D2.1 Background Knowledge and Research Assessment

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Acronym	Description
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DF	Damage Factor
DPM	Damage Probability Matrices
DRR	Disaster Risk Reduction
LDD	Local Development Documents
LRRD	Linkage between the Relief, Rehabilitation, and Development
LPA	Local Planning Authorities
NDRA	National Disaster Risk Assessment
PCCIP	President's Commission on Critical Infrastructure Protection
RA	Risk Assessment
RP	Responsible Person
RPB	Regional Planning Bodies
RSS	Regional Spatial Strategies
RFRA	Regional Flood Risk Appraisals
SUDS	Sustainable Drainage Systems
UNISDR	United Nations Office for Disaster Risk Reduction

EXECUTIVE SUMMARY

This deliverable provides a literature review on the natural hazards and what is a disaster. Additionally, this deliverable provides an overview on the Risk Assessment (RA) for earthquakes, floods, and fires. Also, the vulnerability and fragility terms are discussed along with the measuring indices for damage. The disaster risk management and reduction are discussed as wells as the mitigation and preparedness of the disaster risk.

Keyword List: Natural Hazards, Risk Assessment, Risk Management, Disaster Risk Reduction, Mitigation and Preparedness

1 DISASTER

Disaster is a vague term (Kreps, 1984) and the definition of disaster is difficult and contested because of the diversity of intellectual and cultural interpretations of what disasters are and how they are caused (Twigg, 2011). Most definitions refer to the physical impacts of or problems caused for human communities by unplanned and socially disruptive events (Kreps, 1984). Disasters are unplanned and socially disruptive events that can be designated in time and space, which have impacts, on social units and the social units enact responses or adjustment to these impacts (Kreps 1984). A disaster is any manifestation in a geophysical system, which differs substantially or significantly from the mean (Alexander, 2001). If human socio-economic and physiological systems do not have the capacity sufficiently to reflect, absorb or buffer the impact, then disaster may occur (Alexander, 2001). Disaster is “a serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources.” (UN ISDR, 2004)

Disasters are understood differently according to intellectual and cultural viewpoints, of which the following are introduced here: religious, scientific, and technocratic, ecological, sociological, and structural (Twigg, 2011). Other significant perspectives are derived from anthropology (particularly regarding the influence of disasters on societies and risk perceptions and comping strategies), epidemiology (regarding risk factors for mortality and morbidity in disasters), and emergency medicine and publica health (issues such as trauma, disease, and the response capacity of public health facilities) (Twigg, 2011). Common approaches at disaster classification or taxonomy include the hazard type, the impact or losses, the speed and duration of impact, the hybrid schemes and the extent to which society can cope.

Disasters widen the gap between rich and poor by hitting poor and marginalized groups hardest (creating a vicious circle of vulnerability) (Twigg, 2011). Many disaster events have highlighted the linkage between impact and other kinds of marginalization – gender, age, disability, religion, and ethnicity (Twigg, 2011). From these ideas a theory of the ‘social causation’ of disasters is generated (Wisner et al., 2004).

Over the last years, disasters have continued to exact a heavy toll and, as a result, the well-being and safety of persons, communities and countries have been affected (SFA 2015-2030). Over 700 thousand people have lost their lives, over 1.4 million have been injured and approximately 23 million have been made homeless because of disasters (SFA 2015-2030). Overall, more than 1.5 billion people have been affected by disasters in various ways, with women, children and people in vulnerable situations disproportionately affected (SFA 2015-2030). The total economic loss was more than $1.3 trillion (SFA 2015-2030). In addition, between 2008 and 2012, 144 million people were displaced by disasters (SFA 2015-2030).

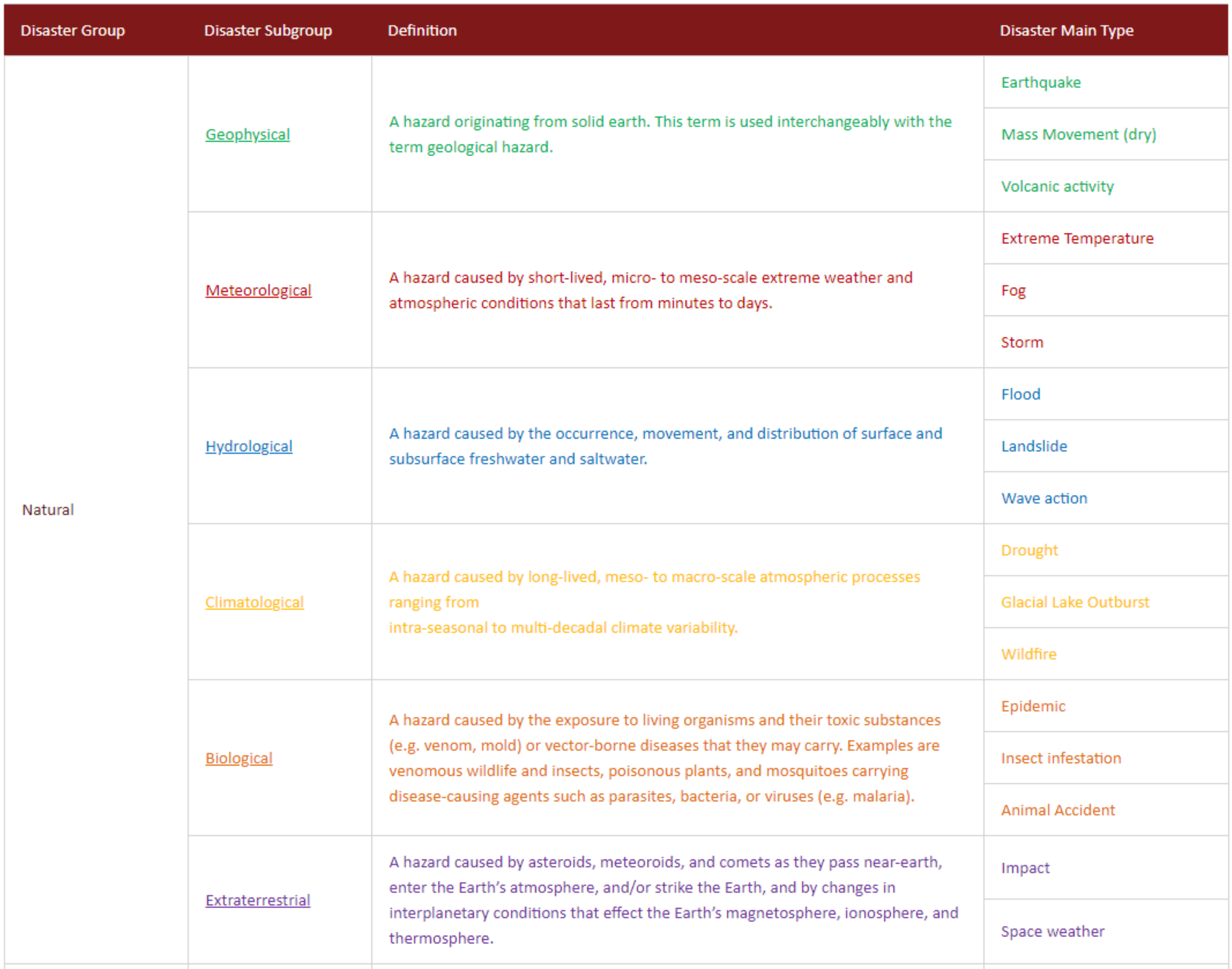
Disasters, many of which are exacerbated by climate change and which are increasing in frequency and intensity, significantly impede progress towards sustainable development (SFA 2015-2030). Evidence indicates that exposure of persons and assets in all countries has increased faster than vulnerability has decreased, thus generating new risks and a steady rise in disaster-related losses, with a significant economic, social, health, cultural and environmental impact in the short, medium, and long term, especially at the local and community levels (SFA 2015-2030). Recurring small-scale disasters and slow-onset disasters particularly affect communities, households, and small and medium-sized enterprises, constituting a high percentage of all loses (SFA 2015-2030). All countries – especially developing countries, where the mortality and economic losses from disasters are disproportionately higher – are faced with increasing levels of possible hidden costs and challenges to meet financial and other obligations (SFA 2015-2030).

2 NATURAL HAZARDS

Hazards and disasters are different, and this is a fundamental issue (Twigg, 2011). The significance of hazards is – as opposed to other social and institutional factors – in creating disasters (Twigg, 2011). Hazard is “a potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation.” (UN ISDR, 2004).

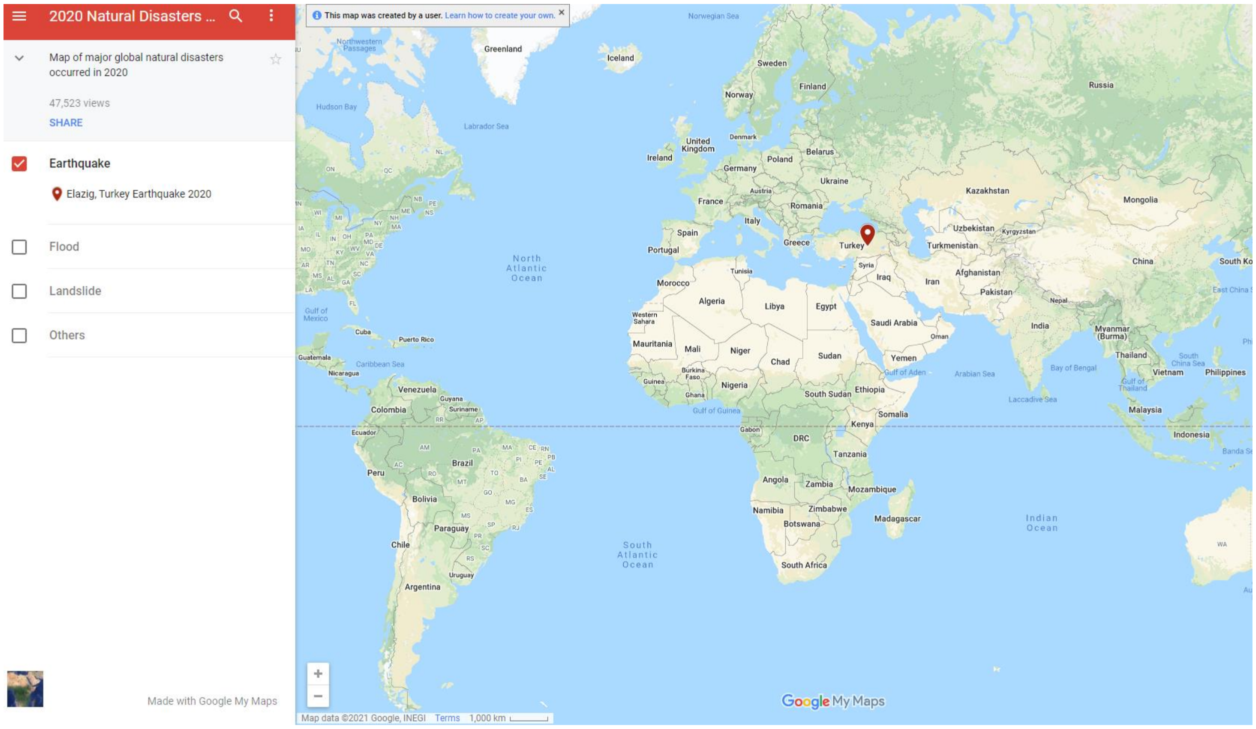
Categorizations are made by hazard type. The classification system used by the global EM-DAT database, the principal data set on disasters around the world broke disasters down into 15 main types, some with several sub-types (Twigg, 2011). All classifications based on hazard types must deal with the problem of how to record secondary hazards (e.g., a hurricane or earthquake triggering a landslide through rainfall and seismic shock respectively) (Twigg, 2011). The natural disaster group has six subgroups, and they are shown in Table 1. The geophysical, meteorological, hydrological, climatological, biological, and extraterrestrial disasters, which are found in EM-DAT database. Disasters triggered by natural hazards such as earthquakes, cyclones, floods, landslides, avalanches, volcanic eruptions, and disease epidemics. They occur suddenly, often with very little warning.

Table 1. Natural disaster groups (Source: https://www.emdat.be/classification)



Disaster Group	Disaster Subgroup	Definition	Disaster Main Type
Natural	Geophysical	A hazard originating from solid earth. This term is used interchangeably with the term geological hazard.	Earthquake
			Mass Movement (dry)
			Volcanic activity
	Meteorological	A hazard caused by short-lived, micro- to meso-scale extreme weather and atmospheric conditions that last from minutes to days.	Extreme Temperature
			Fog
			Storm
	Hydrological	A hazard caused by the occurrence, movement, and distribution of surface and subsurface freshwater and saltwater.	Flood
			Landslide
			Wave action
	Climatological	A hazard caused by long-lived, meso- to macro-scale atmospheric processes ranging from intra-seasonal to multi-decadal climate variability.	Drought
			Glacial Lake Outburst
			Wildfire
	Biological	A hazard caused by the exposure to living organisms and their toxic substances (e.g. venom, mold) or vector-borne diseases that they may carry. Examples are venomous wildlife and insects, poisonous plants, and mosquitoes carrying disease-causing agents such as parasites, bacteria, or viruses (e.g. malaria).	Epidemic
			Insect infestation
			Animal Accident
	Extraterrestrial	A hazard caused by asteroids, meteoroids, and comets as they pass near-earth, enter the Earth's atmosphere, and/or strike the Earth, and by changes in interplanetary conditions that effect the Earth's magnetosphere, ionosphere, and thermosphere.	Impact
			Space weather

The map of major global natural disasters occurred in 2020 is shown in Figures 1-4. As shown, most of the natural disasters occurred in 2020 are floods and weather disasters. It is shown that the majority of natural disasters was regarding climate change in the Mediterranean area and there is a need to further study these hazards for Cyprus.


2020 Natural Disasters ...

Map of major global natural disasters occurred in 2020

47,523 views

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☑ Earthquake

Elazig, Turkey Earthquake 2020

☐ Flood

☐ Landslide

☐ Others

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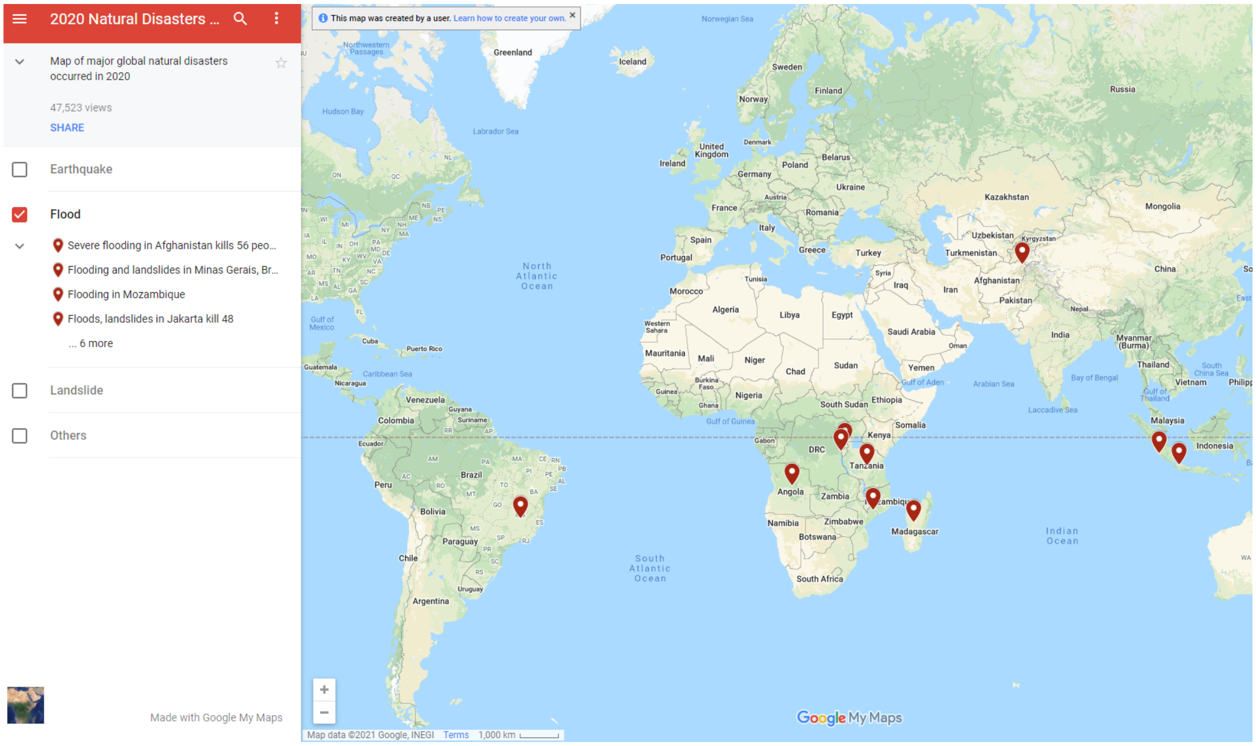
Figure 1 – Map of major global natural disasters occurred in 2020, Earthquakes (Source: https://www.recentnaturaldisasters.com/)


2020 Natural Disasters ...

Map of major global natural disasters occurred in 2020

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☐ Earthquake

☑ Flood

Severe flooding in Afghanistan kills 56 peo...

Flooding and landslides in Minas Gerais, Br...

Flooding in Mozambique

Floods, landslides in Jakarta kill 48

... 6 more

☐ Landslide

☐ Others

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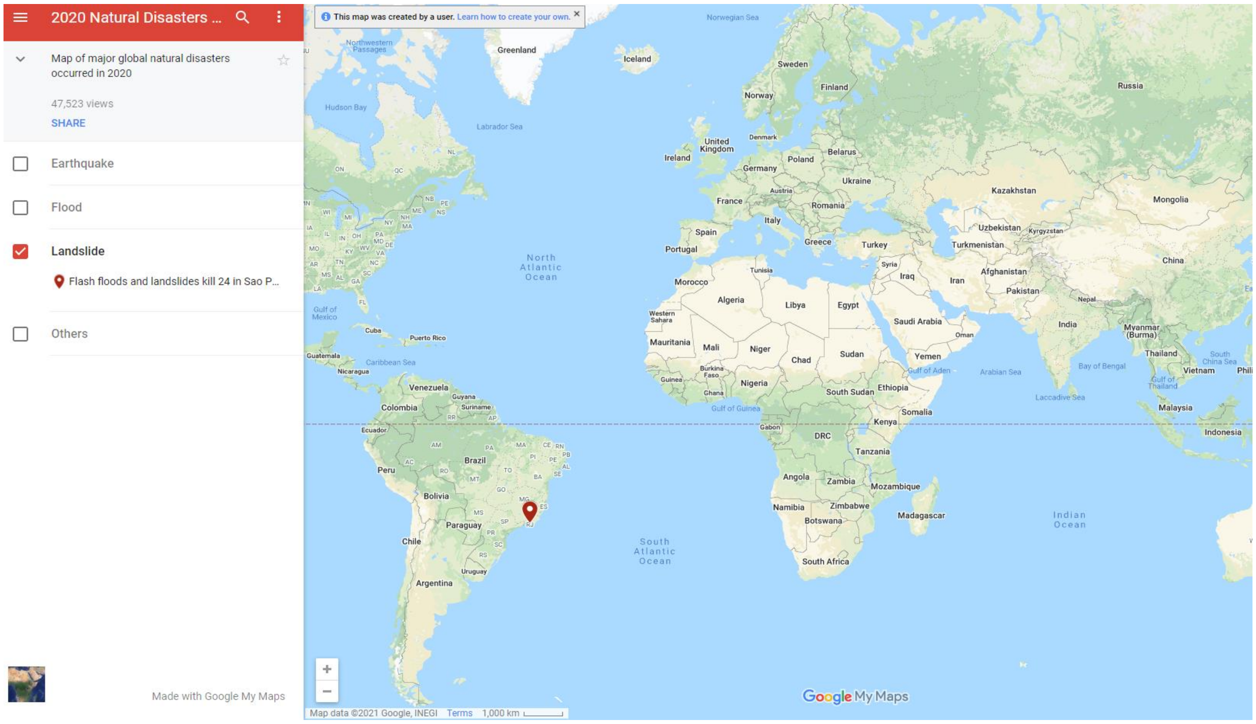
Figure 2 – Map of major global natural disasters occurred in 2020, Floods (Source: https://www.recentnaturaldisasters.com/)



2020 Natural Disasters ...

Map of major global natural disasters occurred in 2020

47,523 views

SHARE

☐ Earthquake

☐ Flood

☑ Landslide

- Flash floods and landslides kill 24 in Sao P...

☐ Others

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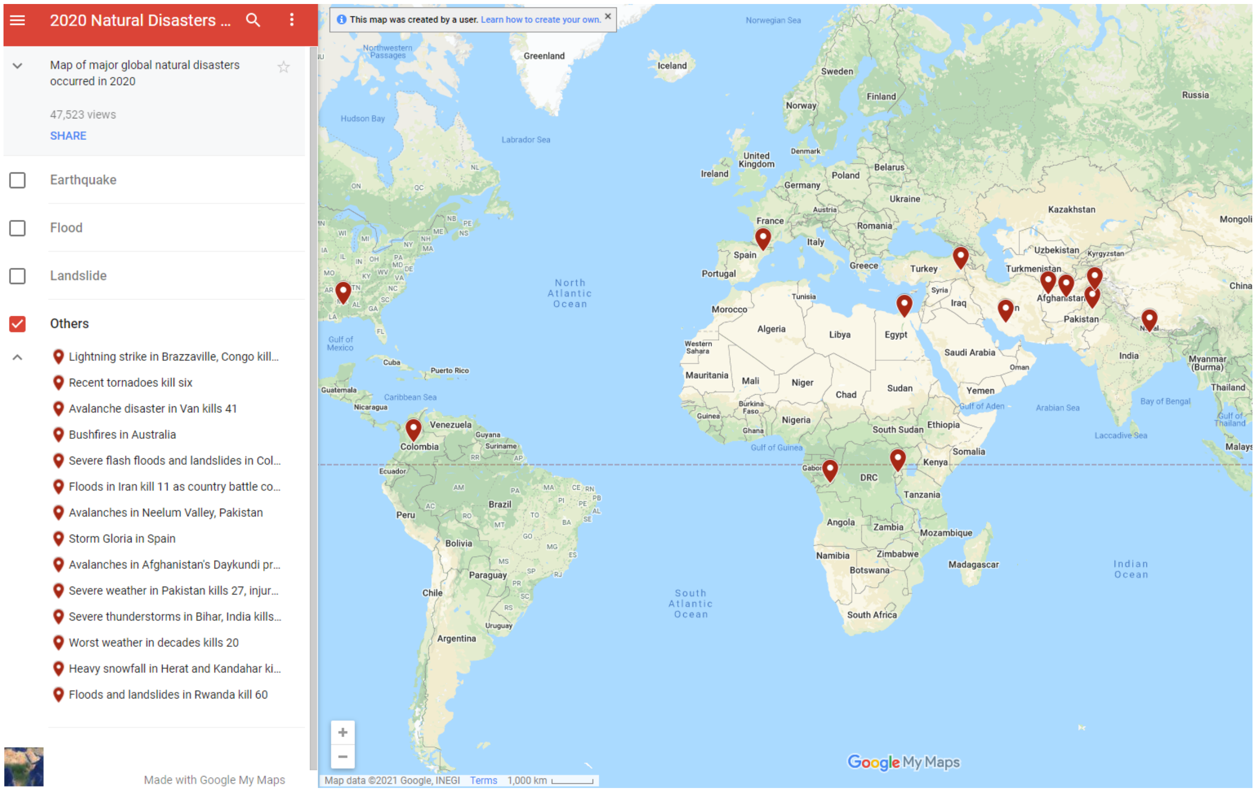
Figure 3 – Map of major global natural disasters occurred in 2020, Landslide (Source: https://www.recentnaturaldisasters.com/)



2020 Natural Disasters ...

Map of major global natural disasters occurred in 2020

47,523 views

SHARE

☐ Earthquake

☐ Flood

☐ Landslide

☑ Others

- Lightning strike in Brazzaville, Congo kill...
- Recent tornadoes kill six
- Avalanche disaster in Van kills 41
- Bushfires in Australia
- Severe flash floods and landslides in Col...
- Floods in Iran kill 11 as country battle co...
- Avalanches in Neelum Valley, Pakistan
- Storm Gloria in Spain
- Avalanches in Afghanistan's Daykundi pr...
- Severe weather in Pakistan kills 27, injur...
- Severe thunderstorms in Bihar, India kills...
- Worst weather in decades kills 20
- Heavy snowfall in Herat and Kandahar ki...
- Floods and landslides in Rwanda kill 60

Made with Google My Maps

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Map data ©2021 Google, INEGI Terms 1,000 km

Figure 4 – Map of major global natural disasters occurred in 2020, Others (Source: https://www.recentnaturaldisasters.com/)

It is essential, therefore, to examine how the community, the environment, and the hazards interact when performing a vulnerability assessment (WHO, 1999). Risk is a probabilistic measure of the consequence of a probabilistically defined hazardous event. It is often the unconditional probability or the mean annual frequency (probabilistic measure) of a component or system exceeding a pre-defined limit-state (consequence). Risk is also used to indicate the expected value, and possibly variance (with the reference time frame) of: Economic value of physical damage; casualties/fatalities, downtime, economic loss, direct (physical damage/lives) and indirect (downtime, etc.). (SYNER-G, 2011)

The seismic, flood and fire natural hazards will be discussed more in the next chapters for the risk assessment and disaster management and their definition as found in the literature is shown below.

Evaluation of natural hazards

Two approaches can be followed to evaluate the natural hazards. The deterministic and the probabilistic assessment.

<u>The deterministic hazard assessments</u> are carried out when a specific hazard scenario is defined for the design (Rossetto, 2012). i.e., the client states that wants the building designed to resist an earthquake of magnitude M whose focus is located at horizontal distance d from the site of construction. In this case, the design values of the strong ground motion parameters (e.g., pga) are found by substituting the specified values of d and M into an appropriately chosen attenuation relationship (Rossetto, 2012).

A slightly more complicated version of the deterministic approach involves assigning a characteristics of natural hazard event. Several assumptions need to be made regarding the magnitude and location of the event at the source. However, we often cannot predict with much confidence exactly where the next natural hazard will occur. Also, it is often too conservative to just assume the maximum credible hazard event will occur at the closest source-to-side distance. (Rossetto, 2012)

<u>The probabilistic hazard assessment</u>, account for uncertainties in natural hazards and probabilistic hazard assessments are carried out. These provide a description of the likely natural hazard to be experienced at a site, as well as the probability of their occurrence. (Rossetto, 2012)

In general, the main steps of a probabilistic hazard assessment are as follows:

a) Definition of the nature and locations of the hazard source
b) Magnitude-frequency relationships for each source
c) Attenuation of hazard with distance from sources

d) Determination of hazard at a site and associated probabilities, considering all defined hazard sources.

(Rossetto, 2012)

Probabilistic risk analysis has been performed for consequences estimate with given probabilities of occurrence, while it allows for selection of several scenarios with return periods frequently used in disaster planning (NHAZ-D-20-01634, 2020). Probabilistic hazard analysis, with all its uncertainties and complexities, is a quantitative comprehensive tool, god for design purposes, when it is necessary to associate for instance ground motion intensities with exceedance probabilities, accounting for all possible earthquake ruptures with their return period. Strategic decisions upon the selection of the most appropriate scenario are taken in a lea arbitrary way (NHAZ-D-20-01634, 2020). The information extracted from the probabilistic hazard analysis is summarized in the hazard curve which combines the rate at a given site. For a probabilistic seismic hazard analysis, the curve is composed by considering all possible earthquake ruptures included in the seismic source model, which, within the given investigation time of 50 years, exceed the ground motion parameter levels (NHAZ-D-20-01634, 2020).

3 RISK ASSESSMENT (RA)

Risk assessment is a risk management process which involves identifying potential hazards and analyze what could happen if the hazard results to an accident. RA is also defined as the determination of quantitative or qualitative estimate of risk related to a well-defined situation and a recognized threat hazard. Quantitative RA requires calculations of two components or risk: the magnitude of the potential loss (L), and the probability (p) that the loss will occur. RA is very important as it can form an integral part of a good occupational health and safety management plan. They help to create awareness of hazards and risks, to identify who may be at risk, to try and determine if existing control measures are adequate or if more should be done, to prevent injuries or illneses when done at the design or planning stage and to prioritize hazards and control measures. In summary, to conduct RA, five main steps are always adopted. 1. Identify the hazard (be it physical, mental, chemical, or biological), 2. Decide who could be harm, 3. Assess the risk, 4. Make record of findings. (Health and Safety Articles, 2021)

There are five major steps to RA. After the establishment of the context and environment, the first step of risk assessment is the hazard analysis (identify the internal and external risks / hazards that poses the threat). Then, the next step is to analyze the risks, a systemic analysis of various contributing and leading factors (e.g., extend of the exposure, multiple exposures). Then, to evaluate and prioritize the risks for further action and finally to tackle the risks. To identify the range of options to tackle the risk and implement the best choice using available resources. (Health and Safety Articles, 2021)

RA takes into consideration of majorly two (variables), which is the likelihood and severity of occurrence. To analyze the risk level the definition of the risk levels is necessary (very low to very high). RA value is arrived at by multiplying the likelihood value with the severity value (Risk = Likelihood x Severity or Risk = Hazard x Vulnerability).

In general, to do an assessment, you should:

- Identify hazards.
- Evaluate the likelihood of an injury or illness occurring, and its severity.
- Consider normal operational situations as well as non-standard events such as shutdowns, power outages, emergencies, etc.
- Review all available health and safety information about the hazard such as MSDSs, manufacturer’s literature, information from reputable organizations, results of testing, etc.

- Identify actions necessary to eliminate or control the risk.
- Monitor and evaluate to confirm the risk is controlled.
- Keep any documentation or records that may be necessary. Documentation may include detailing the process used to assess the risk, outlining any evaluations, or detailing how conclusions were made.

(Health and Safety Articles, 2021)

The general process for RA as depicted in Figure 5, **risk assessment** is the overall process of risk identification, risk analysis and risk evaluation.

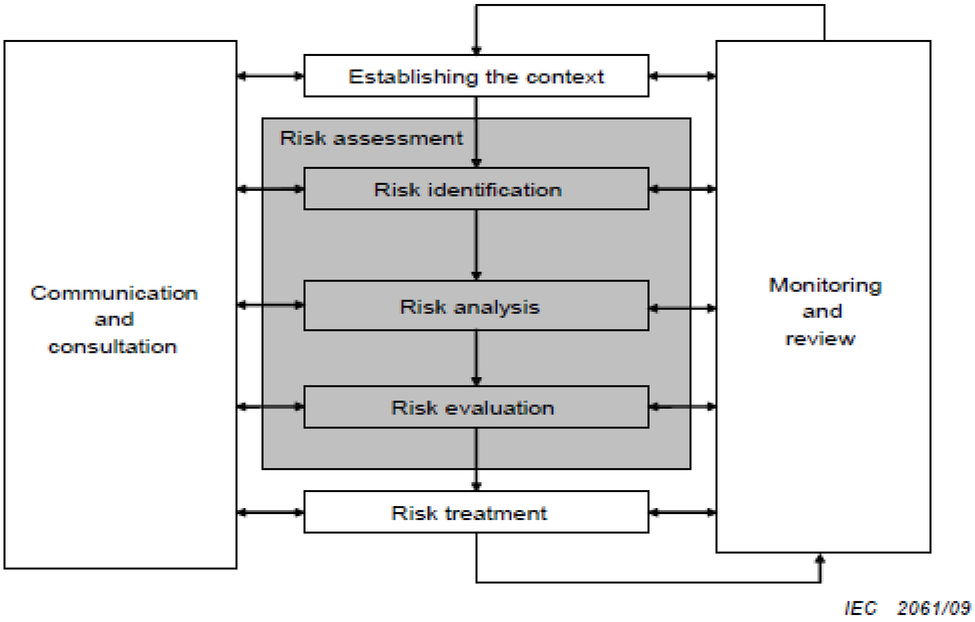

Figure 5 – Contribution of risk assessment to the risk management process (ISO31010)

The **risk identification** process includes identifying the causes and source of the risk i.e., hazard, events, situations or circumstances, which could have a major influence upon objectives and the nature of that impact. For this project, whereas the hazards have already been identified by the contracting authority (CA), the pending task regards the development of hazard scenarios. This will be followed by the risk analysis and evaluation.

Risk analysis consists of determining the consequences and their probabilities for identified risk events, taking into account the presence (or not) and the effectiveness of any existing controls. The consequences and their probabilities are then combined to determine a level of risk. All three items, namely consequences, probabilities and existing control measures will be considered in this study. Furthermore, consequences analysis will be considered in terms of human, economic & environmental and political/social impacts, which each impact will be analysed in terms of vulnerability and exposure. The risk will be estimated considering the probability of hazard's occurrence, vulnerability and exposure.

For the proposed study, both single-risk analysis and multi-risk assessments will be performed as per EU guidelines[1] on the subject. To determine the singular risk from a pre-defined hazard in isolation (independent) from the other hazards a single-risk assessment is necessary, and it will be followed. On the other hand, multi-risk assessment determines the total risk considering the interaction and interdependency between several hazards in terms of possibility and vulnerability, e.g., follow-on hazardous events such as earthquake and tsunami. Therefore, this approach will be used to determine the risk due to the hazards synergy through identified multi-risk scenarios considering the interdependent hazards and also for the development of the risk matrix and mapping for all the hazards analysed.

Risk evaluation involves comparing estimated levels of risk with risk criteria defined when the context was established, in order to determine the significance of the level and type of risk. Risk evaluation uses the understanding of risk obtained during risk analysis to make decisions about future actions on issues like whether a risk needs treatment, priorities for treatment, whether an activity should be undertaken and which of a number of paths should be followed. In the context of this study, risk-based criteria will be established to enable for risk evaluation. These base criteria will be defined regarding their magnitude of acceptability and tolerance, which will be the benchmark of assessing and calibrating the severity of each type of risk.

Sendai Framework

The ***Sendai Framework for Disaster Risk Reduction 2015-2030*** (Sendai Framework 2015-2030) is the successor instrument to the ***Hyogo Framework for Action (HFA) 2005-2015***: *Building the Resilience of Nations and Communities to Disasters*.

The Sendai Framework is the first major agreement of the post-2015 development agenda, with seven targets and four priorities for action [UNISDR[1]].

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[1] https://www.unisdr.org/

The Seven Global Targets →

(a) Substantially reduce global disaster mortality by 2030, aiming to lower average per 100,000 global mortality rates in the decade 2020-2030 compared to the period 2005-2015.

(b) Substantially reduce the number of affected people globally by 2030, aiming to lower average global figure per 100,000 in the decade 2020 -2030 compared to the period 2005-2015.

(c) Reduce direct disaster economic loss in relation to global gross domestic product (GDP) by 2030.

(d) Substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030.

(e) Substantially increase the number of countries with national and local disaster risk reduction strategies by 2020.

(f) Substantially enhance international cooperation to developing countries through adequate and sustainable support to complement their national actions for implementation of this Framework by 2030.

(g) Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to the people by 2030.

The Four Priorities for Action

Priority 1. Understanding disaster risk

Disaster risk management should be based on an understanding of disaster risk in all its dimensions of vulnerability, capacity, exposure of persons and assets, hazard characteristics and the environment. Such knowledge can be used for risk assessment, prevention, mitigation, preparedness and response.

Priority 2. Strengthening disaster risk governance to manage disaster risk

Disaster risk governance at the national, regional and global levels is very important for prevention, mitigation, preparedness, response, recovery, and rehabilitation. It fosters collaboration and partnership.

Priority 3. Investing in disaster risk reduction for resilience

Public and private investment in disaster risk prevention and reduction through structural and non-structural measures are essential to enhance the economic, social, health and cultural resilience of persons, communities, countries and their assets, as well as the environment.

Priority 4. Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction

The growth of disaster risk means there is a need to strengthen disaster preparedness for response, take action in anticipation of events, and ensure capacities are in place for effective response and recovery at all levels. The recovery, rehabilitation and reconstruction phase is a critical opportunity to build back better, including through integrating disaster risk reduction into development measures.

Sendai- Risk Assessment Guidelines

To support the implementation of priority 1, in 2016 the United Nations Office for Disaster Risk Reduction (UNISDR) commissioned the development of guidelines on national disaster risk assessment (NDRA) as part of a series of thematic guidelines under its “Words into Action” initiative to support national implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030.

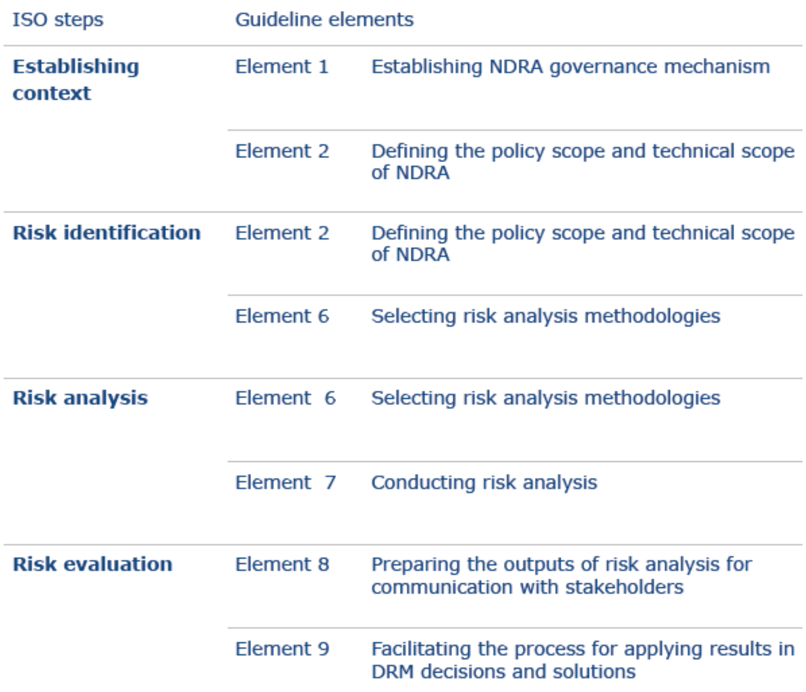
These Guidelines are the result of the collaboration between over 100 leading experts from national authorities, international organizations, non-governmental organizations, academia, think tanks and private-sector entities. They focus on Sendai Framework’s first Priority for Action: Understanding Disaster Risk, which is the basis for all measures on disaster risk reduction and is closely linked to the other three Priorities for Action.

The first part of the Guidelines presents 10 enabling elements for designing and implementing an assessment, clustered in three stages. The elements are interlinked through many common topics for attention and feedback loops.

Figure 6 – Ten enabling elements in three strages of the NDRA process, interlinked through overlapping areas of concern and feedback loops

The NDRA guidelines are in-line with the risk assessment process flow outlined in the international standards on risk management (ISO 31000:2009) and on risk assessment (31010:2009). It starts with setting the context and then consists of three steps: risk identification, risk analysis and risk evaluation. This relationship is depicted in the Table 2 below.

Table 2. Mapping of ISO steps to the elements of the NDRA guidelines



ISO steps	Guideline elements	
Establishing context	Element 1	Establishing NDRA governance mechanism
	Element 2	Defining the policy scope and technical scope of NDRA
Risk identification	Element 2	Defining the policy scope and technical scope of NDRA
	Element 6	Selecting risk analysis methodologies
Risk analysis	Element 6	Selecting risk analysis methodologies
	Element 7	Conducting risk analysis
Risk evaluation	Element 8	Preparing the outputs of risk analysis for communication with stakeholders
	Element 9	Facilitating the process for applying results in DRM decisions and solutions

The seismic, flood, and fire risk assessment are discussed in the following sections and more information for Cyprus is provided in the following sections.

Seismic Risk Assessment

The seismic risk is quantified by seismic losses – monetary or otherwise and is given by:

Seismic risk = Hazard * Vulnerability * Exposure

Seismic risk = Hazard * Vulnerability * Cost * Exposure

Seismic risk is the rate of exceeding different levels of seismic losses (monetary/human...). Hazard is the rate of exceeding different measures of earthquake ground motion (e.g., PGA, Spectral Acceleration ordinates). Vulnerability is the expected damage (and loss) in different types of buildings given different levels of earthquake ground motion. Exposure are proportions and total quantities of different building types in inventory (study area). Cost is the expected cost of repair, downtime or human casualties given different levels of damage. (Rossetto, 2012)

The multiple interactions that exist between infrastructures have been identified as an integral part. According to President's Commission on Critical Infrastructure Protection (PCCIP) 1997, infrastructure is a "*network of interdependent, mostly privately-owned, manmade systems and processes that function collaboratively and synergistically to produce and distribute a continuous flow of essential goods and services*". Infrastructure is also defined as the "*framework of interdependent networks and systems comprising identifiable industries, institutions (including people and procedures), and distribution capabilities that provide a reliable flow of products and services essential to the defense and economic security, the smooth functioning of governments at all levels, and society as a whole*" (The Clinton Administration's Policy on Critical Infrastructure Protection: Presidential Decision Directive 63, CIAO, 1998).

Seismic Risk Assessment for lifeline systems

Even though the seismic risk assessment of buildings has been studied in depth for Cyprus, the lifeline systems have not been studied yet. The risk assessment of lifeline systems is discussed in more detail in this section.

The risk assessment of lifeline systems is a very complex and challenging issue. System's co and post seismic performance and functionality are determined by the seismic hazard, the vulnerability of its elements and their interconnectedness, and as well as the interconnectedness with other lifeline systems. Lifelines are, indeed, highly intra-dependent and inter-dependent systems, showing a great degree of coupling between sub-components of the same system and with other infrastructures. Considering important dependencies among different lifeline systems and with other essential facilities are very important for the global seismic risk management at a city scale. Incorporating infrastructure dependencies allows a more rigorous assessment of lifeline seismic vulnerability, system reliability and risk mitigation actions, while interactions between different critical infrastructures may seriously affect the seismic risk management (response, recovery, and mitigation). (SYNER-G D2.09, 2011) Therefore, an integrated earthquake disaster reduction system should take into consideration the multiple interactions among lifeline systems (Hada and Meguro, 2000).

Interdependencies among civil infrastructure systems such as transportation, telecommunication, power, energy, and water systems may increase their vulnerability to natural or manmade disasters. Indeed, interdependencies can manifest in multiple ways: (i) the failure or disruption in one system can propagate to other systems in a cascading manner, (ii) an event can cause adverse impacts on several systems simultaneously, or (iii) the negative effects on one infrastructure system can build up over time, and then cause problems for other systems. As infrastructures are complex interacting systems, an explicit understanding of their linkages for design, planning, and operation can influence the effectiveness and the efficiency of the individual systems. The significance of the economic, engineering and security implications of identifying infrastructure interdependencies, understanding their consequences, and incorporating them into practical problems in the context of analysis and decision-making, motivates the need for a new generation of theoretical and computational approaches that can incorporate multiple infrastructure systems in a single modeling framework. In general, dependencies refer to relationships or influences that an element in one infrastructure imparts upon elements of the same or another infrastructure. Dependencies are therefore distinguished between components within (intra) the same system, or between (inter) different systems (Figure 7). (SYNER-G D2.01, 2011)

In practice, interdependencies among infrastructures dramatically increase the overall complexity of the “system of systems”. Rinaldi et al. (2001) provide a visual representation of this intertwining and the potential cascading effects (Figure 7). These complex relationships are characterized by multiple connections among infrastructures, feedback. and feedforward paths, and intricate, branching topologies. Figure 8 depicts infrastructure interdependencies from a “system of systems” perspective (Peerenboom et al., 2001). The complexity of multiple infrastructure linkages, and the implications of multiple contingency events that may affect the infrastructures, are apparent even in this highly simplified representation. Several definitions of systems interactions have been proposed, by Rinaldi et al. (2001), Little (2002), Bush et al. (2003) and Yao et al. (2004).

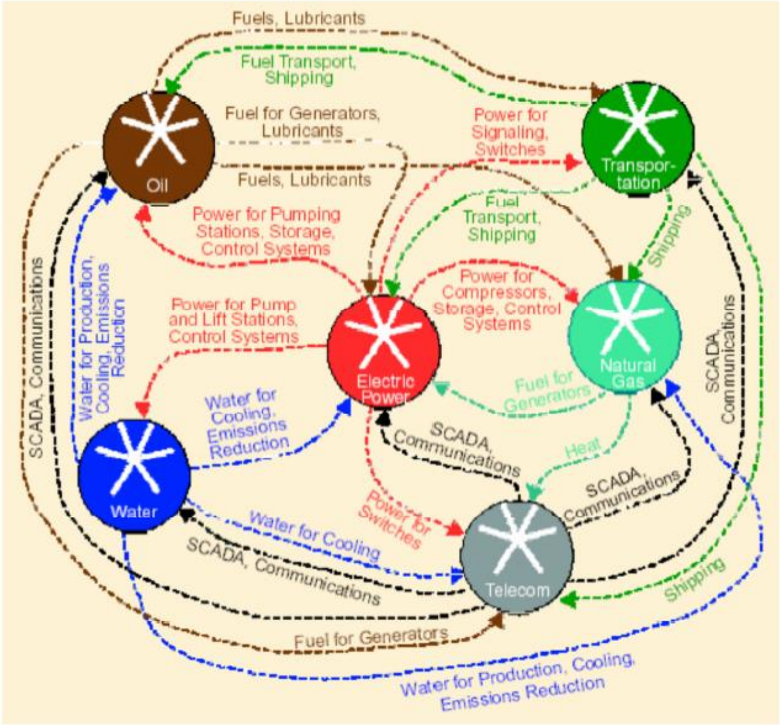


Figure 7 – Ten enabling elements in three strages of the NDRA process, interlinked through overlapping areas of concern and feedback loops

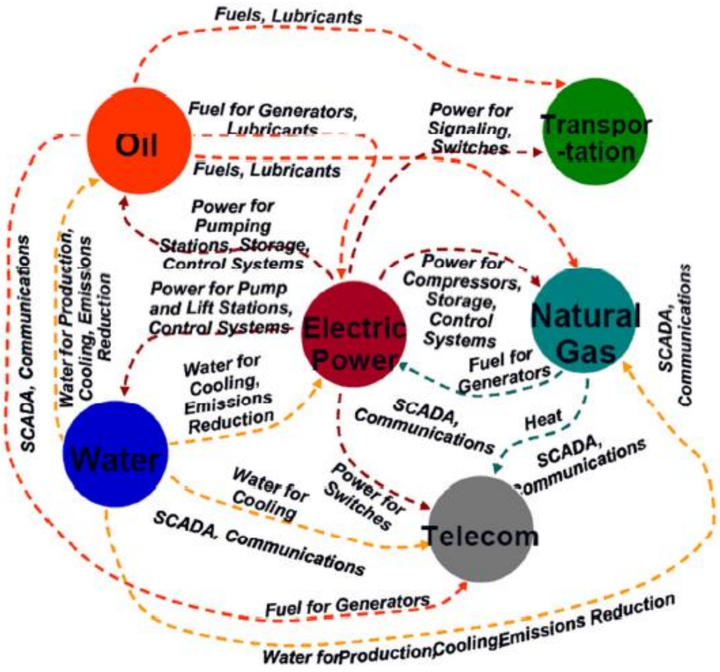


Figure 8 – Infrastructure interdependencies mechanisms (Peerenboom et al., 2001)

In parallel to defining the notion of dependencies between multiple infrastructures, complex relations between them have been identified and/ or illustrated by several researchers. A quite common approach is the adoption of the **graph theory concept** to represent interactions. Basic notions of the graph theory are used by Dudenhoeffer et al. (2006), who simulate individual infrastructure networks on a single plane, where the nodes represent infrastructure components and edges represent the ties and dependencies existing within each infrastructure between the different sectors. Under the same framework, lies the proposal of Pederson et al. (2006) (Figure 9) for the simulation of infrastructure dependencies based on the scenario of a flooding event and the subsequent response. Individual infrastructure networks are represented on a single plane, while internal dependencies are represented by in-plane lines. Key infrastructure components are identified and represented as nodes. The energy sector infrastructure, for example, contains the sectors of electrical generation and distribution, natural gas production and distribution, etc. Ties and dependencies that also exist between different infrastructures (inter-dependencies) are represented by lines connecting the key components of different planes.

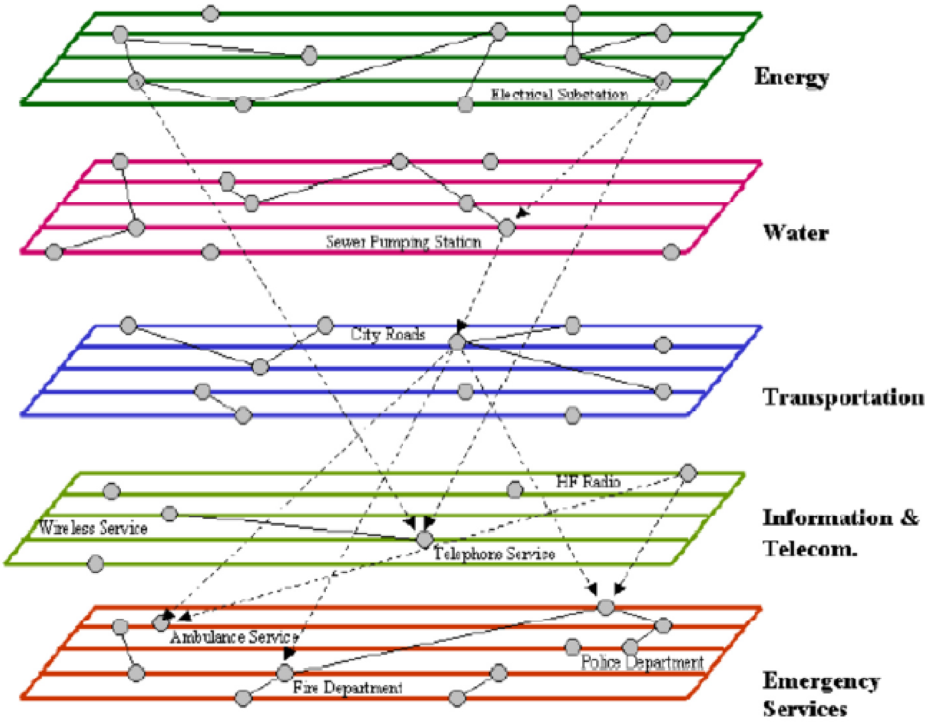


Figure 9 – Infrastructure interdependencies (Pederson et al., 2006)

Interactions among critical infrastructures during the restoration process following the occurrence of an earthquake event are modeled by Shoji and Toyota (2009) using «qualitative» graphs or **flow**

diagrams (Figure 10). Miles and Chang (2006) present a model of community recovery from earthquake disasters. Damage propagation caused by interdependency for three types of damages (physical damage, functional damage, and restoration trouble) is graphically illustrated by Tsuruta et al. (2008) in Figure 11. A framework showing major systems interacting in a metropolitan environment is proposed by Menoni (2001). Based on a strictly linear structure, which is generally different from the parallel connections between real infrastructure systems, Little (2002) illustrates the cascading effects from systems failures. A more complex realization of infrastructure dependencies and interdependencies is used on system dynamics approach to complex problems, where focus is given on feedback processes (Figure 12, Ventana Systems, 2006). A different approach consists of using **matrices** for the representation of interdependencies between infrastructure networks and their relative impact. The Critical Infrastructure Protection Task Force of Canada used a dependency matrix to relate the interdependencies among six sectors identified as crucial: Government, Energy and Utilities, Services, Transportation, Safety, and Communications (Dunn and Wigert, 2004). The matrix is an attempt to better understand the level of dependency and the potential impact among sectors. Tsuruta et al. (2008) also use matrices for determining damage propagation due to interdependency in three periods (immediately after disaster, in emergency response activity and in restoration work) based on earthquake data and expert judgment. Critical infrastructure networks under study are electric power, gas, waterworks, sewerage, telecommunication, road, railroad, port, airport, and social functions like transportation, finance, medical treatment, and administration. (SYNER-G D2.01, 2011)

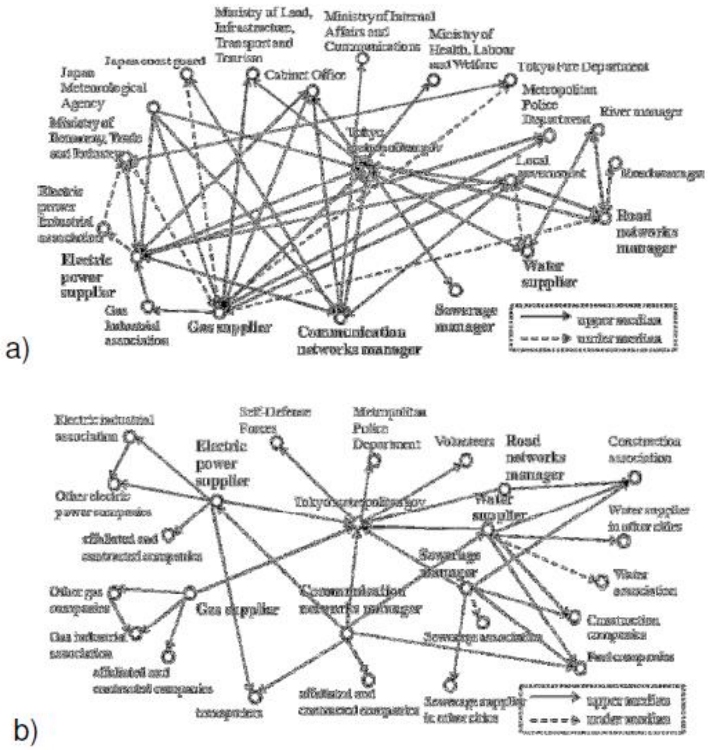


Figure 10 – Interdependency in the restoration process associated with critical infrastructures in respect to related (a) information, (b) human resources and materials (Shoji and Toyota, 2009)

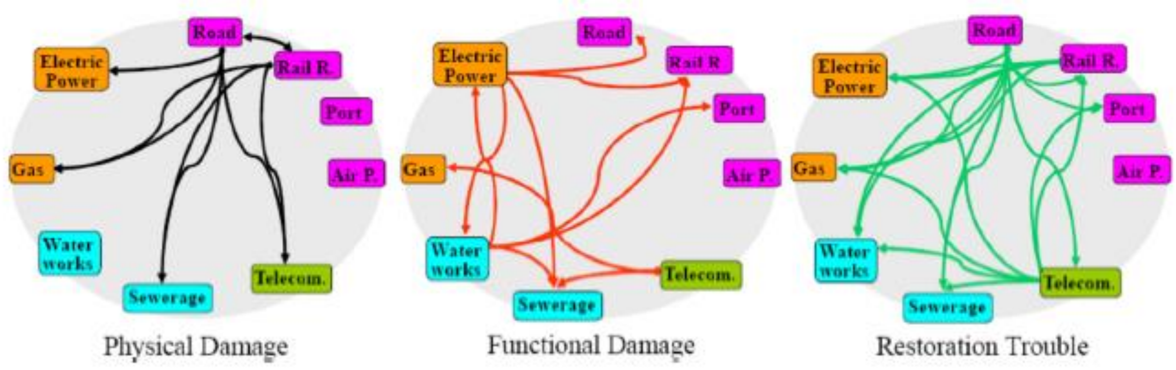


Figure 11 – Inflience diagraphs of damage popagation caused by interdependency (Tsuruta et al., 2008)

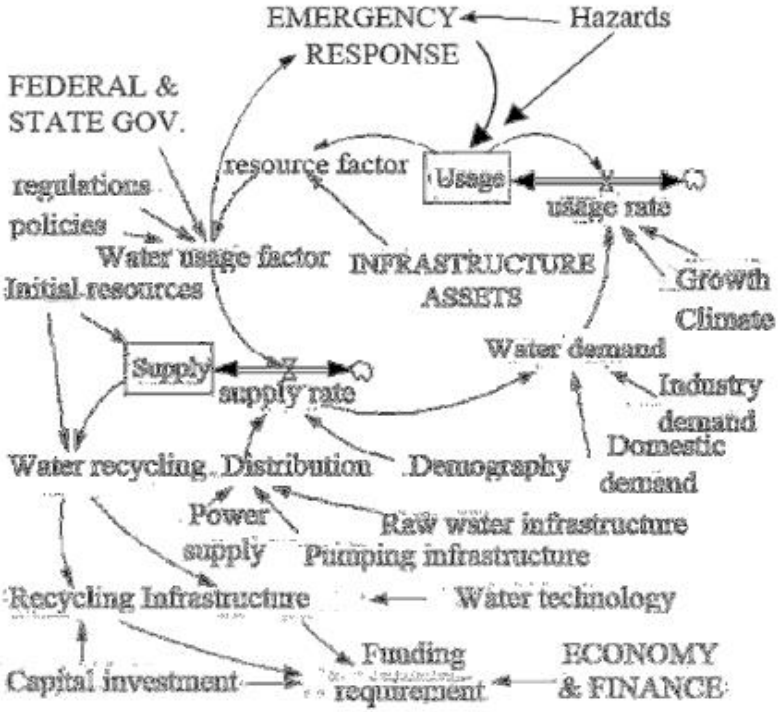


Figure 12 – Example of system dynamic modelling for the water supply system (Ventana Systems, 2006)

A table was proposed by Pitilakis et al. (2006) for the identification of possible interactions between different systems. Influences on and influences by different infrastructure networks are described during three periods in respect to the occurrence of an earthquake event, and in respect to the strength and importance of the link. The method proposed by Cheng (2007) for modeling and analyzing interdependencies of critical infrastructures is based on the use of asymmetrical fuzzy relation matrices representing direct relationships between nodes in infrastructure networks and direct and cascade relationships between infrastructure networks. Using a mathematical framework, direct and indirect relations are identified, and infrastructures are ranked in terms of relative importance (SYNER-G D2.01, 2011).

Interdependent analysis can enhance loss estimation methodologies and indicate strategies for robust design and growth of infrastructures. Investors, owners, and operators of utility companies can use the results from an interdependent analysis to make better decisions on prioritizing scarce resources for mitigation actions. The dependencies between networks are classified in SYNER-G

D2.01 (2011) and the available methods for the assessment of interdependencies among different systems are classified and summarized.

To classify interactions, it is essential to know the typology and functioning of systems involved, the nature of the reciprocal influence, the importance of the link (slight/ strong) and the period evolved (normal, seismic and restoration/recovery period). Several researchers have proposed different classification schemes of lifeline interdependencies. Rinaldi et al. (2001) describe four general categories of infrastructure interdependencies, the physical, cyber, geographic, and logical. The same categories are proposed by Peerenboom et al. (2001). In the slightly different classification proposed in Dudenhoeffer and Permann (2006) additional categories are introduced (Pederson et al., 2006): Policy/Procedural Interdependency (An interdependency that exists due to policy or procedure that relates a state or event change in one infrastructure sector component to a subsequent effect on another component. Note that the impact of this event may still exist given the recovery of an asset) and Societal Interdependency (The interdependencies or influences that an infrastructure component event may have on societal factors such as public opinion, public confidence, fear, and cultural issues) (SYNER-G D2.01, 2011).

Even if no physical linkage or relationship exists, consequences from events in one infrastructure may impact other infrastructures. This influence may also be time sensitive and decay over time from the original event grows (SYNER-G D2.01, 2011).

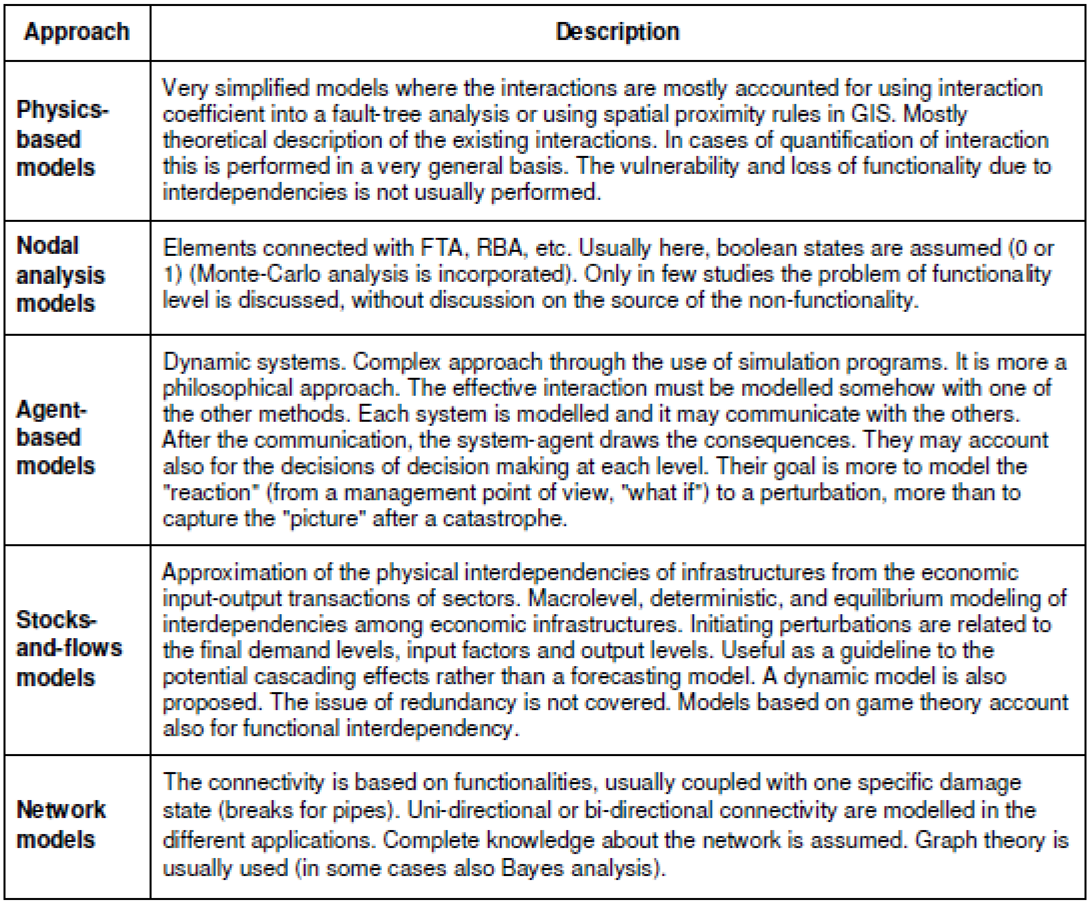
Zhang and Peeta (2011) summarize the classification schemes of interdependencies among the infrastructure systems as following: o Functional Interdependency, o Physical Interdependency. o Budgetary Interdependency, o Market and Economic Interdependency. Additional categories of infrastructure interdependencies are proposed by several researchers: Recovery interruption, restoration interaction (Kameda, 2000; Felix et al., 1995), Back-up functions of substitute systems, substitute interaction (Kameda, 2000; Yao et al., 2004), Cascade interaction (Yao et al., 2004), General interaction (Yao et al., 2004), and Laprie et al. (2007).

As infrastructure interdependencies represent an emerging problem domain, there are many dimensions to be addressed. According to Rinaldi et al. (2001), interdependence-related disruptions or outages are classified in terms of three general categories. To fully understand and analyze infrastructure interdependencies, it is necessary to determine for each infrastructure the other systems it depends on, continuously or nearly continuously, in three periods in respect to the occurrence of a perturbation: normal operating conditions, times of high stress or disruption and restoration period, as for example is performed in Pitilakis et al. (2006).

It is worth mentioning the study of Pederson et al. (2006), who performed a detailed bibliographic survey of the available in U.S. and internationally critical infrastructure interdependency modeling tools. The authors provide information in respect to the overview and the development goals of each tool, the intended users, the maturity, the areas modelled, and the customers/ sponsors. They also describe the model framework (underlying model, simulation, data format, sensor data, coupling with other models and human activity modelling), the system requirements (hardware and software), as well as some notes and references. Finally, a distinction is made between integrated models, where multiple infrastructures and their interdependencies are modelled within one framework, and coupled models, where a series of individual infrastructure simulations are coupled together, explaining then the cascading influence between them.

Table 3 summarizes the available methodologies for the simulation of interdependencies. It seems that most available approaches are still on an early stage of development or even under research. They are mostly based on the use of coupled models, while few of them propose integrated analysis models (still under development). Furthermore, they do not intent to assess the seismic risk of interconnected infrastructures. They are limited to the systems' serviceability analysis also considering the influence from a single (in most cases) interdependent network, by simulating the various types of interactions and their induced impact (cascading or not). (SYNER-G D2.01, 2011)

Table 3. Summary of available methodologies for the simulation of interdependencies



Approach	Description
Physics-based models	Very simplified models where the interactions are mostly accounted for using interaction coefficient into a fault-tree analysis or using spatial proximity rules in GIS. Mostly theoretical description of the existing interactions. In cases of quantification of interaction this is performed in a very general basis. The vulnerability and loss of functionality due to interdependencies is not usually performed.
Nodal analysis models	Elements connected with FTA, RBA, etc. Usually here, boolean states are assumed (0 or 1) (Monte-Carlo analysis is incorporated). Only in few studies the problem of functionality level is discussed, without discussion on the source of the non-functionality.
Agent-based models	Dynamic systems. Complex approach through the use of simulation programs. It is more a philosophical approach. The effective interaction must be modelled somehow with one of the other methods. Each system is modelled and it may communicate with the others. After the communication, the system-agent draws the consequences. They may account also for the decisions of decision making at each level. Their goal is more to model the "reaction" (from a management point of view, "what if") to a perturbation, more than to capture the "picture" after a catastrophe.
Stocks-and-flows models	Approximation of the physical interdependencies of infrastructures from the economic input-output transactions of sectors. Macrolevel, deterministic, and equilibrium modeling of interdependencies among economic infrastructures. Initiating perturbations are related to the final demand levels, input factors and output levels. Useful as a guideline to the potential cascading effects rather than a forecasting model. A dynamic model is also proposed. The issue of redundancy is not covered. Models based on game theory account also for functional interdependency.
Network models	The connectivity is based on functionalities, usually coupled with one specific damage state (breaks for pipes). Uni-directional or bi-directional connectivity are modelled in the different applications. Complete knowledge about the network is assumed. Graph theory is usually used (in some cases also Bayes analysis).

Within SYNER-G, an integrated methodology has been developed in order to assess the seismic vulnerability of an interconnected Infrastructure, including: a detailed taxonomy of interconnected infrastructure systems, an object-oriented model describing the relations between all systems and components (inter- and intra-dependencies) within the taxonomy, consideration of all uncertainties in the problem, a categorization of performance indicators in three groups and an integrated evaluation of physical and socio-economic performance indicators. The developed methodology and simulation framework is being implemented into a software.

As far the time dimension is concerned, two aspects are of interest: the *time-frame* and the *observation point-in-time*. Typically, three frames are considered, the short-term (in the aftermath of the event the damaged Infrastructure operates in a state of emergency), the mid-term (the Infrastructure progressively returns to a new state of normal functionality) and the long-term (the Infrastructure is upgraded/retrofitted with available resources to mitigate the risk from the next event).

Correspondingly, the spatial extent of interest to the study of the Infrastructure response increases with time, initially (short-term) involving only the local struck area, then, an increasingly wide area covering adjacent regions up to the national scale in the economic recovery phase and long-term risk mitigation actions. The position on the time axis of the observer with respect to the time-frame changes the goal of the systemic study:

o **before the time-frame**: the goal of the system analyst is forecasting the impact in order to set-up mitigation measures. It is important to underline how the information basis in this case can be considered as constant.

o **within the time-frame**: the goal of the system analyst is that of providing the managers with a real-time decision support system, which updates the Infrastructure state based on the continuously incoming flow of information.

o **after the time-frame**: the goal of the system analyst is to validate the models against occurred events.

(SYNER-G D2.01, 2011)

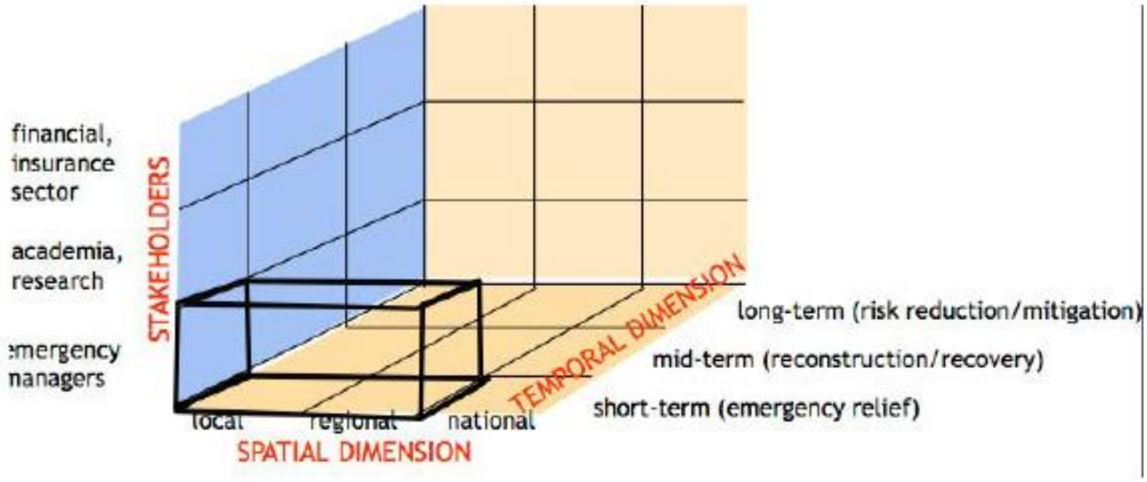


Figure 13 – The three dimensions in an infrastructure vulnerability study (SYNER-G D2.01, 2011)

Systemic studies of different nature most commonly address the two phases: The Emergency phase: short-term (a few days/weeks) at the urban/regional scale and Economic recovery phase: medium to long-term, at the regional/national scale. The contribution of Engineering disciplines is obviously capital to the first phase. During the second phase their role becomes to some extent ancillary, due to the intervention of political and economic factors in the decision-making process.

The developed SYNER-G methodology focuses on the first phase only, with Emergency managers as the reference Stakeholders, and with the goal of forecasting before the event the expected impact for the purpose of planning and implementing risk mitigation measures.

Flood Risk Assessment

Flooding from rivers and coastal water is a natural process that plays an important role in shaping the natural environment. However, flooding threatens life and causes substantial damage property. The effects of weather events can be increased in severity both because of previous decisions about the location, design and nature of settlement and land use, and as a potential consequence of future climate change. Climate change over the new few decades is likely to mean milder wetter winters and hotter drier summers, while sea levels will continue to rise. These factors lead to increased and new risks of flooding within the lifetime of planned developments. Although flooding cannot be wholly prevented, its impacts can be avoided and reduced through good planning and management. (Planning Policy Statement 25, 2010)

Flood risk assessment is an assessment of the risk of flooding from all flooding mechanisms, the identification of flood mitigation measures and should provide advice on actions to be taken before and during a flood. The sources of water which produce floods include groundwater (saturated groundwater), vadose (water flowing the ground in an unsaturated state), surface water, artificial water (burst water mains, canals, or reservoirs), rivers, streams or watercourses, sewers and drains and flooding of low-lying coastal regions due to sea level rise.

Flood risk has always been an important material planning consideration. It is the most widespread and frequently occurring of natural hazards. Guidance in the more recent post-war period was formerly given in DOE Circular 17/82 (Development in Flood Risk Areas) and updated in the joint DOE/MAFF Circular 30/92 (Development and Flood Risk), FDI/92. This was comprehensively overhauled in PPG25, 2001. Concern about flood hazard as a development consideration in recent years was raised significantly by major floods in the Midlands in1998 and the widespread flooding in 2000. PPG25 was the response to this. Linked to forecasts that with climate change we can expect more frequent severe weather events, both general and localized, concern over flood risk will continue to rise. Flooding can be very closely to society. (Planning Policy Statement 25, 2006)

Annual reports produced by the Environment Agency have shown the progress of taking flood risk into account, during the development control process. Flooding is particularly sensitive for housing, both because of the threat to people at vulnerable times (at night) and in vulnerable groups (the elderly and less mobile) and because of the risk to homes and property. housing is also much less 'flood tolerant' than much of industry, notably the former process and port industries now yielding so much of the previously developed land for development. There are some areas where new housing should not be located but it is possible with careful design and local protection measures to enable housing to be built in some areas not previously thought suitable. Flood resistance and resilience measures (including, electrical wiring protection and water-resistant plaster/floors) can greatly reduce potential insurance losses by speeding up and simplifying clean-up and drying out and allowing people to re-occupy flooded homes sooner and thus cutting temporary accommodation costs. without clear and up-to-date development and flood risk policy from Government there is a danger that land allocations for development and individual developments will not take account of the most recent developments in climate change prediction, placing people and property at increased exposure to flooding, and providing no updated policy framework for making informed judgements. (Planning Policy Statement 25, 2010)

All forms of flooding and their impact on the natural and built environment are material planning considerations. Planning Policy Statement 1 *Delivering Sustainable Development* sets out the Government's objectives for the planning system, and how planning should facilitate and promote sustainable patterns of development, avoiding flood risk and accommodating the impact of climate change. The Planning Policy Statement *Planning and Climate Change*, provides expanded policy on planning's contribution to mitigating and adapting to climate change. (Planning Policy Statement 25, 2010)

The aims of planning policy on development and flood risk are to ensure that flood risk is considered at all stages in the planning process to avoid inappropriate development in areas at risk of flooding, and to direct development away from areas at highest risk. Where new development is, exceptionally, necessary in such areas, policy aims to make it safe without increasing flood risk elsewhere and where possible, reducing flood risk overall. Regional planning bodies (RPBs) and local planning authorities (LPAs) should prepare and implement planning strategies that help to deliver sustainable development by appraising risk (by identifying land at risk and the degree of risk of flooding from river, sea and other sources in their areas and by preparing Regional Flood Risk Appraisals (RFRAs) or Strategic Flood Risk Assessments (SFRAs) as appropriate, as freestanding assessments that contribute to the Sustainability Appraisal of their plans), managing risk (by framing policies for the location of development which avoid flood risk to people and property where possible, and manage any residual risk, taking account of the impacts of climate change and only permitting development in areas of flood risk when there are no reasonably available sites in areas of lower flood risk and benefits of the development outweigh the risk from flooding) and reducing risk (by safeguarding land from development that is required for current and future flood management e.g. conveyance and storage of flood water, and flood defenses, by reducing flood risk to and from new development through location, layout and design, incorporating sustainable drainage systems (SUDS) and by using opportunities offered by new development to reduce the causes and impacts of flooding e.g. surface water management plans; making the most of the benefits of green infrastructure for flood storage, conveyance and SUDS; re-creating functional floodplain; and setting back defenses). (Planning Policy Statement 25, 2010)

To ensure spatial planning supports flood risk management policies and plans, a partnership approach is necessary. By working efficiently with the Environment Agency, other operations authorities, and other stakeholders to ensure that best use is made of their expertise and information sot that plans are effective and decisions on planning applications can be delivered expeditiously. (Planning Policy Statement 25, 2010)

A risk-based approach should be adopted at all levels of planning. Applying the source pathway-receptor model to planning for development in areas of flood risk requires a strategic approach through policies in RSSs and LDDs which avoid adding to the causes or “sources” of flood risk, by such means as avoiding inappropriate development in flood risk areas and minimizing run-off from new development onto adjacent and other downstream property, and into the river systems. Also, managing flood “pathways” to reduce the likelihood of flooding by ensuring that the design and location of the development maximizes the use of SUDS, and takes account of its susceptibility to flooding, the performance and processes of river/coastal systems and appropriate flood defense infrastructure, and of the likely routes and storage of floodwater, and its influence on flood risk downstream; and reducing the adverse consequences of flooding on the “receptors” (i.e. people, property, infrastructure, habitats and statutory sites) by avoiding inappropriate development in areas at risk of flooding. (Planning Policy Statement 25, 2010)

Flood risk assessment should be carried out to the appropriate degree at all levels of the planning process, to assess the risks of all forms of flooding to and from development taking climate change into account and to inform the application of the sequential approach and effective monitoring and review is essential to reducing and managing flood risk (Planning Policy Statement 25, 2010).

Fire Risk Assessment

Fire risk assessment is an in-depth review/evaluation of a building, complex or a facility for fire risks and provide recommendations to either eliminate the risk or control it. Without a good fire risk assessment, the fire safety plan will just be based on assumptions. There is a law which governs carrying out this risk assessment. The law stipulates that any building, structure, or facility which can accommodate five persons or more at a time should have a fire risk assessment drawn out, written down, communicated to occupants of the building and documented. It also states that the risk assessment should be done by a Responsible Person (RP). The responsible person may be a fire assessment professional, the facility owner, or an assigned worker. (Health and Safety Articles, 2021)

The steps for the Fire Risk Assessment are:

- Identifying fire hazards and possible sources of ignition.
- Evaluate the risks and decide whether existing precautions are adequate or more needs to be done.
- Determine additional control where necessary.
- Communicate and document the result of the risk assessment.
- Review where necessary.

Things to consider when carrying out this risk assessment may include:

- Emergency exit routes, emergency lighting, fire doors, etc.
- Fire detection and warning systems like the smoke detector, fire alarm, etc.
- Firefighting equipment like the fire extinguishers, hose reels, etc.
- Storage of dangerous substances which could serve as fuel for fire.
- Emergency fire evacuation plan
- Identification of the muster point
- Consider vulnerable people, like the elderly, children, pregnant women, and those with disabilities.
- Information dissemination about the premises and the emergency evacuation plan.
- Collaboration with external emergency services like the fire service, road safety, police, etc.
- Staff training and assigning of responsibilities.

(Health and Safety Articles, 2021)

A review of methods for modelling forest fire and hazard is available in Yakubu et al., (2015). Wildfires are inevitable companions of forests and foresters across the world and its spread revolves around four main factors: (i) the state and nature of the fuel, that is, proportion of live or dead vegetation, compactness, morphology, species, density, stratification, and moisture content (ii) the physical environment, that is, weather conditions and topography (iii) causal factors (human-or natural-relate) and (iv) means of prevention and suppression. Fire hazard is defined by both (i) and (ii) and has two types of variations: a spatial and long-term one, related to fuel types and topography and a temporal and short-term one, related to fuel moisture content and weather conditions. Fire risk accounts for (iii) and (iv) (Chuvwarnero and Martin, 1994). Wildfires are considered as a serio problem that distresses many terrestrial ecosystems in the Earth system and causes economic damage to people such as missing income relative to the land use, destruction and loss of property, damages to agriculture, and loss of biodiversity. It is also one of the most important parts of land degradation that is caused by deforestation and deser-tification (Hernandez-Leal et al., 2006).

Stolle and Lambin (2003) noted that flammable fuel depends on climatic conditions, soil, vegetation and previous fire events. The ignition source is natural (for example lightening) or anthropogenic. If the ignition source is anthro-pogenic, it can be caused deliberately (as part of land management) or accidently through negligence. Preventing a small fraction of these fires would account for significant savings in the natural and human resources. Apart from preventive measures, early detection and suppression of fires is the only way to minimize the damage and casualties. Systems for early detection of forest fires have evolved over the past decades based on advances in related technologies. Wildfire is a paradox; it kills plants and animals and can cause wide-ranging damages to the ecosystem. On the other hand, it can be very beneficial in terms of nutrient recycling and forest regeneration. In some areas, natural wildfires have historically adapted with ecologically positive effects. Other ecosystems are susceptible to severe damages, causing a local extinction of species or considerable changes in ecosystem functions (e.g., soil, hydrology). Integrated modelling approaches could provide helpful insights into wildfire-environmental interactions. Globally, the majority of wildfires are caused by human activities in a direct or indirect form. An anthro-pogenic influenced wildfire regime (frequency, distribution) will potentially affect human activities. This inter-relationship between humans and wildfires has initiated many scientific studies.

The factors influencing fire behavior can either be natural or man induced. Fire behavior is a descriptive term used to designate what fire does and how it behaves. It estimates what a fire will do and relates to intensity, flame and rate of spread of specific fire. A product of environmental factors which interact with each other includes fuel, topography, weather and fire. The intensity and speed with which a fire travels depends on the amount and arrangement of the fine dead fuel, moisture content of the dead fuel, wind speed near the flaming zone, terrain and slope (Gould, 2005). The behavior of a spreading fire is determined by factors such as weather, topography, fuel quantity and fuel moisture content. Countryman (1972) in Pyne et al. (1996) presented the concept of the fire environment- the surrounding conditions, influences, and modifying forces that determine the behavior of a fire. Topography, fuel, weather and the fire itself are the interacting influences that make up the fire environment. The changing states of each of the environmental components; fuel, topography and weather and their interaction with each other as well as the fire itself determine the characteristics and behavior of a fire at any given moment. Changes in fire behavior in space and time occur in relation to changes in the environmental components. From a wildland fire standpoint, topography does not vary with time, but can vary greatly in space. The fuel component varies in both space and time. Weather is the most variable component, changing rapidly in both space and time (Pyne et al., 1996)

To model and evaluate fire risk and hazard, there is the need for proper fire risk assessment. Fire risk assessment should be seen as a specific part of a wider, overall, assessment of the risk to which the ecosystem is exposed and may be part of an overall program of risk reduction. There are three parts to fire risk assessment:

Initial assessment involves the identification of the hazards and sizing the risks. After identification of the hazard, one important thing is to decide whether the hazard from fire is important enough to be a source of serious potential harm or in any given situation may cause loss, death, injury or damage. Consideration is made on how likely it is that each hazard could cause harm. This will determine whether or not there is the need to do more to reduce the risk. Even after all precautions have been taken, some risk usually remains. A decision is made for each significant hazard whether the remaining risk requires any control measures.

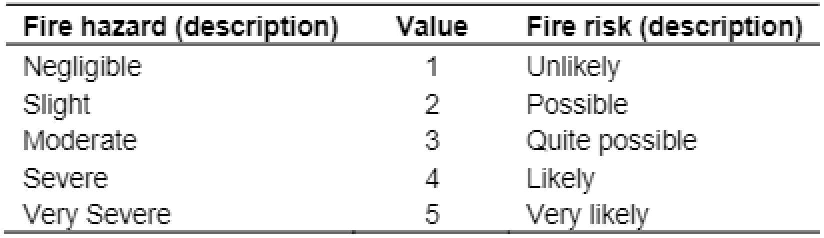
Risk reduction: Having made the initial assessment there follows the important task of reducing the hazards and risks. It will almost certainly be the case that some reductions may be affected immediately, and these short-term measures would include such things as improving the environmental practices- the management of waste and rubbish, and the implementation of a program of fire safety training for employees and community members. Other long-term measures would include such things as the installation of a fire suppression system, the change in some negative beliefs and the substitution of hazardous processes and materials with less hazardous ones.

Final risk assessment: When the hazards and risks have been reduced to what, at the time, appears to be an irreducible level, there follows a more rigorous final assessment of the risk. The final assessment will determine the risk categorization which conventionally will be defined as high, normal, or low. Of course, in larger premises such as a forest, it will be quite normal to have different risk categories for different parts of the area. The final assessment will have three outcomes: it will determine whether the areas, or parts of it, are to be categorized as being of high, normal, or low risk; this in turn will determine the fire precautionary measures required in the area, and it will be the starting point in the formulation of an emergency plan. In carrying out the risk assessment it will be necessary to have in mind but not limited to the following factors: the living things present in the area, the use to which the area is put, the sources of ignition present, the use of flammable materials, the contents of the area, the structural features of the area, traditional beliefs of the people in the area and fire education level in the area. It is worth mentioning that precautionary measures of people are directly connected to their risk perceptions (Rosenstock et al., 1988). For example, people who expect higher probability of being hurt by fire will tend to take more precautionary measures.

Risk assessment techniques provide a valuable tool in attempting to categorize the degree and severity of risk to which an organization, nation or the ecosystem might be liable. While no method is infallible, sensible use of risk assessment and application of the lessons drawn can result in more cost-effective introduction of fire protective measures. Risk assessment methods There is no single ‘correct’ way of carrying out risk assessment, there are three methods which might be useful, each of which makes clear what is to be understood by the terms high, normal and low risk. These are:1. The risk category indicator method: This is a diagnostic method in which the various elements in the area are classified in such a way as to indicate the area in which they are found and should be categorized as being high, normal, or low risk. Elements which may give rise to high-risk indicators in the case of forest include communities; vegetation; wind; topography; road network; and negative traditional beliefs. 2. The risk value matrix method: Unlike the Risk Category Indicator method, this method attempts to put the risk assessment onto a quantitative basis. However, it cannot be strongly stressed that the numbers involved are purely relative, and therefore they have no absolute significance whatsoever. Whilst all risks are made up of two elements- the probability that an event will occur and the consequences of that occurrence, the relative contributions of these two elements to risk may vary considerably. Formula for risk value: Remembering that the two elements of risk are the fire hazard and the fire risk, the risk value is defined by the simple formula: Risk value = fire hazard value x fire risk value. If the size of the fire hazard and the fire risk is expressed by assigning values to them then, by applying the formula, a number obtain would be a measure of the risk value. The size of the risk value then becomes the basis for categorizing the area as being of high, normal or low risk.

Quantifying the fire hazard and the fire risk: This is easily done by: classifying the fire hazards. Describing them as being between negligible and very severe; and assigning a numerical value to each description. Similarly, it may classify the fire risks by describing them as being between unlikely to very likely, and by assigning a numerical value to each of these descriptions. Table 3.3 is a classification of fire risk and hazard. Using the risk value formula for all possible combinations of fire hazard values and fire risk values, a set of twenty-five numbers are obtained. The risk values obtained can then be displayed as a two-dimensional grid (risk value matrix). Figure 14 shows a risk rating matrix (Anon., 2011). The final task in this method is to decide the ranges of the risk values that will correspond to our three categories of risk. 3. The algorithmic method: An algorithm is a two-dimensional diagrammatic representation of the steps to be undertaken in order to decide, solve a problem, or carry out a process. In short, it is a flowchart.

Table 4. Classifications of fire risk and hazard



Fire hazard (description)	Value	Fire risk (description)
Negligible	1	Unlikely
Slight	2	Possible
Moderate	3	Quite possible
Severe	4	Likely
Very Severe	5	Very likely

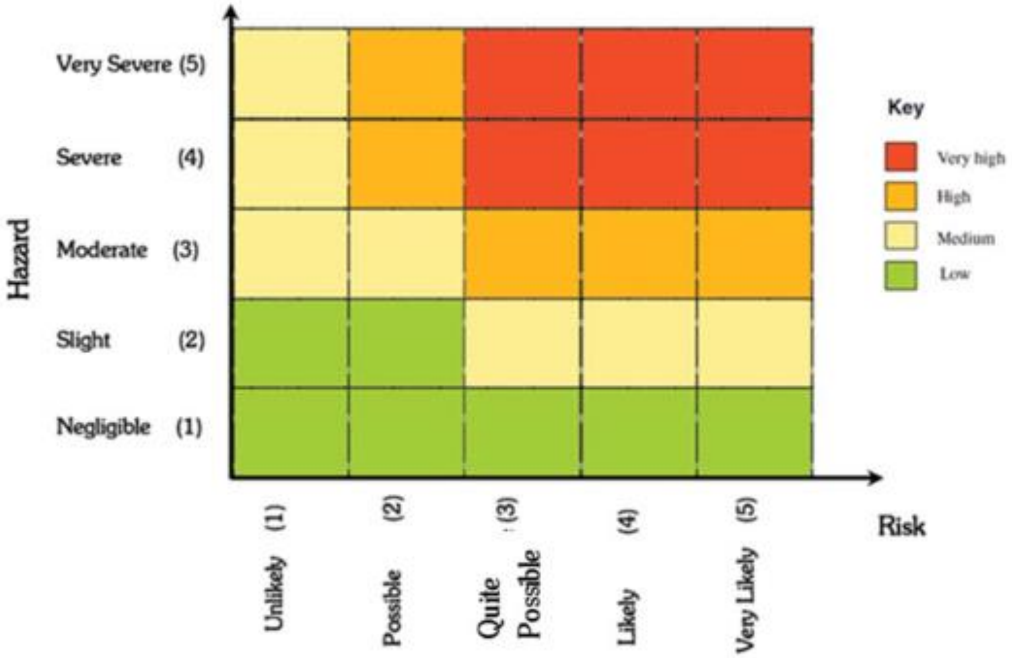


Figure 14 – Risk rating matrix (Anon, 2011)

Forest fire risk assessment is very important for fire management. It may be considered at different spatial and temporal resolutions: global and local; short term, and long-term fire risk estimation.

Global scales can contribute to the establishment of general guidelines for fire management at continental level, while local scales are adapted to specific fire prevention resources of small regions (Chuvieco et al., 1999). Risk should, however, be estimated in order to plan for the necessary resources for fire management.

Vulnerability

The starting point for reducing disaster risk and for promoting a culture of disaster resilience lies in the knowledge of the hazards and the physical, social, economic, and environmental vulnerabilities to disasters that most societies face, and of the ways in which hazards and vulnerabilities are changing in the short and long term, followed by action taken based on that knowledge (Hyogo Framework for Action 2005-2015).

Theories of vulnerability began to appear in the 1970s. The availability of better data sets and case studies on disasters' impact permitted analysis of the type, frequency, and location of disaster events, and particularly of the social and economic damage that they caused (Twigg, 2011). Investigating of vulnerability involves taking a closer look at the many social, economic, and political processes that cause people to live in hazardous locations and in vulnerable economic, social, and power relationships (Twigg, 2011). Vulnerability is a broad and complex subject on which there has been a great deal of research and debate in the past 40 years or so (Twigg, 2011). Inevitably, there are many different opinions on the subject; there is certainly no unified perspective (Twigg, 2011).

There are many definitions of the term 'vulnerability'. Definitions vary, partly according to the different academic or professional disciplines and intellectual perspectives of those working with the concept and its application (Twigg, 2011). 'Vulnerability' has been appropriated and understood differently by a range of such groups. The definitions are quite different from older emergency management and disaster relief notions of vulnerability as expected damage to property, typically expressed in terms of the cost of repair or replacement; or the usage by engineers to refer to the physical or structural vulnerability of the built environment (Twigg, 2011). The most used and accepted definitions of the term 'vulnerability' are:

"The conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards". (United Nations International Strategy for Disaster Reduction)

"A human condition or process resulting from physical, social, economic and environmental factors, which determine the likelihood and scale of damage from the impact of a given hazard". (United Nations Development Programme)

Vulnerability is "the conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards" (UN ISDR, quoted in Birkmann ed. 2006)

"A human condition or process resulting from physical, social, economic and environmental factors, which determine the likelihood and scale of damage from the impact of a given hazard" (UNDP, quoted in Birkmann ed. 2006 and Twigg, 2011)

"The characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard (an extreme hazard event or process). It involves a combination of factors that determine the degree to which someone's life, livelihood, property and other assets are put at risk by a discrete or identifiable event (or series or 'cascade' of such events) in nature and in society" (Wisner et al. 2004)

"the inability of people, organizations, and societies to withstand adverse impacts from multiple stressors to which they are exposed" (Warner 2007)

"Vulnerability is the likelihood (or probability) of the occurrence of destruction in a building or buildings when exposed to an earthquake effect. It is therefore commonly represented by a relationship between the level of earthquake effect and the level of damage (structural, potential life loss or economic loss) expected to result. Vulnerability is reducible through rigorous seismic design and construction or through strengthening of existing structures" (Rossetto, 2012)

"The conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards" Hyogo Framework for Action

The term 'capacity' is also defined in many ways, including:

'a combination of all strengths and resources available within a community or organization that can reduce the level of risk, or the effects of a disaster'. (United Nations International Strategy for Disaster Reduction)

The logical consequence of the structural perspective is that natural disasters are no longer seen as one-off, unexpected, extreme events that disrupt normality and the stability of regular life, but as the results of 'normal' economic and social relationships that are characteristic features of society and place. The very notion of 'ordinary life' is seen as a myth: societies, economies and political systems evolve (sometimes with rapid and unpredictable change) and it is this which shapes the relationship between humans and their environment. Hence every disaster (or its impact) is characteristic of the time, place, and society in which it occurs. This leads to a denial of the idea of a 'natural' disaster: only hazards can be natural. 'Soft' versions of this way of thinking, which acknowledge the importance of underlying social-economic-institutional factors in creating vulnerability but stop short of accepting the new-Marxist determinism of structural analysis, have become a very important influence on contemporary disaster thinking in academic, policy and operational circles. (Twigg, 2011)

Vulnerability and capacity assessment and analysis (VCA)

VCA is ‘a method of investigation into the risks that people face in their locality, their vulnerability to those risks and their capacity to cope with and recover from disasters (IFRC, 2007a:6). VCA takes a holistic view (Twigg, 2011). It views vulnerability as a concept in the broadest sense (see Figure 15) and therefore considers a wide range of environmental, economic, social, cultural, institutional, and political pressures that create vulnerability (Twigg, 2011). VCA also considers the capacities, resources and assets people use to resist, cope with, and recover from disasters and other external shocks that they experience (WHO, 1999). Capacity is a key element in understanding and reducing vulnerability, and VCA methodologies should be designed to take it into account (Twigg, 2011).

‘Vulnerability assessments provide a means for systematically identifying, analyzing, monitoring, and explicitly integrating social vulnerability into all aspects of preparedness, response, recovery, and mitigation’ (Thomas, Stephens and Goldsmith in Phillips et al, eds, 2009).

VCA is a key component of disaster risk analysis and hence of disaster risk reduction planning (Twigg, 2011). Its purpose is to identify groups who are vulnerable, identify the factors that make them vulnerable and how they are affected, assess their needs and capacities (and empower them to do so) and to ensure that projects, programs, and policies address these needs, through targeted interventions or prevention and mitigation of potentially adverse impacts (Twigg, 2011).

VCA is used principally as a diagnostic tool (to understand problems and their underlying causes), a planning tool (to prioritize and sequence actions and inputs), a risk assessment tool (to help assess specific risks), and a tool for empowering and mobilizing vulnerable communities (Twigg, 2011).

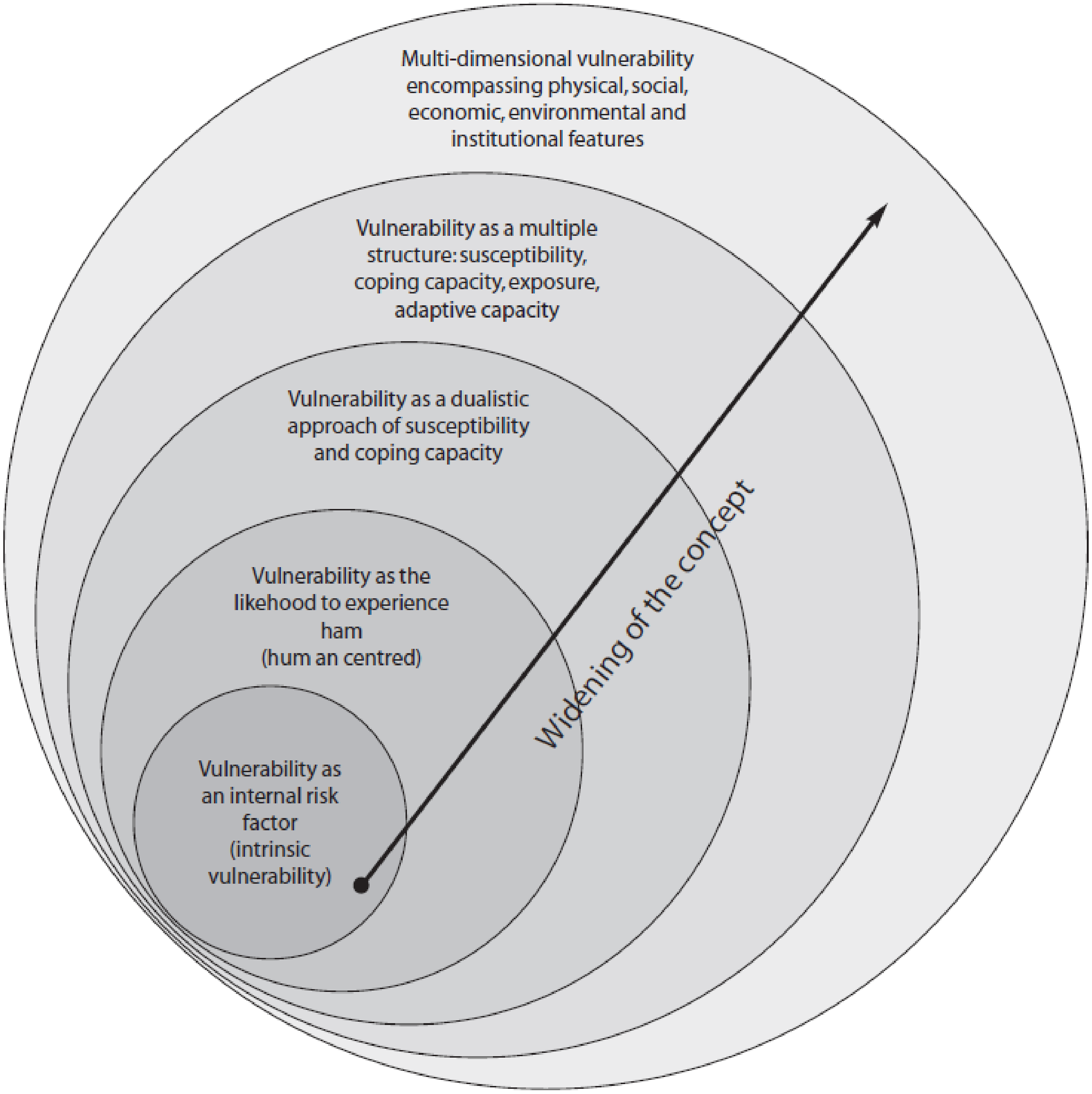
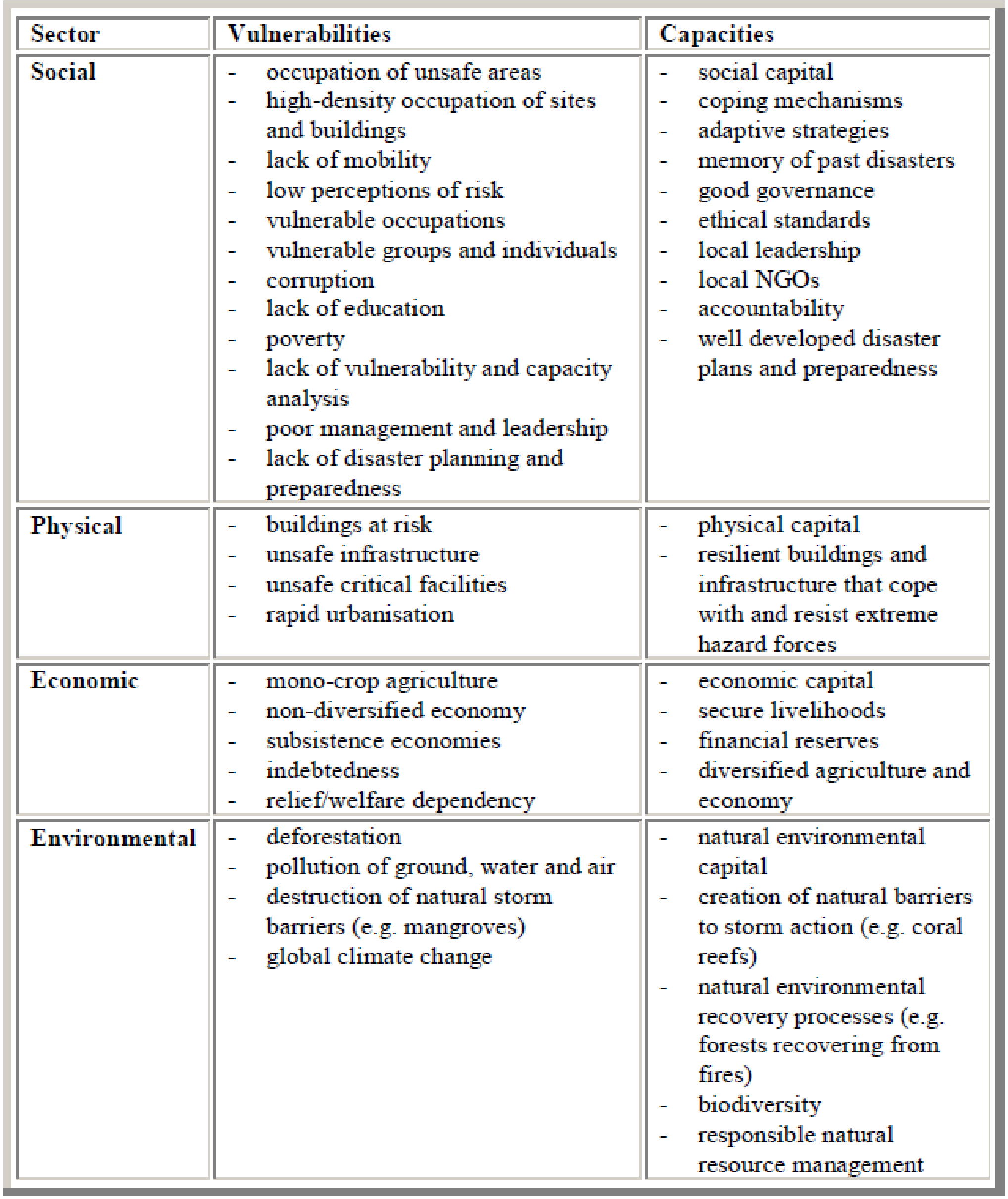


Figure 15 – Key spheres of the concept of Vunerability (Birkmann and Wisner, 2006)

Table 5, produced at a recent workshop on VCA, illustrates the range of factors that may be relevant in assessing vulnerabilities and capacities (Twigg, 2011). However, this is just one way of viewing and categorizing the subject, which can be conceived and framed in a variety of ways (Twigg, 2011).

Table 5. Hazard-related vulnerabilities and capacities of different sectors



Sector	Vulnerabilities	Capacities
Social	- occupation of unsafe areas - high-density occupation of sites and buildings - lack of mobility - low perceptions of risk - vulnerable occupations - vulnerable groups and individuals - corruption - lack of education - poverty - lack of vulnerability and capacity analysis - poor management and leadership - lack of disaster planning and preparedness	- social capital - coping mechanisms - adaptive strategies - memory of past disasters - good governance - ethical standards - local leadership - local NGOs - accountability - well developed disaster plans and preparedness
Physical	- buildings at risk - unsafe infrastructure - unsafe critical facilities - rapid urbanisation	- physical capital - resilient buildings and infrastructure that cope with and resist extreme hazard forces
Economic	- mono-crop agriculture - non-diversified economy - subsistence economies - indebtedness - relief/welfare dependency	- economic capital - secure livelihoods - financial reserves - diversified agriculture and economy
Environmental	- deforestation - pollution of ground, water and air - destruction of natural storm barriers (e.g. mangroves) - global climate change	- natural environmental capital - creation of natural barriers to storm action (e.g. coral reefs) - natural environmental recovery processes (e.g. forests recovering from fires) - biodiversity - responsible natural resource management

Davis, Haghebaert and Peppiatt 2004:19

The importance of striking a balance between hazards, vulnerabilities, and capacities in VCA has already been noted (Twigg, 2011).

Vulnerability representation

The most widely used forms of representation of vulnerability are the Damage Probability Matrices (DPM), the Vulnerability Curves or Fragility Curves and the Fragility or Damage Surfaces.

Damage Probability Matrices (DPM)

A damage probability matrix specifies the discrete probabilities of reaching a damage state at different ground motion levels. these probabilities are defined as follows:

$p_{ik} = \mathrm{P}[D=d_i|GM=gm_k]$

where p_{ik} = the probability of reaching damage state d_i given that the ground motion is gm_k. although any ground motion parameter can be used for the DPM's, most existing DPM's adopt Intensity. This is a weakness of the method. Intensity evaluation is carried out based on damage evaluation. It is a subjective scale and prone to uncertainty and scatter. Furthermore, although commonly used by seismologists, it cannot strictly be used to represent seismic hazard, as its value is dependent on the built environment and not purely on the seismo-tectonic environment and seismic activity or an area. An added disadvantage is that Intensity is not a continuous scale, nor are intensities equally spaced. Hence, DPM's derived using intensity cannot be directly transformed into a continuous vulnerability curve, that would provide an estimated damage value for any level of seismic hazard.

DPMs can be based on expert opinion or data from real earthquakes.

(Rossetto, 2012)

Vulnerability and Fragility Curves

These curves consist of a set of relationships between hazard and the probability of exceedance of certain threshold of damage. In mathematical terms, the probability of reaching or exceeding damage state d_i given that the ground motion level is gm_k, is given by:

$$P_{ik} = P[D \geq d_i|GM = gm_k] = \sum_{j=1}^{n} P[D = d_j|GM = gm_k]$$

If P_{ik} is evaluated by varying k, (i.e., the ground motion severity), whilst keeping i constant, a fragility curve is obtained for the damage state i. The vulnerability curve shape is dependent on the construction material and lateral load resting system of the structure. This means that several fragility curves are required to evaluate the vulnerability of a city.

The data source is often used to classify the curve. Curve shapes change for different structural types, due to variations in their rate of accumulation of damage with increasing ground motion. However, the same general procedure is followed for the derivation of fragility curves in the case of all structural classes. This presented in [ref Rossetto, 2004]. The main choices to be made at each stage of the derivation process are:

- Choice of a source/s, (empirical, analytical, judgment), for the building population damage distributions and associated ground motion values, used as the statistical basis for the fragility curve generation.

- Choice of a ground motion parameter representative of the damage potential of earthquake time histories.
- Determination of a building classification system, for the grouping together of damage statistics concerning buildings of similar dynamic response characteristics.
- Selection of damage scale and the definition of limit states for the assessment of building performance.
- Choice of a structural response parameter for the estimation of global building damage, and determination of its value at the thresholds of the chosen limit states.
- Determination of a procedure for the interpretation of the building damage statistics in terms of the chosen damage scale.
- Choice of a methodology for the damage data combination and confidence bound determination.
- Selection of shape functions for the fragility curves and of a regression procedure.

Vulnerability and fragility curves and DPM's have mostly been developed from the effort of individuals rather than a united research community, and little agreement exist regarding the derivation methodology, performance criteria and ground motion characterization adopted for their development. Hence, a variety of damage data sources, damage scales, ground motion parameters and curve derivation methodologies exist. All choices made have a large influence on the result and determine the range of application of the curves. Each must be addressed in the assessment of existing curves, and for the proposal of new fragility curve generation methodologies. Furthermore, the effect on the uncertainty associated with each chosen parameter should be considered.

(Rossetto, 2012)

Vulnerability and Fragility Surfaces

Vulnerability or fragility surfaces express the probability of damage with respect to more than one parameter, in order to better account for uncertainties related to the hazard description (Gehl et al., 2011). These surfaces, provide a unique characterization of the hazard. For instance, the characterization of a ground motion by a single parameter (e.g., the Peak Ground Acceleration (PGA)), can be unsatisfactory since event with the same PGA can cause very different damages (Grigoriu and Mostafa 2002).

Fragility

Fragility can be defined as the likelihood of damage given a certain intensity measure type. Fragility is a function representing the conditional probability of a component or system (component fragility, system fragility) exceeding a pre-defined limit-state as a function of a parameter.

Fragility curves are constructed from post- damage statistics which derive from:

- Post-damage surveys – Empirical
- Expert opinion – Judgement-based
- Analysis of sets of structure models under increasing severities – Analytical
- A combination of sources – Hybrid

Fundamental to any fragility assessment is the characterization of the structure stock and choice of a damage scale (Rossetto, 2012). Existing fragility curves can be classified into the four generic groups of – see previous section vulnerability and fragility curves -, according to whether the damage data used in their generation stems mainly from observed post-earthquake surveys, expert opinion, analytical simulations, or combinations of these, respectively. Each data source has associated advantages and disadvantages. (Rossetto, 2012)

The empirical fragility curves are the most accurate, as directly reflects real data (soil-structure interaction, topography, site, path, source characteristics, realistic building models – i.e., real buildings, including masonry infill panels, etc.) (Rossetto, 2012). Empirical fragility curves assume that the past reflects the future. There is limited good quality data. Rossetto and Elnashai (2003) based on a large database of earthquake reports.

Judgment-based curves are derived from damage statistics derived from the opinion of experts. A common method used is to ask experts to give estimates of the probable damage distribution within structure populations when subjected to hazards of different sizes. For each hazard size, probability distribution functions representing the range of damage estimates can be fit to the expert predictions. The probability of a specified damage state can then be obtained from these distributions and plotted against the corresponding hazard level to obtain a set of fragility curves and associated uncertainty bounds. Expert opinion is an unlimited source as experts can be asked to provide damage estimated for any number of structural types. The choice of experts, the method of collection and aggregation of their opinions is crucial to the reliability of the curves (Pate-Cornell 2002). Bias may exist amongst the experts and it is almost impossible to assess the conservatism inherent in the expert's opinions. Hence, in the absence of Bayesian updating with observational or experimental data the reliability of judgement-based curves is questionable. The Judgement-Based fragility curves are soliciting expert opinion, e.g., "what percentage of RC MRF low-rise buildings would collapse in a big earthquake ground motion?" "what percentage would be heavily damaged?" "what about masonry?" "what about other intensities?". Primary advantage is that they can be used for any building types or hypothetical earthquake scenario. Expert opinion is only as good as the anecdotal evidence the "expert" has accumulated over his/her career (empirical, analytical). Is difficult to assess quality of expert opinion (Bayesian updating procedure used to adjust prior probabilities from empirical data). Psychological biases can exist (anchoring especially important if getting an opinion from group of experts, difficulty in estimating small probabilities).

Analytical fragility curves adopt damage distributions simulated from the analyses of structural models under increasing disaster loads as their statistical basis. Compared to expert opinion, analyses can result in a reduced bias and increased reliability of the vulnerability estimate for different structures. Despite this fact, few analytical fragility curves have been generated in the past. This is mainly due to the substantial computational effort involved and limitations in modelling capabilities. A variety of analysis procedures have been used to assess the response of structures under natural hazard actions, ranging from the elastic analysis of equivalent single degree of freedom systems (Mosalam et al. 1997), to non-linear time history analyses of 3D models (Singhal and Kiremidjian 1997). The analytical fragility curves can use types and any possible natural hazard scenario (probably the most flexible of the approaches). As with any engineering method, accuracy is only as good as the input data (modelling of infills, architectural finishes, soil, foundation rocking, modelling difficulties for collapse limit state, capturing the full range of different building configurations possible for the category).

Hybrid fragility curves attempt to compensate for the scarcity of observational data, subjectivity of judgmental data and modelling deficiencies of analytical procedures, by combining data from the different sources. The most complete discussion for this type of curve is given by Kappos et al. (1998).

Measuring damage

There is a need for classifying damage in risk assessments. The classification is required in order to use relationships between level of damage and consequences of interest (e.g., damage, homelessness, human losses, financial losses, other effects on transport/communications, hospitals/schools, businesses, etc.). Damage scales use different approaches to classify damage according to their design aims. The classification we could require will depend on consequences of interest. (Rossetto, 2012)

The damage is classified from the in the field observations (descriptions, imagery: graphics/photos), from experimental observations (more closely linked to physical response parameters), from physical response parameter (drift, interstorey-drift, rotational capacity etc.) and from empirical factors (damage factors, cost ratios (cost of repair/cost of replacement), etc.) (Rossetto, 2012).

Several national and sub-national indices of risk have been produced, which combine data on disaster mortality, economic impact, hazards and other aspects of vulnerability and capacity (Twigg, 2011). Each index is based on different assumptions and data, so the scores and rankings assigned to individual countries vary (Twigg, 2011).

Damage scales or limit states or performance levels are a key part of the risk assessment. The way that damage is defined, and any associated relationships is of importance to the assessment. Lack of consideration of how damage is defined in the scale can lead to further uncertainty in the results. Damage factor (DF) are damage indices, and this is a quantitative measure of damage. (Rossetto, 2012)

Damage scales define the state when a demand quantity reaches a corresponding threshold/capacity. It is not limited to extreme states (such as collapse of a structure or structural element), but it can be formulated for any intermediate state of performance/damage, e.g., continued functionality/operativity, light, medium or severe structural and non-structural damage. It can be expressed in terms of different performance measures, such as physical, structural quantities (drift, shear), or socio-economic ones (number of casualties, economic value of loss, downtime, number of unfed users on a network, etc.). (SYNER-G D. 2.01, 2011)

The choice damage scale is fundamental to the vulnerability and fragility curves generation. Global structural damage must be used as the structural unit and loss evaluation parameter, respectively. It is desirable that the selected damage scale is defined in terms of at least three damage limit states, corresponding to serviceability, damage control and collapse prevention. The scale’s limit states must be clearly defined in terms of the damage expected with different load resisting systems. For analytical curve derivation, the damage scale should further be calibrated to a measurable structural response parameter. The choice of response parameter for the calibration and its values, are important in determining the reliability of the vulnerability and fragility relationships. (Rossetto, 2012)

Damage prediction forms the backbone of any vulnerability analysis (Rossetto, 2012). The Damage Indices are used to predict damage and to do a vulnerability analysis.

Damage Indices (DI)

Employed primarily in the 1990s, a technique to quantify damage to a structure or an element is to use damage indices (Williams et al. 1995). Damage indices are straightforward and quantitative tools to assess the damage of structures under earthquakes. Strictly speaking, a damage index is a dimensionless parameter intended to range between 0 for undamaged structural state and 1 for collapse state, with intermediate values representing the degree of structural damage. (Yikun Qiu et al. 2020)

Various indices based on structural response are proposed in the literature for use in the prediction of damage. They can be classified as either, **energy-based**, **force-based,** or **deformation-based** damage models, according to the response parameters measured in their evaluation. (Rossetto, 2012) Williams and Sexsmith (1995) provide a didactic review of several damage indices applicable to reinforced concrete, categorizing the indices in Local element/connection indices (non-cumulative indices, cumulative indices and combined non-cumulative and cumulative indices) and Global structure-level indices (weighted average indices).

Damage indices in each category, may be further classified as local or global, according to whether they use member or structure response in their determination. Information on many existing damage indices can be found in Ghobarah et al (1999), Williams and Sexmith (1995) and Banon (1980). Quantitative measures of damage; typically, 0= no damage 1=collapse. Usually used by analytical methods to infer damage from analysis models (Hill and Rossetto, 2008). A Homogenized Reinforced Concrete Damage Scale is (Rossetto and Elnashai 2003): A damage scale with a difference.

4 DISASTER RISK MANAGEMENT

In 1983 Hewitt (Hewitt K., 1983) talked of a 'dominant view' of disasters in which socio-economic factors were seen as subordinate to the physical environment. In disaster management, this dominant view led (and in many cases, still leads) to responses to the disaster threat based on public policy and managerial, geophysical, and geotechnical capacity (e.g., an emphasis on monitoring, scientific understanding, early warning systems, technical control and construction measures, and finally emergency response and relief). This 'technocratic' and materialist approach is favored by bureaucracies and professional groups. This paradigm denies or at least underestimates the influence of human agency and responsibility for disasters, and it separates natural disasters from the wider range of human-environment interactions. (Twigg, 2011)

The alternative paradigm, based on the structural theory of vulnerability, has a very different emphasis. It demands more fundamental and structural changes to society and development processes, in addition to the conventional disaster management approaches, because without this the dominant approach cannot have a significant long-term effect on disaster reduction. The alternative paradigm is less optimistic: it does not put its faith in technology and materialism; and it recognizes that development processes are not necessarily positive and can undermine resilience. But it does put more emphasis on communities' own strategies for coping and knowledge of hazards and how to live with them. (Twigg, 2011). This question of people's vulnerability and capacity in the context of natural hazards is very important for understanding the potential impact of disasters and making choices about how to intervene. More generally, socio-economic vulnerability is also now seen as a key to understanding poverty and designing poverty reduction programs (Twigg, 2011.)

A growing body of evidence demonstrated that disaster events were becoming more frequent, that their impact on societies and economies was increasing (Figure 16), and that they had a disproportionate impact on poor countries and poorer or marginalized sectors in industrialized countries (Twigg, 2011). Drawing on this evidence to analyze disaster causation and impact, vulnerability theorists gave much greater prominence to social, economic, political, and institutional factors compared to environmental factors (Twigg, 2011). This new outlook soon led to more extensive and systematic enquiry into the causes of disasters, especially by human geographers and anthropologists working on developing country societies (Twigg, 2011). Within a few years it had generated a body of vulnerability research that 'produced a series of recurrent and consistent findings which led to a fundamental reconceptualization of disaster causation' (Clarke Guarnizo C 1991) demonstrating beyond doubt the fundamental role of people, their institutions, and social systems in making people vulnerable to disasters (Twigg, 2011). It was not until the late 1980s that serious thought began to be given to the application of such thinking to disaster management through the development of field methodologies for vulnerability and capacity analysis, and it was only in the mid-1990s that such tools began to appear in any number (Twigg, 2011).

Economically and socially marginalized groups in society generally suffer worst from natural disasters. Their vulnerability to disaster has many dimensions: economic, social, environmental, demographic, political, cultural, and psychological. It is influenced by several factors at different levels, from the local to the global. It is also dynamic, altering under the pressure of these many different forces. (Twigg, 2011)

Many commentators have identified the most significant shifts as a strong emphasis on disaster risk management as opposed to disaster management. The reduction of disaster risk as an expected outcome, a goal focused on preventing new risk, reducing existing risk and strengthening resilience, as well as a set of guiding principles, including primary responsibility of states to prevent and reduce disaster risk, all-of-society and all-of-State institutions engagement (Sendai Fr). In addition, the scope of disaster risk reduction has been broadened significantly to focus on both natural and man-made hazards and related environmental, technological, and biological hazards and risks (Sendai Fr). Health resilience is strongly promoted throughout (Sendai Fr). The Sendai Framework articulates the need for improved understanding of disaster risk in all its dimensions of exposure, vulnerability, and hazard characteristics. There is also clear recognition of the Global Platform for Disaster Risk Reduction and the regional platforms of disaster risk reduction as mechanisms for coherence across agendas, monitoring and periodic reviews in support of UN Governance bodies.

Since the adoption of the Hyogo Framework for Action 2005-2015, as documented in national and regional progress reports on its implementation as well as in other global reports, progress has been achieved in reducing disaster risk at local, national, regional, and global levels by countries and other relevant stakeholders, leading to a decrease in mortality in the case of some hazards (Sendai Framework for Action 2015-2030). Reducing disaster risk is a cost-effective investment in preventing future losses (Sendai Framework for Action 2015-2030). Effective disaster risk management contributes to sustainable development (Sendai Framework for Action 2015-2030). Countries have enhanced their capacities in disaster risk management (Sendai Framework for Action 2015-2030). International mechanisms for strategic advice, coordination, and partnership development for disaster risk reduction, such as the Global Platform for Disaster Risk Reduction and the regional platforms for disaster risk reduction, as well as other relevant international and regional forums for cooperation, have been instrumental in the development of policies and strategies and the advancement of knowledge and mutual learning (Sendai Framework for Action 2015-2030).

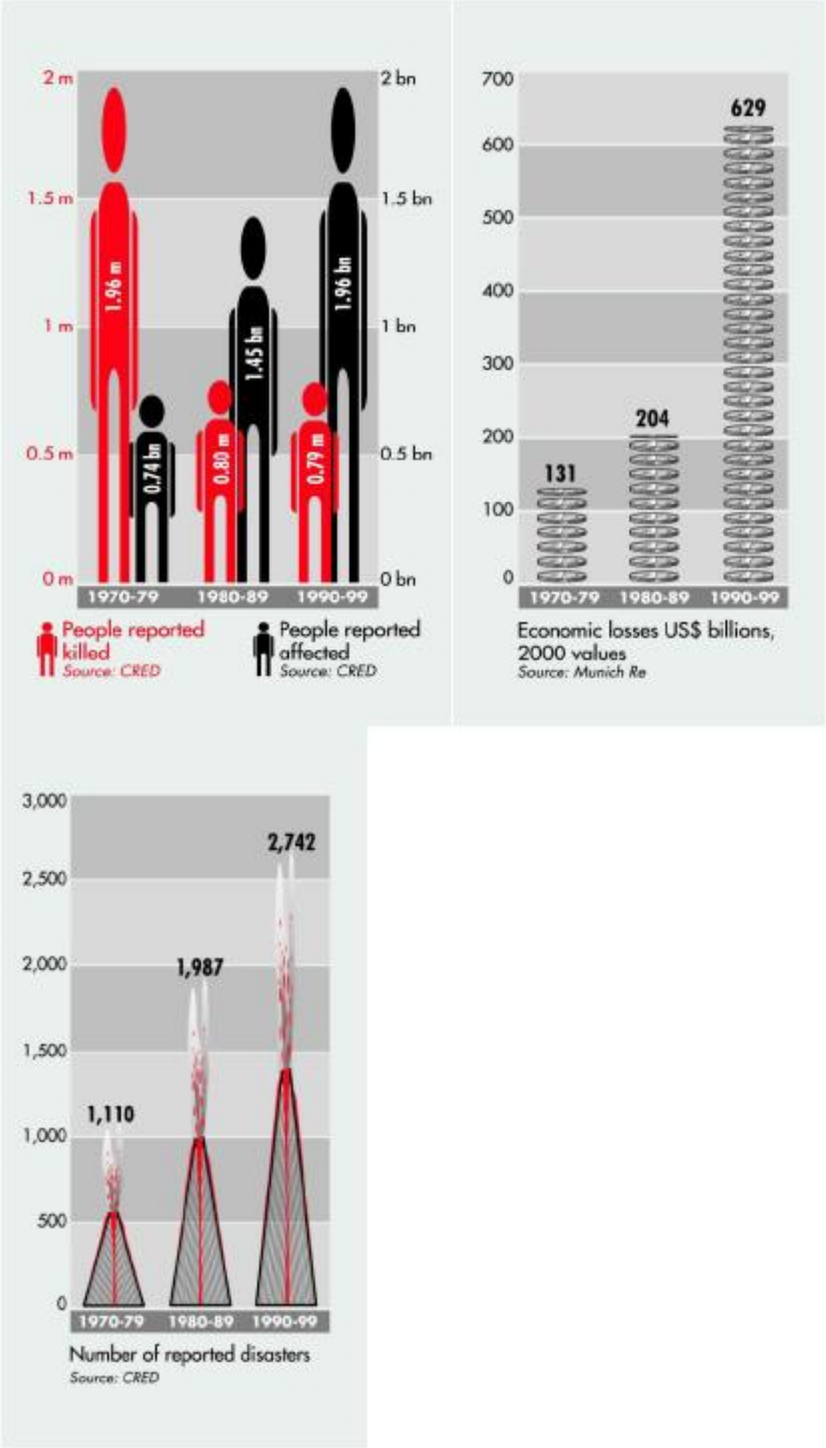


Figure 16 – Increase in number and impact of disasters (World Disasters Report Geneva: IFRC, 2002)

It is urgent and critical to anticipate, plan for and reduce disaster risk in order to protect persons, communities and countries, their livelihoods, health, cultural heritage, socioeconomic assets and ecosystems, and thus strengthen their resilience more effectively. Enhanced work to reduce exposure and vulnerability, thus preventing the creation of new disaster risks, and accountability for disaster risk creation are needed at all levels. More dedicated action need to be focused on tackling underlying disaster risk drivers, such as the consequences of poverty and inequality, climate change and variability, unplanned and rapid urbanization, poor land management and compounding factors such as demographic change, weak institutional arrangements, non-risk-informed policies, lack of regulation and incentives for private disaster risk reduction investment, complex supply chains, limited availability of technology, unsustainable uses of natural resources, declining ecosystems, pandemics and epidemics. Moreover, it is necessary to continue strengthening good governance in disaster risk reduction strategies at the national, regional, and global levels and improving preparedness and national coordination for disaster response, rehabilitation, and reconstruction, and to use post-disaster recovery and reconstruction to “Build Back Better”, supported by strengthened modalities of international cooperation. (Sendai Framework for Action 2015-2030)

Risk management is ‘an iterative process consisting of well-defined steps which, taken in sequence, support better decision-making by contributing a greater insight into risks and their impacts. Risk management takes an all-risks approach (which can include financial and political risks), and the iterative method means that risk management can be improved progressively, in cycles, rather that needing to be performed all at once (Twigg, 2011). The risk management process can be applied to any situation where an undesired or unexpected outcome would be significant or where opportunities are identified’ (Risk Management. AS/NZS 4360:1999 Strathfield: Standards Association of Australia).

‘Understanding resilience and vulnerability is a key element of effective disaster management’ (Buckle, Marsh and Smale 2000). Resilience is a potentially influential concept in disaster management (Twigg, 2011). Resilience is defined as “The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions” United Nations Office for Disaster Risk Reduction (UNISDR)”, 2009 UNISDR Terminology on Disaster Risk Reduction, Geneva, May 2009.

5 DISASTER RISK REDUCTION (DRR)

Overall, the Hyogo Framework for Action has provided critical guidance in efforts to reduce disaster risk and has contributed to the progress towards the achievement of the Millennium Development Goals (Sendai Fr). The Hyogo Framework priorities for action 2005-2015 were: (1) ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation, (2) identify, assess, and monitor disaster risks and enhance early warning, (3) use knowledge, innovation, and education to build a culture of safety and resilience at all levels, (4) reduce the underlying risk factors, and (5) strengthen disaster preparedness for effective response at all levels. Ten years after the adoption of the Hyogo Framework for Action, disasters continue to undermine efforts to achieve sustainable development. It is recalled that the outcome document of the United Nations Conference on Sustainable Development, held in 2012, entitled “The future we want”, called for disaster risk reduction and the building of resilience to disasters to be addressed with a renewed sense of urgency in the context of sustainable development and poverty eradication and, as appropriate, to be integrated at all levels. (Sendai Framework for Action 2015-2030)

The implementation of Hyogo Framework for Action has, however, highlighted several gaps in addressing the underlying disaster risk factors, in the formulation of goals and priorities for action, in the need to foster disaster resilience at all levels and in ensuring adequate means of implementation. The gaps indicate a need to develop an action-oriented framework that Governments and relevant stakeholders can implement in a supportive and complementary manner, and which helps to identify disaster risks to be managed and guides investment to improve resilience. There must be a broader and a more people-centered preventive approach to disaster risk. Disaster risk reduction practices need to be multi-hazard and multisectoral, inclusive and accessible to be efficient and effective. While recognizing their leading, regulatory and coordination role, Governments should engage with relevant stakeholders, including women, children and youth, persons with disabilities, poor people, migrants, indigenous peoples, volunteers, the community of practitioners and older persons in the design and implementation of policies, plans and standards. There is a need for the public and private sectors and civil society organizations, as well as academia and scientific and research institutions, to work more closely together and to create opportunities for collaboration, and for businesses to integrate disaster risk into their management practices. (Sendai Framework for Action 2015-2030)

International, regional, subregional, and transboundary cooperation remains pivotal in supporting the efforts of States, their national and local authorities, as well as communities and businesses, to reduce disaster risk. Existing mechanisms may require strengthening in order to provide effective support and achieve better implementation. Developing countries, in particular the least developed countries, small island developing States, landlocked developing countries and African countries, as well as middle-income countries facing specific challenges, need special attention and support to augment domestic resources and capabilities through bilateral and multilateral channels in order to ensure adequate, sustainable, and timely means of implementation in capacity-building, financial and technical assistance and technology transfer, in accordance with international commitments. Moreover, addressing climate change as one of the drivers of disaster risk, while respecting the mandate of the United Nations Framework Convention on Climate Change, represents an opportunity to reduce disaster risk in a meaningful and coherent manner throughout the interrelated intergovernmental processes. (Sendai Framework for Action 2015-2030)

The World Disasters Report in 2014, took on a challenging theme that looked at different aspects of how culture affects DRR and how disasters and risk influence culture. The report asks, for example, what should be done when people blame a flood on an angry goddess (River Kosi, India, in 2008) or a volcanic eruption on the mountain god (Mount Merapi). After the tsunami in 2004, many people in Aceh (Indonesia) believed that Allah had punished them for allowing tourism or drilling for oil, and similar beliefs were widespread in the United States regarding Hurricane Katrina, showing God’s displeasure with aspects of the behavior of the people who live in or visit New Orleans. Most people who live in places that are exposed to serious hazards are aware of the risks they face, including earthquakes, tropical cyclones, tsunami, volcanic eruptions, floods, landslides, and droughts. Yet they still live there because, to earn their living, they need to or have no alternative. Coasts and rivers are good for fishing and farming; valley and volcanic soils are very fertile; drought alternates with good farming or herding. Culture and beliefs, for example, in spirits or gods, or simple fatalism, enable people to live with risks and make sense of their lives in dangerous places. Sometimes, though, unequal power relations are also part of culture, and those who have little influence must inevitably cope with threatening environments.

Several organizations that engage in DRR, with the Red Cross Red Crescent knew about people’s beliefs and cultures and their different interpretations of risk. However, we find it challenging to fit these seamlessly into our organizational framework and funding models. Instead, we tend to assume (or hope) that the people we want to support use the same logic and rationality as we do and that they will want to reduce the disaster risk. Sometimes there is also an institutional reluctance to deal with the issues of inequality and power that make people vulnerable in the places where they make a living. The one thing that is certain is that we will have less sustained impact if we do not adequately take account of people’s cultures, beliefs, and attitudes in relation to risk. With climate change leading to damaged livelihoods, and therefore more vulnerability, and making hazards more extreme and/or frequent, we must get this right. One important goal of this edition of the World Disasters

Report is to bring these complex issues and clashes of cultures into the open for discussion, so that they can be much better incorporated into DRR work. It is difficult for most people to be concerned about occasional and unpredictable severe events (or climate change) when many of their problems are ‘development’ needs that have not been fulfilled. Fortunately, the need for convergence between DRR and development is part of the discussions of the successors to the Hyogo Framework for Action and the Millennium Development Goals. This World Disasters Report also explains how DRR must take account of all the causes of vulnerability – including cultural ones – as the starting point for risk reduction.

The World Disasters Report in 2015, focused on local actors, the key to humanitarian effectiveness. The Ebola crisis in West Africa, the Nepal earthquake, the conflict in Syria, floods in Germany and Hurricane Sandy in the United States mobilized our humanitarian response. They were all very different crises, but they shared one common feature. Each of them highlighted the critical yet often undervalued role of local actors. Their effectiveness goes beyond their proximity. They are also effective because of the perspective they bring. Because they are present in communities before a crisis hits, they see it not as an event in and of itself, but as something that is linked to the past, to unaddressed risks, vulnerabilities, and inequalities. Emergencies – disasters, health crises, even conflicts – are not beginnings or ends, no matter how severe. They are moments that need to be overcome; simply overcoming them, however, will not put an end to the challenges faced by communities. Local actors are uniquely placed to find solutions that reduce underlying risks because of their understanding of local contexts – of weather patterns, of community leaders, of vulnerabilities and of sources of strength. They can support communities to pre-empt and address future crises and threats, and to become stronger and more resilient in the process. However, the whole responsibility for responding to large-scale disasters cannot be transferred to local actors. The international community still has a very important role to play, but a better balance needs to be struck. International actors can provide specialized resources and technical expertise, brought with humility, trust and respect, and with a true commitment to building local capacity.

In order to reduce disaster risk, there is a need to address existing challenges and prepare for future ones by focusing on monitoring, assessing and understanding disaster risk and sharing such information and on how it is created; strengthening disaster risk governance and coordination across relevant institutions and sectors and the full and meaningful participation of relevance stakeholders an appropriate levels; investing in the economic social, health, cultural and educational resilience of persons, communities and countries and the environment, as well as through technology and research; and enhancing multi-hazard early warning systems, preparedness, response, recovery, rehabilitation and reconstruction. To complement national action and capacity, there is a need to enhance international cooperation between developed and developing countries and between States and international organizations. (Sendai Framework for Action 2015-2030)

While some progress in building resilience and reducing losses and damages has been achieved, substantial reduction of disaster risk requires persistence, with a more explicit focus on people and their health and livelihoods, and regular follow-up. The substantial reduction of disaster risk and losses in lives, livelihoods, and health and in the economic, physical, social, cultural, and environmental assets of persons, businesses, communities, and countries. The realization of this outcome requires the strong commitment and involvement of political leadership in every country at all levels. To attain the expected outcome, it is necessary to prevent new and reduce existing disaster risk through 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 pursuance of this goal requires the enhancement of the implementation capacity and capability of developing countries, in particular the least developed countries and African countries, as well as middle-income countries facing specific challenges, including the mobilization of support through international cooperation for the provision of means of implementation in accordance with their national priorities. (Sendai Framework for Action 2015-2030)

Sendai Framework for Action considering the experience gained through the implementation of the Hyogo Framework for Action, and in pursuance of the expected outcome and goal, set four priorities to focus action within and across sectors by States at local, national, regional, and global levels. Specifically, the priority is understanding disaster risk, the second is strengthening disaster risk governance to manage disaster risk, the third is investing in disaster risk reduction for resilience and the fourth priority is enhancing disaster preparedness for effective response and to “Build Back Better” in recovery, rehabilitation, and reconstruction. Also, the role of stakeholders and the international cooperation and global partnership are analyzed in Sendai Framework. The Sendai Framework will apply to the risk of small-scale and large-scale, frequent, and infrequent, sudden, and slow-onset disasters caused by natural or man—made hazards, as well as related environmental, technological, and biological hazards and risks. It aims to guide the multi-hazard management of disaster risk in development at all levels as well as within and across all sectors.

6 MITIGATION AND PREPAREDNESS

During the World Conference, States also reiterated their commitment to address disaster risk reduction and the building resilience to disasters with a renewed sense of urgency within the context of sustainable development and poverty eradication, and to integrate, as appropriate, both disaster risk reduction and the building of resilience into policies, plans, programs, and budgets at all levels and to consider both within relevant frameworks (Sendai Framework for Action 2015-2030). Emphasis towards longer-term counter-disaster planning using mitigation instruments is given since the 1980s (Twigg, 2011). The relationship between human actions and the effects of disasters -the socio-economic dimension of vulnerability – was increasingly well documented and argued (Twigg, 2011). This process received added impetus from the UN International Decade for Natural Disaster Reduction (1989-99).

The most important early intellectual influence on the shift towards mitigation and a wider range of counter-disaster options was probably hazard ‘adjustment’ theories (Twigg, 2011). These alternatives are commonly grouped into classes of adjustment (Twigg, 2011). There are various forms of classification: the scheme in the table below (Hewitt 1997) is a standard one (Twigg, 2011). The range of possible adjustments is very wide, although not all are necessary or possible (Twigg, 2011). The key element in adjustment theory is choice: i.e., the adjustments that are adopted for any hazard and in any place or society represent personal or collective decisions about hazards, priorities, values, costs, etc. (Twigg, 2011).

Structural and vulnerability theories argued a causal link between underdevelopment and disasters were beginning to have an influence on attitudes towards mitigation, especially in international aid (relief and development) agencies (Twigg, 2011). The need for sustainable solutions to have long-term significance to the development community (Twigg, 2011). ‘A concern for risk, and with it a motivation to improve disaster mitigation and preparedness has tended to fall between the cracks of the conceptual frameworks that have driven development co-operation and humanitarian assistance. Disaster mitigation and preparedness (DMP) has either the allure of directly “saving lives” nor of providing an “escape from poverty”.’ (Christoplos I, et al., 2001).

The link of the two separate fields of emergency response and socio-economic development, particularly in the relief-recovery phases of disaster found operational form in the mid-1990s. By creating greater linkage between the relief, rehabilitation, and development (LRRD), and of relief-development continuum LRRD acknowledges the relationship between emergencies and development it seeks to produce mutual advantages for international relief and development agencies and aid recipients. The basic idea is that emergencies are costly in terms of human life and resources, and they disrupt development, while development can be insensitive to risk and fail to protect vulnerable people. Improved development can reduce the need for emergency relief, and improved emergency relief can contribute to development. (Twigg, 2011)

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