers of risk** New and emerging technologies and science for improved understanding of dynamic drivers of risk (Ward et al., 2020). Progressing towards truly comprehensive analyses of global multi-hazard risk is a significant need while accounting for multiple, interrelated hazards and their dynamic influence on system collapse and natural systems. **Defining tipping points** Defining the tipping points (thresholds) is an important task to evaluate the dynamic drivers of risk and their impact in complex systems such as major cities and coastal agglomerations (Ahmed et al., 2018). The adaptation of Tipping Point approach gives insight into how much pressure a system (physical or social) can absorb, what the acceptable limits are for impacts, and when they are reached. **Risk-informed digital twin** Developing a risk-informed multicriteria decision support system is an important approach for sustainable and resilient designing in the early stage under the uncertainty of smart buildings and infrastructure systems (Alibrandi, 2022). In this approach understanding the concept of risk-informed digital twin (RDT) is important as RDT conceptualises the integration of the methods and tools of statistics and risk analysis with machine learning. **Understanding the human choices and experience that drive the disaster risk.** The prevailing perception of risk especially long-term threats is one of optimism, underestimation, and invincibility provided that human choices and experience drive the vulnerability, exposure and disaster risk (UNDRR, 2022). Therefore, exploring the gaps in the current risk reduction efforts with reference to the human actions that lead to increased disaster vulnerability and exposure is important for identifying the root causes of vulnerability (Surjan et al., 2016). Learning from indigenous knowledge and ways of knowing provides the understanding of the connection between communities and ecosystems that can provide a strong local or traditional knowledge into scientific decision making.
	Pursue resilient urban development and	• Update zoning and land-use regulations and building codes to avoid generation of new risks, reduce current ones and enhance resilience based on up-to-date local information.	**Developing science-based methodologies** Development of science-based methodologies to consolidate disaster risk information and strengthen disaster risk modelling, mapping, and monitoring

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	design (Essential 4)	• Ensure suitable land for different urban needs (residential, industrial, recreational, etc.) and adequate housing (in terms of size, quality, and location). • Plan and make sure that different land uses receive appropriate infrastructure and services. • Manage urban development in risk-prone areas (e.g., floodplains, slopes and coastal areas). Enforce regulations. • Anticipate urban changes and plan for the short, medium, and long-term.	(including geospatial and space-based technologies) based on spatial patterns is an effective way to implement DRR and CCA measures within regeneration processes at various scales (Zuccaro & Leone, 2018). Especially within the current COVID-19 emergency, the urban development strategies must focus on developing pandemic-resilient cities and management to tackle the infectious diseases in the future as well as in the present (Afrin et al., 2021).
	Safeguard natural buffers to enhance ecosystems' protective functions (Essential 5)	• Identify local ecosystems and understand their role in reducing disaster impacts (e.g., slope stabilization, flood protection and enhancement of water quality, reduction of heat island effect, etc.) and their contribution to climate change mitigation (within the city and the surrounding region). • Have updated information on natural areas and their current and potential uses. Consider multiple information sources.	**Utilising earth observation and remote sensing technology in disaster monitoring** Earth observation and remote sensing technology can be used to acquire important data on geo spatial locations based on the spatial and temporal coverage of the satellite or the observation object (Sousa et al., 2021). The data acquired from the most recent missions can be used for a detailed reconstruction of past events but also to continuously monitor sensitive areas on the lookout for potential geohazards (Melet et al., 2020). Earth observation is especially important to effective monitoring of the global ocean, with synoptic views of large areas, good spatial and temporal resolution, and sustained time-series covering several years to decades.
Priority for action 2. Strengthening governance to manage disaster risk	**Organize for disaster resilience (Essential 1)**	• Ensure disaster risk governance is a key component of the city vision and/ or strategic development plan of the city, recognizing the relevance of participatory and inclusive mechanisms for DRR and resilience. • Discuss and agree on the levels of disaster risk that are acceptable to your city. Revise them over time. • Establish a single point of coordination (focal point/government office) which is accepted by all actors and with strong leadership, political support (e.g., from the highest elected level) and resources (human and financial). • Ensure that all departments in the local government understand the importance of DRR and resilience and how they relate to their everyday work and to overall city development goals. • Define clear roles and responsibilities among city government's staff and decision makers, but also between civil society and the private sector, so that all stakeholders contribute to DRR and resilience. • Build up alliances and collaboration processes horizontally (across sectors and actors within the city and with neighbouring cities) and vertically (across different political-administrative levels). • Have a clear operational framework to make collaboration possible. • Approve codes and bylaws and/or revise existing ones to integrate resilience attributes. • Have in place reporting mechanisms for all stakeholders that collect/process/ consolidate key information.	**Identifying the synergies in DRR** Established links and synergies between national and local DRR strategies are important to break silos in planning DRR (Thaler et al., 2022). Novel institutional procedures in risk management are required to combine different functions (e.g., risk management strategy, sustainable land-use development, individual preparedness, and well-being) that can save space, time and possible arising costs linked with mitigation systems. **Use of indigenous knowledge in policy formulation** Use of traditional, indigenous, and local knowledge of at-risk communities to complement scientific knowledge in the development of policies, strategies, plans and programmes (Hermans et al., 2022). The social relations and experiences of local communities can be an invisible knowledge to improve early warning to impending disasters (Lin & Chang, 2020). Therefore, the reality known to the local communities can be used to interpret the policy perspectives of disaster risk management which could help succeeding the community needs in the national disaster risk management policies. **Governance in the context of systemic risk** Governance in the context of systemic risk requires considering dynamic evolutions of multiple causes and effects, feedback mechanisms marked by uncertainties and the potential for cascading or compounding events that lead to failure of the systems that humans depend upon (Renn, 2021). This can be ensured via a carefully designed interface which can translate the scientific findings into policies in practice (Izumi et al., 2019; Koetz et al., 2012). However, to ensure science gets disseminated and used in implementation of policy in practice, understanding how learning occurs individually and collectively across cultures and stakeholders is an important factor (UNDRR, 2022). Therefore, bridging the science and policy divide via applied approaches and strengthening the interface can be considered as a significant factor in delivering good governance among systemic risks (Nursey-Bray & Harvey, 2013).

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	Pursue resilient urban development and design (Essential 4)	• Approve codes and by-laws and/or revise existing ones to integrate resilience attributes into building codes and spatial planning, aiming to prevent the creation of new risk and reduce existing risk.	**Identifying the interlinkages and synergies in risk resilient development** Identifying the interlinkages and synergies when pursuing risk-resilient development pathways are highly useful in DRR practices (Saunders & Kilvington, 2016). The following innovative approaches are identified by Orimoloye et al. (2021) to identify the synergies among the DRR silos. These include geographic information system and remote sensing, disaster risk insurance, social networking systems and materials that are resilient to disasters. **Adopting eco-system based/inspired solutions and experiences.** Contribution of science and technology for integration of eco-system based/inspired solutions and experiences from case studies on nature based/inspired resilience applications is identified as a pivotal factor in multi-hazard ecosystems, and mainstreaming policy-level strategies (Mukherjee & Shaw, 2021). **Identifying the driver specific systemic risk mitigation measures** Utilising the drivers of systemic risk and attribution of driver specific strength for systemic risk mitigation and long-term resilience, holistic, and systemic perspective (Mitra & Shaw, 2023). A systemic innovation approach in practice requires to build a collective intelligence through experiential learning (Saunders & Kilvington, 2016). This requires the transition to risk-based planning considering the aspects such as satisfactorily defining acceptable, tolerable, and intolerable risk, incorporating the views of stakeholders, and affected communities, and ensuring that potentially controversial decisions over land use options are robust and defensible.
	Safeguard natural buffers to enhance ecosystems' protective functions (Essential 5)	• Ensure appropriate legislation to safeguard ecosystems and their protective functions, including funding schemes for multiple uses and collaborative conservation. • Develop programmes to ensure all citizens understand the protective role of ecosystems (among other services). • Consider green and blue infrastructure or nature-based solutions to enhance local resilience. • Work in collaboration with neighbouring cities and broader administrative levels (e.g., region or basin) to safeguard ecosystems and their protective functions.	**Identifying the role of local ecosystems in DRR** Identify local ecosystems and understand their role in reducing disaster impacts (e.g. slope stabilization, flood protection and enhancement of water quality, reduction of heat island effect, etc.) and their contribution to climate change mitigation (within the city and the surrounding region) via promoting ecosystem-based disaster and climate resilience (Maki, 2021).
	Strengthen institutional capacity for resilience (Essential 6)	• Identify local capacities among different actors and agree on division of responsibilities. Secure effective communication so everyone knows "who does what". • Strengthen local capacities to better understand the relevance of integrated responses, linking DRM to climate change and sustainable development. • Develop capacities and local know-how via training activities and knowledge exchange (within your city, with other cities, with the private sector, etc.). • Develop a portfolio of project proposals that address different issues in your city, and which are ready for submitting to different funding opportunities. • Share information and knowledge; work towards guaranteeing access and interoperability.	**Leveraging partnerships for multi-stakeholder cooperation** Identify measures to improve the national DRR governance system and its accountability to achieve good governance (Okada et al., 2018). According to Fjäder (2021) the multi-stakeholder cooperation is often either ad hoc and reactive in nature or principally limited to sharing of information and good practices. Therefore, leveraging partnerships for the development and implementation of DRR strategies requires the comprehensive development of capabilities in resilience, long term, and concrete partnerships with clear value proposal throughout the entire life cycle of disasters. **Promoting disaster risk reduction in formal and non-formal education** Promote the incorporation of disaster risk knowledge, including disaster prevention, mitigation,

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			preparedness, response, recovery, and rehabilitation, in formal and non-formal education (Cabello et al., 2021).
	understand and strengthen societal capacity for resilience (Essential 7)	• Work with local actors to consider their views/opinions on different development alternatives. • Secure mechanisms for participation in planning, implementation and monitoring and evaluation processes. • Support the work of community-based organizations and local NGOs (e.g., from work on housing and water and sanitation to specific emergency response). • Target different groups and/or sectors, such as businesses and industries, schools, professional associations, etc.	**Identifying the personal biases in decision making** Understanding the relationships between individuals' decisions, their decision-making styles, and personality traits can provide explanations about why people respond differently to post-disaster situations and provide better understanding of how people would react after a disaster (Golazad et al., 2022). They can be influenced by social, psychological, and individual factors in their risk perception. **Improving social capacity** Improved capacity of communities to effectively anticipate, respond to, and recover from, the mobility consequences of disasters, through strengthened disaster preparedness and building capacity for response (Gil-Rivas & Kilmer, 2016; Reis et al., 2021). In this process focusing an ecological framework grounded in such values as collaboration, social justice, empowerment, and an appreciation of diversity to guide disaster work with communities can be considered as important factors.
	Increase infrastructure resilience (Essential 8)	• Assess if current infrastructure is adequately designed, built, and maintained to respond to current and future risk scenarios. Prioritize areas for investment in existing and new infrastructure. • Have guidelines for risk-sensitive development of future infrastructure. • Have processes in place to ensure operability of critical infrastructure in the event of acute shocks or stresses. Have spare capacity (e.g., redundancy) to cope with a combination of risks. • Ensure that service providers understand disaster risk and the role of infrastructure in reducing current and future risks.	**Assessing the infrastructure resilience** Identifying the factors for simulating the infrastructure systems is crucial for assessing their corresponding resilience (Haggag et al., 2022). According to Haggag et al. (2022) following factors provide important information in assessing the infrastructure resilience (the concept of resilience, city assessment and urban planning, critical infrastructure systems, infrastructure interdependence, risk and disruption, complex systems modelling, complex network theory, power, gas and/or water systems, and disasters and system disruption). **Ensure the operability of critical infrastructure in the event of acute shocks.** Availability of processes to ensure operability of critical infrastructure in the event of acute shocks or stresses (Shakou et al., 2019). This requires the urban infrastructure systems to equip with spare capacity (e.g. redundancy) to cope with a combination of risks (Argyroudis et al., 2022). In this purview, emerging and disruptive digital technologies have the potential to provide flexible, modular, and diverse transformation in the critical infrastructures to improve resilience by incorporating rapid and accurate assessment of asset condition and support decision-making and adaptation. **Improving resilience via the development of green infrastructure** Improve the understanding of green infrastructure development in cities and urban areas through the development of guidance material (Staddon et al., 2018). Green infrastructure can enhance urban resilience and maintaining critical system multi-functionality across complex integrated social–ecological and technical systems (Meerow & Newell, 2017). Accordingly, in such approaches considering the following factors are essential, (1) standards; (2) regulation; (3) socio-economic factors; (4) finance ability; and (5) innovation.

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Priority for action 3. Investing in disaster risk reduction for resilience	**Strengthen financial capacity for resilience (Essential 3)**	• Work on financial planning and definition of priorities to ensure that actions to build resilience receive support. • Earmark an annual budget for DRR and resilience – it can be distributed between different offices/sectors. • Develop an inventory of financing mechanisms and potential sources. Ensure adequate financial support to vulnerable groups (e.g., via social protection, microfinance, etc.). • Ensure that funds invested in response and recovery also include 'building back better' and pursue sustainable development.	**Identifying cost-effective risk mitigation measures** Proposing strategies for the use of cost-effective risk mitigation measures coupled with insurance can rework the structure of risk mitigation and financial investments in disaster risk reduction (Kunreuther, 2001). **Addressing the biases in social behaviours via local level risk financing mechanism** Addressing the biases of behavioural characteristics, including individual time and risk preferences are important to promote disaster risk financing in the local level (Mol et al., 2020).
Priority for action 4. Enhancing disaster preparedness for effective response, and to 'build back better' in recovery, rehabilitation, and reconstruction	**Ensure effective disaster response (Essential 9)**	• Have emergency plans/protocols in place with clearly defined roles and responsibilities for all local actors. Establish coordination mechanisms and assign resources where needed. • Validate emergency plans/protocols with all local actors. • Communicate emergency plans/protocols and test them periodically (e.g., design regular drills according to type of emergency and sector). • Have early warning systems (EWS) broadcasted to all citizens for effective and quick response. • Ensure availability of equipment and supplies. • Assess and evaluate response capacity to continuously improve it.	**Establish an effective monitoring system and real time loss estimation mechanisms.** Reliable real time loss estimation allows proper decision making on response and rescue operation to reduce the number of causalities by increasing the number of promptly extracted people from the impact areas (Fakhruddin et al., 2022). Develop a plan to address any bias, assumptions, or interpretations by establishing protocols to monitor the data, providing regular training to keep skills of the user accurate, and validating the risk assessment data (Fakhruddin et al., 2022). **Developing multi-hazard early warning systems** Development of effective, internationally compatible multi-hazard early warning mechanisms and community centres for the promotion of public awareness especially consisting of the capacity to embrace information in social media platforms (Mayhorn & McLaughlin, 2014; Sutton et al., 2014). **Ensuring rapid, effective, and risk-informed emergency response** Rapid, effective, and risk-informed emergency response mechanism is important to address the immediate needs of disaster-affected populations, as well as secondary risks generated because of prolonged displacement (Bodin et al., 2022). The risk informed diagnostic also helps assessing what cognitive, preparatory, and planning capacities are needed to ensure more effective responses to compound emergencies.
	Expedite recovery and 'build back better' (Essential 10)	• Have emergency plans/protocols in place with clearly defined roles and responsibilities for all local actors. Establish coordination mechanisms and assign resources where needed. • Validate emergency plans/protocols with all local actors. • Communicate emergency plans/protocols and test them periodically (e.g., design regular drills according to type of emergency and sector). • Have early warning systems (EWS) broadcasted to all citizens for effective and quick response. • Ensure availability of equipment and supplies. • Assess and evaluate response capacity to continuously improve it.	**Enabling build back greener initiatives** Post-disaster recovery planning is an opportunity to 'build back greener' by fostering ecosystem approaches towards social and ecological resilience (Mabon, 2019). According to Mabon (2019), further understanding in empirical contexts is required of how cultural services especially citizen participation can be integrated with more technical approaches to post-disaster ecosystem management. **Effective business continuity plans in social recovery.** Ensure the continuity of business operations and including social and economic recovery, and the provision of basic services is important during the recovery phase (Niemimaa et al., 2019). Especially during COVID-19 outbreak entrepreneurs experience business cancellation or closure and reduced income due to the closure of several supporting sectors such as retails and transportation (Universiti Malaysia Sabah et al., 2020). Therefore, effective support mechanisms associated with entrepreneurial development

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			organizations for micro-entrepreneurs is crucial to thrive during and after a crisis.

3.4 Case study analysis and key lessons learned.

Data and information for the analysis are collected from the intra case analysis templates filled by respective partners. Key lessons learned from each case are identified against the identified preparedness strategies to demonstrate the areas of improvement for the future tasks including the Task 3.5 - Community resilient strategy. The template covers the following aspects in disaster preparedness in the identified cases:

- What were the public information sharing challenges?
- What were the ethical issues?
- What lessons have been learned?
- What were the cascading effects across events, sectors, and supply chain disruptions? Including the inevitability or unforeseen chain of events affecting the response to the disaster? What were the societal vulnerabilities in health and retail sectors?
- What was preparedness before and after the event with regards to prepositioning, training, framework contracts and supplier management.
- What was the role, influence, and impact of social media communications during this incident?
- What positive benefits can be derived from the use of satellite images and Unmanned Aerial Vehicle data during this disaster to inform decision-making?
- Type of hazards – Understanding the disaster risk
- Disaster resilience and preparedness strategies including mitigation, response, recovery, and monitoring and evaluation.
- Identify people vulnerable categories in the different phases of disaster management.
- Importance of culture and heritage in the disaster affected areas.
- Disaster risk governance mechanisms
- International DDR frameworks
- Accountability in disaster governance
- Cascading effects and systemic risks in the cases
- Social media information/misinformation and risk communication

The following cases were analysed based on the above template to derive the key lessons learned about the state-of-the-art of preparedness strategies.

Case Study 1: Terrorist Attack - Manchester Arena, England (2017)

The largest city of northern England, Manchester, features significantly in the annals of UK terrorism. On 15 June 1996, the Irish Republican Army (IRA) detonated a 1,500 kg lorry bomb in the principal shopping centre. On that evening, Salman Abedi had managed to evade the attention of security staff and police at the Arena, despite carrying a large rucksack on his back. From this same Arndale shopping centre, Salman Abedi, a 22-year-old Mancunian of Libyan parentage, bought a rucksack on Friday, 19 May 2017. Shreds of this rucksack were found in the foyer of the Manchester Arena concert venue on the following Monday night, 22 May 2017.

Unlike an attack on the transportation infrastructure or against commercial targets, there was an absolute fixed deadline of the Ariana Grande concert date on the evening of 22 May 2017. Salman Abedi had a highly organized and busy schedule of international travel and bomb preparation in the period leading up to this date. His two years of business and management studies at Salford University ultimately trained him only to succeed in this singular ultimate project with a tight deadline. The student loans he took out to pay for his university course, including the period after he had dropped out, will never be paid back. So, the actual cost of the suicide bombing to ISIS, (including foreign travel

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and procurement of materials for the bombing operation), was essentially minimal. The terrorist attack leverage, defined as the ratio of impact to cost, was therefore massive, as demanded for ISIS operations. The foyer of the Manchester Arena adjoins the Manchester Victoria station, a key transport hub in the city, with both rail and tram links. Salman Abedi might have detonated his bomb within the station, or on a train, or in a store; instead, he chose the Manchester Arena concert venue. Terrorism is the language of being noticed. The bomb explosion created carnage but caused limited damage in the foyer. There was some structural damage to the Manchester Victoria station, which was closed for eight days for repairs, and the police investigation. The adjoining concert venue was closed until September, with scheduled concerts being cancelled or relocated to venues elsewhere. Whilst the physical damage caused by the Arena bombing was repaired quite soon, the psychological impact of the terrorist attack on the survivors remains, even five years afterwards. Post-Traumatic Stress Disorder (PTSD) has been a common outcome, with longstanding mental health consequences for those who attended the concert as children in their teens. One of these, Eve Aston, took her own life in 2021 having experienced depression and PTSD since the Arena bombing.

Case Study 2: Earthquake - L'Aquila, Italy (2009)

The name 2009 L'Aquila earthquake refers to a series of earthquake events, which began in December 2008, with epicentres in the entire area of the city of L'Aquila, the L'Aquila basin, and part of the province of L'Aquila (Alto Aterno, Monti della Laga, and lower Aterno Valley). The name refers mainly to the main earthquake, which occurred on 6 April 2009 at 3.32 a.m. (moment magnitude 6.3), with epicentre between the hamlets around L'Aquila, affecting to varying degrees much of the territory located between central and southern Italy. The moment magnitude (Mw) 6.3 mainshock of 6 April 2009, represented the most damaging event in Italy since the 1980 Irpinia earthquake (Mw 6.9) (Chiaraluce, 2012). Thousands of foreshocks, started in December 2008, preceded this mainshock event. The largest foreshock event was the Mw 4.0, recorded on 30 March 2009. The area involved is in one of the zones with the highest seismic hazard in Italy (Akinci et al., 2009).

During the sequence Giampaolo Giuliani, an INAF technician (Istituto Nazionale di Astrofisica), noticed significant spikes in radon emissions in the L'Aquila region in late March 2009. He warned the authorities that a significant earthquake might occur in the final week of March 2009, possibly close to Sulmona, which is 50 kilometres southeast of L'Aquila. The National Commission on the Forecasting and Prevention of Major Risk, which responsibility was to offer counsel and direction on scientific issues to the Dept. of Civil Protection, met in L'Aquila on 31 March 2009 because of the unrest and the magnitude 4.0 on 30 March 2009. At this conference, it was explicitly stated that there was no need to worry about how the dominant earthquake swarm was developing because seismic energy was only being produced in brief bursts. The terrible earthquake struck six days later, on 6 April. Around 18,000 aftershocks followed the main event in one year, and five events with moment magnitude larger than 5.0 have been recorded, among which the strongest were a Mw 5.6 and a Mw 5.4, occurred on 7 April and 9 April, respectively. A total of 81 municipalities were affected by the earthquake (EERI Special Earthquake, 2009).

At 4.15 a.m., the Civil Protection Department's Crisis Unit met, and the situation immediately appears very serious. With the declaration of a state of emergency by the Prime Minister, at 9.00 a.m. the following morning the Direzione di Comando e Controllo (Di.Coma.C.), the coordinating body for the emergency is formed at the headquarters of the Guardia di Finanza School in L'Aquila. In 2009, L'Aquila was home to approximately 73,150 inhabitants and a population of commuters of up to 100,000 people. The earthquake destroyed 3,893 buildings (ancient and modern) and damaged 69,591 others, including many buildings of medieval, renaissance, and baroque architecture. New Town in the L'Aquila suburbs with earthquake-proof houses in addition to real semi-permanent villages, were discussed to be placed outside the affected centres, which would prevent the exodus of the population. This was accomplished with the subsequent C.A.S.E. project and M.A.P. project, but the people of L'Aquila and the municipality of L'Aquila, fearing that the core of the city might become a "museum city," opposed the idea with pressing demands for the reconstruction and rehabilitation of the historic centre soon organizing themselves into reconstruction committees (Contreras et al., 2017).

Case Study 3: Flash Flooding - Aude Region, France (2018)

Aude is a department in the Occitan region of southern France. The population in 2018 was approximately 370k, and the region is semi-rural in nature, with the largest town being the historic fortified mediaeval city of Carcassonne. Aude is one of 15 departments considered to be part of the "Mediterranean Basin", a region at particular risk from flooding as it is exposed to very specific weather conditions which bring heavy rainfall every year, mainly in early autumn. These episodes are caused by hot, humid, and unstable air rising and moving inland from the Mediterranean, leading to

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violent and occasionally locally sustained storms. Given the topography of the land with steep sided narrow valleys, this often results in potentially dangerous flash floods.

With the severest rain falling from 9.00 a.m. onwards on the 14th, in just 12 hours overnight, 295 mm of rainfall was recorded in Trèbes, which is the equivalent of 4 months of rain. 244 mm of that total fell in just a 6-hour period. Worst hit was the town of Trèbes, where 6 residents were killed. Across the Department, 75 people were seriously injured, 1800 were evacuated, whilst 10,000 homes were without drinking water for over 24 hours, and 1500 homes had no electricity supply for several days. 126 municipalities in the Department were declared disaster zones, and Finance Minister Bruno Le Mair estimated that the material damage amounted to €200 million, with the government making €80 million immediately available. Later estimates suggested the damage totalled €269 million. Rebuilding after the 1999 flooding may have impacted on the scale of the 2018 events. Official data shows one in four French people (17 million) lives in an area prone to flooding, with half of all cities, towns and villages in France having some built-up areas in flood-risk zones, whereas in the Aude region, 39% of residents live in flood-risk areas.

As demonstrated, the floods of October 2018 were not a rare event in the Aude region. Nonetheless, the scale and ferocity of the October floods appear to have taken the authorities and responders by surprise. The sudden rise in water levels severely tested the preparedness and planning of the Department, and the individual municipalities. There is evidence also that the Aude Department was only placed on red alert (Vigilance Rouge) at 6.00 a.m. on Monday morning (15 October 2018), when the heaviest rains had already passed, and rivers had already burst their banks. There seems ample evidence that first responders in the emergency services, together with volunteers and NGO staff reacted to the events with courage, speed, and resourcefulness. Given the history of flooding in the region however – with innumerable smaller scale floods as well as frequent major incidents – there is obviously much that can be learned about preparedness, planning, and communication.

Case Study 4: Wildlife - Mountains of Jerusalem, Israel (2021)

This case-study discuss the wild-fire in the western slopes of Jerusalem mountains, which was one of the largest wildfires in Israel, but due to the first responder's operation concluded with no injuries, and minimal property damages. The fire broke out between 15 -19 August 2021, in several locations in the moshav Beit Meir area in the Mateh Yehuda Regional Council. It later spread to Tzuba, Ein Naquba, Ein Rafa, and Givat Ye'arim. This fire is considered the most extensive in the Jerusalem Hills compared to the fires recorded in previous years. According to the conclusions of the fire authority's investigation, this was intentionally manmade (Sources: Knesset News, 2021; Israel Fire and Rescue, 2021; Yaniv, 2021)

The fire started on Sunday, 15 August 2021, at noon at only three spots, but due to the high tense eastern winds (up to 6.7 m/sec), the fire expanded fast (almost 4 km/hr) (Israel Fire and Rescue, 2021; Knesset News, 2021). The fire started near the village of Beit Meir, and then bypassed Beit Meir from the east, entering the clefts, and started running through the mountain slopes. On this first day, as early as 2.00 p.m., evacuations started in Ramat Raziel, Givat Ye'arim, Kislon Sho'eva, and Shoresh (Knesset News, 2021; Golditch et al., 2021; Shlomi & Deutsch, 2021; HML System, 2021).

On the second day, 16 August 2021, the fire continued towards the outlet of Elite, Ein Aquba Ein Rafa, and even went towards Hadassah Ein Kerem hospital and Even Sapir. The fire had already spread to more than 100 spots. The wildfire continued spreading as the wind picked up, leading the police to evacuate some residents of Sho'eva as the blaze neared the community. The Israeli Defense Forces (IDF) dispatched several transport helicopters to assist in the evacuation of Giv'at Ye'arim due to the massive forest fire raging outside Jerusalem. The change in the wind condition (from western winds during the morning to eastern winds afternoon) made the distinguishing operation very complex.

During the 2nd day, approx. 155 patients needed to be evacuated from the mentally ill hospital, Eitanim, which is located within the forest. A special fire fighters team also had to be called to conduct very extensive defensive tactics to protect the hospital of Ein Kerem because its evacuation was challenging. This procedure involved a massive aerial firefighting operation and 15 firefighting vehicles which used foams and water to prevent fire movement into the hospital. Israel Fire and Rescue Services chief, Dedy Simchi, said the enormous forest fire outside Jerusalem was on the same scale as the 2010 Mount Carmel fire (Knesset News, 2021; Golditch et al., 2021; Shlomi & Deutsch, 2021; HML System, 2021).

The third day of the fire marked the complete control of the fire, decreasing the number of fire spots to only 50. All citizens from the villages returned to their homes (Knesset News, 2021; Golditch et al., 2021; Shlomi & Deutsch, 2021; HML System,2021). The fourth and fifth days focused on full control and final extinguishing of the fire. The weather condition during this day was 29°C, with 40% humidity: Wind – approx. 2-3 m/sec east (IMS, 2022).

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Case Study 5: Industrial Accident - LG Polymers Plant, India (2020)

The polymers plant at Venkatapuram was established in 1961 to produce alcohol rather than petrochemicals. From this time, the main products manufactured at the site have been various types of polystyrene, and the constituent chemicals are produced and stored at the site The site comprises a total area of 213 acres, producing around 450 tonnes of product for the Indian and export markets. The main constituent – Styrene - is a colourless liquid with a flashpoint as low as 31 degrees centigrade. Due to the COVID-19 lockdown, the factory was closed from 25 March 2020, and staff were retained on maintenance duties. By 4 May, the factory was preparing to restart production. Styrene vapour is first identified as being released from the storage tank at around 2.40 a.m. on 7 May 2020. By 2.55 a.m., a vapour cloud had formed. An automatic alarm sounded in the control room, and the vapour release became uncontrolled. The reasons for this release are complex and can perhaps be summarised as poor tank design; poorly carried out maintenance; outdated storage technology; ineffective temperature measurement and control; insufficient refrigeration; staff failure, and poor tank contents management.

It was not until 3.26 a.m. that calls were made to external services fire, police, and ambulance to alert them to the issue - by citizens rather than by the plant staff. Police response was very swift, although the fire service has been criticised for not arriving on scene until 21 minutes after the call. From this moment until dawn, the communities around the Venkatapuram industrial plant are subject of a rapid but chaotic evacuation focused on approximately 300 families, in a toxic environment. This work was led by staff of the National Disaster Response Force experienced in Chemical, Biological, Radiological and Nuclear (CBRN) issues who arrived at 6.45 a.m. on the same day. They discovered that the styrene cloud was still present within the factory and using their own Personal Protective Equipment (PPE) equipment, entered, and liaised with LG Chemicals staff. They later also measured styrene gas levels and took water samples from the villages surrounding the plant. Casualties are identified as 12 fatalities, and 585 people requiring hospital treatment. A significant inquiry team ("The High-Level Committee") was appointed within 72 hours and much of this case study is derived from their report, and from those of the agencies who submitted papers. This inquiry however focused almost exclusively on the technical reasons for the leakage and the culpability or otherwise of LG Polymers and the authorities responsible for licencing and inspection of the facilities.

Case Study 6: Tsunami - Sendai, Japan (2011)

Japan earthquake and tsunami of 2011, also called Great Sendai Earthquake or Great Tōhoku Earthquake, severe natural disaster that occurred in north-eastern Japan on 11 March 2011 (Rafferty & Pletcher, 2022). The tsunami also instigated a major nuclear accident at a power station along the coast. Cabinet_Office_Japan (2011) on 11 March 2011, experienced the strongest earthquake in its recorded history. Earthquakes occurred one after the other in the short space of 30 minutes in three different areas, producing severe shaking and large tsunamis. The Tohoku earthquake caused a tsunami. Epicentre of earthquake – 80 miles (130km) east of the city of Sendai, North-eastern coast of Honshu Japan's main island at a depth of 18.6 miles (30km) below the floor of the western Pacific Ocean (Sato, 2015).

Tsunami affected areas – A wave measuring some 33 feet (10m) high inundated the coast and flooded parts of the city of Sendai, including its airport and the surrounding countryside. According to some reports, one wave penetrated some 6 miles (10 km) inland after causing the Natori River, which separates Sendai from the city of Natori to the south, to overflow. Damaging tsunami waves struck the coasts of Iwate prefecture, just north of Miyagi prefecture, and Fukushima, Ibaraki, and Chiba, the prefectures extending along the Pacific coast south of Miyagi. The tsunami raced outward from the epicentre at speeds that approached about 500 miles (800 km) per hour.

According to the Reconstruction Agency of Japan (2022) the number of confirmed deaths is 19,729 and more than 2,500 people are still reported missing and 6,233 are reported as injured. Less than an hour after the earthquake, the first of many tsunami waves hit Japan's coastline. The tsunami waves reached run-up heights of up to 128 feet (39 meters) at Miyako city and travelled inland as far as 6 miles (10km) in Sendai (Cabinet_Office_Japan, 2011). The tsunami flooded an estimated area of approximately 217 square miles (561 square kilometres) in Japan, according to the National Oceanic and Atmospheric Administration. The waves overtopped and destroyed protective tsunami seawalls at several locations (Sato, 2015). The massive surge destroyed three-story buildings where people had gathered for safety. Near Oarai, the tsunami generated a huge whirlpool offshore. In addition to the thousands of destroyed homes, businesses, roads, and railways, the tsunami caused the meltdown of three nuclear reactors at the Fukushima Daiichi Nuclear Power Plant. The Fukushima nuclear disaster released toxic, radioactive materials into the environment and forced thousands of people to evacuate their homes and businesses under a nuclear emergency. The direct economic loss from the earthquake, tsunami, and nuclear disaster is estimated at $360 billion.

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At the international and regional level, Japan is part of the ICG/PTWS (Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System), one of four ICGs for tsunami warning and mitigation systems, the others being the Indian Ocean, Caribbean, and adjacent regions, and the north-eastern Atlantic, the Mediterranean and connected seas. These are all part of the Intergovernmental Oceanographic Commission (IOC) Tsunami Programme, which aims at reducing the loss of lives and livelihoods that could be produced worldwide by tsunamis. Through a Working Group on Tsunamis and Other Hazards Related to Sea-Level Warning and Mitigation Systems (TOWS-WG), the IOC supports the coordinated development of warning and mitigation system for tsunamis and other hazards related to sea level that are of common interest to all the ICGs.

In recognition of the potential for cross-basin learning, in addition to the 2011 Japan earthquake and tsunami and ICG/PTWS, the CORE project will also draw upon lessons from the governance arrangements established for the Indian Ocean Tsunami Warning and Mitigation System (IOTWMS), which was formed in response to the tragic tsunami on 26 December 2004. The following provides a summary of the IOTWMS and its governance arrangements, which will be considered further in CORE Deliverable 3.3, Governance Strategy.

Indian Ocean earthquake and tsunami (2004)

On Sunday, 26 December 2004 a powerful undersea earthquake truck off the coast of Sumatra Island, Indonesia, and set off the 2004 Indian Ocean tsunami (Suppasri et al., 2012). The magnitude of the earthquake was measured at 9.1 on the Richter scale which ruptured a 900-mile stretch of fault line where the Indian and Australian tectonic plates meet. The epi centre of the earthquake was located at 30 kilometres under the seabed and approximately 250 kilometres south to south-west of Banda Aceh. The earthquake generated a series of waves at a height of 40 meters and reached the shallow waters at a speed of 80 km/h (Gupta & Gahalaut, 2013). Within 20 minutes of the earthquake, a 100 feet wave hit the shoreline of Banda Aceh pounding the city into rubble and causing more than 100,000 fatalities (Borrero et al., 2006). Further, a succession of tsunami waves strikes over coastlines in Thailand, India, and Sri Lanka, killing tens of thousands more (EEFIT, 2006). Eight hours after the earthquake, the tsunami waves hit the coast of South Africa which is located at 5000 miles far from its epicentre. The 2004 tsunami caused for nearly 230,000 fatalities making it one of the deadliest disasters in the recorded history. The worst affected countries from this event were India, Indonesia, Malaysia, Maldives, Myanmar, Sri Lanka, Seychelles, Thailand, and Somalia (Anugrah & Setiawati, 2022). Financial impact in the Maldives represented approximately 45 per cent of its Gross Domestic Production (GDP). The financial impact in Indonesia was recorded as $4.5 billion which is equivalent to the entire GDP of the Aceh Province.

Since the 2004 tsunami, the international organisations and aid groups have initiated disaster risk reduction and preparedness initiatives in their agendas (Haigh et al., 2019). Three weeks after the incident, 168 nations in the world agreed on the Hyogo Framework for Action which enabled the way for global cooperation for disaster risk reduction (UNISDR, 2005). The Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWMS) was formed which established a regional early warning system linking to the ocean floor earthquake sensors and organising training workshops for at risk communities about evacuation and disaster response.

Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWMS)

The IOTWMS is governed by the Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO) (UNESCO/IOC, 2020). The IOC Tsunami Programme aims at reducing the loss of lives and livelihoods that could be produced worldwide by tsunamis. The IOC Tsunami Unit supports the IOC member states by providing substantial information on tsunami risk assessment, Tsunami Early Warning Systems (EWS) and training and education for communities at risk about preparedness measures. The IOC Assembly, during its twenty-third Session on 21-30 June 2005, formally established the ICG/IOTWMS through Resolution IOC-XXIII-12. Under the ICG/IOTWMS the following working groups and task teams are formulated for implementing the working plans in the Indian Ocean region.

- Working Group 1 - Tsunami Risk, Community Awareness and Preparedness
- Working Group 2 - Tsunami Detection, Warning and Dissemination
- Working Group 3 - Tsunami Ready Implementation
- Regional Working Group for the North-West Indian Ocean
- Task Team on Scientific Tsunami Hazard Assessment of the Makran Subduction Zone

Task Team on Exercise Indian Ocean Wave 2023

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Further, Tsunami National Contacts (TNCs) and Tsunami Warning Focal Points (TWFPs) for coordination and rapid dissemination of warning information to the at-risk communities (IOC/UNESCO, 2023).

The TNC is the person designated by an ICG Member State government to represent his/her country in the coordination of international tsunami warning and mitigation activities. The person represents the country in the main stakeholders of the national tsunami warning and mitigation system program. The TWFP is a 24 x 7 point of contact which can be the office, operational unit or position officially assigned by the National Tsunami Warning Centre (NTWC) or the government to receive and disseminate tsunami information from an ICG Tsunami Service Provider (TSP) according to established National Standard Operating Procedures.

Further, as subsidiary bodies of the IOC-UNESCO, the ICG thrives to promote, organize, and coordinate regional tsunami mitigation activities, including the issuance of timely tsunami warnings. This task is facilitated by many national and international seismic, sea level, communication, and dissemination facilities throughout the region. From global to local coordination is carried out via carefully established Tsunami Service providers (TSP), National Tsunami Warning Centres (NTWC) and designated authorities.

Case Study 7: Pandemic – Global, focus on Finland (2019)

The corona crisis is caused by the SARS-CoV-2 -corona virus causing a disease named COVID-19. It was first detected in Wuhan, China, in the end of the year 2019. The European Centre for Disease Prevention and Control (ECDC) gave the first threat assessment of the novel virus 9 January 2020. At that point there was no certainty on the human-to-human transmission of the virus. The Emergency Committee convened by World Health Organization (WHO) confirmed the novel coronavirus as a Public Health Emergency of International Concern on the 30 January 2020. The focus here is on the first seven months of the pandemic: from December 2019 to June 2020. In that time span, Hanken focuses on Finland, and the national level government response that took place, including a summary of key events and some reflections on how the health care system managed the crisis.

In Finland, the Finnish Institute for Health and Welfare (THL) got a notification about the novel virus on the 31 December 2019 when the WHO launched in their early warning system information about the unusual strain of pneumonia identified in Wuhan, China through their early warning system. Since then, the Finnish Institute of Health and Welfare started to assess the severity of the spreading of the virus. The first situational report focused on the spreading of the virus was released on the 20 January 2020. At that point, the risk of the virus spreading to Finland was considered low. Face masks were sold out in the pharmacies in Finland due to the stocks being limited. This was most likely due to the media coverage on the spreading of the virus abroad as there was no public communication about the need to protect oneself in the media in Finland at that time. The development of the situation activated preparedness measures in several administrative branches. The first case was diagnosed in the end of January when a Chinese tourist was admitted to Lapland Central Hospital and tested for the novel virus. On the last day of January 2020, the heads of preparedness of all ministries convened for an extraordinary meeting focused solely on the coronavirus. The message from the THL in that meeting was that Finland had to immediately be prepared for a global pandemic and the spreading of the disease to Finland and that cross-sectoral preparedness had to be activated immediately. This corresponded with point 5/6 in the national pandemic preparedness plan where the threat of the pandemic was considerable. (Safety Investigation Authority, 2021).

An operations Centre of Prime Minister's Office (PMO) focused on the COVID-19 situational picture started to operate on the 1st of April. Its task was to improve situational picture and to monitor the impacts of Government policies and decisions on the COVID-19 situation. A national testing strategy was published April the 9th based on a principle of test-trace-treat. Several organizations mediated instructions given by authorities via different kinds of campaigns and provided advice and help to citizens in coping with everyday lives, e.g., volunteers assisted people belonging to risk groups in running errands and buying groceries. The capacity strain was at the highest in the week 15 (6.-12.4.) when there were simultaneously 83 patients in the intensive care units. In the worst situation, there were 49 corona patients in intensive care and 96 on the hospital wards the Hospital District of Helsinki and Uusimaa. After mid-April the number of intensive care patients started to steadily go down and the reduction of the capacity of intensive care was initiated. The closure of Uusimaa region was ended on April the 15th. 700 police officers and executive assistance units of the Finnish Defense Forces had participated daily in the execution of the closure. (Safety Investigation Authority 2021.)

May 2020 marked a switch to the hybrid strategy and gradual dismantling of restrictions in Finland. In its resolution on May 6, the Government stated that it was possible to follow the hybrid strategy and shift from extensive restrictions to more targeted measures with the goal of causing as little harm as possible to people, businesses, society, and the implementation of fundamental rights.

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4 State of the art and lessons learned from case studies under the SFDRR Priority for action 1. Understanding disaster risk.

4.1 Identify, understand, and use current and future risk scenarios.

4.1.1 Carrying out a comprehensive risk diagnosis

Hazard risk diagnosis is a holistic way of applying risk assessment tools in natural hazard assessment evolving from the experiences from past events (Zharikova et al., 2021). The hazard risk diagnosis mainly identifies the disposition of the set of valuable objects at critical risk, the set of active disasters, and the set of manpower and resources for response operations provides the ability to pre-position the necessary resources in disaster preparedness. According to Gill and Malamud (2014) scientists have highlighted the importance of relationships between specific natural hazards, anthropogenic processes and technological hazards or catastrophes when carrying out the hazard risk diagnosis. The World Bank studies demonstrates a Systematic Country Diagnostic approach which is structured around a framework that places meeting citizens' aspirations as the route for putting the country's economic and social transition back on track, and a more stable and inclusive political settlement as the foundational pre-requisite (Word_bank, 2022). In addition to the relationships across above elements, these interactions can be identified in a combined form for assessing the impact of hazard interactions.

The lessons from The L'Aquila earthquake of 2009 and the Japan earthquake and tsunami of 2011 demonstrate that the development of improved risk assessment and characterization system of networked hazards will help better classify and respond to different types of hazards, improve the integration of interoperability networks into multi-hazard methodologies, and conduce theoretical and practical understanding of hazards. Comprehensive understanding of situation diagnosis in natural and man-made systems is extremely important to support real-time decision-making in conditions of multi-hazards and cascading effects (Aksha et al., 2020). This will ensure the assessment of critical levels in infrastructure and response systems that will increase the risk of disruptions during single or multiple disasters.

4.1.2 Understanding the dynamic drivers of risk

A global level understanding of dynamic drivers of risk is important for identifying regions most at risk, providing science-based information for DRR advocacy, and assessing the potential effectiveness of DRR solutions (Afifi & Afifi, 2021). The new and emerging technologies and science provide improved ways of understanding the dynamic drivers of risk (Ward et al., 2020). According to Ward et al. (2020) the use of new technologies can assist the comprehensive analyses of global multi-hazard risk while accounting for multiple, interrelated hazards and their dynamic influence on system collapse and natural systems. According to the case studies of the L'Aquila earthquake of 2009 and the Japan earthquake and tsunami of 2011 this requires an understanding of how risk may change in the future and how that risk may be reduced through disaster risk reduction (DRR) efforts. According to Ward et al. (2020), in understanding the dynamic nature of risk drives the following aspects can provide a significant assessment approach.

- Assessing the interaction among the elements of risk

The hazard, exposure, and vulnerability elements should be explicitly represented in any risk assessment. Further, the static or dynamic nature of these elements over time should be represented to incorporate necessary future projections in the risk assessment and preparedness

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planning (Pittore et al., 2017). The static nature of an element represents that no future projections are included which considers only current representation, and dynamic nature of an element represents that future projections are included.

- Identifying the resolution of risk elements

The spatial resolution at which each risk element is represented can provide significant information about the impact area and the underlying vulnerable categories.

- Reflecting on the indicators that expresses the disaster risk.

Identifying the range of risk indicators that could express the multifaceted aspects of multi-hazards is an important way of representing multi as well as single hazard risk.

- Future DRR measures

The incorporation of future DRR measures in the modelling framework can enable contingency planning for unforeseen events.

- Appropriate methods of risk analysis

The methods that can be incorporated in risk assessment can be classed as either non-probabilistic or probabilistic (Korswagen et al., 2019). The probabilistic mean that expected annual impacts are assessed either by integrating across return periods or based on a probabilistic stochastic event set. Further the risk assessment represents hazard using stochastic event sets, return period maps, periodic maps of yearly or monthly hazard, past events, or the radius around a specific hazard.

4.1.3 Understanding the human choices and experience that drive the disaster risk.

The prevailing perception of risk especially on long term threats can reflect underestimated disaster risk if the vulnerable communities are not aware of the comprehensive extent of the risk (UNDRR, 2022). Therefore, exploring the gaps in the current risk reduction measures which fail to identify the human choices and experiences is an important task for addressing the root causes of vulnerability (Surjan et al., 2016). Especially the Japan earthquake and tsunami of 2011 shows that learning from indigenous knowledge and ways of knowing provides the understanding of the connection between communities and ecosystems that can provide a strong local or traditional knowledge into scientific decision making. In this purview, community based approaches have been accepted as one of the standard practices for solving disaster risk reduction issues (Shaw, 2016).

Once the appropriate community-based approaches are formulated, the “Change Agents” for effective implementation and monitoring of community-based approaches should be identified (Gibson, 2015). To ensure the sustainability of the community-based approaches the existing governance system, preferably at the local level should be appropriately linked with the identified “Change Agents”.

4.1.4 Identifying the systemic nature of risks

Navigating the risk management through the new normalities of COVID-19 requires the understanding of integrative risk concept including evaluation criteria, cascading effects, different risk classes and corresponding management strategies for the handling of systemic

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risks (Renn, 2021). According to Lucas et al. (2018) the systemic risk denotes the embeddedness of any risk to human health and the environment in a larger context of social, financial, and economic risks and opportunities. Systemic risks are at the crossroads between natural events, economic, social, and technological developments and policy driven actions. Systemic risk analysis requires a holistic approach to hazard identification, risk assessment and risk management. More specifically, systemic risks can be characterized by the following formal properties (Renn et al., 2019):

- Transboundary or cross-sectoral in its scope of consequences.
- Highly interconnected and intertwined leading to complex causal structures and dynamic evolutions.
- Nonlinear in the cause-effect relationships showing often unknown tipping points or tipping areas.
- Stochastic in their effect structure.

When dealing with systemic risks, four major components of this category of risk need to be considered (Renn et al., 2011):

I. Complexity

Complexity refers to the difficulty of identifying and quantifying causal links between a multitude of potential elements and specific adverse effects. The nature of this difficulty may be traced back to interactive effects among these elements, positive and negative feedback loops, short or long delay periods between cause and effect, inter-individual variation, intervening variables, and others.

II. Uncertainty

Uncertainty comprises different and distinct components such as statistical variation, measurement errors, ignorance, and indeterminacy.

III. Ambiguity

Ambiguity denotes the variability of interpretations based on identical observations or data assessments.

IV. Ripple-Effects beyond the source of risk

The negative physical impacts have the potential to trigger severe ripple effects outside of the domain where the risk is located resulting ripple effects can cause a dramatic sequence of secondary and tertiary spin-off impacts.

4.1.5 Defining tipping points

Defining the tipping points (thresholds) is an important task to evaluate the dynamic drivers of risk and their impact in complex systems such as major cities and coastal agglomerations (Ahmed et al., 2018). The two case studies of L'Aquila earthquake of 2009 and Japan earthquake and tsunami of 2011 demonstrates that the adaptation of Tipping Point approach gives insight into how much pressure a system (physical or social) can absorb, what the acceptable limits are for impacts, and when they are reached. A "tipping point" in biophysical terms means the point of no return, while an "Adaptation Tipping Point" is the threshold value or specific boundary

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condition where ecological, technical, economic, spatial or socially acceptable limits are exceeded (Haasnoot et al., 2011).

According to Haasnoot et al. (2011) the Adaptation Tipping Points are vital for ascertaining the resilience and adaptation capacity of physical as well as social systems under current or future policy regimes. The system may exceed a tipping point due to either a slow-moving variable (e.g., climate change) or a sudden extreme event (e.g., Aude Region (France) Flash Flooding). According to Gao et al. (2016) if the parameter that influences a system's resilience can be properly identified, then appropriate measures can be taken on that basis to either enhance or restore the level of resilience. The four necessary conditions for defining a tipping point can be mentioned as below (Milkoreit et al., 2018).

1. Multiple Stable States (implying a certain Magnitude of Change and a structural reconfiguration of the system),
2. Abruptness (also Non-linearity or Disproportionality between Cause and Effect),
3. Feedbacks as system-internal drivers of change between the two system states as well as state stabilizers, and
4. Irreversibility. The fourth condition needs to be weakened in the sense that limited reversibility (Hysteresis)and Irreversibility on a timescale relevant for human societies are sufficient to fulfil that condition.

4.1.6 Risk-informed digital twin

Developing a risk-informed multicriteria decision support system is an important approach for sustainable and resilient designing in the early stage under the uncertainty of smart buildings and infrastructure systems (Alibrandi, 2022). In this approach understanding the concept of risk-informed digital twin (RDT) is important as RDT conceptualises the integration of the methods and tools of statistics and risk analysis with machine learning.

The digital twin (DT) is defined as a living digital model of real-world buildings, processes, structures, people, and systems created and maintained to answer questions about its physical part, the Physical Twin (PT). In the case of the built environment, the PT is represented by the smart buildings and infrastructures (Alibrandi, 2022). To consider all the sources of uncertainty during the whole lifecycle, the concept of Risk-informed Digital Twin (RDT) was introduced in which integrates methods and tools of Statistics, Uncertainty Quantification, Risk Analysis with Machine Learning. The underlying features in the RDT can be mentioned as below (Jensen & Nielsen, 2007):

- Ability for probabilistic updating of contexts when new information is acquired, e.g., through a network of sensors or from observations after inspection,
- Ability for transparent modelling, which allows the adoption by users with limited background in probabilistic or reliability analysis,
- The ability to model time-dependent uncertain parameters easily.

The applications of RDT can be identified in the Japan earthquake and tsunami of 2011 which allowed a transparent lifecycle modelling of the involved space- and time- dependent uncertainties and a clear description of the dynamic spatial evolution of the optimal decision.

Key lessons from case studies about carrying out a comprehensive risk diagnosis and identifying the systemic nature of risks.

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The L'Aquila earthquake of 2009 (Mw6.3)

The INGV provided the seismic hazard map, whose most recent version dates to 2004 (Stucchi et al. 2004), before the L'Aquila earthquake. Most of the region, comprising the city of L'Aquila, was in the two most dangerous categories in terms of seismic risk. Even due part of the city was subject to ground amplification (De Luca et al. 2005, only study about site effects before the earthquakes), the buildings, mainly in the old town were not reinforced before the earthquake and the damage was very large in terms of collapsing buildings and loss of life. Cascading effects, such as possible landslides, have been considered through the IFFI catalogue. After the earthquake, several studies from several points of view have been carried out. Now the knowledge of the fault responsible for the earthquake, the seismic micro zonation, fluid migration, new geological studies, and maps of the faults, have been carried out.

Japan earthquake and tsunami of 2011

(AKA: Great Sendai earthquake or Great Tohoku earthquake)

Assessing risks and communicating them clearly and widely helps citizens make timely decisions to protect themselves (World_Bank, 2012). The digital technology is providing new insights and information that can be shared around the world to help the vulnerable in future disasters and crises. The rise in the number of smart phones, mobile internet and access to social media is transforming the world in an unprecedented manner. As the experiences of Japan's survivors demonstrates the internet can play a crucial role in the aid effort during a natural disaster. However, the reality of the digital divide in these situations must not also be underestimated (Peary et al., 2012). Getting information to people on the side of the digital divide, where there is no internet, may help them survive in times of crisis and help communities rebuild after immediate danger has passed. Informal communication tools include local knowledge such as tendenko, practiced on the Sanriku coast, where self- evacuation without waiting for family members and others is encouraged as soon as a large ground shaking is felt. These types of approaches and local knowledge based on experiences with large tsunamis should be preserved and passed from generation to generation. Participatory DRM planning by the local community is an effective way of communicating risk. Different forms of communication may have to be used for different age groups. The local social structure can be leveraged to facilitate emergency planning, for example, by enlisting local leaders in their various roles and functions.

4.2 Pursue resilient urban development and design.

4.2.1 Developing science-based methodologies

Development of science-based methodologies to consolidate disaster risk information and strengthen disaster risk modelling, mapping, and monitoring (including geospatial and space-based technologies) based on spatial patterns is an effective way to implement DRR and CCA measures within regeneration processes at various scales (Zuccaro & Leone, 2018). Especially within the current COVID-19 emergency, the urban development strategies must focus on developing pandemic-resilient cities and management to tackle the infectious diseases in the future as well as in the present (Afrin et al., 2021). During the two events of the L'Aquila earthquake of 2009 and Japan earthquake and tsunami of 2011 the risk of multi-hazards was stressed through a comprehensive all-hazards approach to identify trade-offs, co-benefits of integrated mitigation and adaptation measures, common resilience pathways and management approaches. Especially the need to provide effective multi-hazard assessments, paying attention to cascading effects, hybrid threats and their impacts on increasingly complex societies is explicitly recognized in these case studies. The following two key domains in terms of science-based risk assessment methodologies drive the major advancement in DRR research and implementation (Zuccaro & Leone, 2018).

1) Simulation-based impact quantification and assessments, targeting multi-hazard, 'Natech' - Natural Hazards Triggering Technological Accidents and cascading effects conditions.

2) "Adaptive mitigation" design and "build back better" solutions, targeting resilience based urban regeneration and building retrofitting scenarios.

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The simulation scenario analysis allows the understanding alternative options of physical and economic impacts due to natural, technological or natech hazards which would enable resilient land-use planning for long term DRR (Steinberg et al., 2008). “Adaptive mitigation” ("Climate Change and Cities," 2018) and “build back better” (Mannakkara & Wilkinson, 2014), are emerging as effective approaches to drive scientific results and policy updates towards a holistic resilient design perspective by combining traditional hazard mitigation strategies with measures including blue/green infrastructures systems.

Key lessons from case studies about developing science-based methodologies.

The L’Aquila earthquake of 2009 (Mw6.3)

The L’Aquila region is an area characterized by high seismic risk, but with a low risk perception (Marincioni et al., 2012) by the population. Mr Gioacchino Giampaolo Giuliani was a technician who worked in the National Gran Sasso Physics Laboratory 40 km east of L’Aquila. For some years his hobby has been to monitor atmospheric radon emissions to correlate them with heightened seismic activity and thus gain a means of making short-term predictions of violent earthquakes. He maintained a radon meter in the basement of a school in L’Aquila and took frequent readings from it. He noted increases in radon emissions shortly before the October 2002 San Giuliano di Puglia earthquake, which occurred 240 km southeast of L’Aquila but was unable to pinpoint the epicentre. Radon is an inert gas that is transferred in increasing quantities to air or groundwater when micro-fracturing around an active geological fault is induced by seismic strain. However, it should be emphasized that with current knowledge and technology, earthquakes cannot be predicted in the short-term with such measurements. After the earthquake, several studies from several points of view have been carried out. Now the knowledge of the fault responsible for the earthquake, the seismic micro zonation, fluid migration, new geological studies, and maps of the faults, have been carried out.

Japan earthquake and tsunami of 2011

(AKA: Great Sendai earthquake or Great Tohoku earthquake)

Regarding building relocation and reconstruction, disaster risk management (DRM) consists of three components (World_Bank, 2014): disaster prevention facilities, community relocation to safer ground, and evacuation facilities. This approach was reflected in the government’s basic policy on reconstruction, after the GEJE Reconstruction Council’s report recommended a shift in DRM from prevention to risk reduction. Since the Sanriku region has often sustained severe tsunami damage, its local governments and communities have developed a high level of disaster preparedness (Rajib et al., 2012a). Local governments conduct tsunami evacuation drills every year on days commemorating past large-scale tsunamis, and residents learn how to evacuate safely and quickly from their own houses to designated shelters. The Japanese government is reinforcing DRM systems by introducing land-use regulations based on lessons learned from the GEJE (Rajib et al., 2012b). The Act on Building Communities Resilient to Tsunami was legislated in December 2011 to prepare for low-probability, high-impact tsunamis. The goal of the act is to protect human lives at all costs.

4.3 Safeguard natural buffers to enhance ecosystems’ protective functions.

4.3.1 Utilising earth observation and remote sensing technology in disaster monitoring

Earth observation and remote sensing technology can be used to acquire important data on geo spatial locations based on the spatial and temporal coverage of the satellite or the observation object (Sousa et al., 2021). The earth observation exercises were carried out during Aude Region (France) Flash Flooding, Wildfire - Israel, Mountains of Jerusalem, Western slopes and Japan earthquake and tsunami of 2011 for effective monitoring of the context, with synoptic views of large areas, good spatial and temporal resolution, and sustained time-series covering several time periods. The data acquired from the most recent missions can be used for a detailed reconstruction of past events but also to continuously monitor sensitive areas on the lookout for potential geohazards (Melet et al., 2020). Over the past two decades, several methods based on Synthetic Aperture Radar (SAR) data have been developed and were proven effective in determining deformations of the Earth’s crust (Sharma et al., 2008). This work brings significant advancements concerning the exploitation of earth observation data, resulting in a deeper understanding of the associations between multiple geohazards and their causing factors.

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Key lessons from case studies about utilising earth observation and remote sensing technology in disaster monitoring

Aude Region (France) Flash Flooding

Satellite imagery, particularly through the European Union funded Copernicus project, was available very quickly, but it is not possible to assess whether it had any value in decision-making during the crisis. There is no evidence of strategic or tactical use being made of UAVs by the first responders, and the first apparent use of this technology is in imagery used for broadcast or imagery by media staff. The Aude Feedback Report 2019 does not reference any use of satellite data or UAV imagery in its review of either the preparation and planning or response to the flooding.

Wildfire - Israel, Mountains of Jerusalem, Western slopes

During this event, aerial imagery capabilities were used, including satellite imagery, tactical drones, unmanned aerial vehicles (UAVs), and imagery from command-and-control helicopters. The primary usage was to understand the movement of the fire, locate the spots and the fire front, thus forcing the evacuation of villages, and place the forces in the optimal location. Those means also helped to better understand the fire pattern in those specific topographic conditions and the current weather conditions. The images also allowed remote teams to understand and evaluate the same situation. The imagery helps much with the publication and civilian orders, so they help transferring the message to the communication organization, and public affairs.

Japan earthquake and tsunami of 2011

(AKA: Great Sendai earthquake or Great Tohoku earthquake)

As Japan copes with the aftermath of the earthquake and tsunami, earth reconnaissance satellites and aerial reconnaissance aircraft and unmanned vehicles are deployed to the area to assist emergency operations with real time situational assessment and efficient response to the events of the highest priority (Kaku et al., 2015). Aerial manned and unmanned Intelligence Surveillance and Reconnaissance (ISR) systems dispatched to the area in support of the relief operations include the U-2 high-altitude, all-weather surveillance and reconnaissance aircraft from the Reconnaissance Squadron and RQ-4 Global Hawk remotely piloted aircraft from the Operations Group's Detachment at Andersen Air Force Base, Guam (Eshel, 2011). U-2 has been deployed to capture high-resolution, broad-area synoptic imagery, by using an optical bar camera producing traditional film products which are developed and analysed after landing (Griffin, 2014).

A Tsunami sediments study has been carried out by the British Geological Survey (BGS) using high-resolution satellite imagery from before and after the tsunami, combined with the state-of-the-art digital mapping system (BGS•SIGMAmobile) and traditional field mapping expertise (Tappin, 2011). The findings of the study have the potential to improve the ability to discriminate between high-energy sediments in the geological record that were laid down by tsunami and those laid by storms. This can help scientists to better understand older earthquake events, including their magnitude and frequency.

As part of the International Charter for Space and Major Disasters, the United States Geological Survey (USGS) coordinated a volunteer effort comprised of ten organizations to aid in the response to the disaster (Messinger et al., 2011). This study was aimed to assist the Japanese government with printable, large-format maps of the affected areas that highlighted regions of destruction and, where possible, the 'inundation line' (i.e., the extent the tsunami moved inshore). Where available before and after imagery were used to provide visual change-pairs for additional context for the relief workers. Space-based Worldview-2 sensor (DigitalGlobe) 3 was used to collect images in eight spectral bands from the visible to the near infrared (NIR). Pre-earthquake images were obtained from (January 16, 2011) Worldview-2 multispectral images for Hachinohe, the lesser damaged of the two sites. Post-earthquake images were obtained on March 14, 2011. A large-area map was produced using the NIR band to highlight vegetation and water-affected areas. A series of NIR image-derived maps were produced covering Kesennuma using Worldview-2 imagery on March 13, 2011, two days after the earthquake. In this case, the damage was extensive and ranged further inland. Flooded areas were still visible, particularly in the NIR bands. A post-earthquake GeoEye4 panchromatic image of Kesennuma was used to accurately identify the spatial features. Visual inspection was used to delineate the extent of the debris field. Several map layers were produced displaying the large-area image with the debris field extent identified as well as a close-up image of the region of interest. To aid in the damage assessment at the Fukushima Dai'ichi Nuclear Power Station, Worldview-2 high-resolution panchromatic images were used from March 12, 2011, after the earthquake and tsunami, but before the explosions at the power station. A second Worldview-2 image over the area was collected on March 17, 2011, after three of the reactor buildings had suffered damage. The before and after images were combined into a high-resolution map and distributed to relief workers on the evening of March 18, 2011, within 24h of image collection. On March 19, 2011, a GeoEye panchromatic image was used to produce an image pair showing the nuclear plant from both perspectives, providing better context for the extent of the damage to the facility.

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The 2011 events at the Fukushima Daiichi Nuclear Power Plant (FDNPP) released considerable quantities of highly radioactive material into the global environment. The University of Bristol launched a study in direct response to the incident at Fukushima, is the combined low-altitude multi-rotor unmanned aerial vehicle coupled with a lightweight radiation detection and mapping system (Martin, 2016). Via this system, it was possible to determine the spread of contamination with sub-meter resolution as well as attributing the species responsible. The results were used to determine the distribution of such contamination not only in response to disaster-release scenarios but also for the potential application to wider monitoring following a nuclear dispersion incident.

Taiwan's National Space Organization (NSPO) of the National Applied Research Laboratories (NARLabs) used FORMOSAT-2, and Thailand's Geo-Informatics and Space Technology Development Agency (GISTDA) used THEOS, to survey the coast on 12 March (Kaku et al., 2015). The Indian Space Research Organisation (ISRO) also observed the Sendai area using CARTOSAT-2 on 14 March, in addition to FORMOSAT-2. FORMOSAT-2 is unique because it follows the same orbit every day and continued to monitor affected zones every day. The result of these studies was used in following response activities.

1. Satellite images overlaid on maps to search for and rescue missing persons.
2. To show areas flooded by the tsunami and the situation of houses and buildings.
3. Value-added results (analysed by specialists) for evaluating the overall scenario and detecting debris, landslides, and collapsed houses and buildings.

Information from images on places where 'no damage' has occurred is also valuable to assess availability of access roads. Following a disaster, satellite data are the first to become available, followed by aerial photographs, which provide more detailed images (Kaku et al., 2015). As early as five days after the tsunami, the GSI announced the first estimate of the total inundation area as 400 square kilometres (km2), based on manual interpretation of aerial photographs taken on March 12 and 13. One month after the event, on April 18, the government officially announced the total inundation extent to be 561 km2. The increase reflected the availability of additional aerial photographs and high-resolution optical satellite images of areas previously not covered.

5 State of the art and lessons learned from case studies under the SFDRR Priority for action 2. Strengthening governance to manage disaster risk.

5.1 Organize for disaster resilience.

5.1.1 Identifying the synergies in Disaster Risk Reduction

Established links and synergies between national and local DRR strategies are important to break silos in planning DRR (Thaler et al., 2022). The L'Aquila earthquake of 2009, Aude Region (France) Flash Flooding, COVID-19 Global – focus on Finland and Japan earthquake and tsunami of 2011 highlighted the requirement of novel institutional procedures in risk management to combine different functions (e.g., risk management strategy, sustainable land-use development, individual preparedness, and well-being) that can save space, time and possible arising costs linked with mitigation systems. Thaler et al. (2022) mentioned key elements about upscaling the local innovations in mainstreaming multi-functional protection schemes in natural hazard risk management especially for strengthening the synergies among silos in planning DRR.

1. Legislation

Examining the current situation in legal provision for the implementation of multifunctional technical mitigation measures in high-risk areas. The current situation must change if there are barriers in outcomes of disaster situations and the legal framework is not more flexible.

2. Risk acceptance

Risk acceptance can be used to test whether risk is heightened by multiple uses of mitigation systems and whether this risk can be compensated by improved warning systems.

3. Implementation

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Identifying the time frame of implementing DRR measures can be considered as vital since communities can bounce back to a stable state very quickly. Therefore, using the window of opportunity to implement multifunctional technical mitigation measures in the right time is significant in building community resilience.

4. Risk communication

Risk communication has the effect of increasing the self-responsibility of communities towards natural hazards. Thereby the active participation of communities is vital since as people take responsibility for themselves and their safety vulnerability towards a hazard can be decreased.

5. Technical innovation

Technical innovation is concerned with the state of the art in construction and protection technology. New solutions and innovative outcomes are important.

6. Demand

Identifying the social as well as seasonal changes which requires a larger demand for innovative mitigation solutions can be considered as a significant need in focusing on more sustainable land uses (lifestyle).

7. Policy entrepreneur

Policy entrepreneurs decide on the establishment of mitigation measures, in many cases decide on the behalf of individual interests. Further these decisions can be supported by the Change Agents who have a large influence on the decisions made.

8. Funding

The funding of a mitigation measure is a vital resource for the realization of new projects. Considering private-public funding and private interest (self-financing) motivating single interests to fund projects can be considered vital in the DRR sector.

9. Land-use pressure

Land-use pressure is a very important factor as it decides largely on the possibility of development in space If there is only limited space available. Certain structures will not be possible and thereby considering the need of multiple-use mitigation measures within limited space and high land-use pressure is important.

10. Risk transfer

When the costs of an impact are shifted from one party to another is a common example of risk transfer in disaster. In such instances different financial resources can be used to fair transfer of risks.

5.1.2 Use of indigenous knowledge in policy formulation

Use of traditional, indigenous, and local knowledge of at-risk communities to complement scientific knowledge in the development of policies, strategies, plans and programmes (Hermans et al., 2022). The social relations and experiences of local communities can be an invisible knowledge to improve early warning to impending disasters (Lin & Chang, 2020). Local knowledge for DRR can be effectively incorporated as their everyday lives were closely associated

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with the natural environment (McDermott & O'Dell, 2001), and they could identify disaster risk factors, such as long-term changes in topography, hydrology, flora, and fauna, and recognize disaster warnings (e.g., premonitory symptoms of debris flow, typhoon floods, and earthquakes during L'Aquila earthquake of 2009, and Aude Region (France) Flash Flooding). The Japan earthquake and tsunami of 2011 demonstrated how involuted knowledge can be used to identify evacuation shelters as local communities have learned ways to harmoniously live in their natural environment and have developed unique local knowledge for disaster response based on their cumulated disaster experiences. According to Lin and Chang (2020) the involution process of local disaster knowledge is illustrated as mentioned in following Figure 6.

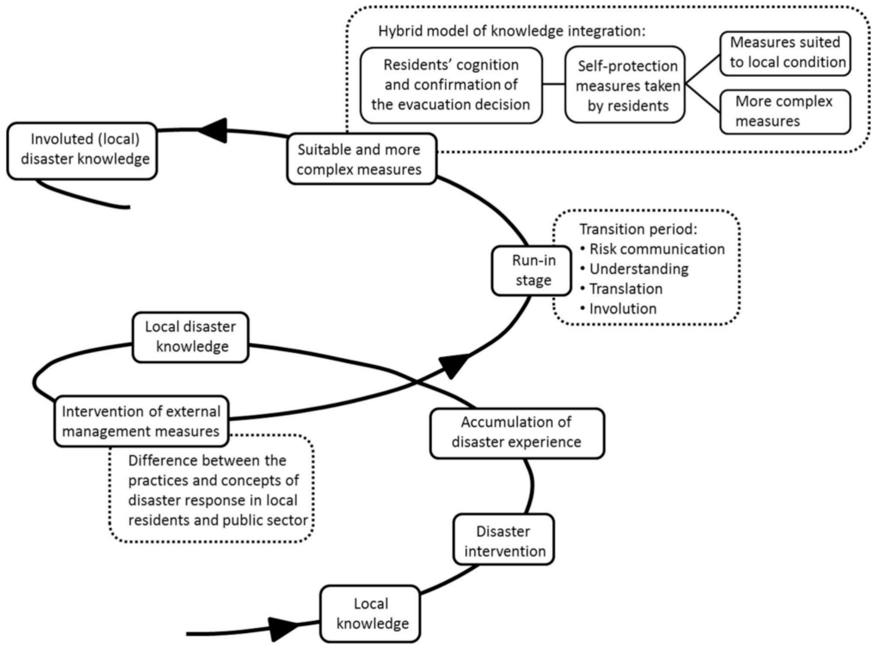

Figure 6: Involution process of local disaster knowledge (Lin & Chang, 2020)

In the involution process the local knowledge serves as the base from which external knowledge's contributions can diversify viewpoints and practice to allow for the involuted knowledge to face the changing world more flexibly. The government manages communities' needs mainly through regulations, plans, and applied scientific knowledge, seldom including local knowledge.

5.1.3 Governance in the context of systemic risk

High complexity events which trigger systemic risks can overextend the established risk management measures and create new, unsolved challenges for policymaking in risk assessment and risk governance (Renn et al., 2022). The lessons learned from COVID-19 Global – focus on Finland case explained that the governance in the context of systemic risk requires to consider dynamic evolutions of multiple causes and effects, feedback mechanisms marked by uncertainties and the potential for cascading or compounding events that lead to failure of the systems that humans depend upon (Renn, 2021). This can be ensured via a carefully designed interface which can translate the scientific findings into policies in practice (Izumi et al., 2019; Koetz et al., 2012). Bridging the science and policy divide via applied approaches and strengthening the interface can be considered as a significant factor in delivering good governance among systemic risks (Nursey-Bray & Harvey, 2013). In bridging the science and policy divide and governing systemic risks requires special steps within the familiar sequence of risk

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identification, assessment, evaluation, and management. The IRGC report on systemic risk governance (Florin & Nursimulu, 2018) lists the following seven of these steps that are crucial for coping with this new challenge:

- Step 1: Explore the system in which the risk management organization or agency operates; define the boundaries of the systems that are and might be affected and identify the agents that are part of the risk network in a dynamic environment.
- Step 2: Develop scenarios, considering ongoing and potential future transitions.
- Step 3: Determine goals and the level of tolerability for risk and uncertainty.
- Step 4: Codevelop management strategies to deal with each scenario and the systemic risks that affect or may affect the various systems that are at risk.
- Step 5: Address unanticipated barriers and sudden critical shifts that may come up during the process.
- Step 6: Decide, test, and implement strategies.
- Step 7: Monitor, learn from, review, and adapt.

Key lessons from case studies about identifying the synergies and indigenous knowledge in DRR policy formulation.

The L'Aquila earthquake of 2009 (Mw6.3)

Through the enactment of Law No. 225 of Feb. 24, 1992, the National Civil Protection Service was established in Italy to protect the integrity of life, property, settlements and the environment from damage or the danger of damage resulting from natural disasters, catastrophes, and other disasters. Since 2001, the Civil Defense Department has issued guidance with the aim of improving the organization of relief and medical assistance in emergencies. The first directive "Broad Criteria for the Organization of Relief in Disasters" came out in 2001, which was followed in 2003 by the document on "Broad Criteria on the Provision of Medicines and Medical Devices for an Advanced Medical Post." In 2006, the Department chooses to devote an internal document to a very delicate aspect of emergency management that is psychological and psychiatric care during a disaster: with the "Outline Criteria on Psychosocial Interventions in Disasters" common objectives and organizational schemes are identified. In 2007, the directive "Procedures and Forms for Health Triage" is published, outlining procedures for dividing patients by severity and treatment priority in the event of a disaster (Alexander, 2010)

Aude Region (France) Flash Flooding

For example, a project led by the environmental management section of L'Aude Département Local Authority seeks to bring together climate scientists, and satellite imaging specialists with local authority planners. The intention is to use new technology including satellite images and potentially artificial intelligence to become more predictive and proactive in flood prevention activity. This project has drawn support nationally and from elsewhere in Europe including the EU Copernicus earth observation programme and the Space Climate Observatory. Visakhapatnam ("Vizag") Industrial Accident – Styrene Vapour Release - LG Polymers Plant, Venkatapuram Village, Visakhapatnam, Andhra Pradesh, India, The National Disaster Management Plan is a comprehensive document produced by national government and published in 2016. It is a high-level plan which requires all ministries, agencies, and local government bodies to develop in respect of their individual responsibilities. There is no evidence that this document was considered in any preparations prior to the vapour leak on Tuesday 7th of May 2020. The Andhra Pradesh State Disaster Management Authority was in operation since the creation of the master plan. Below them there are district disaster authorities. these bodies are responsible for carrying out approval and supervision of action plans by agencies and arranging for exercises. One identified source suggested that ten specific disaster management exercises had been carried out prior to this critical incident, but none were related to this issue and there is no coherent documentation to suggest whether this work was effective.

COVID-19 Global – focus on Finland.

During the pandemic, a new team for strategic communication started at the Finnish Prime Minister's Office. The task of this team was to support citizen's crisis resilience, considered as one of the vital societal functions in Finland (Security Strategy for Society 2018). A communication project, called Finland Forward was launched to implement this task. The project had as its aim to help people cope with the prolonged crisis, and to strengthen people's resilience to crisis, promote interaction, create a sense of community, and help people cope with everyday life through communication. It included various means for communication: campaigns, video material, pod casts, events and daily cooperation with civil society actors, NGOs, and companies, all together almost 200 actors and organisations. Social media were widely

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used as well. Although the project approach and the related campaigns were novel and in line with modern approaches to crisis communication theory, they did not reach wide audiences. (Hakala & Ruggiero 2022.)

In crisis response, challenges emerged in sharing information across different administrative branches. In the future, contacts are needed across national borders, so in international organisations, and across sectoral borders. Although Finland has adopted the concept of comprehensive societal security, in practice, analysing and preparations are conducted in silos within the borders of branches and ministries. This is an important point that needs to be tackled as future crises are likely to be of intersectoral and international concern. (Mörttinen, 2021.)

National Audit Office of Finland explains the lessons learnt from the security of supply perspective from the COVID-19 in Finland. According to the report, the pandemic risk management was successful even though preparedness was in principle for other kinds of crises, such as a military threat or smaller scale events, such as major accidents. The massive demand of protective equipment and the long duration of the crisis were issues that there were no preparations for. Besides material preparedness, security of supply is important also in ensuring adequate resources in terms of, e.g., personnel in critical sectors, such as health care, and human resources. In the future, as Finland is not able with its resources to be prepared in detail for all the possible crises, the security of supply measures needs to be planned in a way that as many as possible kinds of exceptional conditions can be responded to. (National Audit Office of Finland, 2021.)

Japan earthquake and tsunami of 2011

(AKA: Great Sendai earthquake or Great Tohoku earthquake)

Recent experiences from the Great East Japan Earthquake (GEJE) showed that when the local community was involved in planning for disaster preparedness, and people took ownership of their own safety plans, they were better prepared and better able to take the necessary actions to protect themselves (Edgington, 2022).

In Aneyoshi District, Miyako City, Iwate Prefecture, villagers who followed the practices of their ancestors survived and saved their properties from the tsunami (Suppasri et al., 2013). A stone monument, set up after the 1933 Showa Sanriku Tsunami, is 60 meters above sea level—20 meters higher than the level of the 1933 tsunami. Communities in the Sanriku region have built 150 monuments to raise public awareness among future generations.

According to the World_Bank (2014) report, community- based DRM activities are well integrated in the daily lives of the residents, ensuring that awareness of natural hazards is maintained, for example, by marking the anniversary of a large catastrophe with disaster drills, and linking awareness raising activities with local festivals.

5.2 Pursue resilient urban development and design.

5.2.1 Identifying the interlinkages and synergies in risk resilient development

Identifying the interlinkages and synergies when pursuing risk-resilient development pathways are highly useful in DRR practices (Orimoloye et al., 2021; Saunders & Kilvington, 2016). According to Mitra and Shaw (2023) the Integrated Disaster Resilience (IDR) framework based on the systemic perspective is structured around three high-level dimensions that span the resilience building lifecycle. 'Design' dimension which outlines the need for effective leadership, ‘strategy’ dimension which illustrates the shared goal to drive long-term decision-making, and the 'Resilience' dimension which considers the mainstreaming of CCA and DRR into the development planning process, collaborative decision-making and goal setting between key systems, actors, and sectors.

UNISDR (2004) highlight the importance of Risk-based planning for risk resilient development where the role of land use plans to control or prevent development in extreme risk areas, and to mitigate risk in existing developments. A risk-based approach supports smarter development, allowing long-term potential impacts and costs to be factored into development choices (Kilvington & Saunders, 2019). The lessons from Aude Region (France) Flash Flooding and Japan earthquake and tsunami of 2011 demonstrates that it allows local government agencies to determine the acceptable level of risk in discussions with their communities. Accordingly, a risk-based planning assessment can be used to address the effects of a particular natural hazard,

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either, with other hazards at the same location (i.e., cumulative), or with cascading hazards (e.g., an event such as an earthquake can trigger other hazards such as liquefaction, tsunami, and landslides). According to Saunders and Kilvington (2016) the 'Risk-Based Planning Approach' RBPA framework is consistent with international risk management best practice as mentioned below.

1. Know your hazard.

2. Determine the severity of the consequences.

3. Evaluate the likelihood of an event.

4. Take a risk-based approach and,

5. Monitor and evaluate.

Each step has options enabling stakeholders and affected communities to participate in the risk analysis, evaluation, and decision-making process.

5.2.2 Adopting eco-system based/inspired solutions and experiences.

Contribution of science and technology for integration of eco-system based/inspired solutions and experiences from case studies on nature based/inspired resilience applications is identified as a pivotal factor in multi-hazard ecosystems, and mainstreaming policy-level strategies (Mukherjee & Shaw, 2021). Wildfire - Israel, Mountains of Jerusalem, Western slopes and the Japan earthquake and tsunami of 2011 cases demonstrated that the selection of a suitable Nature based Solutions (NbS) will depend on the nature and scale of interactions between an urban centre's internal and external sustainability components, as well as, in the buffer spaces of their nexus. Some of the pertinent NbS interventions that are adopted by cities (Dhyani et al., 2020) are listed below:

1. The large-scale implementation of cost-effective NbS as Blue-Green Infrastructure (BGI), such as permeable pavement systems with integrated sub-surface recharge cisterns.
2. Effective use of brownfield spaces and growth of fringe green spaces and buffer zones.
3. Multi-scalable utilization of NbS with support from local designers. This integrating more natural products in building material that reduces energy, water, and carbon footprint.
4. Engagement of proper spatial planning and design to distribute NbS throughout urban areas.
5. Inclusion of NbS concepts in urban planning and design, policy formulation, and city-level decision-making processes 12 Scaling-up Nature-Based Solutions for Mainstreaming.
6. Encouragement of dialogues on the co-benefits, as well as disservices and/or limitations associated with the NbS already implemented or planned.
7. Evolving flexible institutional frameworks, as well as incentives to promote NbS at corporate and individual levels to realize the transformative potentials of NbS over long terms.
8. Mainstreaming NbS in decision-making, policy, and urban planning.

5.2.3 Identifying the driver specific systemic risk mitigation measures/ planning initiatives

Utilising the drivers of systemic risk and attribution of driver specific strength for systemic risk mitigation and long-term resilience, holistic, and systemic perspective (Mitra & Shaw, 2023). A systemic innovation approach in practice requires to build a collective intelligence through

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experiential learning (Saunders & Kilvington, 2016). This requires the transition to systems approach considering the aspects such as satisfactorily defining acceptable, tolerable, and intolerable risk, incorporating the views of stakeholders, and affected communities, and ensuring that potentially controversial decisions over land use options are robust and defensible. As proposed by Mitra and Shaw (2023) the following conceptual framework (Figure 7) for Integrated disaster resilience (IDR) identifies a 'Whole Systems Approach' for systemic risk mitigation.

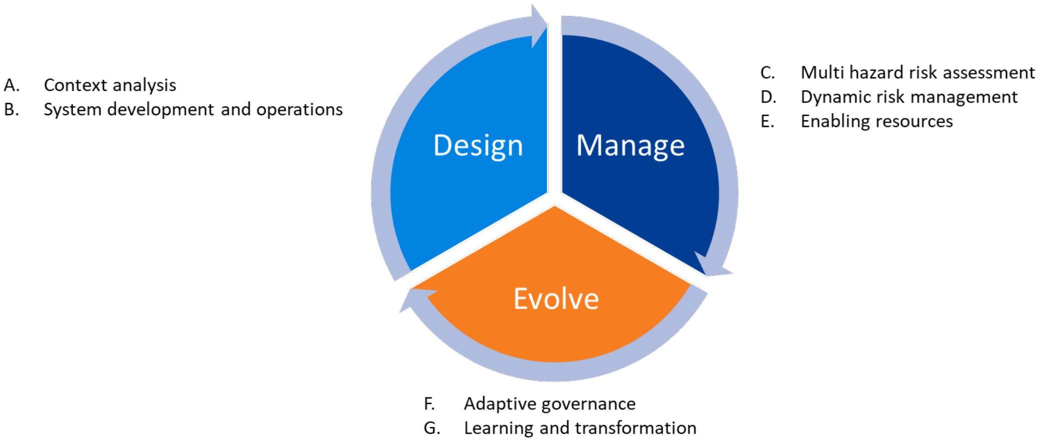

Figure 7: Conceptual framework for Integrated disaster resilience (IDR) based on a 'Whole Systems Approach (Mitra & Shaw, 2023)

- The 'Design' dimension outlines the need for effective leadership, strategy, and shared goal to drive long-term decision-making around 'Resilience', mainstreaming of CCA and DRR into the development planning process, collaborative decision making and goal setting between key systems, actors, and sectors.
- The 'Manage' dimension outlines the need for holistic risk assessment and its management through coordination across interdependent systems and to plan for and respond to shocks and stresses by means of effective disaster response and enabling resources including funding.
- The 'Evolve' dimension sets forth the need for adaptive, reflexive, and transboundary governance mechanisms coupled with learning and transformation in the context of the evolving risk landscape. In its emphasis on integrating feedback loops and continuous learning as a key ingredient of resilience, this dimension overlaps connects back to the 'Design' dimension, completing the circle.

Key lessons from case studies about identifying the interlinkages and synergies in risk resilient development and adopting eco-system based/inspired solutions and experiences.

Aude Region (France) Flash Flooding

The integrated flood governance approach in France is compliant with the national Disaster Risk Reduction strategy, described in studies as comprising 3 elements.

- Risk Prevention – Hazard analysis, intended to identify for example flood risk, as well as the associated issues such as landslides or infrastructure damage. Following this planning phase, weaknesses in the local environment are identified, including human factors such as age and infirmity, or ageing infrastructure and weak public services. Mitigation measures are then identified which may be physical or structural.
- Emergency management - This is clearly the responsibility of first responders, and planning may be at a local or regional level to identify scenarios and arrange appropriate training for the agencies involved. Warning systems are part of this structure. Could naturally include the warning systems identified for flood prevention.
- Disaster Recovery - in France, this is focused on government support for regions suffering critical incidents, which must achieve a certain level to trigger supporting payments both to local authorities and the individual

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members of the public affected. This is supported by private sector insurance provision for both individuals and corporate bodies. As a result of the Sendai international approach, afflicted communities and their leadership are encouraged to adopt the concept of "Build Back Better", thus always aiming to increase resilience and resistance to natural or man-made risks.

Wildfire - Israel, Mountains of Jerusalem, Western slopes

1. Protecting the villages
   This wildfire emphasizes the importance of the Buffer zone between the villages and the forest. Protecting communities and vital assets are the most important and priority task, despite immense pressures from other parties. The aerial order of battle must act as an operational supporter, that is, the defense of settlements.
2. Evacuation of villages to minimize the risk.
   During this event, ten villages were evacuated (Tzova, Givat Yaarim, Shoava, Ramat Raziel, Beit Meir, Eitanim, Shoresh, Ein-Rafa, Ein-Karem, Ein-Nakova).
3. Mental-ill hospital evacuation
   On the first day of the wildfire (15/08/2021), there was a need to evacuate one large-scale (approx. 160 patients) mental-ill hospital near the wildfire area.

The hospital is in the Mateh Yehuda-Har Eitan sector, a forested area, partly in pine plantings and partly in natural woodland. On 15/08/2021, after 15:00, a fire broke out near the community of Beit Meir village. About an hour later, reports started arriving from the Security Department about the direction of the spread of fire that could threaten the hospital and preparations for the feasibility of evacuation began.

Japan earthquake and tsunami of 2011

(AKA: Great Sendai earthquake or Great Tohoku earthquake)

Non-structural measures

In the 1940s and 1950s Japan was repeatedly ravaged by typhoons and earthquakes. In particular, the Isewan Typhoon in 1959 caused tremendous damage; in 1961 the Disaster Countermeasures Basic Act was passed (Makoto, 2012). According to Makoto (2012) the Central Disaster Management Council was established to formulate the overall policy for DRM and to function as the national coordinating body for disaster management.

The Basic Disaster Management Plan is the master plan and the basis for DRM activities in Japan (Suganuma, 2006). It is prepared by the Central Disaster Management Council in accordance with the Disaster Countermeasures Basic Act. Major revisions to the plan included the addition of a new section on tsunami disaster management. Fundamental improvements in disaster management for tsunamis and earthquakes in the light of the GEJE:

- Requirements to prepare for low probability and large- scale earthquakes and tsunamis.
- More careful consideration of multi-hazard and multilocation disasters
- Mandatory inclusion of DRM in urban land use
- Raising of public awareness about evacuation, DRM measures, and hazard maps
- Additional investments nationwide for capacity building of each counter measure
- More resources to be invested in understanding disaster risk and developing innovative systems for monitoring earthquakes and tsunamis.
- Communication tools such as tsunami early warning systems to be strengthened.
- Additional reinforcement and retrofitting of homes and buildings to reduce earthquake damage.

History of building codes in Japan

Due to its location and tectonic settings, Japan is prone to large earthquakes. The Great Kanto Earthquake in 1923 caused some of the most serious damage in Japanese history, as fires consumed a large part of Tokyo, killing more than 100,000 people. Based on the lessons learned from the disaster, a seismic design code was introduced in the building code of 1924, the first national seismic design code applied anywhere in the world (Aoyama, 1981). The importance of retrofitting buildings is demonstrated by the fact that buildings designed under the 1981 building code and retrofitted buildings performed well in the GEJE, whereas most of the damaged buildings were constructed before 1981 and had not undergone any retrofitting.

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5.3 Safeguard natural buffers to enhance ecosystems' protective functions.

5.3.1 Identifying the role of local ecosystems in DRR

Identify local ecosystems and understand their role in reducing disaster impacts (e.g. wildfire - Israel, Mountains of Jerusalem, Western slopes attempts to control fire spread via natural tree buffers, slope stabilization, reduction of heat island effect, etc.) and their contribution to climate change mitigation via promoting ecosystem-based disaster and climate resilience (Maki, 2021). In 2019, National government in Japan published the report "Promoting Strategy of Green Infrastructure" (Maki, 2021). This is the first national government report on Green Infrastructure having a close relation with ecosystem based DRR. This report points out eight things for the green infrastructure such as

1. Adaptation to climate change,
2. Creative city,
3. Biophilic Design,
4. Sustainable Land use and management,
5. Compact city,
6. Smart urban management,
7. Ecology, Natural-Oriented River management, and
8. Living Space with natural environment.

Key lessons from case studies about identifying the role of local ecosystems in DRR.

Wildfire - Israel, Mountains of Jerusalem, Western slopes

In the case of wildfires, there is a national standard related to the buffer zone of the forest. Each village needs to keep a clean layer between the external border of the village and the forest to reduce the density of the forest near the village perimeter and hold firefighting equipment for the first response. This standard also deals with industry infrastructure or warehouses while enforcing buffer zone on the outer boundaries of the building.

Japan earthquake and tsunami of 2011

(AKA: Great Sendai earthquake or Great Tohoku earthquake)

Community action is essential to maintaining the coastal green belt (Rajib et al., 2012a). Local communities had historically developed and maintained the green belt to protect their houses and agricultural lands from coastal hazards. Japan is surrounded by 1,640 km2 of a forested green belt distributed along its sandy coast. For more than four centuries Japan has been developing this green belt composed mainly of Japanese black pine (Rajib et al., 2012a). Japan's Forest Law stipulates that disaster risk management (DRM) forests should be planted in coastal areas to prevent damages from wind, airborne sand, and tsunamis.

5.4 Strengthen institutional capacity for resilience.

5.4.1 Leveraging partnerships for multi-stakeholder cooperation

Identify measures to improve the national DRR governance system and its accountability to achieve good governance (Okada et al., 2018). According to (Fjäder, 2021) the multi-stakeholder cooperation is often either ad hoc and reactive in nature or principally limited to sharing of information and good practices. Therefore, leveraging partnerships for the development and implementation of DRR strategies requires the comprehensive development of capabilities in resilience, long term, and concrete partnerships with clear value proposal throughout the entire life cycle of disasters. According to the Japan earthquake and tsunami of 2011 understanding, a continuous development of resilience partnerships is essential, as partnerships not only need to continuously evolve to fulfil their current mission but also because each disaster is unique and responding to wider variety of incident types requires developing robust capabilities. Such life-

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cycle approach to developing partnerships should overlook the following key aspects (Fjäder, 2021).

- Establishing a clear scope and a unique value proposal
- Accountability, roles, and responsibilities
- Life-cycle approach to partnerships

5.4.2 Promoting disaster risk reduction in formal and non-formal education

Promote the incorporation of disaster risk knowledge, including disaster prevention, mitigation, preparedness, response, recovery, and rehabilitation, in formal and non-formal education (Cabello et al., 2021). Formation of sustainable communities necessarily implies a change in how these communities are inhabited, therefore, the knowledge generated should influence DRR education as well as urban public policy (Paci-Green et al., 2020). In the same way, considering the scarcity of educational initiatives reported that focus on understanding children's ideas about the causes or origins of socio-natural disasters, various local voices should be heard at an international level to raise awareness and thus to advance the DRR education.

Key lessons from case studies about leveraging partnerships for multi-stakeholder cooperation and promoting disaster risk reduction in formal and non-formal education.

COVID-19 Global – focus on Finland.

During the pandemic, a new team for strategic communication started at the Finnish Prime Minister's Office. The task of this team was to support citizen's crisis resilience, considered as one of the vital societal functions in Finland (Security Strategy for Society 2018). A communication project, called Finland Forward was launched to implement this task. The project had as its aim to help people cope with the prolonged crisis, and to strengthen people's resilience to crisis, promote interaction, create a sense of community, and help people cope with everyday life through communication. It included various means for communication: campaigns, video material, pod casts, events and daily cooperation with civil society actors, NGOs, and companies, all together almost 200 actors and organisations. Social media were widely used as well. Although the project approach and the related campaigns were novel and in line with modern approaches to crisis communication theory, they did not reach wide audiences. (Hakala & Ruggiero 2022.)

Japan earthquake and tsunami of 2011

(AKA: Great Sendai earthquake or Great Tohoku earthquake)

A local disaster management plan provides the provisions for development or improvement of DRM facilities, investigation and research, education, drills and other preventive measures, collection, and dissemination of information, issuing and disseminating of forecasts and warnings, evacuation, firefighting, flood fighting, rescue, hygiene, and other emergency measures and rehabilitation efforts. In Kesennuma, students at the Hashikami Junior High School are taught DRM as part of the ESD program (Shaw et al., 2012). The school served as an evacuation center for more than 1,500 people after the GEJE, which occurred just before graduation. Local governments conduct tsunami evacuation drills every year on days commemorating past large-scale tsunamis, and residents learn how to evacuate safely and quickly from their own houses to designated shelters. Preparation for disasters caused by powerful hazards is a primary part of the knowledge imparted at school, especially through fire simulation exercises (Shaw et al., 2012). This activity is mandatory since it figures in the Fire Service Act of July 24, 1948, as well as in the regulation implementing this law taken by the Cabinet on March 25, 1961, and the ministerial regulation for application of April 1, 1961 – the latter requiring a minimum frequency of two per year. Many institutions – even all the public schools in some municipalities such as Kagoshima – also organize at least one earthquake simulation exercise every year, and the number can be as high as six for primary and secondary schools in Tokyo.

5.5 understand and strengthen societal capacity for resilience.

5.5.1 Identifying the personal biases in decision making

Understanding the relationships between individuals' decisions, their decision-making styles, and personality traits can provide explanations about why people respond differently to post-disaster situations and provide better understanding of how people would react after a disaster (Golazad et al., 2022). They can be influenced by social, psychological, and individual factors in their risk perception. Aude Region (France) Flash Flooding incident demonstrated that the people's

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decision-making styles are related to their post disaster decisions and indicate significant trends about the conscientiousness and risk perception. During the L'Aquila earthquake the lack of social resilience in L'Aquila was demonstrated in the lack of ability to return to at least the original situation before the earthquake. The top-down approach adopted by the Italian Government closed the door to grassroots involvement, justified in the urgency of provide housing solutions. Furthermore, the frequency of disaster experience is positively associated with perceiving that as a threat to the person's life (Pan, 2020). Consequently, risk perception could vary by different factors, and its association with personality could be affected.

5.5.2 Improving social capacity

Improved capacity of communities to effectively anticipate, respond to, and recover from, the mobility consequences of disasters, through strengthened disaster preparedness and building capacity for response (Gil-Rivas & Kilmer, 2016; Reis et al., 2021). According to the Aude Region (France) Flash Flooding incident, focusing an ecological framework grounded in such values as collaboration, social justice, empowerment, and an appreciation of diversity to guide disaster work with communities can be considered as important factors. Multiple authors have put forth values and principles to guide and inform community-focused efforts to prepare for, respond to, and recover from disaster (Trickett, 2009). The Aude Feedback Report 2019 identifies that in the event of a larger scale disaster or longer-term problems, anywhere in France, government shrinkage and reduced public spending have diminished capacity to the extent that in this region at least, expected retirements are likely to remove the expertise and capabilities which were already stretched. Following are the identified key principles for improving social capacity in the disaster context.

- Focus on Ecology in Efforts to Build the Community's Capacity for Disaster Preparedness, Response, and Recovery
- Emphasize Increasing the Capacity and Supportive Potential of Community Members' Natural Settings
- Address Power and Resource Inequities in the Community
- Enhance Capacity to Ensure Contextually and Culturally Appropriate Structures, Methods, and Interventions

Key lessons from case studies about identifying the personal biases in decision making and improving social capacity.

Aude Region (France) Flash Flooding

Every household in the region has received written advice which is also available online. This focuses on identifying appropriate supplies and equipment in the event of a flood or fire, and maintaining a state of vigilance, and awareness of how to respond. There are noticeable advertisements both in physical media and online in the region offering potential mitigation or solutions to flooding risks for individual householders. Again, the municipalities and prefecture between them had the capacity to deal with the Aude flooding which was a comparatively short-term event. The Aude Feedback Report 2019 identifies that in the event of a larger scale disaster or longer-term problems, anywhere in France, government shrinkage and reduced public spending have diminished capacity to the extent that in this region at least, expected retirements are likely to remove the expertise and capabilities which were already stretched. While cash donations to support victims were effectively dealt with by an existing voluntary sector body, donations of in-kind materials and support were found to be a problem. In some municipalities, capacity was found within local authority resources, but elsewhere storage pending use was an issue. Much of the responsibility for coordinating resources for recovery is vested in the municipality. This was found to cause problems in the deployment of military assets, when a deployment might need to extend across a municipality border, and later in the recovery process when there were competing demands for resources. Whilst there is an association of mayors which can assist, there is clearly a requirement for command-and-control functions to be augmented at the prefecture and indeed regional level.

The L'Aquila earthquake of 2009 (Mw6.3)

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Resilience should be the main principle in guiding urban reconstruction to reduce emerging vulnerability in urban environments. The lack of spatial resilience in L'Aquila is demonstrated in the lack of ability to return to at least the original situation before the earthquake. The top-down approach adopted by the Italian Government closed the door to grassroots involvement, justified in the urgency of provide housing solutions. Lack of resilience is a problem in countries with low capacity to anticipate, to cope and to recover. The post-disaster phase offers an opportunity to reduce the existing vulnerability and improve the conditions of the community in the physical, social, economic, cultural, institutional, and environmental dimension. It means to build a resilient community, through application of lessons learned. Nevertheless, it seems that this opportunity has not been harnessed yet in L'Aquila. Source: Contreras et al., 2017

5.6 Increase infrastructure resilience.

5.6.1 Assessing the infrastructure resilience

The Japan earthquake and tsunami of 2011 demonstrated that identifying the factors for simulating the infrastructure systems is crucial for assessing their corresponding resilience (Haggag et al., 2022). According to Haggag et al. (2022) following factors provide important information in assessing the infrastructure resilience (the concept of resilience, city assessment and urban planning, critical infrastructure systems, infrastructure interdependence, risk and disruption, complex systems modelling, complex network theory, power, gas and/or water systems, and disasters and system disruption). The resilience metrics quantification approach relates system resilience to its behaviour, whereby three capabilities were suggested (Ouyang & Wang, 2015) to measure system resilience as:

1. Absorptive Capability: the ability of a system to minimize the consequences of an extreme event, which can be linked to the robustness of the underlying system and can be enhanced by increasing resilience means (i.e., redundancy or resourcefulness).
2. Adaptive Capability: the ability of a system to adapt (i.e., reorganize) itself after an extreme event to minimize the corresponding consequences, which can also be linked to the two resilience means; and
3. Restorative Capability: the ability of a system to be repaired after an extreme event, which can be directly related both resourcefulness as a resilience means and rapidity as a resilience goal. As can be observed from the definitions of the three resilience capabilities, they can be related to the system behaviour rather than its inherent properties.

5.6.2 Ensure the operability of critical infrastructure in the event of acute shocks.

According to the Japan earthquake and tsunami of 2011, the availability of processes to ensure operability of critical infrastructure in the event of acute shocks is a crucial need when planning critical infrastructure (Tajima, 2018). This requires the urban infrastructure systems to equip with spare capacity (e.g. redundancy) to cope with a combination of risks (Argyroudis et al., 2022). In this purview, emerging and disruptive digital technologies have the potential to provide flexible, modular, and diverse transformation in the critical infrastructures to improve resilience by incorporating rapid and accurate assessment of asset condition and support decision-making and adaptation.

Traditional infrastructure management accounts for resilience to a limited extent, whilst sparsely exploits the full potential of digital technologies. Emerging digital technologies will facilitate the solution of a central problem in infrastructure resilience – balancing efficiency and resilience trade-offs (Thorisson et al., 2017). Many current infrastructure systems are more vulnerable to systemic shocks and cascading disruption since the practices on which they depend, overly prioritise system efficiency over resilience. More resilient systems may be less efficient, but they recover better from systemic disruptions.

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The infrastructure systems should embrace system complexity to minimise cascading failures resulting from unexpected disruptions, by decoupling unnecessary dependencies across infrastructure and making necessary connections controllable, visible, and resilient (Hare et al., 2016). Especially in the Japan earthquake and tsunami of 2011 there was very limited understanding of the interdependencies between assets and diverse networks, which is the result of siloed and fragmented approaches that prevent the delivery of overall solutions for combating nuclear crisis. Hence, it is essential to design communication between interconnected parts of the infrastructure and add resources and redundancies in system-crucial components, to safeguard functionality.

5.6.3 Improving resilience via the development of green infrastructure.

Improve the understanding of green infrastructure development in cities and urban areas through the development of guidance material (Staddon et al., 2018). Green infrastructure has been successfully enhanced urban resilience during the Japan earthquake and tsunami of 2011 and maintained critical system multi-functionality across complex social–ecological and technical systems. According to Meerow and Newell (2017) in such approaches considering the following factors are essential, (1) standards; (2) regulation; (3) socio-economic factors; (4) finance ability; and (5) innovation.

Cities can enhance their sustainability or resilience through spatial land-use planning. Some spatial planning takes an "ecosystem approach," in which effective management of land and water provides a suite of ecosystem services for the benefit of humans and the natural environment (Wilson & Piper, 2010). The expansion of green infrastructure in cities has emerged as a popular strategy to operationalize this ecosystem-based approach to spatial land-use planning (Lennon & Scott, 2014). According to Lennon and Scott (2014) the Green Infrastructure Spatial Planning (GISP) model harnesses the interconnected network of green space that conserves natural ecosystem values and functions while providing associated benefits to its inhabitants via following key considerations.

- Managing stormwater
- Reducing social vulnerability
- Increasing access to green space
- Reducing the urban heat island effect
- Improving air quality
- Increasing landscape connectivity

Key lessons from case studies about assessing the infrastructure resilience and improving resilience via the development of green infrastructure.

Japan earthquake and tsunami of 2011

(AKA: Great Sendai earthquake or Great Tohoku earthquake)

Structures such as dikes play a crucial role in preventing disasters by controlling tsunamis, floods, debris flows, landslides, and other natural phenomena (World_Bank, 2014). According to the World_Bank (2014) report when the tsunami hit eastern Japan in March 2011, 300 km of coastal dikes, some as high as 15 meters high, had been built. Prefectural governments, which have the main responsibility for building the dikes (supported by national subsidies that cover two- thirds of the cost), built 270 km of the total, with the national government building the remaining 30 km.

The national government also had developed technical standards, guidelines, and manuals for use in the design and construction of coastal structures (Ishiwatari & Sagara, 2012). In response to the economic damage caused by the Great East Japan Earthquake (GEJE)— ¥300 billion ($3.75 billion) in destroyed dikes— the government has invested several hundred billion yen in dike construction in the Iwate, Miyagi, and Fukushima prefectures. It has also invested ¥400

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billion ($5 billion) in constructing bay mouth breakwaters in major ports, such as Kamaishi, Kuji, and Ofunato, to protect them from tsunamis.

The disaster- affected region had frequently sustained devastating damage from tsunamis, including the Sanriku tsunamis of June 1896 and March 1933, and a tsunami caused by a massive earthquake off the coast of Chile in May 1960. The 1933 Showa Sanriku Tsunami was the first disaster to provoke modern tsunami countermeasures at the initiative of the central and prefectural governments. According to the report by Ishiwatari and Sagara (2012) certain breakwaters were also effective in mitigating damage from the tsunami. The breakwater at the mouth of Kamaishi Bay in Kamaishi City, Iwate, was completed in 2009, at a total cost of some ¥120 billion ($1.5 billion). It was the world's deepest breakwater. Although destroyed by the GEJE tsunami, the breakwater reduced the tsunami's force, and therefore its height, by about 40 percent and delayed its arrival by some six minutes, allowing more time for people to evacuate to higher ground.

The following multi-functional infrastructures have also being identified by Ishiwatari and Sagara (2012) as effective mitigatory measures.

- Expressways and roads mitigated damage resulting from the Great East Japan Earthquake (GEJE). The East Sendai Expressway, a 24.8-kilometer (km) toll road running through the Sendai Plain, about 4 km off the coast and at an elevation of 7 to 10 meters, acted as a secondary barrier or dike and prevented tsunamis from penetrating further inland (Figure 18).
- Roadside service stations, service areas, and parking areas along highways also helped in the disaster management effort, providing bases of operation for rescue teams and evacuation shelters for residents.
- When Iwaizumi Town in the Iwate Prefecture was severely hit by the massive tsunami, an evacuation stairway constructed at the Omoto Elementary School two years before saved the lives of 88 children.

After the GEJE, emergency measures were implemented to restore coastal dikes to prevent coastal flooding from storm surges. Emergency rehabilitation was first implemented along about 50 of the 190 km of damaged coastline. Those 50 km were selected because of the important facilities and properties in the area, or because of the urgency of restoring livelihoods, industrial activities, transportation, and agricultural activities.

6 State of the art and lessons learned from case studies under the SFDRR Priority for action 3. Investing in disaster risk reduction for resilience.

6.1 Strengthen financial capacity for resilience.

6.1.1 Identifying cost-effective risk mitigation measures

Proposing strategies for the use of cost-effective risk mitigation measures coupled with insurance can rework the structure of risk mitigation and financial investments in disaster risk reduction (Kunreuther, 2001). In many developing countries there is not an active private insurance market. In these cases, the government may need to rely on other ex-ante risk transfer mechanisms to provide them with financial protection against disaster losses. New capital market instruments such as catastrophe bonds represent an alternative to insurance for offering funds to aid the recovery effort.

6.1.2 Addressing the biases in social behaviours in local level risk financing mechanism

Addressing the biases of behavioural characteristics, including individual time and risk preferences are important to promote disaster risk financing in the local level (Mol et al., 2020). Mol et al. (2020) shows that respondents invested more in self-insurance when they were confronted with a higher probability of loss. Moral hazard is a potential difficulty in the promotion of damage-reduction measures which is information asymmetry between the insurer and the policyholder regarding implemented measures (Di Mauro, 2002). Financial incentives such as premium discount can significantly increase investment in self-insurance thus reduce the moral hazard, although the effect is largest under high probability of loss and low levels of deductibles.

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Key lessons from case studies about identifying cost-effective risk mitigation measures and addressing the biases in social behaviours.

Japan earthquake and tsunami of 2011

(AKA: Great Sendai earthquake or Great Tohoku earthquake)

Japan has a culture of preparedness, where training and evacuation drills are systematically practiced at the local and community levels and in schools and workplace (Nakaya et al., 2018). Kamaishi City has been conducting DRM education programs since 2005 in cooperation with Gunma University (Shaw et al., 2012). The program engages the local community in preparing disaster risk maps and holds evacuation drills four times a year one joint drill with the elementary and junior high school and one annual drill with the local community. In Kesennuma, students at the Hashikami Junior High School are taught DRM as part of the ESD program (Shaw et al., 2012). The school served as an evacuation centre for more than 1,500 people after the GEJE, which occurred just before graduation. Local governments conduct tsunami evacuation drills every year on days commemorating past large-scale tsunamis, and residents learn how to evacuate safely and quickly from their own houses to designated shelters.

7 State of the art and lessons learned from case studies under the SFDRR Priority for action 4. Enhancing disaster preparedness for effective response, and to 'build back better' in recovery, rehabilitation, and reconstruction.

7.1 Ensure effective disaster response.

7.1.1 Establish an effective monitoring system and real time loss estimation mechanism.

Develop a plan to address any bias, assumptions, or interpretations by establishing protocols to monitor the data, providing regular training to keep skills of the user accurate, and validating the risk assessment data (Fakhruddin et al., 2022). According to the case studies of The L'Aquila earthquake of 2009, Terrorist attack - Manchester Arena, England, Japan earthquake and tsunami of 2011 a reliable real time loss estimation allows proper decision making on response and rescue operation to reduce the number of causalities by increasing the number of promptly extracted people from the impact areas. In this aspect, big data have the potential to improve disaster management through data visualisation and predictive analytics (Akter & Wamba, 2019). Data is a critical asset for developing meaningful insights and evidence to make informed decisions, information products and policy building especially in the disaster and climate change management space. Data should be readily and openly available to generate accurate, relevant, and useable information products such as hazard maps and models.

7.1.2 Incorporate information from crowd sourced data in multi-hazard early warning systems.

Development of effective, internationally compatible multi-hazard early warning mechanisms and community centres for the promotion of public awareness especially consisting of the capacity to embrace information in social media platforms (Mayhorn & McLaughlin, 2014; Sutton et al., 2014).

During The L'Aquila earthquake of 2009, Terrorist attack - Manchester Arena, England, and Japan earthquake and tsunami of 2011 social media including Twitter represented an important online venue for social interaction and information exchange in disasters for members of the public and public officials. Within this context, Twitter has been identified as a mechanism for resource mobilization and collaboration as well as a platform for sharing life-safety information (Starbird & Palen, 2010). Research on disaster response has indicated that rapid exchange of up-to-date information about a given situation, through mechanisms such as online social media, is a vital information resource that can affect life safety (Sutton et al., 2014). However, due to their extreme brevity and character limits, Twitter warning messages are incomplete and tend to be posted in

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response to unfolding events. Therefore, warning tweets are likely to focus on one or two themes at a time, rather than being complete messages. Furthermore, few messages (in this disaster situation) include 'guidance' information, such as recommendations to evacuate, but instead provide ongoing situational updates and what might be considered 'advisories' to a broader population that is not at risk.

7.1.3 Ensuring rapid, effective, and risk-informed emergency response

Rapid, effective, and risk-informed emergency response mechanism is important to address the immediate needs of disaster-affected populations, as well as secondary risks generated because of prolonged displacement (Bodin et al., 2022). The risk informed diagnostic also helps assessing what cognitive, preparatory, and planning capacities are needed to ensure more effective responses to compound emergencies. According to Bodin et al. (2022), compound emergencies bring additional challenges associated with interconnected events, communities, tasks, and responses, which underscore the need for certain cognitive, planning, and preparedness capacities.

- Cognitive capacity

Cognitive capacity refers to awareness, specifically the degree to which relevant actors have developed knowledge and understanding about the risk for compound emergencies, and what consequences compound emergencies could bring for communities.

- Planning capacity

High planning capacity implies that the risks for compound events are integrated into planning processes and associated 'output' documents. This requires the planning for possible compound emergencies, designing of emergency response system inclusive of coordination and resource mobilization, engagement of relevant stakeholders and funding allocation, and institutionalised implementation process.

- Preparedness capacity

Preparedness capacity refers to concrete organizational and institutional structures and procedures for addressing challenges specifically associated with compound events. In other words, knowledge and lessons concerning compound emergencies have been effectively translated into practical solutions.

Key lessons from case studies about incorporating information from crowd sourced data in multi-hazard early warning and response systems and establishing an effective monitoring system.

Terrorist attack - Manchester Arena, England

The Manchester Police constantly updated its Twitter account with crisis communication information. Social media platforms were used to enquire about missing friends or relatives and offer condolences. The interplay between social media and the traditional media was a key factor in the challenge faced by public authorities in putting out a consistent message to the public. From a database of millions of messages posted on Twitter within 24 hours of the attack, tweets were largely dominated by resilience messages, requests for help, and reporting of details about the attack. There was also a substantial amount of Islamophobia, some misinformation and hoaxes, and some offensive comments and trolling. Constant negative portrayal of Muslims by British media left them looking for their own media communication platforms that project their unique voice. Intrusion into the privacy of victims' families was a problem. Regarding the overall themes displayed in social media responses, the tweets showed a mix of empathetic and not empathetic responses but also showed presence in the crisis, being rooted on what was happening, rather than looking at the past. Some of the main Manchester Arena Twitter accounts were @ManCityCouncil, @ArianaGrande, @GMPolice. There were numerous Tweets from the hashtags #ManchesterBombing, #Manchester, #OneLoveManchester and the Manchester Bombing Twitter Moment.

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The L'Aquila earthquake of 2009 (Mw6.3)

Within 48 hours of the earthquake, 2,400 firefighters, more than 1,800 members of the Armed Forces, more than 1,500 members of the Police Forces, more than 800 doctors and nurses from the Italian Red Cross, more than 4,000 Civil Defense volunteers and more than 100 canine units are on the ground. Array of seismic stations were installed by institutions coming from Italy, France, and Germany. This response allowed the scientific community to collect a very high-quality dataset (Margheriti et al., 2011), the largest ever acquired in Italy until the 2017 Amatrice-Visso-Norcia seismic sequence. In the same hours, 30 reception areas are set up to aid nearly 18 thousand people and more than 10 thousand beds are made available in private homes and hotels on the coast. More than 20 field kitchens are also activated to distribute thousands of meals. Eight sleeping cars offered by the State Railways are stationed at L'Aquila station in response to requests made by the Civil Defense. By the end of April 2009, the number of assisted populations will rise to 67,459, the highest value reached in emergency management.

Aude Region (France) Flash Flooding

The elected mayors of prefectures have a significant responsibility for disaster operations within their municipality. They operate a system of communal safeguarding plans, although it was noted that these have not always been updated as they should be. The activities of the municipalities are coordinated by a Departmental Operational Centre. Whilst this operated to a satisfactory level throughout the 2018 flooding, comment at the time as well as the official review suggested that this facility would struggle in the event of a longer lasting or more widespread emergency. There is an absence of geographical information systems, and no multi agency accessible command and control system. Municipal responses were therefore based on historic data and in effect responded to the last emergency rather than the current one.

Wildfire - Israel, Mountains of Jerusalem, Western slopes

A special fire fighters team also must be called to conduct very extensive defensive tactics in order to protect the hospital of Ein Kerem because its evacuation was challenging. This procedure involved a massive aerial firefighting operation and 15 firefighting vehicles which used foams and water to prevent fire movement into the hospital. Israel Fire and Rescue Services chief, Dedy Simchi, said the enormous forest fire outside Jerusalem was on the same scale as the 2010 Mount Carmel fire (Knesset News, 2021; Golditch et al., 2021; Shlomi & Deutsch, 2021; HML System, 2021).

Visakhapatnam ("Vizag") Industrial Accident – Styrene Vapour Release - LG Polymers Plant, Venkatapuram Village, Visakhapatnam, Andhra Pradesh, India,

A significant issue was the lack of effective warning for the public. This was a relatively short-term hazard for a population near the source of the crisis. The nature of the chemicals within the plant demands that the warning messages are swift and unambiguous, and the planned method of communication is a simple siren to alert the population to leave the area immediately. This method has been trialled and repeatedly exercised, but on the night of the incident itself the alarm was not sounded by the staff within the plant. Much has been made of this failure by the LG staff, but it is noticeable that no one else such as local police commanders thought to question the lack of an alarm at the time or suggest that it be sounded. This suggests that there was a distinct lack of training and joint working prior to the incident. The area is predominantly residential with some small retail or handcrafting businesses. There were a handful of small-scale livestock farms which required specialist support. Short term styrene exposure at the levels experienced in this incident would not be expected to lead to long term health issues if limited to the airborne polymer alone. Immediate treatment for styrene exposure is based on rinsing and flushing any points of contact, and where inhalation is suspected, lung function may be supported until recovery. Longer term health effects for styrene inhalation and contact are not clinically established and ideally there would be a continuing health monitoring programme since styrene is identified as a potential carcinogenic. However, there was extensive soil and water supply contamination in the affected area. Over the following days, there were repeated attempts to treat water sources and public land, but the economic pressure on the local population meant that they returned to their homes before this was considered complete. Longer term, the quickly established longer term monitoring systems have been closed, and there is local discontent about health provision. Specialist support has not been received, and there have been further deaths attributed to the leak. Local first responder agencies such as police and fire service had no specific training in respect of the chemicals produced and stored at the plant. It was apparent that there were generic LG plans for response, but these appear to have been primarily structured around an explosion at the plant rather than a vapour release. Certainly, none of the responding emergency services had appropriate protective equipment (PPE), and it was not until the arrival of a team from the National Disaster Response Force (NDRF), who had appropriate breathing apparatus and chemicals to treat the styrene contamination that a coherent search and rescue got underway. Indian

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legislation requires that the staff at the facility are fully trained in ameliorative tactics for the chemicals stored on site, and that relevant equipment and chemical treatment stores are pre-placed and available. It was apparent in the immediate aftermath of the incident that, equipment, training, and leadership were all lacking.

Continuity of service and accessibility through COVID-19 pandemic

The loss of access to infrastructure functions and services could thus prove detrimental to households and businesses; consequently, avoiding loss of service or accessibility, even if a customer cannot pay.

Expected increased importance of communication infrastructure in the economy and the need to ensure its resilience, quality of service, and accessibility demand for infrastructure services, with usage of communication infrastructure for both work and leisure expanding significantly. This will mean that the resilience of communication infrastructure, and related applications and distribution of content, will become increasingly important.

More people teleworking from home, or close to home in shared work environments may shift demand for more localised, rather than centralised infrastructure, closer to where people live rather than work. large scale and costly investment in public transportation (such as subways), or increasing airport capacity, may be re-evaluated given the changing context, while more flexible approaches, such as through bus rapid transit. (Laboul, et al., 2022.)

Japan earthquake and tsunami of 2011

(AKA: Great Sendai earthquake or Great Tohoku earthquake)

During the 2011 East Japan Earthquake and Tsunami, newly popular social media such as Twitter and Facebook served as a lifeline for directly affected individuals, a means of information sharing, and a way for people inside and outside Japan to volunteer and to provide information-based support to affected individuals (Watanabe et al., 2021). Social media was used to perform vital relief functions such as safety identification, displaced persons locating, damage information provision, support for disabled individuals, volunteer organization, fund-raising, and moral support systems. During the 2011 East Japan Earthquake and Tsunami, newly popular social media such as Twitter and Facebook acted as a lifeline for directly affected individuals, a means of information sharing, and a way for people inside and outside Japan to volunteer and to provide information-based support to those affected individuals (Peary et al., 2012). Following is some of the dominant social media platforms which were actively functioning during the 2011 GEJE and tsunami.

After the 2011 earthquake, medical care providers (MCPs) considered the possible spread of gastroenteritis, diarrhea, and other illnesses (Daito et al., 2013) caused by contaminated drinking water and food (McCurry, 2011). The gastroenteritis occurred sporadically, not epidemically, at the stricken areas during acute and subacute stages after the disaster (Takahashi et al., 2012). In June 2011, food poisoning caused by Clostridium perfringens occurred through the food provisions of support staff living outside the stricken areas (Takahashi et al., 2012). Volunteers attempted to undertake maximum precautions against food contamination.

In April 2010, 10 members formed a study group on guidelines for first steps and emergency triage to manage elderly evacuees of natural disasters. Two types of guidelines were established (Takahashi et al., 2012): one for MCPs and another for non-MCPs (NMCPs) (the latter including, for example, volunteers, helpers, and family members taking care of elderly relatives), public health nurses (PHNs), or certified social workers (CSWs). The guidelines had three chapters as follows: (1) features and prevention of critical diseases in the elderly in evacuation areas; (2) signs of acute diseases in the elderly; and (3) symptoms of anxiety in the elderly at shelters. After the 2011 earthquake, 20,000 guideline booklets were sent by members of the JGS and the Japan Medical Association Team (JMAT) to NMCPs, PHNs and CSWs working in Iwate, Miyagi, and Fukushima.

The Tohoku Regional Infection Control Network acted functionally and collaboratively on the activities at the shelters and hospitals at the stricken areas (Kanamori et al., 2011). This network had four main activities: (1) infectious disease consultation; (2) infection control educational programs and training; (3) infection control interventions; and (4) regional cooperation with local government against infectious diseases.

With approximately 35 million account holders in Japan, Twitter is the most popular social networking site in that country. This makes Japan the third largest Twitter user in the world behind the USA and Brazil. Official statistics show that the number of Twitter messages grew exponentially during the earthquake (World_Bank, 2012).

In a 2011 report on how Twitter was used, researcher Akihito Kobayashi points out that collaboration was key as Twitter use grew during the Great East Japan Earthquake (Appleby, 2013). For instance, a Twitter hash tag - #j-jhelpme - created at 16:03 on March 11 by a user in southern Japan became a focal point for requests for assistance and was quickly re-tweeted.

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Many media outlets, at national, regional, and local level, used Twitter (Peary et al., 2012). One of the main regional newspapers in the disaster affected region, Kahoku Shimpo in Sendai, used Twitter to update residents while they were unable to print (Appleby, 2013). According to Appleby (2013) various public bodies including the government, their ministries and local municipalities also used Twitter to circulate information and updates. The report further states the use of twitter account in official communication as mentioned below.

- Four days after the earthquake the Japanese government set up its first ever twitter account - @Kantei_Saigai which means Prime Minister's office, Disaster - and within days it was being followed by 200,000 users. The account's most re-tweeted message in the weeks after the disaster was the Chief Cabinet Secretary's announcement on March 15, 2011: "There is a severe shortage of gasoline, fuel and oil in the disaster affected areas, but supplies are stable in the rest of the country. Please refrain from panic buying or hoarding supplies." (Translated from the Japanese).
- Six days after the disaster the Tokyo Electric Power Company, the owner of the crippled Fukushima nuclear power plant, also set up a Twitter account – @OfficialTEPCO – this got over 117,000 followers within the first six hours. The move was not without controversy especially as the Japanese public had begun to distrust official announcements from TEPCO and the government about the risks of radiation at the reactor.

However, the ever-changing advice about evacuation zones, public health guidance and the overall lack of information led to accusations that the government and the power company were withholding information (Appleby, 2013). Meanwhile Twitter was allowing users to access information from various sources and engage in discussions and debates with others online, whether they knew them personally or not (Cho et al., 2013). By using the disaster-related hash tags, users could take part in a global discussion, in real-time. According to the J Government platform, there are now over 104 official twitter accounts run by national and local governmental bodies as well as other independent public authorities.

Tsunami warnings

During a powerful earthquake, the Japan Meteorological Agency's system consults its database containing nearly 100,000 simulations, chooses the closest result and quickly broadcasts a tsunami advisory (chûihô) for waves that might be between 20 cm and 1 m above normal sea level, or a tsunami warning (keihô) for waves that might be taller than 1 m (World_Bank, 2014).

"TSUNAMI TENDENKO"

This is a well-known saying in the Tohoku region. Roughly translated it means: "if a tsunami comes, run to safety, don't go to find others" (Appleby, 2013). This local wisdom is passed down through generations and is considered to have saved many lives. Still, during the Great East Japan Earthquake, there were several cases where people ignored this, going back to help elderly residents or family members evacuate.

In addition to the existing advisories and warning messages, the Japan Meteorological Agency set up an emergency warning system (tokubetsu keihô) on August 30, 2013, notably following the damage caused by the Ise Bay typhoon in 1959, the March 11, 2011, tsunami, and rain from the 12th typhoon of 2011 (Kodera et al., 2016).

7.2 Expedite recovery and 'build back better'.

7.2.1 Enabling build back greener initiatives

Post-disaster recovery planning is an opportunity to 'build back greener' by fostering ecosystem approaches towards social and ecological resilience (Mabon, 2019). According to Mabon (2019), further understanding in empirical contexts is required of how cultural services especially citizen participation can be integrated with more technical approaches to post-disaster ecosystem management.

The post-disaster recovery measures after the Japan earthquake and tsunami of 2011 event the 'build back better' initiatives were integrated in resilience building, Eco-DRR, and wider greening initiatives into urban rebuilding. Hinzpeter and Sandholz (2018) illustrates that 'building back greener' can involve appropriating the recovery planning process to systematically take stock of existing landscape features as part of a green infrastructure, and consider the ecosystem services they provide, in ways that have not been done previously. This is in addition to the development of 'new' nature-based solutions such as coastal forests and illustrates the value of considering in tandem DRR and a much wider suite of resilience benefits provided by nature-based solutions and a green infrastructure across the landscape. Understanding traditional cultural relationships

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with ecosystems and integrating this into recovery planning may offer a pathway to 'building back greener' in a way that links technical approaches with cultural and participatory aspects.

7.2.2 Effective business continuity plans in social recovery.

Ensure the continuity of business operations and including social and economic recovery, and the provision of basic services is important during the recovery phase (Niemimaa et al., 2019). Especially during COVID-19 outbreak entrepreneurs experience business cancellation or closure and reduced income due to the closure of several supporting sectors such as retails and transportation (Universiti Malaysia Sabah et al., 2020). Therefore, effective support mechanisms associated with entrepreneurial development organizations for micro-entrepreneurs is crucial to thrive during and after a crisis.

According to Universiti Malaysia Sabah et al. (2020) the disaster studies focus in two main areas from the entrepreneurs' perspectives.

1. To understand the business continuity strategy and
2. The business recovery plan employed by microenterprise in coping with crisis impact.

The COVID-19 crisis can be regarded as a difficult situation for microenterprises due to its abruptic threats. Entrepreneurs seemed to demonstrate their ability to survive in their business by undertaking several business continuity approaches and recovery strategies, especially in terms of product delivery and marketing.

Key lessons from case studies about enabling build back greener initiatives and effective business continuity plans in social recovery.

Terrorist attack - Manchester Arena, England

As a result of the loss of 22 lives, a UK Public Inquiry was established. This examined in detail all aspects of the preparedness before the terrorist attack, and response to it. Much of what follows here is taken from this extremely thorough Inquiry report. The first volume on security for the Arena was published in June 2021, the second volume on response was published in November 2022.

The L'Aquila earthquake of 2009 (Mw6.3)

Project C.A.S.E.: a new type of reconstruction completely different from those of the past, with a direct shift from tents to new houses in the "New Towns" proposed by Berlusconi and Bertolaso. These new towns are sites devoid not only of any affective and symbolic reference point, but also-in most cases-material and organizational, with services absent or otherwise lacking. The configuration that the territory of L'Aquila has assumed since the earthquake has led to an acceleration and accentuation of the characters of fragmentation and dispersion of the built-up area and population, which, although already present before the earthquake, did not assume such widespread and generalized connotations throughout the territory and its inhabitants. Source: Castellani et al., 2016

Local community was involved in the recovery phase after the earthquake. Many volunteers from different associations have been involved in the reconstruction both from a practical standpoint (such as ANPAS, Misericordia from other regions of Italy) and financial support, with several fundraisers nationwide.

Aude Region (France) Flash Flooding

Since the Aude floods, most major infrastructure has been successfully re-established, and there has been a distinct effort to include risk mitigation in redevelopment plans, as well as ensuring that regional urbanisation and proposed new developments are more closely linked to the flood risk prevention plans (PPRIs). Environmental considerations are built into the standard flood risk prevention plans of the region. The area is heavily reliant upon forestry and waterways for economic reasons, and there is evidence that environmental protection is highly prioritised in all local planning processes.

Supporting livelihood during COVID-19

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Some self-employed, including own-account workers and small business owners, are particularly at risk of falling through the cracks of existing social protection schemes in the current crisis. Informal workers remain beyond the scope of most income-support schemes. This includes employees who are not registered for mandatory social security, who are paid less than the legal minimum wage, who are employed without a written contract. France has announced an additional EUR 39 million will be directed to food aid; with an initial EUR 25 million to support food aid associations and a further EUR 14 million to be distributed in emergency food checks. (Scarpetta, 2020.)

Japan earthquake and tsunami of 2011

(AKA: Great Sendai earthquake or Great Tohoku earthquake)

The Sanriku Expressway being constructed along the seashore in the tsunami- affected Iwate and Miyagi prefectures contributed to the recovery of this area (Suppasri et al., 2012). But the evaluation of the cost-effectiveness of such redundant infrastructure (that is, a road used as part of a DRM facility) has never been considered before in Japan. The Japanese government is now trying to modify its evaluation methodology to include the potential benefits of road projects from the perspective of disaster management and DRM (World_Bank, 2020). Accordingly, industrial firms and parks can play a significant role in minimizing the impacts of infrastructure disruptions by utilizing new technologies that allow redundant access to critical infrastructure such as water and power.

National governments play a significant role to play in establishing policies and guidelines to advance the preparedness of industries against disasters through the promotion and incentivization of business continuity planning and management (World_Bank, 2020). At the subnational level, local governments play an integral role in catalyzing the development of areawide BCPs to complement firm-level BCPs, identifying strategic areas where a coordinated and collaborative approach can be implemented for maintaining business continuity after a disaster event.

The Great East Japan Earthquake and Tsunami on March 11 in 2011, caused immense damage to marine ecosystems and marine products (fisheries and mariculture), both nearshore and offshore, on the Pacific coast of north-eastern Japan (the Tohoku region) (Kijima et al., 2018). Accordingly, the TEAMS (Tohoku Ecosystem-Associated Marine Sciences) project was created as a project at the national level.

Apart from the ongoing natural restoration process, Japan's government has decided to support and enhance the process that has developed and has enacted important statutes and statutory frameworks for this purpose, including the 2012–2020 National Biodiversity Strategy, which turns on certain fundamental components, such as the valuation of ecosystems services, and implementation of Environmental Impact Assessments and Environmental Strategic Assessments, among others (Santiago-Fandiño & Mas, 2018). As result of intense interaction between the stakeholders and the government, many of the initial decisions regarding the characteristics of these structures have been revised, although their impact on the environment will certainly remain large and often unpredictable.

8 Conclusion and key lessons learned.

The disaster risk is increasing globally on multiple phases while the rate of urbanisation along the hazard prone areas increases the exposure to hazards so as the costs of disasters. This includes the intensive and extensive risks that are generated by human actions which consequently increase the impact on communities and overall eco system. Accordingly, human actions cause as a risk driver which could result in global impacts and vice versa. Importantly, the risk of disasters could extend into cascading effects across sectors creating new challenges and systemic risks. Under the current trends, the number of disasters per year globally may increase by 40% during the lifetime of the Sendai Framework from 2015 to 2030.

The climate emergency and the systemic impacts of COVID-19 pandemic possess a new reality in the world where uncertainty and understanding probability is considered as a crucial need in disaster risk assessment. Understanding the systemic nature of risk is fundamental to building resilience against future shocks and achieving sustainable development. This includes reducing the vulnerability, exposure and inequality that drive disasters. The best way forward for the

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understanding of systemic and prepare against is to harness the knowledge from the past experiences and learnings within DRR practices. Learning in real time from the systemic impact of major events like the COVID-19 pandemic, tsunami, earthquake, flood, terrorist attacks, industrial accidents etc. important incidents to build the knowledge. Further, as progressing to the future of systemic risk preparedness the state-of-the-art of such preparedness measures should be explored.

Societal choices are at the heart of why some individuals and groups are more vulnerable to disasters, experience proportionally greater immediate impacts due to exposure and lack of resources and face slower recovery and long-term impoverishment. Unpacking the dynamics that drive vulnerability, including structural inequality, is key to the effective targeting and execution of risk reduction efforts that leave "no one behind". DRM actors and other sectors speak differently about risk and too often operate in sectoral "silos". There is a need to look more at systems, not individual hazards, and to work across disciplines. This requires increased efforts to create common terminologies and provide open access data across disciplines to create shared knowledge, encourage lateral collaboration and speed up the pace of learning. Disaster risk modellers have been learning from tools developed to measure cascading effects during the last financial crisis and from enterprise risk management approaches. But this learning needs to go both ways between governments and communities and be built into planning and budgeting processes.

Modern technology provides opportunities to accelerate learning and to quickly pick up signals essential for effective risk management in an uncertain future. But acting on these signals requires nuanced forms of communication with the public, and particularly better communication with higher-risk groups. Enhanced social protection systems targeted towards at-risk groups can be a good vehicle for better understanding who is most vulnerable to emerging risks and for ensuring effective anticipatory action to prevent acute humanitarian crises. Accordingly, the past disasters identified in this study provides significant inputs about the use of preparedness strategies and the state-of-the-art that can be considered in the future disaster risk reduction strategies.

The Table 6 mentioned below demonstrates the summary of key findings from the analysis of past disasters and related literature with reference to the state-of-the-art for achieving SFDRR (UNDRR, 2015). The findings under each priority for action is categorised under the Ten essentials and local level needs identified in the Words into Action report (UNDRR, 2019). The ten essentials provide the key indication on local level implementation guide under the purview of SFDRR. Accordingly, the lessons learned from the case study analysis synthesised with the relevant recent publications was able to provide the key directions of novelties which are significant elements to consider in building resilience in future DRR planning and implementation.

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Table 6: State-of-the-art for achieving SFDRR identified with reference to the case study analysis.

SFDRR priorities for action	Ten essentials and local level needs in Words into Action report	State of the art identified from the case study analysis
Priority for action 1. Understanding disaster risk	Identify, understand, and use current and future risk scenarios (Essential 2)	• Carrying out a comprehensive risk diagnosis • Identifying the systemic nature of risks • Understanding the dynamic drivers of risk • Defining tipping points • Risk-informed digital twin • Understanding the human choices and experience that drive the disaster risk
	Pursue resilient urban development and design (Essential 4)	• Developing science-based methodologies
	Safeguard natural buffers to enhance ecosystems' protective functions (Essential 5)	• Utilising earth observation and remote sensing technology in disaster monitoring
Priority for action 2. Strengthening governance to manage disaster risk	Organize for disaster resilience (Essential 1)	• Identifying the synergies in DRR • Use of indigenous knowledge in policy formulation • Governance in the context of systemic risk
	Pursue resilient urban development and design (Essential 4)	• Identifying the interlinkages and synergies in risk resilient development • Adopting eco-system based/inspired solutions and experiences. • Identifying the driver specific systemic risk mitigation measures
	Safeguard natural buffers to enhance ecosystems' protective functions (Essential 5)	• Identifying the role of local ecosystems in DRR
	Strengthen institutional capacity for resilience (Essential 6)	• Leveraging partnerships for multi-stakeholder cooperation • Promoting disaster risk reduction in formal and non-formal education
	understand and strengthen societal capacity for resilience (Essential 7)	• Identifying the personal biases in decision making • Improving social capacity
	Increase infrastructure resilience (Essential 8)	• Assessing the infrastructure resilience • Ensure the operability of critical infrastructure in the event of acute shocks. • Improving resilience via the development of green infrastructure
Priority for action 3. Investing in disaster risk reduction for resilience	Strengthen financial capacity for resilience (Essential 3)	• Identifying cost-effective risk mitigation measures • Addressing the biases in social behaviours via local level risk financing mechanism
Priority for action 4. Enhancing disaster preparedness for effective response, and to 'build back better' in recovery, rehabilitation, and reconstruction	Ensure effective disaster response (Essential 9)	• Establish an effective monitoring system and real time loss estimation mechanisms. • Incorporate information from crowd sourced data in developing multi-hazard early warning systems. • Ensuring rapid, effective, and risk-informed emergency response
	Expedite recovery and 'build back better' (Essential 10)	• Enabling build back greener initiatives • Effective business continuity plans in social recovery

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9 References

Afifi, W. A., & Afifi, T. D. (2021). Uncertainty and Coping During COVID-19. In M. Lewis, E. Govender, & K. Holland (Eds.), *Communicating COVID-19: Interdisciplinary Perspectives* (pp. 325-344). Springer International Publishing. https://doi.org/10.1007/978-3-030-79735-5_16

Afrin, S., Chowdhury, F. J., & Rahman, M. M. (2021, 2021-June-14). COVID-19 Pandemic: Rethinking Strategies for Resilient Urban Design, Perceptions, and Planning [Review]. *Frontiers in Sustainable Cities, 3*. https://doi.org/10.3389/frsc.2021.668263

Ahmed, F., Khan, M. S. A., Warner, J., Moors, E., & Terwisscha Van Scheltinga, C. (2018). Integrated Adaptation Tipping Points (IATPs) for urban flood resilience. *Environment and Urbanization, 30*(2), 575-596. https://doi.org/10.1177/0956247818776510

Aitsi-Selmi, A., Egawa, S., Sasaki, H., Wannous, C., & Murray, V. (2015, 2015/06/01). The Sendai Framework for Disaster Risk Reduction: Renewing the Global Commitment to People's Resilience, Health, and Well-being. *International Journal of Disaster Risk Science, 6*(2), 164-176. https://doi.org/10.1007/s13753-015-0050-9

Aksha, S. K., Resler, L. M., Juran, L., & Carstensen, L. W. (2020, 2020/01/01). A geospatial analysis of multi-hazard risk in Dharan, Nepal. *Geomatics, Natural Hazards and Risk, 11*(1), 88-111. https://doi.org/10.1080/19475705.2019.1710580

Akter, S., & Wamba, S. F. (2019, 2019/12/01). Big data and disaster management: a systematic review and agenda for future research. *Annals of Operations Research, 283*(1), 939-959. https://doi.org/10.1007/s10479-017-2584-2

Alibrandi, U. (2022). Risk-Informed Digital Twin of Buildings and Infrastructures for Sustainable and Resilient Urban Communities. *ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part A: Civil Engineering, 8*(3). https://doi.org/https://doi.org/10.1061/AJRUA6.0001238

Amaratunga, D., Sridarran, P., & Haigh, R. (2019). *Making Cities Resilient Report 2019* (A snapshot of how local governments progress in reducing disaster risks in alignment with the Sendai Framework for Disaster Risk Reduction, Issue.

Anugrah, R. D., & Setiawati, M. D. (2022). Integrated Study on Tsunami Impact Assessment in Cilacap, Indonesia: Method, Approach, and Practice. In U. Chatterjee, A. O. Akanwa, S. Kumar, S. K. Singh, & A. Dutta Roy (Eds.), *Ecological Footprints of Climate Change : Adaptive Approaches and Sustainability* (pp. 577-605). Springer International Publishing. https://doi.org/10.1007/978-3-031-15501-7_23

Aoyama, H. (1981). Outline of earthquake provisions in the recently revised Japanese building code. *Bulletin of the New Zealand Society for Earthquake Engineering, 14*(2), 63-80. https://doi.org/https://doi.org/10.5459/bnzsee.14.2.63-80

Appleby, L. (2013). *Connecting the last mile, The role of communications in the great east Japan earthquake*. https://internews.org/wp-content/uploads/legacy/InternewsEurope_Report_Japan_Connecting_the_last_mile_Japan_2013.pdf

Argyroudis, S. A., Mitoulis, S. A., Chatzi, E., Baker, J. W., Brilakis, I., Gkoumas, K., Vousdoukas, M., Hynes, W., Carluccio, S., Keou, O., Frangopol, D. M., & Linkov, I. (2022, 2022/01/01/). Digital technologies can enhance climate resilience of critical infrastructure. *Climate Risk Management, 35*, 100387. https://doi.org/https://doi.org/10.1016/j.crm.2021.100387

Bodin, Ö., Nohrstedt, D., & Orach, K. (2022, 2022/12/01/). A diagnostic for evaluating collaborative responses to compound emergencies. *Progress in Disaster Science, 16*, 100251. https://doi.org/https://doi.org/10.1016/j.pdisas.2022.100251

Borrero, J. C., Sieh, K., Chlieh, M., & Synolakis, C. E. (2006, Dec 26). Tsunami inundation modeling for western Sumatra. *Proc Natl Acad Sci U S A, 103*(52), 19673-19677. https://doi.org/10.1073/pnas.0604069103

Cabello, V. M., Véliz, K. D., Moncada-Arce, A. M., Irarrázaval García-Huidobro, M., & Juillerat, F. (2021). Disaster Risk Reduction Education: Tensions and Connections with Sustainable Development Goals. *Sustainability, 13*(19), 10933. https://www.mdpi.com/2071-1050/13/19/10933

Cho, S. E., Jung, K., & Park, H. W. (2013, 2013/11/01). Social Media Use during Japan's 2011 Earthquake: How Twitter Transforms the Locus of Crisis Communication. *Media International Australia, 149*(1), 28-40. https://doi.org/10.1177/1329878X1314900105

Climate Change and Cities. (2018). In C. Rosenzweig, P. Romero-Lankao, S. Mehrotra, S. Dhakal, S. Ali Ibrahim, & W. D. Solecki (Eds.), *Climate Change and Cities: Second Assessment Report of the Urban Climate Change Research Network* (pp. 1-98). Cambridge University Press. https://doi.org/DOI: undefined

Daito, H., Suzuki, M., Shiihara, J., Kilgore, P. E., Ohtomo, H., Morimoto, K., Ishida, M., Kamigaki, T., Oshitani, H., Hashizume, M., Endo, W., Hagiwara, K., Ariyoshi, K., & Okinaga, S. (2013). Impact of the Tohoku earthquake and tsunami on pneumonia hospitalisations and mortality among adults in northern Miyagi, Japan: a multicentre observational study. *Thorax, 68*(6), 544. https://doi.org/10.1136/thoraxjnl-2012-202658

Dhyani, S., Karki, M., & Gupta, A. K. (2020). Opportunities and Advances to Mainstream Nature-Based Solutions in Disaster Risk Management and Climate Strategy. In S. Dhyani, A. K. Gupta, & M. Karki (Eds.), *Nature-based Solutions for Resilient Ecosystems and Societies* (pp. 1-26). Springer Singapore. https://doi.org/10.1007/978-981-15-4712-6_1

Di Mauro, C. (2002). Ex ante and ex post moral hazard in compensation for income losses: results from an experiment. *The Journal of Socio-Economics, 31*(3), 253-271. https://doi.org/https://doi.org/10.1016/S1053-5357(02)00120-8

Edgington, D. W. (2022). Planning for Earthquakes and Tsunamis: Lessons from Japan for British Columbia, Canada. *Progress in Planning, 163*. https://doi.org/https://doi.org/10.1016/j.progress.2021.100626

EEFIT. (2006). *The Indian Ocean Tsunami of 26 December 2004: Mission Findings in Sri Lanka and Thailand*.

Eshel, T. (2011). *Satellite Imagery, U-2 Chart Japan's Earthquaqe, Tsunami Devastation*. https://defense-update.com/20110314_japan_disaster.html

Fakhruddin, B., Kirsch-Wood, J., Niyogi, D., Guoqing, L., Murray, V., & Frolova, N. (2022, 2022/12/01/). Harnessing risk-informed data for disaster and climate resilience. *Progress in Disaster Science, 16*, 100254. https://doi.org/https://doi.org/10.1016/j.pdisas.2022.100254

Fjäder, C. (2021). Developing Partnerships for Building Resilience. In S. Eslamian & F. Eslamian (Eds.), *Handbook of Disaster Risk Reduction for Resilience: New Frameworks for Building Resilience to Disasters* (pp. 261-278). Springer International Publishing. https://doi.org/10.1007/978-3-030-61278-8_12

Florin, M.-V., & Nursimulu, A. (2018, 2018/10/11/T14:28:31). IRGC Guidelines for the Governance of Systemic Risks. https://doi.org/10.5075/EPFL-IRGC-257279

Gao, J., Barzel, B., & Barabási, A.-L. (2016, 2016/02/01). Universal resilience patterns in complex networks. *Nature, 530*(7590), 307-312. https://doi.org/10.1038/nature16948

Gibson, T. (2015). Reflective practitioners : the importance of critical thought for change agents : lecture. *Jamba : Journal of Disaster Risk Studies, 7*(1), 1-6. https://doi.org/doi:10.4102/jamba.v7i1.128

Gil-Rivas, V., & Kilmer, R. P. (2016). Building Community Capacity and Fostering Disaster Resilience. *Journal of Clinical Psychology, 72*(12), 1318-1332. https://doi.org/https://doi.org/10.1002/jclp.22281

Gill, J. C., & Malamud, B. D. (2014, 2014/12/01). Reviewing and visualizing the interactions of natural hazards [https://doi.org/10.1002/2013RG000445]. *Reviews of Geophysics, 52*(4), 680-722. https://doi.org/https://doi.org/10.1002/2013RG000445

Golazad, S., Heravi, G., & AminShokravi, A. (2022, 2022/12/01/). People's post-disaster decisions and their relations with personality traits and decision-making styles: The choice of travel mode and healthcare destination. *International Journal of Disaster Risk Reduction, 83*, 103395. https://doi.org/https://doi.org/10.1016/j.ijdrr.2022.103395

Griffin, G. F. (2014, 2014/12/01). The Use of Unmanned Aerial Vehicles for Disaster Management. *GEOMATICA, 68*(4), 265-281. https://doi.org/10.5623/cig2014-402

Gupta, H. K., & Gahalaut, V. K. (2013). *Three Great Tsunamis: Lisbon (1755), Sumatra-Andaman (2004) and Japan (2011)*. Springer Netherlands. http://link.springer.com/10.1007/978-94-007-6576-4

Haasnoot, M., Middelkoop, H., van Beek, E., & van Deursen, W. P. A. (2011, 2011/11/01). A method to develop sustainable water management strategies for an uncertain future [https://doi.org/10.1002/sd.438]. *Sustainable Development, 19*(6), 369-381. https://doi.org/https://doi.org/10.1002/sd.438

Haggag, M., Ezzeldin, M., El-Dakhakhni, W., & Hassini, E. (2022, 2022/07/04). Resilient cities critical infrastructure interdependence: a meta-research. *Sustainable and Resilient Infrastructure, 7*(4), 291-312. https://doi.org/10.1080/23789689.2020.1795571

Haigh, R., Sakalasuriya, M. M., Amaratunga, D., Basnayake, S., Hettige, S., Premalal, S., & Jayasinghe Arachchi, A. (2019). The upstream-downstream interface of Sri Lanka's tsunami early warning system. *International Journal of Disaster Resilience in the Built Environment, 11*(2), 219-240. https://doi.org/10.1108/IJDRBE-07-2019-0051

Hare, J., Shi, X., Gupta, S., & Bazzi, A. (2016, 2016/07/01/). Fault diagnostics in smart micro-grids: A survey. *Renewable and Sustainable Energy Reviews, 60*, 1114-1124. https://doi.org/https://doi.org/10.1016/j.rser.2016.01.122

Hermans, T. D. G., Šakić Trogrlić, R., van den Homberg, M. J. C., Bailon, H., Sarku, R., & Mosurska, A. (2022). Exploring the integration of local and scientific knowledge in early warning systems for disaster risk reduction: a review. *Natural Hazards, 114*(2), 1125-1152. https://doi.org/https://doi.org/10.1007/s11069-022-05468-8

Hinzpeter, K., & Sandholz, S. (2018). Squaring the circle? Integrating environment, infrastructure and risk reduction in Post Disaster Needs Assessments. *International Journal of Disaster Risk Reduction, 32*, 113-124. https://doi.org/https://doi.org/10.1016/j.ijdrr.2018.05.016

IOC/UNESCO. (2023, 2023). *IOC/UNESCO*. UNESCO/IOC Project Office for IODE Oostende, Belgium. Retrieved 24/02/2023 from http://www.ioc-tsunami.org/

Ishiwatari, M., & Sagara, J. (2012). *Knowledge notes 1-1, Cluster 1: Structural Measures Structural Measures against Tsunamis*. https://www.preventionweb.net/files/29163_drmkn111.pdf

Izumi, T., Shaw, R., Djalante, R., Ishiwatari, M., & Komino, T. (2019, 2019/07/01/). Disaster risk reduction and innovations. *Progress in Disaster Science, 2*, 100033. https://doi.org/https://doi.org/10.1016/j.pdisas.2019.100033

Jared, B., Louis Hugo, F., & Danielle, W. (2020). Disaster Management: A State-of-the-Art Review. In F. Ehsan Noroozinejad (Ed.), *Natural Hazards* (pp. Ch. 1). IntechOpen. https://doi.org/10.5772/intechopen.94489

Jensen, F. V., & Nielsen, T. D. (2007). *Bayesian Networks and Decision Graphs*. Springer New York. http://link.springer.com/10.1007/978-0-387-68282-2

Kaku, K., Aso, N., & Takiguchi, F. (2015). Space-based response to the 2011 Great East Japan Earthquake: Lessons learnt from JAXA's support using earth observation satellites. *International Journal of Disaster Risk Reduction, 12*, 134-153. https://doi.org/http://dx.doi.org/10.1016/j.ijdrr.2014.12.009

Kanamori, H., Kunishima, H., Tokuda, K., & Kaku, M. (2011, Aug). Infection control campaign at evacuation centers in Miyagi prefecture after the Great East Japan Earthquake. *Infect Control Hosp Epidemiol, 32*(8), 824-826. https://doi.org/https://doi.org/10.1086/661224

Kijima, A., Kogure, K., Kitazato, H., & Fujikura, K. (2018). Reconstruction and Restoration After the Great East Japan Earthquake and Tsunami; Tohoku Ecosystem-Associated Marine Sciences (TEAMS) Project Activities. In V. Santiago-Fandiño, S. Sato, N. Maki, & K. Iuchi (Eds.), *The 2011 Japan Earthquake and Tsunami: Reconstruction and Restoration: Insights and Assessment after 5 Years* (pp. 279-290). Springer International Publishing. https://doi.org/10.1007/978-3-319-58691-5_17

Kilvington, M., & Saunders, W. (2019). Gaining public input on natural hazard risk and land-use planning. *Disaster Prevention and Management: An International Journal, 28*(2), 228-244. https://doi.org/10.1108/DPM-04-2018-0134

Kodera, Y., Saitou, J., Hayashimoto, N., Adachi, S., Morimoto, M., Nishimae, Y., & Hoshiba, M. (2016, 2016/12/01). Earthquake early warning for the 2016 Kumamoto earthquake: performance evaluation of the current system and the next-generation methods of the Japan Meteorological Agency. *Earth, Planets and Space, 68*(1), 202. https://doi.org/10.1186/s40623-016-0567-1

Koetz, T., Farrell, K. N., & Bridgewater, P. (2012, 2012/03/01). Building better science-policy interfaces for international environmental governance: assessing potential within the Intergovernmental Platform for Biodiversity and Ecosystem Services. *International Environmental Agreements: Politics, Law and Economics, 12*(1), 1-21. https://doi.org/10.1007/s10784-011-9152-z

Korswagen, P. A., Jonkman, S. N., & Terwel, K. C. (2019, 2019/01/01/). Probabilistic assessment of structural damage from coupled multi-hazards. *Structural Safety, 76*, 135-148. https://doi.org/https://doi.org/10.1016/j.strusafe.2018.08.001

Kunreuther, H. (2001, 2001/09/14/). Incentives for mitigation investment and more effective risk management: the need for public–private partnerships. *Journal of Hazardous Materials, 86*(1), 171-185. https://doi.org/https://doi.org/10.1016/S0304-3894(01)00253-9

Lennon, M., & Scott, M. (2014). Delivering ecosystems services via spatial planning: reviewing the possibilities and implications of a green infrastructure approach. *Town Planning Review, 85*(5), 563-587. https://doi.org/http://doi.org/10.3828/tpr.2014.35

Lin, P.-S. S., & Chang, K.-M. (2020, 2020/01/01/). Metamorphosis from local knowledge to involuted disaster knowledge for disaster governance in a landslide-prone tribal community in Taiwan. *International Journal of Disaster Risk Reduction, 42*, 101339. https://doi.org/https://doi.org/10.1016/j.ijdrr.2019.101339

Lucas, K., Renn, O., & Jaeger, C. (2018, 2018/11/01). Systemic Risks: Theory and Mathematical Modeling [https://doi.org/10.1002/adts.201800051]. *Advanced Theory and Simulations, 1*(11), 1800051. https://doi.org/https://doi.org/10.1002/adts.201800051

Mabon, L. (2019, 2019/07/01/). Enhancing post-disaster resilience by 'building back greener': Evaluating the contribution of nature-based solutions to recovery planning in Futaba County, Fukushima Prefecture, Japan. *Landscape and Urban Planning, 187*, 105-118. https://doi.org/https://doi.org/10.1016/j.landurbplan.2019.03.013

Maki, N. (2021). Road to Ecosystem-Based Disaster Risk Reduction: Comprehensive Approach for Smart Urban Areas Management. In M. Mukherjee & R. Shaw (Eds.), *Ecosystem-Based Disaster and Climate Resilience: Integration of Blue-Green Infrastructure in Sustainable Development* (pp. 325-334). Springer Singapore. https://doi.org/10.1007/978-981-16-4815-1_14

Makoto, I. (2012). *Disaster Management Plans*. http://hdl.handle.net/10986/16150

Mannakkara, S., & Wilkinson, S. (2014). Re-conceptualising "Building Back Better" to improve post-disaster recovery. *International Journal of Managing Projects in Business, 7*(3), 327-341. https://doi.org/10.1108/IJMPB-10-2013-0054

Martin, P. (2016). *Low-altitude unmanned aerial vehicles for the rapid and high-resolution determination of contamination* https://cord.cranfield.ac.uk/articles/poster/Low-altitude_unmanned_aerial_vehicles_for_the_rapid_and_high-resolution_determination_of_contamination/4288322

Mayhorn, C. B., & McLaughlin, A. C. (2014, 2014/01/01/). Warning the world of extreme events: A global perspective on risk communication for natural and technological disaster. *Safety Science, 61*, 43-50. https://doi.org/https://doi.org/10.1016/j.ssci.2012.04.014

McCurry, J. (2011, 2011/09/17/). Anxiety over radiation exposure remains high in Japan. *The Lancet, 378*(9796), 1061-1062. https://doi.org/https://doi.org/10.1016/S0140-6736(11)61466-9

McDermott, R., & O'Dell, C. (2001). Overcoming cultural barriers to sharing knowledge. *Journal of Knowledge Management, 5*(1), 76-85. https://doi.org/10.1108/13673270110384428

Meerow, S., & Newell, J. P. (2017, 2017/03/01/). Spatial planning for multifunctional green infrastructure: Growing resilience in Detroit. *Landscape and Urban Planning, 159*, 62-75. https://doi.org/https://doi.org/10.1016/j.landurbplan.2016.10.005

Melet, A., Teatini, P., Le Cozannet, G., Jamet, C., Conversi, A., Benveniste, J., & Almar, R. (2020, 2020/11/01). Earth Observations for Monitoring Marine Coastal Hazards and Their Drivers. *Surveys in Geophysics, 41*(6), 1489-1534. https://doi.org/10.1007/s10712-020-09594-5

Messinger, D., McKeown, D., & Raqueño, N. (2011). *Remote sensing aid to the Japanese earthquake and tsunami relief effort*. https://spie.org/news/3785-remote-sensing-aid-to-the-japanese-earthquake-and-tsunami-relief-effort?SSO=1

Milkoreit, M., Hodbod, J., Baggio, J., Benessaiah, K., Calderón-Contreras, R., Donges, J. F., Mathias, J.-D., Rocha, J. C., Schoon, M., & Werners, S. E. (2018, 2018/03/12). Defining tipping points for social-ecological systems scholarship—an interdisciplinary literature review. *Environmental Research Letters, 13*(3), 033005. https://doi.org/10.1088/1748-9326/aaaa75

Mitra, A., & Shaw, R. (2023, 2023/02/01/). Systemic risk from a disaster management perspective: A review of current research. *Environmental Science & Policy, 140*, 122-133. https://doi.org/https://doi.org/10.1016/j.envsci.2022.11.022

Mol, J. M., Botzen, W. J. W., & Blasch, J. E. (2020, 2020/02/01/). Risk reduction in compulsory disaster insurance: Experimental evidence on moral hazard and financial incentives. *Journal of Behavioral and Experimental Economics, 84*, 101500. https://doi.org/https://doi.org/10.1016/j.socec.2019.101500

Mukherjee, M., & Shaw, R. (2021). Uncertainties in Urbanizing World and Nature-Based Resilience Building. In M. Mukherjee & R. Shaw (Eds.), *Ecosystem-Based Disaster and Climate Resilience: Integration of Blue-Green Infrastructure in Sustainable Development* (pp. 1-25). Springer Singapore. https://doi.org/10.1007/978-981-16-4815-1_1

Nakaya, N., Nemoto, H., Yi, C., Sato, A., Shingu, K., Shoji, T., Sato, S., Tsuchiya, N., Nakamura, T., Narita, A., Kogure, M., Sugawara, Y., Yu, Z., Gunawansa, N., Kuriyama, S., Murao, O., Sato, T., Imamura, F., Tsuji, I., Hozawa, A., & Tomita, H. (2018, 2018/06/01/). Effect of tsunami drill experience on evacuation behavior after the onset of the Great East Japan Earthquake. *International Journal of Disaster Risk Reduction, 28*, 206-213. https://doi.org/https://doi.org/10.1016/j.ijdrr.2018.02.037

Niemimaa, M., Järveläinen, J., Heikkilä, M., & Heikkilä, J. (2019, 2019/12/01/). Business continuity of business models: Evaluating the resilience of business models for contingencies. *International Journal of Information Management, 49*, 208-216. https://doi.org/https://doi.org/10.1016/j.ijinfomgt.2019.04.010

Nursey-Bray, M., & Harvey, N. (2013). Bridging the Science–Policy Divide in the Coastal Zone: Is There a Role for Learning Processes? In *Global Challenges in Integrated Coastal Zone Management* (pp. 218-228). https://doi.org/https://doi.org/10.1002/9781118496480.ch17

Okada, N., Chabay, I., & Renn, O. (2018). Participatory Risk Governance for Reducing Disaster and Societal Risks: Collaborative Knowledge Production and Implementation. *International Journal of Disaster Risk Science, 9*(4), 429-433. https://doi.org/https://doi.org/10.1007/s13753-018-0201-x

Orimoloye, I. R., Belle, J. A., & Ololade, O. O. (2021, 2021/03/01). Exploring the emerging evolution trends of disaster risk reduction research: a global scenario. *International Journal of Environmental Science and Technology, 18*(3), 673-690. https://doi.org/10.1007/s13762-020-02847-1

Ouyang, M., & Wang, Z. (2015). Resilience assessment of interdependent infrastructure systems: With a focus on joint restoration modeling and analysis. *Reliability Engineering & System Safety, 141*, 74-82. https://doi.org/https://doi.org/10.1016/j.ress.2015.03.011

Paci-Green, R., Varchetta, A., McFarlane, K., Iyer, P., & Goyeneche, M. (2020, 2020/04/01/). Comprehensive school safety policy: A global baseline survey. *International Journal of Disaster Risk Reduction, 44*, 101399. https://doi.org/https://doi.org/10.1016/j.ijdrr.2019.101399

Pan, A. (2020). Study on the decision-making behavior of evacuation for coastal residents under typhoon storm surge disaster. *International Journal of Disaster Risk Reduction, 45*. https://doi.org/https://doi.org/10.1016/j.ijdrr.2020.101522

Peary, B. D. M., Shaw, R., & Takeuchi, Y. (2012). Utilization of Social Media in the East Japan Earthquake and Tsunami and its Effectiveness. *Journal of Natural Disaster Science, 34*(1), 3-18. https://doi.org/10.2328/jnds.34.3

Pittore, M., Wieland, M., & Fleming, K. (2017, 2017/03/01). Perspectives on global dynamic exposure modelling for geo-risk assessment. *Natural Hazards, 86*(1), 7-30. https://doi.org/10.1007/s11069-016-2437-3

Rajib, S., Brett, P., Ai, I., & Yukiko, T. (2012a). *Knowledge notes 2-6, Cluster 3: Nonstructural Measures Green Belts and Coastal Risk Management*. https://openknowledge.worldbank.org/bitstream/handle/10986/16156/793700BRI0drm000Box377374B00Public0.pdf?sequence=1&isAllowed=y

Rajib, S., Brett, P., Ai, I., & Yukiko, T. (2012b). *Knowledge notes 2-7, Cluster 2: Nonstructural Measures Urban Planning, Land UseRegulation, and Relocation*. https://openknowledge.worldbank.org/bitstream/handle/10986/16168/793690BRI0drm000Box377374B00Public0.pdf?sequence=1&isAllowed=y

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Reis, A. L. Q., Stenders, R. M., Alves, I. S., Câmara, R. A., Arana, A. R. A., Amorim, J. C. C., & Andrade, E. R. (2021). Potential influence of cognitive bias on decision-making in a flood scenario. *International Journal of Disaster Risk Reduction, 57*. https://doi.org/https://doi.org/10.1016/j.ijdrr.2021.102198
Renn, O. (2021, 2021/01/02). New challenges for risk analysis: systemic risks. *Journal of Risk Research, 24*(1), 127-133. https://doi.org/10.1080/13669877.2020.1779787
Renn, O., Klinke, A., & van Asselt, M. (2011, Mar). Coping with complexity, uncertainty and ambiguity in risk governance: a synthesis. *Ambio, 40*(2), 231-246. https://doi.org/10.1007/s13280-010-0134-0
Renn, O., Laubichler, M., Lucas, K., Kröger, W., Schanze, J., Scholz, R. W., & Schweizer, P.-J. (2022, 2022/09/01). Systemic Risks from Different Perspectives [https://doi.org/10.1111/risa.13657]. *Risk Analysis, 42*(9), 1902-1920. https://doi.org/https://doi.org/10.1111/risa.13657
Renn, O., Lucas, K., Haas, A., & Jaeger, C. (2019, 2019/04/03). Things are different today: the challenge of global systemic risks. *Journal of Risk Research, 22*(4), 401-415. https://doi.org/10.1080/13669877.2017.1409252
Richard Eiser, J., Bostrom, A., Burton, I., Johnston, D. M., McClure, J., Paton, D., van der Pligt, J., & White, M. P. (2012, 2012/10/01/). Risk interpretation and action: A conceptual framework for responses to natural hazards. *International Journal of Disaster Risk Reduction, 1*, 5-16. https://doi.org/https://doi.org/10.1016/j.ijdrr.2012.05.002
Santiago-Fandiño, V., & Mas, E. (2018). The Coastal Environment and the Reconstruction Process After the Great East Japan Earthquake: A Few Notes. In V. Santiago-Fandiño, S. Sato, N. Maki, & K. Iuchi (Eds.), *The 2011 Japan Earthquake and Tsunami: Reconstruction and Restoration: Insights and Assessment after 5 Years* (pp. 291-338). Springer International Publishing. https://doi.org/10.1007/978-3-319-58691-5_18
Saunders, W. S. A., & Kilvington, M. (2016, 2016/09/01/). Innovative land use planning for natural hazard risk reduction: A consequence-driven approach from New Zealand. *International Journal of Disaster Risk Reduction, 18*, 244-255. https://doi.org/https://doi.org/10.1016/j.ijdrr.2016.07.002
Shakou, L. M., Wybo, J.-L., Reniers, G., & Boustras, G. (2019, 2019/10/01/). Developing an innovative framework for enhancing the resilience of critical infrastructure to climate change. *Safety Science, 118*, 364-378. https://doi.org/https://doi.org/10.1016/j.ssci.2019.05.019
Sharma, R. K., Kumar, B. S., Desai, N. M., & Gujraty, V. R. (2008). SAR for disaster management. *IEEE Aerospace and Electronic Systems Magazine, 23*(6), 4-9. https://doi.org/10.1109/MAES.2008.4558001
Shaw, R. (2016). Community Based Approaches of Sustainable Development and Disaster Risk Reduction. In J. I. Uitto & R. Shaw (Eds.), *Sustainable Development and Disaster Risk Reduction* (pp. 207-214). Springer Japan. http://link.springer.com/10.1007/978-4-431-55078-5_13
Shaw, R., Takeuchi, Y., & Arnold, M. (2012). *Knowledge notes 2-3, Cluster 2: Nonstructural Measures The Education Sector*. https://openknowledge.worldbank.org/bitstream/handle/10986/16166/793640BRI0drm000Box377374B00Public0.pdf?sequence=1&isAllowed=y
Sousa, J. J., Liu, G., Fan, J., Perski, Z., Steger, S., Bai, S., Wei, L., Salvi, S., Wang, Q., Tu, J., Tong, L., Mayrhofer, P., Sonnenschein, R., Liu, S., Mao, Y., Tolomei, C., Bignami, C., Atzori, S., Pezzo, G., Wu, L., Yan, S., & Peres, E. (2021). Geohazards Monitoring and Assessment Using Multi-Source Earth Observation Techniques. *Remote Sensing, 13*(21), 4269. https://www.mdpi.com/2072-4292/13/21/4269
Staddon, C., Ward, S., De Vito, L., Zuniga-Teran, A., Gerlak, A. K., Schoeman, Y., Hart, A., & Booth, G. (2018, 2018/09/01). Contributions of green infrastructure to enhancing urban resilience. *Environment Systems and Decisions, 38*(3), 330-338. https://doi.org/10.1007/s10669-018-9702-9
Starbird, K., & Palen, L. (2010). Pass it on?: Retweeting in mass emergency. International Conference on Information Systems for Crisis Response and Management,
Steinberg, L. J., Sengul, H., & Cruz, A. M. (2008, 2008/08/01). Natech risk and management: an assessment of the state of the art. *Natural Hazards, 46*(2), 143-152. https://doi.org/10.1007/s11069-007-9205-3
Suganuma, K. (2006). Science & Technology Trends Quarterly Review2006 April. *Science & Technology Trends*. https://nistep.repo.nii.ac.jp/?action=pages_view_main&active_action=repository_view_main_item_detail&item_id=6363&item_no=1&page_id=13&block_id=21
Suppasri, A., Muhari, A., Ranasinghe, P., Mas, E., Shuto, N., Imamura, F., & Koshimura, S. (2012). Damage and reconstruction after the 2004 Indian Ocean tsunami and the 2011 Great East Japan tsunami. *Journal of Natural Disaster Science, 34*(1), 19-39. https://doi.org/10.2328/jnds.34.19
Suppasri, A., Shuto, N., Imamura, F., Koshimura, S., Mas, E., & Yalciner, A. C. (2013, 2013/06/01). Lessons Learned from the 2011 Great East Japan Tsunami: Performance of Tsunami Countermeasures, Coastal Buildings, and Tsunami Evacuation in Japan. *Pure and Applied Geophysics, 170*(6), 993-1018. https://doi.org/10.1007/s00024-012-0511-7
Surjan, A., Kudo, S., & Uitto, J. I. (2016). Risk and Vulnerability. In J. I. Uitto & R. Shaw (Eds.), *Sustainable Development and Disaster Risk Reduction* (pp. 37-55). Springer Japan. https://doi.org/10.1007/978-4-431-55078-5_3
Sutton, J., Spiro, E. S., Johnson, B., Fitzhugh, S., Gibson, B., & Butts, C. T. (2014, 2014/07/03). Warning tweets: serial transmission of messages during the warning phase of a disaster event. *Information, Communication & Society, 17*(6), 765-787. https://doi.org/10.1080/1369118X.2013.862561
Tajima, Y. (2018). Challenges in Reconstruction and Strategies for Prevention and Mitigation of Coastal Disasters Five Years After the GEJE. In V. Santiago-Fandiño, S. Sato, N. Maki, & K. Iuchi (Eds.), *The 2011 Japan Earthquake and Tsunami: Reconstruction and Restoration: Insights and Assessment after 5 Years* (pp. 405-421). Springer International Publishing. https://doi.org/10.1007/978-3-319-58691-5_23
Takahashi, T., Goto, M., Yoshida, H., Sumino, H., & Matsui, H. (2012, 2012/02/01/). Infectious Diseases after the 2011 Great East Japan Earthquake. *Journal of Experimental & Clinical Medicine, 4*(1), 20-23. https://doi.org/https://doi.org/10.1016/j.jecm.2011.11.013
Tappin, D. (2011). *Tsunami sediments study and satellite mapping | Japan fieldwork 2011*. https://www.bgs.ac.uk/news/tsunami-sediments-study-and-satellite-mapping-japan-fieldwork-2011/
Thaler, T., Attems, M.-S., & Fuchs, S. (2022, 2022/01/01/). Bottom-up innovations in natural hazard risk management in Austria. *International Journal of Disaster Risk Reduction, 67*, 102689. https://doi.org/https://doi.org/10.1016/j.ijdrr.2021.102689
Thorisson, H., Lambert, J. H., Cardenas, J. J., & Linkov, I. (2017, 2017/07/01). Resilience Analytics with Application to Power Grid of a Developing Region [https://doi.org/10.1111/risa.12711]. *Risk Analysis, 37*(7), 1268-1286. https://doi.org/https://doi.org/10.1111/risa.12711
Trickett, E. J. (2009). Community psychology: individuals and interventions in community context. *Annu Rev Psychol, 60*, 395-419. https://doi.org/10.1146/annurev.psych.60.110707.163517
UNDRR. (2015). *Sendai Framework for Disaster Risk Reduction 2015-2030*. United Nations Office for Disaster Risk Reduction (UNDRR). https://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf
UNDRR. (2019). *Local disaster risk reduction and resilience strategies - Words into action*.
UNDRR. (2022). *Global Assessment Report on Disaster Risk Reduction 2022: Our World at Risk: Transforming Governance for a Resilient Future*.
UNESCO/IOC. (2020). *Preparing for Community Tsunami Evacuations: from inundation to evacuation maps, response plans and exercises* (Manuals and Guides, 82, Issue.
UNISDR. (2004). *Living with Risk: A Global Review of Disaster Reduction Initiatives*. United Nations Interagency Secretariat of the International Strategy for Disaster Reduction (UN/ISDR).
UNISDR. (2005). *Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters* [World Conference on Disaster Reduction]. United Nations. https://www.unisdr.org/files/1037hyogoframeworkforactionenglish.pdf
Universiti Malaysia Sabah, M., Fabeil, N. F., Pazim, K. H., & Langgat, J. (2020, 2020/06/30/). The Impact of Covid-19 Pandemic Crisis on Micro-Enterprises: Entrepreneurs' Perspective on Business Continuity and Recovery Strategy. *Journal of Economics and Business, 3*(2). https://doi.org/10.31014/aior.1992.03.02.241
Ward, P. J., Blauhut, V., Bloemendaal, N., Daniell, J. E., de Ruiter, M. C., Duncan, M. J., Emberson, R., Jenkins, S. F., Kirschbaum, D., Kunz, M., Mohr, S., Muis, S., Riddell, G. A., Schäfer, A., Stanley, T., Veldkamp, T. I. E., & Winsemius, H. C. (2020). Review article: Natural hazard risk assessments at the global scale. *Nat. Hazards Earth Syst. Sci., 20*(4), 1069-1096. https://doi.org/10.5194/nhess-20-1069-2020
Watanabe, K. S., Ogawa, A., & Kubota, A. (2021). Roles of Mass Media and Community Media in Multiple Great Disaster: From the Experience of Great East Japan Disaster in 2011. *Procedings of the 1st ICA Regional Conference, ICA 2019, October 16-17 2019, Bali, Indonesia*. https://doi.org/10.4108/eai.16-10-2019.2304350
Wilson, E., & Piper, J. (2010). *Spatial Planning and Climate Change* (0 ed.). Routledge. https://www.taylorfrancis.com/books/9781136934964
Word_bank. (2022). *Tunisia Systematic Country Diagnostic - Rebuilding trust and meeting aspirations for a more prosperous and inclusive Tunisia* (Systematic Country Diagnostics, Issue. https://openknowledge.worldbank.org/handle/10986/23099
World_Bank. (2012). The Great East Japan Earthquake--Learning from Megadisasters : Knowledge Notes, Executive Summary.
World_Bank. (2014). *Learning from Megadisasters: Lessons from the Great East Japan Earthquake* (Ranghieri, Federica, Mikio Ishiwatari, & eds., Eds.). World Bank. https://doi.org/10.1596/978-1-4648-0153-2
World_Bank. (2020). *Resilient Industries in Japan: Lessons Learned in Japan on Enhancing Competitive Industries in the Face of Disasters Caused by Natural Hazards* W. Bank.
Zharikova, M., Smolarz, A., Komada, P., Sherstyuk, V., & Sakovych, B. (2021). Situation Diagnosis Based on Multi-Hazard Risk Assessment.
Zuccaro, G., & Leone, M. F. (2018, 2018/01/01/). Building Resilient Cities: A Simulation-Based Scenario Assessment Methodology for the Integration of DRR and CCA in a Multi-Scale Design Perspective. *Procedia Engineering, 212*, 871-878. https://doi.org/https://doi.org/10.1016/j.proeng.2018.01.112
Raju, E., Boyd, E. & Otto, F. Stop blaming the climate for disasters. *Commun Earth Environ* **3**, 1 (2022). https://doi.org/10.1038/s43247-021-00332-2
Sendai Framework for Disaster Risk Reduction 2015 – 2030, available at: https://www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030
THE ICF: AN OVERVIEW, Available at: https://www.cdc.gov/nchs/data/icd/icfoverview_finalforwho10sept.pdf
UNDDR, Vulnerability, Available at: https://www.preventionweb.net/understanding-disaster-risk/component-risk/vulnerability
Age Inclusive Disaster risk Reduction– A toolkit, HelpAge International, Available at: https://www.preventionweb.net/files/68082_ageinclusivedisasterriskreductionat.pdf
Grech, S. (2022), Disability Inclusive Disaster Risk Reduction: Critical Insights and Good Practices from the Field. Cape Town: CBM& IDEA (University of Cape Town)
Sasser D., (2005), LSU AgCenter, Age Groups React Differently To Calamity, Available at: https://lsuagcenter.com/topics/family_home/hazards_and_threats/recovery_assistance/personal_financial_recovery/personal/age-groups-react-differently-to-calamity
ATM (2016), The Center on Conflict and Development at Texas A&M University, The impact of disaster on childhood education, Evidence from Nepal, Available at: https://pdf.usaid.gov/pdf_docs/PA00TH32.pdf
CDC (2020), Centers for Disease Control and Prevention, Caring for Children in Disaster, How are Children Different from Adults? Available at: https://www.cdc.gov/childrenindisasters/differences.html
CDC (2021), Centers for Disease Control and Prevention, Caring for Children in Disaster Children and Youth with Special Healthcare Needs in Emergencies, Available at: https://www.cdc.gov/childrenindisasters/children-with-special-healthcare-needs.html
Betty S. Lai and Annette La Greca (2020), Understanding the Impacts of Natural Disasters on Children, Edited by Rebekah Levine Coley, Available at: https://www.srcd.org/research/understanding-impacts-natural-disasters-children
Lai, B.S., Esnard, A.-M., Lowe, S., & Peek, L. (2016). Schools and disasters: Safety and mental health assessment and interventions for children. Current Psychiatry Reports, 18(12), 109. https://doi.org/10.1007/s11920-016-0743-9
(SFM) Sendai Framework Monitor, 2021, Sex, Age and Disability Disaggregated Data (SADDD), Available at: https://www.undrr.org/publication/sendai-framework-monitor-sfm-sex-age-and-disability-disaggregated-data-saddd
UNDRR, Disability Inclusion in Disaster Risk Reduction, Available at: https://www.undrr.org/disability-inclusion-disaster-risk-reduction
Twigg, J. et al (2018) Disability Inclusion and Disaster Risk Reduction: Overcoming barriers to progress.London: ODI
Grech, S. (2015) Disability and Poverty in the Global South: Renegotiating Development in Guatemala.London: Palgrave
DSM-5-TR, 2022, American Psychiatric Association, Diagnostic and Statistical Manual of Mental Disorders, Text Revision Dsm-5-tr 5th Edition, Amer. Psychiatric Pub Inc., March 16, 2022, 1142 pages, ISBN-13: 978-0890425763
T. Meyers (2019), Pregnant Women are Particularly Vulnerable to Disasters , Available at: https://reliefweb.int/report/world/pregnant-women-are-particularly-vulnerable-disasters
Van Den Berg, Bernard; Brouwer, Werner B. F.; Koopmanschap, Marc A. (2004). "Economic Valuation of Informal Care: An Overview of Methods and Applications". The European Journal of Health Economics. 5 (1): 36–45. doi:10.1007/s10198-003-0189-y. JSTOR 3570100. PMID 15452763. S2CID 23720519
NIH, National Cancer Institute, Available at: https://www.cancer.gov/publications/dictionaries/cancer-terms/def/caregiver
ABS, Australian Bureau of Statistics (2018), Disability, Ageing and Carers, Australia: Summary of Findings, available at: https://www.abs.gov.au/statistics/health/disability/disability-ageing-and-carers-australia-summary-findings/latest-release#cite-window1
K. Patton, R. Ware, L. McPherson., E. Emerson, N. Lennox, Parent-related stress of male and female carers of adolescents with intellectual disabilities and carers of children within the general population: a cross-sectional comparison, J App Research in Intellectual Disability. 31(1) (2018) 51–61.
ADA, The Americans with Disabilities Act, Service Animals in Emergency Situations, How does the ADA apply to disasters, weather emergencies, or other emergency response situations? Available at: https://adata.org/service-animal-resource-hub/emergencies
Erda Rindrasih, Thomas Hartmann, Patrick Witte, Tejo Spit, Annelies Zoomers (2018), Travelling without a helmet: tourists' vulnerabilities and responses to disasters in Indonesia, Disasters, https://doi.org/10.1111/disa.12281
S.Karma, et. al, 2021, Multi-hazard Risk Approach and Inclusive Community Engagement in Disaster Risk Management:Experiences & Lessons learned by a recent Wildfire Event in the Greek Island of Rhodes amidst COVID-19 pandemic crisis, Available at: https://rm.coe.int/publication-multi-hazard-risk-approach-and-inclusive-community-engagem/1680a4e348
Gin, June L., et al (2022), Including Homeless Populations in Disaster Preparedness, Planning, and Response: A Toolkit for Practitioners, Journal of Public Health Management and Practice 28(1):p E62-E72, DOI: 10.1097/PHH.0000000000001230
Morris, S. (2020). Disaster Planning for Homeless Populations: Analysis and Recommendations for Communities. Prehospital and Disaster Medicine, 35(3), 322-325. doi:10.1017/S1049023X20000278
Ramin B & Svoboda T 2009, Health of the homeless and climate change. Journal of Urban Health, 86(4), pp. 654-64.
Every D., Thompson K., (2014), Disaster resilience: can the homeless afford it? Australian Journal of Emergency Management I Volume 29, No. 3.
Emmett, T. and Alant, E. (2007) Women and disability: exploring the interface of multiple disadvantage. Development Southern Africa, 23(4), 445-460
Ryan, S. and Runswick-Cole, K. (2007) Repositioning mothers: mothers, disabled children and disability studies. Disability & Society, 23(3), 199-210.
WIN DRR, Women's International Network for Disaster Risk Reduction, UNDRR, Available at: https://www.undrr.org/event/2022-win-drr-leadership-awards-finalist-roundtable
GRID 2022, IDMC's Global Report on Internal Displacement, Available at: https://www.internal-displacement.org/global-report/grid2022/
OCHA, Global Humanitarian Overview 2022, 2 December 2021, Available at: https://www.unocha.org/2022GHO
S. Barrett, D. Steinbach and S. Addison, 2021, Assessing vulnerabilities to disaster displacement, A good practice review, available at: https://www.undrr.org/media/76315/download
Oxford Dictionary, Meaning of illegal immigrant in English, Available at: https://dictionary.cambridge.org/dictionary/english/illegal-immigrant
Méndez M, Flores-Haro G, Zucker L. 2020. The (in)visible victims of disaster: Understanding the vulnerability of undocumented Latino/a and indigenous immigrants. Geoforum. Nov;116:50-62. doi: 10.1016/j.geoforum.2020.07.007. Epub 2020 Aug 7. PMID: 32834081; PMCID: PMC7413658.
CoE, Council of Europe, Migrants, Available at: https://www.coe.int/en/web/europarisks/migrants1
UNHCR, The United Nations Refugee Agency, Glossary, Available at: https://www.unhcr.org/449267670.pdf
B.Pauvert, J.Twigg, S.Sagramola, Council of Europe, 2016 MAJOR HAZARDS, MIGRANTS, ASYLUM SEEKERS AND REFUGEES, Their inclusion in Disaster Preparedness and Management, Available at: https://rm.coe.int/16806acd58
Convention on the Rights of Persons with Disabilities (CRPD): https://www.un.org/development/desa/disabilities/convention-on-the-rights-of-persons-with-disabilities.html
G. Romano, A. Porcu, L. Manselli, M. Battaglia, S. Zanut, Ergonomics and Emergency Response: An Inclusive Approach. Emergency Preparedness and Response to People with Disabilities: The Italian National Fire Fighters Corps Experience, 2019
Katsunori Fujii, "The Great East Japan Earthquake and Disabled Persons Their High Mortality Rate, Factors that Hindered the Support and the Current Challenges", 2015 https://www.dinf.ne.jp/doc/english/resource/JDF/un_expert_group_meeting_120420_fujii_en.html

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