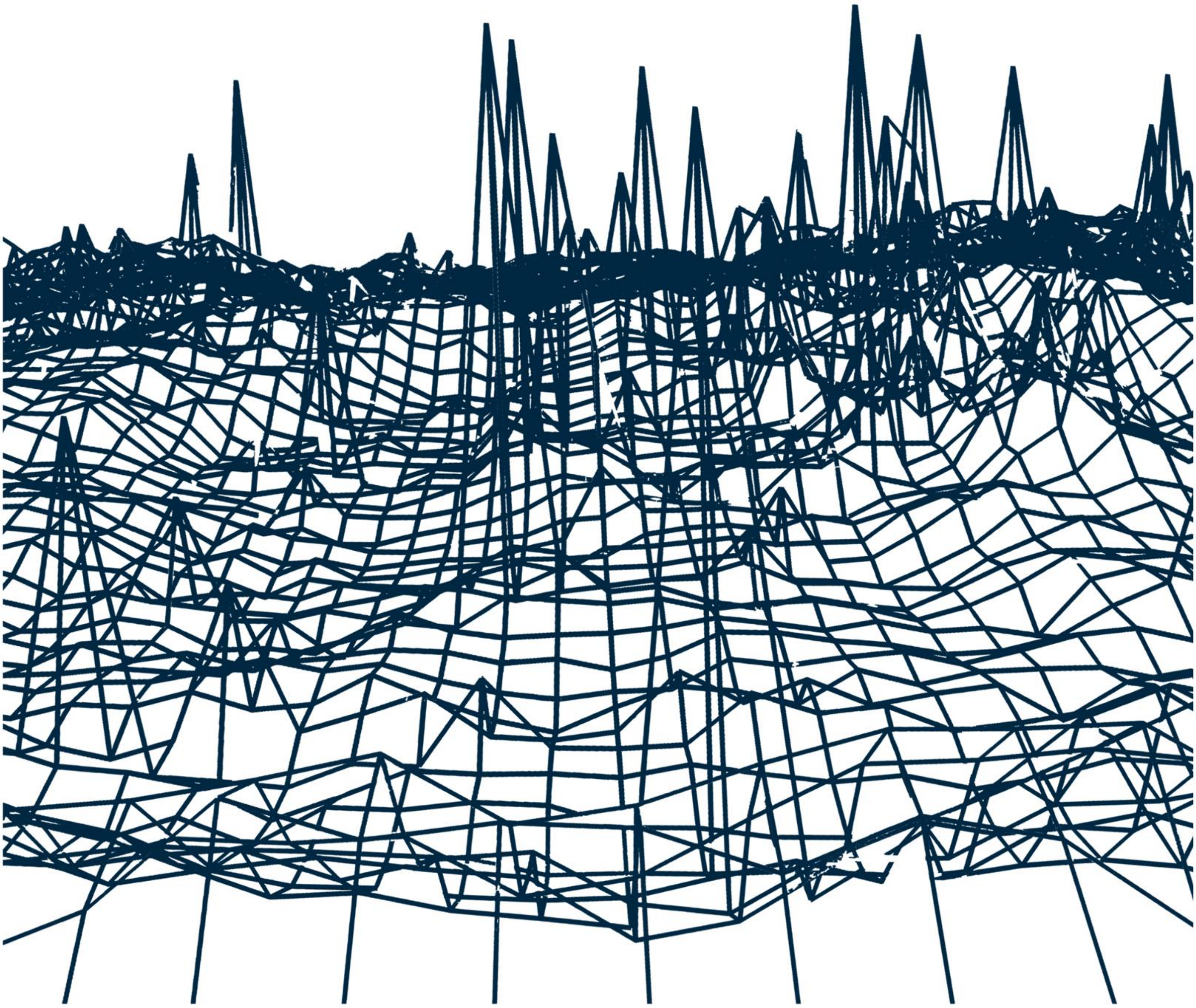
ICT for Disaster Risk Management

Academy of ICT Essentials for Government Leaders



UNITED NATIONS ESCAP
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/ APCICT

The Academy of ICT Essentials for Government Leaders

ICT for Disaster Risk Management

APCICT ASIAN AND PACIFIC TRAINING CENTRE FOR INFORMATION AND COMMUNICATION TECHNOLOGY FOR DEVELOPMENT

The Academy of ICT Essentials for Government Leaders Module Series

ICT for Disaster Risk Management

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ABOUT THE MODULE SERIES

In today's "Information Age", easy access to information is changing the way we live, work and play. The "digital economy", also known as the "knowledge economy", "networked economy" or "new economy", is characterized by a shift from the production of goods to the creation of innovative ideas. This underscores the growing, if not already central, role being played by information and communication technologies (ICTs) in the economy in particular, and in society as a whole.

As a consequence, governments worldwide have increasingly focused on ICT for development (ICTD). For these governments, ICTD is not only about developing the ICT industry or sector of the economy, but also encompasses the use of ICTs to stimulate economic growth, as well as social and political development.

However, among the difficulties that governments face in formulating ICT related policies is the unfamiliarity with the rapidly changing technology landscape and the competencies needed to harness ICT for national development. Since one cannot regulate what one does not understand, many policymakers have shied away from ICT policymaking. But leaving ICT policymaking to technologists is also erroneous because often, technologists are unaware of the social and policy implications of the technologies they are developing and using.

The Academy of ICT Essentials for Government Leaders module series has been developed by the Asian and Pacific Training Centre for Information and Communication Technology for Development (APCICT) for:

1. Policymakers at the national and local government level who are responsible for ICT policymaking;
2. Government officials responsible for the development and implementation of ICT-based applications; and
3. Managers in the public sector seeking to employ ICT tools for project management.

The module series aims to develop familiarity with the substantive issues related to ICTD from both a policy and technology perspective. The intention is not to develop a technical ICT manual. Rather, its purpose is to provide a good understanding of what the current digital technology is capable of achieving, where technology is headed and what this implies for policymaking. The topics covered by the modules have been identified through a training needs analysis and a survey of other training materials worldwide.

The modules are designed in such a way that they can be used for self-study by individuals or as a resource in a training course or programme. The modules are stand-alone as well as linked together, and effort has been made in each module to link to themes and discussions in the other modules in the series. The long-term objective is to make the modules a coherent course that can be certified.

Each module begins with a statement of module objectives and target learning outcomes against which readers can assess their own progress. The module content is divided into sections that include case studies and exercises to help deepen understanding of key concepts. The exercises may be done by individual readers or in groups during a training workshop. Figures and tables are provided to illustrate specific aspects of the discussion. Several case studies and best practices included in this module have been sourced from reports, books, scientific journals, and other published materials. Relevant references and online resources are listed for readers to look up in order to gain additional perspectives.

The use of ICTD is so diverse that sometimes case studies and examples within and across modules may appear contradictory. This is to be expected. This is the excitement and the challenge of this discipline and its promise, as countries leverage the potential of ICTs as tools for development.

Supporting the Academy of ICT Essentials for Government Leaders module series in print format is an online distance learning platform—the APCICT Virtual Academy (http://e-learning.unapcict.org) with virtual classrooms featuring the trainers' presentations in video format and PowerPoint presentations of the modules.

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ICT FOR DISASTER RISK MANAGEMENT

This module introduces disaster risk management (DRM) and provides an overview of how information and communication technologies (ICTs) can be used for DRM. A large number of examples and case studies on the applications of ICTs in DRM have been included in the module.

MODULE OBJECTIVES

The main objective of the module is to introduce the basic concepts of DRM and the applications of ICTs in disaster mitigation and prevention, preparedness, response, and recovery.

LEARNING OUTCOMES

At the end of this module, participants will:

- Be familiar with DRM and its associated terminologies, including the linkages between the Sendai Framework for Disaster Risk Reduction and the United Nations Sustainable Development Goals;
- Be able to identify the data necessary for DRM, such as remote sensing data, digital elevation data, thematic data and historical disaster data;
- Appreciate the ways in which ICTs can be used in disaster risk assessment, analysis and visualization, and know the basic steps for conducting risk assessment;
- Understand how risk information can be used for selecting appropriate disaster risk mitigation and prevention measures at various levels (regional, national, local), and for making decisions by considering likely future risk scenarios;
- Appreciate the ways in which ICTs can be used for community-based preparedness planning, alerting and evacuating, shelter planning, establishing an early warning system, and impact-based forecasting;
- Be aware of the freely available satellite-based resources and products for emergency mapping, mobile apps for reporting disaster incidents, and robots for search and rescue operations;
- Know the ways in which ICTs can be used to support disaster recovery, including post-disaster building damage assessment and post-disaster recovery monitoring; and

- Recognize the role of ICTs in addressing issues related to gender inequality in DRM.

TARGET AUDIENCES

The target audiences of this module are policymakers and civil servants at the national and local government levels who are responsible for or engaged in DRM activities.

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ABBREVIATIONS AND ACRONYMS

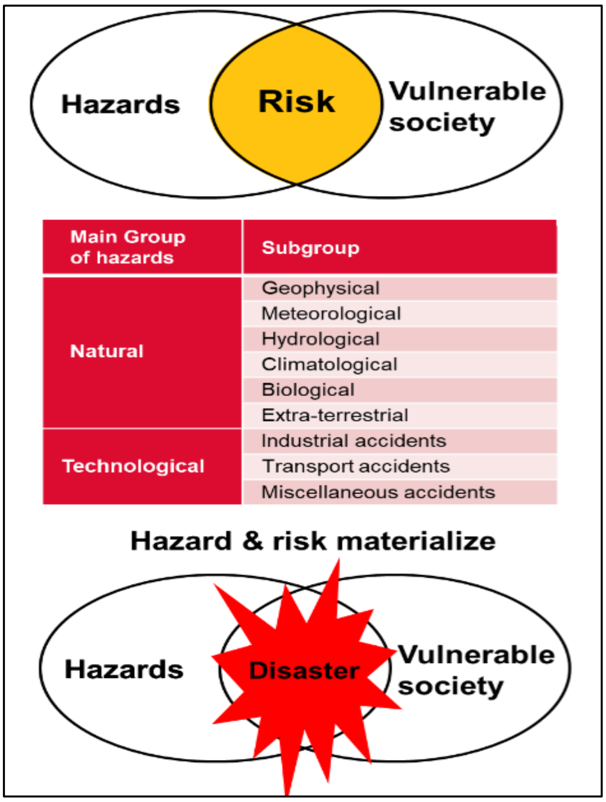
APCICT	Asian and Pacific Training Centre for Information and Communication Technology for Development
APDIM	Asian and Pacific Centre for the Development of Disaster Information Management
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
CAP	Common Alerting Protocol
CAPRA	Comprehensive Approach to Probabilistic Risk Assessment
DEM	Digital Elevation Model
DRM	Disaster Risk Management
ESCAP	Economic and Social Commission for Asia and the Pacific
FAO	Food and Agriculture Organization
GAR	Global Assessment Report on Disaster Risk Reduction
GDACS	Global Disaster Alert and Coordination System
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HTML	Hypertext Markup Language
ICT	Information and Communication Technology
ICTD	Information and Communication Technology for Development
IPCC	Intergovernmental Panel on Climate Change
NASA	National Aeronautics and Space Administration (United States of America)
NSDI	National Spatial Data Infrastructure
OSM	OpenStreetMap
QZSS	Quasi Zenith Satellite System
RESAP	Regional Space Applications Programme for Sustainable Development
SDG	Sustainable Development Goal
SMS	Short Message Service
UNDP	United Nations Development Programme
UNDRR	United Nations Office for Disaster Risk Reduction
UNOSAT	United Nations Institute for Training and Research's Operational Satellite Applications Programme
USGS	United States Geological Survey
XML	Extensible Markup Language

1. INTRODUCTION TO DISASTER RISK MANAGEMENT

1.1 What is a Disaster and Disaster Risk?

A disaster is defined as a serious disruption of the functioning of a community or a society at any scale due to hazard events interacting with conditions of exposure, vulnerability and capacity (Figure 1), leading to one or more of the following: human, material, economic and environmental losses and impacts. The term “emergency” is sometimes used interchangeably with the term “disaster”, as, for example, in the context of biological and technological hazards or health emergencies.[1] A disaster can be characterized as:

Figure 1: Disaster occurs when the threat of a hazard becomes reality and impacts on a vulnerable society



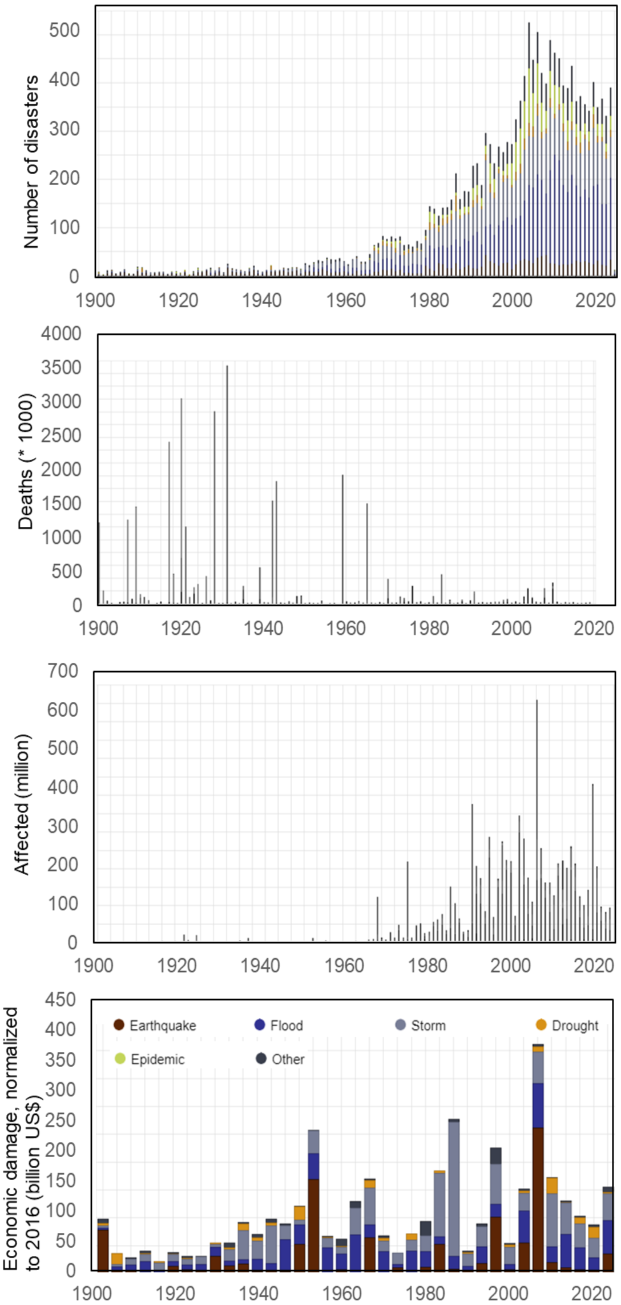
- An extreme phenomenon of different origin;
- With a certain intensity (a measurable quantity that vary over space and time, such as earthquake intensity or water depth);
- With a certain duration (from seconds in the case of explosion to months or years in the case of drought);
- Occurring at a certain location (from very local to global);
- Involving a complex interplay between hazard interactions and human systems;
- Causing negative impact (from loss of lives, injuries and threats to public health, to physical and economic damage);
- Disrupting society (including livelihood systems and society);
- Exceeding local capacities and resources; and
- Requiring outside assistance to cope with the consequences (in the form of humanitarian, physical and/or economic support).

The interaction of potentially dangerous phenomena (hazards) with a vulnerable society results in risk. “Disaster risk” is defined as the potential loss of life, injury, or

[1] UNDRR, "Terminology". Available at https://www.undrr.org/terminology.

destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity.[2] Disaster risk comprises different types of potential losses that are often difficult to quantify. However, with knowledge of prevailing hazards and the patterns of population and socioeconomic development, disaster risks can be assessed and mapped.

Figure 2: Disaster trends, including the number of disasters, deaths and people affected, and the amount of economic damage



Source: EM-DAT, The emergency event database, University of Louvain, Belgium.

Figure 2 shows that there is a rising trend of disaster occurrences in terms of the number of disasters. Due to extensive news coverage today, hardly any disasters go unnoticed, which was still the case in the first half of the last century. The rise in the number of disasters is mainly caused by meteorological triggers, and is attributed partly to climate change, according to the Intergovernmental Panel on Climate Change (IPCC).[3] Economic damage also shows a strong upward trend, due to population growth and economic development, combined with the increase in extreme events. The peaks in economic damages are caused by extreme events (e.g., 1995 Kobe Earthquake, 2004 Indian Ocean Tsunami, 2005 Hurricane Katrina and 2011 Tohoku Tsunami). These peaks are also reflected in the number of people affected. The number of deaths,

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[2] Ibid.
[3] IPCC, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (New York, Cambridge University Press, 2012). Available at https://www.ipcc.ch/report/managing-the-risks-of-extreme-events-and-disasters-to-advance-climate-change-adaptation/.

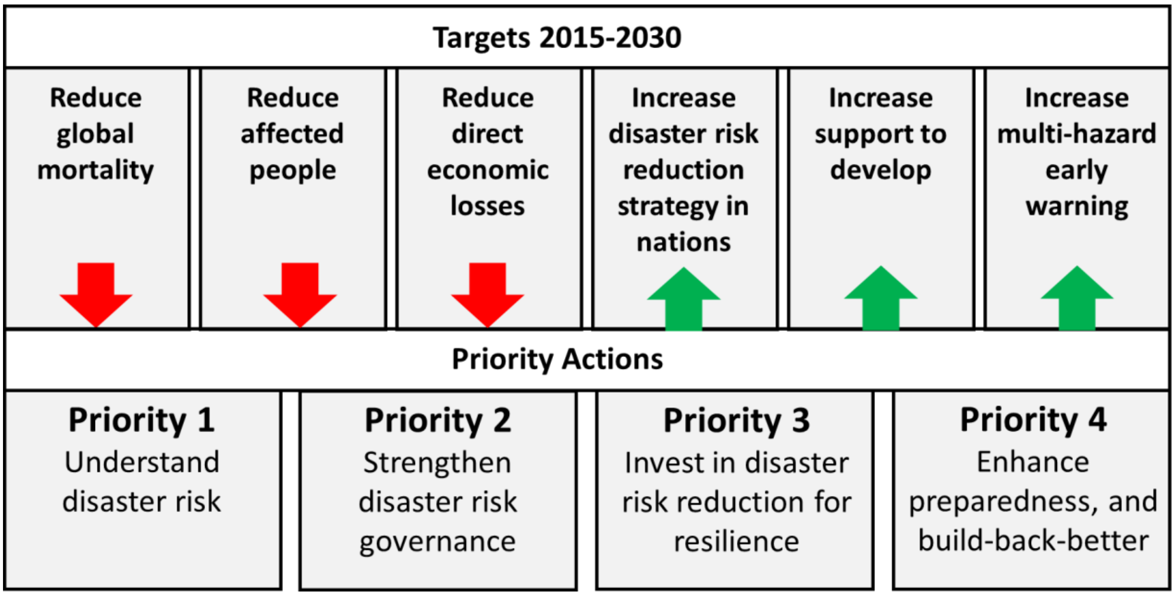
however, is showing a downward trend due to improved preparedness planning and early warning systems. The graphs in Figure 2 do not include the impact of the 2020 COVID-19 pandemic, which is likely to tip the scale of all graphs.

1.2 Disaster Risk Reduction and Disaster Risk Management

"Disaster risk reduction" is aimed at preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and therefore to the achievement of sustainable development.[4] It is the policy objective of disaster risk management (DRM), and its goals and objectives are defined in disaster risk reduction strategies and plans.

The Sendai Framework for Disaster Risk Reduction 2015-2030 (Figure 3) is a 15-year, voluntary, non-binding agreement, adopted by 187 member States of the United Nations in March 2015 at the Third World Conference on Disaster Risk Reduction, which is designed to support the reduction of current level of risks and prevent new risks from emerging.[5]

Figure 3: Targets and priority actions of the Sendai Framework for Disaster Risk Reduction 2015-2030



The framework aims for the substantial reduction of disaster risk and losses in lives, livelihoods and the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries.

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[4] UNDRR, "Terminology". Available at https://www.undrr.org/terminology.
[5] United Nations, *Sendai Framework for Disaster Risk Reduction 2015–2030* (Geneva, 2015). Available at https://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf.

The Sendai Framework's first priority action—understanding disaster risk—states that policies and practices for DRM 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. It also outlines a set of recommendations for ensuring that policies, measures and investments use risk information effectively to reduce disaster risk. While the State has the primary role and responsibility to facilitate risk assessment and make risk information understandable and readily available to people, the Sendai Framework emphasizes that all stakeholders and actors need to understand the risks they are exposed to and are clear about the actions they need to take to reduce those risks.

In addition, the Sustainable Development Goals (SDGs) adopted by 193 countries at the United Nations Sustainable Development Summit in September 2015 explicitly target disaster risk reduction under three of the seventeen goals.[6] The relevant goals focus on ending poverty in all its forms (Goal 1, Target 1.5), making cities and human settlements inclusive, safe, resilient and sustainable (Goal 11, Targets 11.5, 11.B), and taking urgent action to combat climate change and its impacts (Goal 13, Target 13.1, 13.3).

The "Asia-Pacific Disaster Report 2015" of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP)[7] stresses the importance of disaster risk reduction in achieving each and every one of the SDGs, because a major disaster or crisis could jeopardize development efforts and gains built up over the years, as evident in the current COVID-19 pandemic.

DRM is defined as the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses.[8] This is often portrayed as a DRM cycle (Figure 4).

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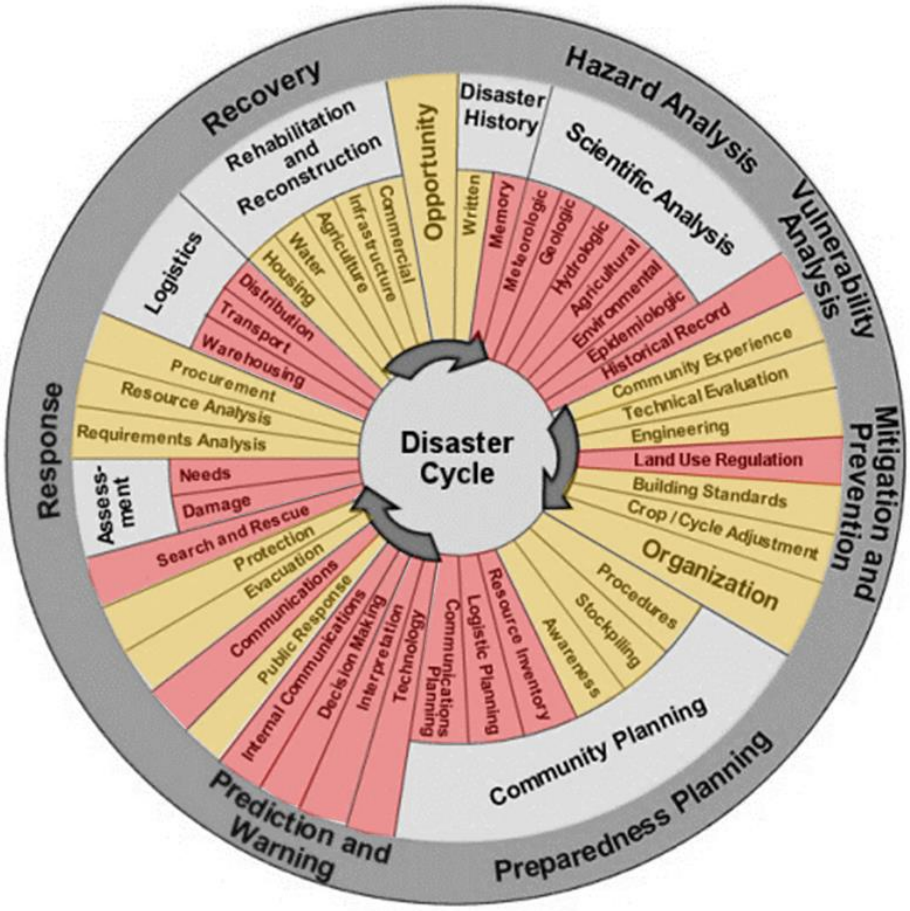
[6] United Nations General Assembly, "Transforming our World: The 2030 Agenda for Sustainable Development", seventieth session, agenda items 15 and 116 (A/RES/70/1), 2015. Available at https://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E.

[7] ESCAP, *Disasters without Borders: Regional Resilience for Sustainable Development - Asia-Pacific Disaster Report 2015* (Bangkok, 2015). Available at https://www.unescap.org/publications/asia-pacific-disaster-report-2015-disasters-without-borders.

[8] UNDRR, "Terminology". Available at https://www.undrr.org/terminology.

Figure 4: DRM cycle and the importance of ICTs in various activities and phases



Notes: Areas in red indicate ICTs playing a main role; and areas in orange indicate ICTs playing a lesser role.

Source: C.J. Van Westen and others, "Multi-Hazard Risk Assessment: Distance education course – Guidebook", United Nations University – ITC School on Disaster Geo-information Management, 2011. Available at http://ftp.itc.nl/pub/westen/Multi_hazard_risk_course/Guidebook/Guidebook%20MHRA.pdf.

As illustrated in Figure 4, ICTs play an important role in DRM. The advances in ICTs and their high uptake have made it possible to play a critical role in all phases of the DRM cycle. For example, ICTs are essential for risk assessment (consisting of hazard and vulnerability analysis), which forms the basis for decision-making in the mitigation and prevention phase. ICTs can also help to formulate possible scenarios of future emergencies in the preparedness phase. Precursor information is converted into actual expected losses in impact-based forecasting for prediction and early warning, and after a disaster, the risk assessment again forms the basis for building back better in the recovery phase.

Since there is a need for systematic data collection for the four key phases of the DRM cycle—disaster mitigation and prevention, preparedness, response, and recovery, ICTs can help to not only collect data, but also analyse and disseminate the outputs to the "last-mile" for effective DRM. Important ICT applications for DRM include satellite remote sensing, global navigation satellite systems (GNSS) and geographic information systems (GIS).

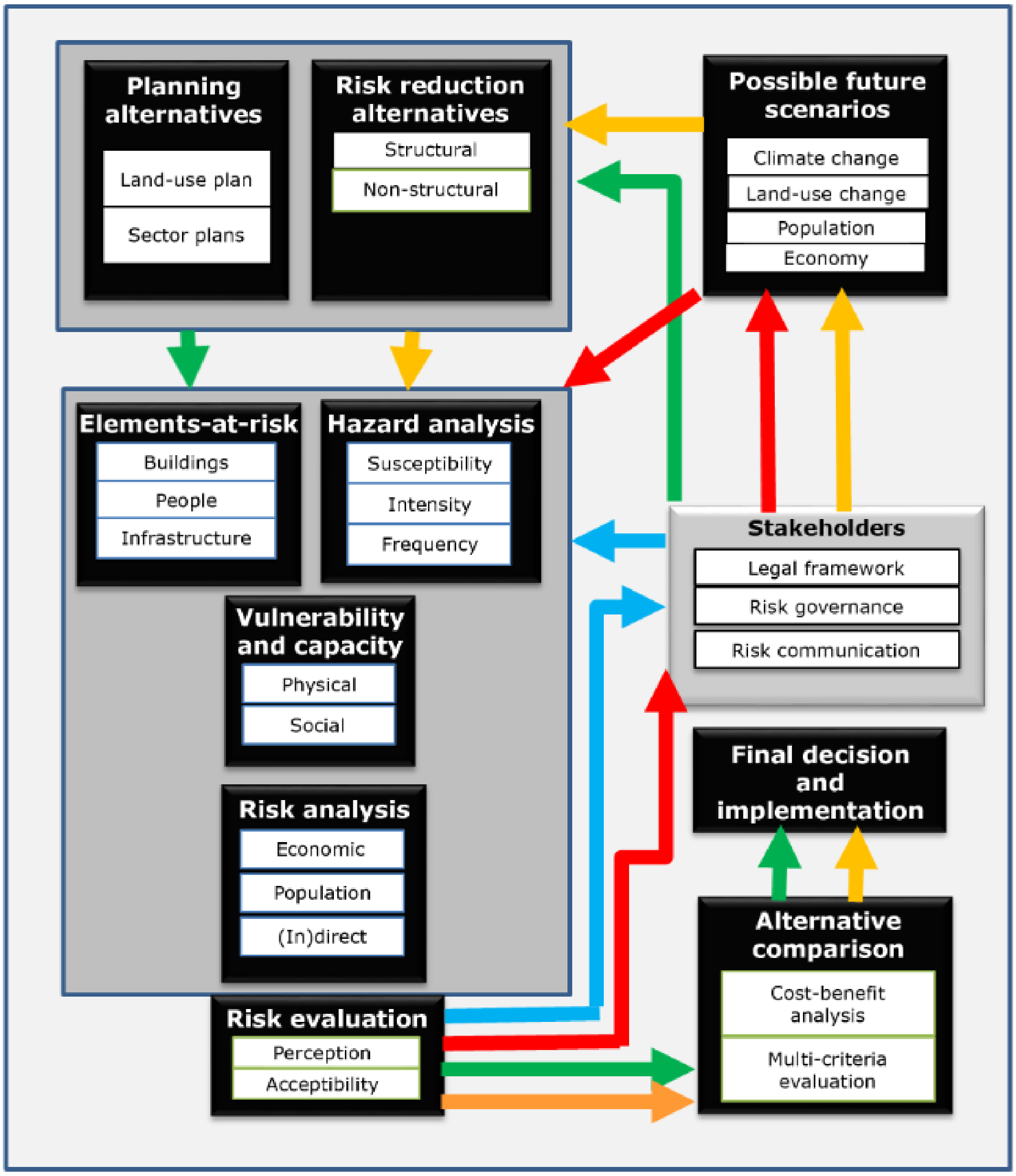
Earth observation satellites provide very detailed information about the elements-at-risk as well as elevations that are very useful for carrying out multi-hazard risk assessments and for developing high-quality risk maps for mitigation and prevention activities, such and land-use planning and regulations. Earth observation satellites are also contributing in post-disaster response activities by providing information on the extent and severity of damages in disaster-affected areas. Communication satellites are being used in disaster preparedness activities such as early warning, evacuation and mobilization of emergency assistance.

GNSS-enabled services are being used for: (1) disaster preparedness activities, including the monitoring of earth movements (e.g., landslides), sending early warnings to remote locations including to fisherman in deep sea (a few GNSS satellites have such capabilities); and (2) disaster response activities, including providing location-specific information through crowdsourcing.

GIS is a more widely-used technology in all phases of the DRM cycle as it has the capability to incorporate data from not only remote sensing satellites, communication satellites and navigation satellites, but also data from surveys and census. GIS enables the integration and analysis of data from multiple sources, and is able to prepare specific products for the different phases of the DRM cycle. GIS-based methods are widely used for multi-hazard risk assessment of both properties and casualties, which can be useful for disaster mitigation and prevention planning through land-use and building code regulations. GIS-based warning and evacuation systems are very useful for location-specific response activities, while GIS-based decision-support systems are being extensively used for disaster response activities.

A general strategy for disaster risk reduction must first establish the DRM context and criteria and characterize the potential threats to a community and its environment (hazard). Secondly, the social and physical vulnerabilities need to be analysed to determine the potential risks from several hazardous scenarios in order to implement measures to reduce them, as shown in the DRM workflow diagram (Figure 5).

Figure 5: The four workflows of DRM



Notes: Blue arrow = analysing existing risk; green arrow = analysing optimal risk reduction planning alternatives; red arrow = analysing possible changing risk in future scenarios; and orange arrow = analysing change-proof risk reduction alternatives using future scenarios.

Source: C.J. Van Westen and others, "Multi-Hazard Risk Assessment: Distance education course – Guidebook", United Nations University – ITC School on Disaster Geo-information Management, 2011. Available at http://ftp.itc.nl/pub/westen/Multi_hazard_risk_course/Guidebook/Guidebook%20MHRA.pdf.

Central to the whole DRM process are the stakeholders. They are organizations involved in spatial planning, planning of risk reduction measures, or emergency preparedness and response. They work in a country with a specific legislation and planning process. The stakeholders can be divided into:

- Government departments responsible for the construction, monitoring, maintenance and protection of critical infrastructure (e.g., the Ministry of Public Works);
- Physical planning departments responsible for land-use planning at different scales; and
- Emergency management organizations.

Stakeholders usually begin with an assessment of the existing risk, which is carried out at the appropriate scale, based on the objectives of the stakeholders (blue workflow in Figure 5). The risk assessment can be divided into the following components:

- **Hazard analysis** – Models the intensity and frequency of hazardous processes;
- **Exposure analysis** – Overlays hazard intensities and elements-at-risk;
- **Vulnerability analysis** – Translates hazard intensities into expected degree of loss; and
- **Risk analysis** – Integrates losses for different hazards and return periods.

Following a risk assessment, stakeholders can identify high-risk areas for interventions. This is called the risk evaluation stage where stakeholders consider the risks and the associated social, economic and environmental consequences, in order to identify a set of alternatives for managing the risks. Important considerations at this stage include:

- **Risk perception** – How stakeholders perceive the severity of the risk; and
- **Risk acceptability** – Whether the risk is within pre-defined thresholds.

Based on the outcome of the risk assessment, stakeholders can define and evaluate the best risk reduction alternative or a combination of alternatives (green workflow in Figure 5). The alternatives are analysed to find the optimal risk reduction measures for a given risk scenario. Once updated maps are available, the new risk level is analysed and compared with the baseline risk to estimate the potential level of risk reduction for each of the alternative. This is then further evaluated against the costs and the best risk reduction alternative is selected.

Next, stakeholders usually analyse and evaluate the changes in risk based on possible future scenarios (red workflow in Figure 5). The scenarios are based on forecasted changes in climate, land use or population, which are only partially under the control of local planning organizations. Here, stakeholders evaluate how these changes will affect the hazard and thereby the exposures of the elements-at-risk, their vulnerabilities and risks.

The evaluation of how different risk reduction alternatives will lead to overall risk reduction for different future scenarios is represented by the orange workflow in Figure 5. These alternatives or their combinations will allow stakeholders to choose the optimal “change-proof” risk reduction measures, which means they continue to be relevant and useful in the future, when the risk changes.

The final goal, reduction of disaster risk in the present and control of future disaster risk, should be achieved by combining structural and non-structural measures in DRM in an integrated manner as part of the community development process, and not just as post-disaster response. There are three main types of DRM activities or alternatives:[9]

1. **Corrective** DRM activities address and seek to remove or reduce disaster risks which are already present, and which need to be managed and reduced. For example, retrofitting of critical infrastructure;

2. **Prospective** DRM activities address and seek to avoid the development of new or increased disaster risks. They focus on addressing disaster risks that may develop in future if disaster risk reduction policies are not put in place. For example, land-use planning based on risk levels; and

3. **Compensatory** DRM activities strengthen the social and economic resilience of individuals and societies in the face of residual risk that cannot be effectively reduced, for example, insurance.

DRM requires deep understanding of the root causes and underlying factors that lead to disasters in order to arrive at solutions that are practical, appropriate and sustainable for the community at risk. These DRM workflows will be discussed in more detail in subsequent sections.

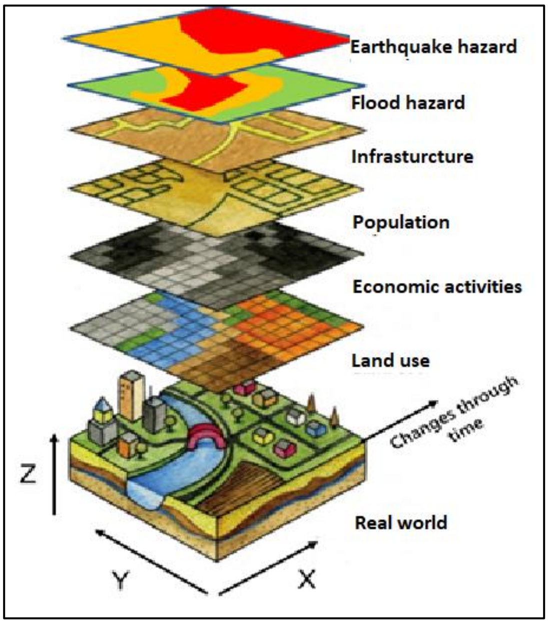
[9] Ibid.

2. DATA NECESSARY FOR DISASTER RISK MANAGEMENT

The first priority action of the Sendai Framework states that policies and practices for DRM should be based on an understanding of disaster risk, and thus disaster risk assessment is an important basis for decision-making. Such decisions are based on specific questions, for example:

- Which areas could be affected by flooding?
- What is the expected loss of earthquakes?
- Which mitigation measures would be best?
- Where are the emergency shelters and are they enough?
- Which area has the highest damage?
- Which roads are still reachable?

Figure 6: DRM requires many types of data, many of which have a spatial component and changes over time



A wide range of data is required for answering such questions. Most of this data have a spatial component (a location and a height) and changes over time (Figure 6). The most relevant types of data required for DRM are:

- Remote sensing data;
- Digital elevation data;
- Thematic data to analyse hazards and risks; and
- Historical disaster data.

In this section some of the most widely-used data are discussed, focusing on those datasets that can be obtained online. In addition, the contributions from remote sensing technology are highlighted.

2.1 Remote Sensing

Remote sensing can be described as the process of making measurements or observations without direct contact with the object being measured or observed. While in the geoinformatics context, satellites often come to mind, drone photography is also a form of remote sensing. It usually results in images, but includes measurements such as temperature and texture.

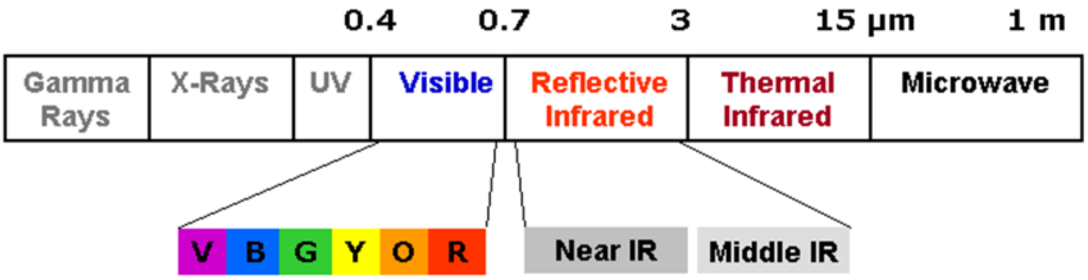
For remote sensing, a sensor device (e.g., a camera or scanner) is required, and a platform to carry the sensor device, such as a drone, helicopter, airplane or satellite. The choice of platform directly affects what can be observed and how. Drones are cheap and can be easily deployed, but cover small areas and their use may be restricted. Airplanes and helicopters are flexible in their operation, and by flying relatively low, provide good spatial detail. However, such operations can be expensive and initiatives requiring regular imaging can be costly. Satellites fly on a fixed orbit and are thus less flexible, but can provide data at regular intervals.

There are different types of satellites. One type is the polar orbiters that continuously circle the Earth at an altitude of 500-900km, passing over or near the poles. Normally, only a relatively narrow strip of the Earth underneath the sensor is observed. However, modern satellites can point the sensor sideways for greater flexibility.

Another type of satellite is positioned in geostationary orbit. This means the satellite is always directly above a designated place on the equator, moving with the rotating Earth at an altitude of 36,000km. At that height the sensor can usually observe an entire hemisphere (the side of the Earth facing it) and provide data at any desired frequency. Many weather and communication satellites fall in this category, while most Earth observation satellites are polar orbiters.

The data obtained depends primarily on the type of electromagnetic energy that the sensors can detect, such as ultraviolet, infrared, thermal or other energy (Figure 7). For instance, reflective infrared is used for vegetation mapping, thermal infrared for wildfire detection and microwave for flood mapping.

Figure 7: Electromagnetic spectrum used in remote sensing applications



Notes: UV = ultraviolet; and IR = infrared.

Remote sensing data comes in many forms, often described by sensor type, as well as by spatial, temporal and spectral resolution, as follows:

- **Sensor type** – Sensors that record reflected sunlight or energy emitted by the Earth are called passive sensors. However, there are sensors that emit their own energy, which is reflected by the Earth, just like a flash on a camera. These are active sensors, well-known examples being radar or laser scanning.

- **Spatial resolution** – Describes the size of the ground area represented in a single pixel. This largely depends on the distance between the sensor and the object. While drone images may have a resolution of a few centimetres, data from polar orbiters range between about 50cm and 1km per cell. Sensors on geostationary satellites, being very far away, record data at resolutions of a few kilometres.

- **Temporal resolution** – Describes the possible frequency of repeat observations. For drones and aerial surveys this is not fixed and depends on the decision to make another flight in the same area. For sensors on polar orbiters, the temporal resolution varies between 1 and 44 days, while sensors on geostationary satellites can record data up to every 15 minutes.

- **Spectral resolution** – Describes how narrow a slice of the electromagnetic spectrum a sensor band records.

Determining the data needed requires an understanding of hazard and risk characteristics. It also depends on whether the data is available and how much it costs to obtain the data. Different hazard types have different spatial, temporal and spectral characteristics. Table 1 gives a summary of the types of remote sensing data needed for different hazard types and DRM phases. The following checklist can help you decide what remote sensing data you need:

- Identify data type(s) needed (e.g., thematic layers, images, maps). Understanding the risk components and the ways to assess and map hazards, elements-at-risk and their vulnerabilities is a prerequisite.

- Identify dates of data (including images) needed (e.g., archived, current, future). Risk assessments may require archived and recent data (e.g., statistics on a given hazard phenomenon) to detect changes over time, or may require future data not yet acquired. It is important to keep in mind that the natural environment looks different throughout the year. To map vegetation changes, looking at a winter image may be of little use.

- Identify the number of datasets / images needed. To assess change, at least two datasets / images are needed. To cover a large area, several images may be required. Some relevant statistics or thematic data may be stored in different databases or datasets.

- Identify cost and check budget. While some data may be free of charge, others are very expensive. Once a list of needed data has been created, check how much the data costs and if the budget supports the choice. If not, some data may have to be replaced with lower-cost alternatives.

- Identify relevant sources and search for appropriate data once the data list has been finalized. Pay particular attention to the suitability of data, for example with respect to coverage and extent, but also cloud cover. Identify whether the data needs to be ordered or can be downloaded directly.

Something To Do: Identify remote sensing needs

- Identify the hazard type you are most interested in and list the ways it can be characterized in terms of its spatial, temporal and spectral properties.
- Based on these properties, what data types are useful for observing the hazard selected? What relevant information can they provide?
- Go through the checklist provided to identify the remote sensing needs for assessing the risk of the selected hazard.

Table 1: Requirements for the application of remote sensing and other spatial data in various phases of DRM

	Phase	Data type	Spatial (m)	Temporal	Other tools	Satellite sensors				
						VIS/IR	TH	SAR	INSAR	Other sensors
Flood	Hazard mapping / prevention	Land use / land cover	10 - 1000	Months	API + field survey	X		X		
		Historical events	10 - 1000	Days	Historical records, media	X		X		
		Geomorphology	10 - 30	Years	API + field survey	Stereo				
		Topography, roughness	1 - 10 *	Years	Topographic maps	Stereo		X	X	Laser altimetry
	Preparedness	Rainfall	1000	Hours	Rainfall stations	X	X			Weather satellites / passive microwave / ground radar
		Detailed topography	0.1 - 1 *	Months	GPS, field measurements				X	Laser altimetry
	Response	Flood mapping	10 - 1000	Days	Airborne + field survey	X		X		
		Damage mapping	1 - 10	Days	Airborne + field survey	X				
Earthquake	Hazard mapping / prevention	Land use / land cover	1 - 10	Years	API + field survey	X				
		Geomorphology	1 - 10	Decades	API + field survey	Stereo				
		Lithology	30 - 100	Decades	API + field survey	X				Hyperspectral
		Faults	5 - 10	Decades	API + field survey	Stereo		X		
		Soil mapping	10 - 30	Decades	API + drilling + lab. Testing	X				
	Preparedness	Strain accumulation	0.01 *	Months	GPS, SLR, VLBI				X	
	Response	Damage assessment	1 - 5	Days	Airborne + field survey	X		X		
		Associated features	10 - 30	Days	Airborne + field survey	X		X		
Volcano**	Hazard mapping / prevention	Topography	10 *	Years	Topo maps	Stereo			X	Laser altimetry
		Lithology	10 - 30	Decades	API + field survey	X		X		Hyperspectral
		Geomorphology	5 - 10	Years	API + field survey	Stereo				
		Land cover / snow	10 - 30	Months	API + field survey	X				
	Preparedness	Thermal anomalies	10 - 120	Weeks	Field measurements		X			
		Topography/deformation	0.01 *	Weeks	GPS, tilt meters				X	Laser altimetry
		Gas (composition, amount)	50 - 100	Weeks	IR spectrometer (COSPEC, FTIR)	X				Weather satellites
		Instability	10 - 30	Months	Field spectrometer				X	
	Response	Mapping ash cover	10 - 30	Days	Airborne + field surveys	X				
		Mapping flows	10 - 30	Days	Airborne + field surveys	X	X	X		
		Ash cloud monitoring	1000	Hours	Field surveys, webcams	X				Hyperspectral / weather satellites
Landslide	Hazard mapping / prevention	Landslide distribution	1 - 5	Years	Multi-temporal API, field survey, historical records	Stereo				
		Geomorphology	1 - 10	Decades	API + field survey	Stereo				
		Geology	10 - 30	Decades	API + field survey	X				Hyperspectral
		Faults	5 - 10	Decades	API + field survey	Stereo				
		Topography	10 *	Decades	Topographic maps	Stereo			X	Laser altimetry
		Land use	10 - 30	Years	API + field survey	X				
	Preparedness	Slope movement	0.01 *	Days	GPS, field instrumentation				X	Laser altimetry
		Rainfall	100 - 1000	Hours	Rainfall stations	X	X			Weather satellites / passive microwave / ground radar
	Response	Damage mapping	1 - 10	Days	API + field survey	X		X		

Notes: For each data type, an indication is given of the optimal spatial resolution (spatial), the minimum time for which successive data should be available (temporal) and the sensor types that could be used; API = aerial photos; GPS = global positioning system; SLR = satellite laser ranging; VLBI = very long baseline interferometry; COSPEC = correlation spectrometer; FTIR = fourier transform infrared spectroscopy; VIS = visible; IR = infrared; TH = thermal; SAR = synthetic aperture radar; INSAR = interferometric SAR; * = the minimum resolution of the resulting digital elevation model value; and ** = eruptive activity. Depending on the subhazard the data types have to be adapted.

2.2 Free or Low-Cost Image Data

There are numerous satellites and sensors that are sources for image data.[10] First, it is important to understand the difference between an image data and a picture. Many satellite images comprise several spectral bands that contain valuable information, such as the near-infrared band for vegetation mapping mentioned previously. When the image data is converted to a picture, such as a *.jpg or *.tif, the individual bands are merged and the quantitative information is lost. The pictures can still be used but the information content is reduced.

The following gives an overview of a selection of data providers that provide free or low-cost image data:

- **Free satellite images from Google Earth** – Google Earth is an example of satellite imagery that has been converted to pictures. Google Earth shows the highest resolution and most recently available satellite images, but as raster pictures, which means it is not possible to change bands or manipulate the image. However, users can add available data layers on top, create new data or load data from other sources as *.kml files, and also have an underlying digital elevation model (DEM) for three-dimensional viewing. With the history viewer, it is possible to compare images at different times and integrate them with spatial data in a GIS. This can be very valuable when performing detailed elements-at-risk mapping or when detecting for changes over time.

Figure 8: Example of using Google Earth history viewer with additional data to map landslides caused by the 2018 monsoon in Kerala, India

[10] A good overview is available at https://webapps.itc.utwente.nl/sensor/Default.aspx?view=allsensors.

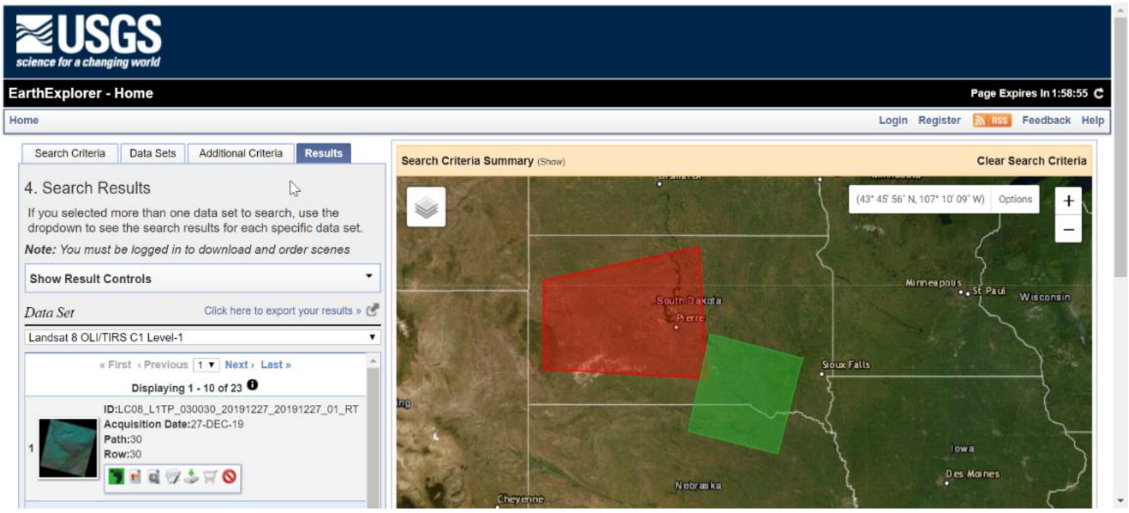
Something To Do

- Install and open Google Earth.
- Review the data coverage for your country, keeping in mind the hazards that are present.
- Evaluate how useful the data can be (consider also three-dimensional data) for studying the hazards and elements-at-risk. What are the limitations?

- **Free satellite images from Landsat data** – One of the oldest and best-known satellite missions is Landsat, which has been providing Earth surface data since 1972. Initially, the data had a resolution of 60m, which was later improved to 30m (lower in the thermal bands). The latest from the Landsat series is Landsat 8, launched in 2013, which carries nine spectral bands from the Operational Land Imager and two bands from the thermal infrared sensors. The multispectral bands have a resolution of 30m, and include a newly-introduced cirrus band and a 15m panchromatic band. The thermal bands provide 100m resolution of data. Landsat 9 is scheduled to be launched in 2021.

  For many years the Landsat data was commercially sold at several thousand dollars per scene. In 2009, the United States government made the entire Landsat data archive available free of charge. Landsat data can be searched and downloaded using the United States Geological Survey (USGS) Earth Explorer[11] and the USGS Global Visualization Viewer, which gives a useful graphical overview.[12]

Figure 9: Landsat data ready for download on the USGS Earth Explorer



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[11] USGS Earth Explorer. Available at https://earthexplorer.usgs.gov/.
[12] USGS Global Visualization Viewer. Available at https://glovis.usgs.gov/.

- **Free satellite images from ASTER** – The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) has become a widely-used satellite image source.[13] Launched in 1999, the sensor carries 15 channels, with four bands at 15m resolution, six at 60m and five at 90m. The spatial and spectral details are thus excellent, and the data can be used to create DEMs. The best way to search for ASTER data is via the USGS Earth Explorer[14] or the Land Processes Distributed Active Archive Center Data Pool[15] where other data from the National Aeronautics and Space Administration (NASA)-operated satellites can be found (e.g., Landsat, MODIS). Since there are many different data products, it is advisable to read up on how these products have been generated and what they are useful for.

- **Free satellite images from Sentinel** – The Copernicus Programme is an ambitious initiative headed by the European Commission in partnership with the European Space Agency. Their Sentinel missions include radar and super-spectral imaging for land, ocean and atmospheric monitoring. For example, all-weather radar images from Sentinel 1A and 1B, high-resolution optical images from Sentinel 2A and 2B, as well as ocean and land data suitable for environmental and climate monitoring from Sentinel 3. Sentinel data can be accessed through different platforms.[16] The European Space Agency also provides the Sentinel Application Platform to process Sentinel imagery, with free toolboxes for each Sentinel mission.[17]

- **Partially-free miniature satellite images from Planet** – Planet is an American private Earth imaging company with the aim to image the entire globe on a daily basis to detect changes and support DRM. The company has put into orbit hundreds of Triple-CubeSat miniature satellites called Doves, each equipped with a high-powered telescope and camera programmed to capture different areas of the Earth. The images can be accessed online, some of which are available under an open data access policy.[18]

- **Commercial satellite images** – Commercial satellite data is costly and can quickly reach thousands of dollars. Hence, the well-known commercial data types are often not affordable. However, some commercial satellite operators have managed to increase the spatial resolution by a very impressive margin, for the first time reaching 50cm with GeoEye.

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[13] NASA Jet Propulsion Laboratory, “ASTER”. Available at https://asterweb.jpl.nasa.gov/.
[14] USGS Earth Explorer. Available at https://earthexplorer.usgs.gov/.
[15] USGS, "Data Pool". Available at https://lpdaac.usgs.gov/tools/data-pool/.
[16] Sentinel Hub, "EO Browser". Available at https://apps.sentinel-hub.com/eo-browser/.
[17] European Space Agency, "Science Toolbox Exploitation Platform: SNAP". Available at https://step.esa.int/main/toolboxes/snap/.
[18] Planet. Available at https://www.planet.com/products/planet-imagery/.

Maxar is one of the leading commercial companies with very-high-resolution optical images from WorldView and GeoEye satellites. The earlier versions such as Ikonos and Quickbird are no longer in operations. Maxar has created an Open Data Program to support the geospatial community by providing the most accurate data and analytics in times of disaster. Very-high-resolution satellite images of crisis areas can be downloaded from their website.[19]

In addition, many countries have their own space technology now. Besides the traditional space powers—the United States, Canada, Europe, Russia and Japan—other countries such as China and India are building and operating their own satellites. Often, these are small and relatively inexpensive satellites, such as micro- and nano-satellites (less than 100kg and 10 kg, respectively), thus the Earth observation arena is very active, making it easier to obtain data. India is operating one of the largest fleets of Earth observation satellites and has very ambitious plans, which are matched by China that is collaborating with Brazil on a satellite programme. In Africa, Algeria, Egypt, Nigeria and South Africa are operating their own Earth observation satellites, with plans for an African Resource Management Satellite Constellation.

- **Free drone images** – It is generally easier to find data from sensors with a global coverage than from dedicated campaigns, for example for drone images. However, there are initiatives that make drone images publicly available, such as OpenAerialMap.[20] This is an open service to provide access to a commons of openly-licensed imagery and map layer services.

[19] Maxar, "Open Data Program". Available at https://www.maxar.com/open-data.
[20] OpenAerialMap. Available at https://map.openaerialmap.org.

Case Study 1: Regional Space Applications Programme for Sustainable Development

With rapid advances in space technology and increasing access to space-based information for DRM, the Regional Space Applications Programme for Sustainable Development (RESAP) has made concerted efforts to promote geospatial services to support disaster risk reduction, as well as inclusive and sustainable development.

As part of the cross-country transfer of good practices and knowledge, ESCAP through its RESAP network promptly responds to requests for support from disaster-affected member States by mobilizing satellite data-derived products and services.

More than 120GB of remote sensing data, products and relevant services have been provided free of charge to governments of severely disaster-affected countries for damage and impact analysis from floods, cyclones, earthquakes, tsunamis, volcanic eruptions, droughts and saltwater intrusions. These data and services are worth over USD 1 million.

This access to Earth observation data for member States addresses technical gaps and challenges in accessibility identfied in the Asia-Pacific Plan of Action on Space Applications for Sustainable Development (2018-2030). The plan recognizes that rapid digital innovation continues to augment the availability of geospatial data, providing countries of Asia and the Pacific, particularly those with special needs, with an expanded choice of tools to implement the 2030 Agenda. Furthermore, it underlines the need for expanding the use of new data sources and analytics associated with enabling integrative technologies, processes and tools, so that timely, reliable and quality information is delivered to citizens, businesses, organizations and governments. This is key for evidence-based decision-making and enhanced accountability of actions.

Source: ESCAP, "Asia-Pacific Plan of Action on SpaceApplications for Sustainable Development (2018-2030)". Available at https://www.unescap.org/resources/asia-pacific-plan-action-space-applications-sustainable-development-2018-2030.

2.3 Digital Elevation Models

DEMs consist of a digital representation of the elevation, which can be the surface of the Earth (in which case they are called digital terrain models or bare surface models), or the surface of the objects and vegetation on the Earth (in which case they are called digital surface models). DEMs can be derived in different ways but are mostly obtained from remote sensing data. The most used techniques are the following:

- **Photogrammetric techniques** – The use of stereoscopic aerial photographs or satellite images to sample a large number of ground points, with X, Y and Z elevation values, by means of specially-developed software. The points are then interpolated into a regular grid (raster). Ready-made DEM products on medium scale created from ASTER, SPOT and other satellite systems are available. Higher-accuracy DEMs can be derived for specific areas using very-high-resolution satellite images (e.g., Pleiades).

- **Structure from motion** is a photogrammetric technique for generating three-dimensional point-clouds from two-dimensional image sequences that may be derived from drones or other moving objects.

- **Laser scanning** – Light detection and ranging data can be obtained from a laser scanner mounted on an aircraft, drone or even on the ground that emits laser beams with a high frequency to record the reflections together with the time difference between the emission and reflection. Laser scanning is capable of penetrating vegetation and provides digital terrain models and digital surface models with the highest accuracy.

- **Radar interferometry** – A radar signal is emitted from the satellite and reflected from the Earth's surface. It is recorded with antennas at two slightly different positions and complex modelling is used to obtain the elevation of the terrain.

Nowadays a wide range of DEMs are available with almost complete global coverage. The most important ones are the following:

- **Shuttle Radar Topography Mission** – The DEMs collected in 2000 when a radar pair mounted on a space shuttle mapped nearly the entire globe at 30m resolution.[21]

- **ASTER GDEM** – A global DEM from ASTER covering land surfaces between 83°N and 83°S that was produced through automated photogrammetric processing of 2.3 million scenes from the ASTER archive.[22]

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[21] NASA Jet Propulsion Laboratory, "Shuttle Radar Topography Mission: U.S. Releases Enhanced Shuttle Land Elevation Data". Available at https://www2.jpl.nasa.gov/srtm/. Data can be downloaded from http://srtm.csi.cgiar.org/srtmdata/.
[22] Data can be downloaded from https://lpdaac.usgs.gov/products/astgtmv003/.

- **ALOS PALSAR** – A DEM product derived from synthetic aperture radar on board the ALOS satellite. The DEM data has a resolution of 12.5m.[23]

- **WorldDEM** – A commercial high-resolution DEM product that is available globally. It has the highest accuracy of all global DEM products—2m (relative) / 4m (absolute) vertical accuracy in a 12m x 12m raster. Data is not freely available.[24]

2.4 Thematic Datasets

There are many thematic datasets available on the Internet. Some examples are provided:

- **Google Earth Engine** – One of the new tools is Google Earth Engine. Its public data archive includes more than forty years of historical imagery and scientific datasets, updated and expanded daily.[25]

- **GeoNetwork** – The Food and Agricultural Organization (FAO) of the United Nations has prepared a number of useful tools, including the GeoNetwork. The available data comprises base layers (e.g., boundaries, roads, rivers), thematic layers (e.g., protected areas) or a backdrop image (e.g., World Forest 2000).[26]

- **Geology and soils** – There are several global datasets for geology and soils. OneGeology[27] is an attempt to bring together geological maps from all over the world into a single data portal. USGS has a global geological map at scale 1:35 million that can be used as a GIS layer.[28] Soil data can be obtained from SoilGrids,[29] a system for global digital soil mapping that uses machine learning methods to map the spatial distribution of soil properties across the globe at 250m resolution.

- **Land cover** – There are many global land cover products available that can be accessed online. For Europe, the CORINE Land Cover database was initiated in 1985, and updates have been produced in 2000, 2006, 2012 and 2018.[30] At the

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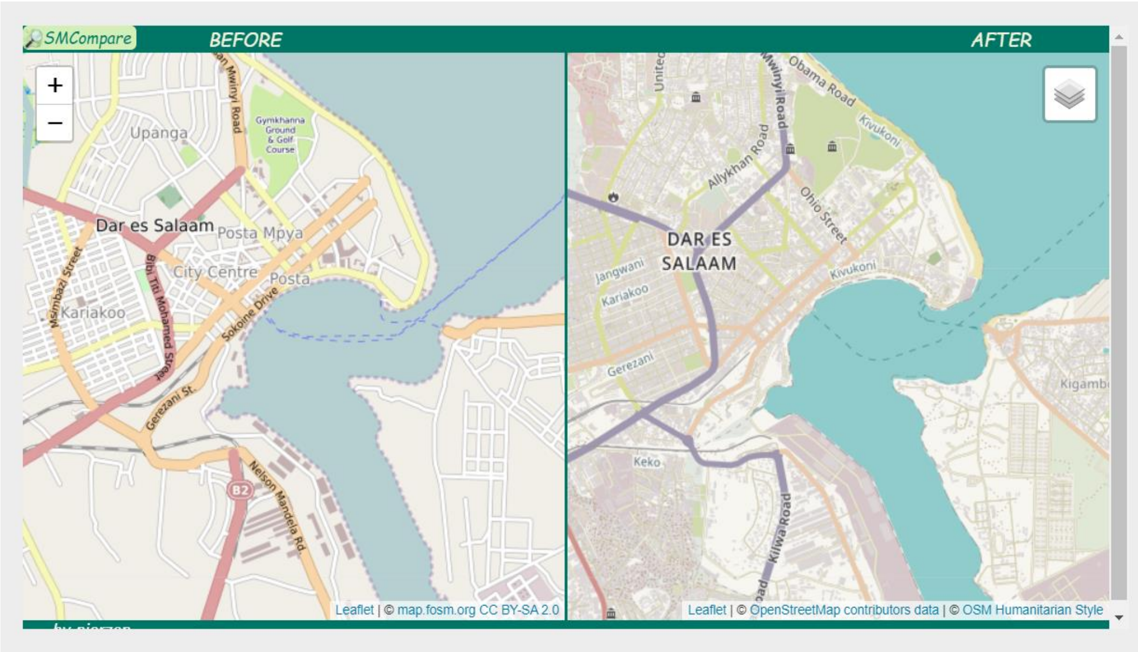
[23] Data can be downloaded from https://asf.alaska.edu/data-sets/derived-data-sets/alos-palsar-rtc/alos-palsar-radiometric-terrain-correction/.
[24] Quick looks can be seen from https://worlddem-database.terrasar.com/.
[25] Google Earth Engine Data Catalogue. Available at https://developers.google.com/earth-engine/datasets/.
[26] FAO GeoNetwork. Available at http://www.fao.org/geonetwork/srv/en/main.home.
[27] OneGeology. Available at http://portal.onegeology.org/OnegeologyGlobal/.
[28] USGS Global Geological Map. Available at https://mrdata.usgs.gov/geology/world/map-us.html.
[29] SoilGrids. Available at https://soilgrids.org/.
[30] Copernicus, “CORINE Land Cover”. Available at https://land.copernicus.eu/pan-european/corine-land-cover.

global level, there is the Copernicus Global Land Service,[31] GlobalForestWatch[32] and GlobCover—a European Space Agency initiative to deliver global land cover maps using as input, observations from the 300m MERIS sensor on board the ENVISAT satellite mission.[33]

- **OpenStreetMap (OSM)** – A collaborative project to create a global spatial database of built-up areas. Anyone can contribute to OSM, and OSM's data is free to share and use.[34] In several GIS programmes, the OSM files can be imported and used with other data sources, such as QGIS3 and QuickOSM.[35] An example of the use of OSM data for DRM is Ramani Huria, a community-based mapping project in Dar es Salaam, Tanzania. University students and local community members were involved to create highly accurate maps of the most flood-prone areas of the city (Figure 10).[36]

Figure 10: Example of community-based mapping using drones and OSM for DRM in Dar es Salaam, Tanzania



Notes: Left image shows OSM before the start of the project; and right image shows OSM at the end of the project.

Source: Ramani Huria. Available at https://ramanihuria.org/en/.

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31 Copernicus, "Global Land Cover". Available at https://lcviewer.vito.be/.
32 GlobalForestWatch. Available at https://www.globalforestwatch.org/.
33 European Space Agency, "GlobCover". Available at http://due.esrin.esa.int/page_globcover.php.
34 OpenStreetMap. Available at https://www.openstreetmap.org/.
35 See Hatari Labs, "How to smart download OpenStreetMap spatial data with QGIS3 and QuickOSM", YouTube video, 1 October 2018. Available at https://www.youtube.com/watch?v=GHEO9mljbqo.
36 Ramani Huria. Available at https://ramanihuria.org/en/.

- **Population data** – There are several initiatives for global population mapping. The LandScan dataset was first produced in 1998 as an improved resolution global population distribution database for estimating populations at risk. Different data sources are integrated and a multi-variable dasymetric modelling approach is used to disaggregate census counts within an administrative boundary.[37]

  Other initiatives include WorldPop that produces different types of gridded population count datasets, including the estimated total number of people per 100m grid-cell,[38] and the Global Human Settlement Layer produced by the Joint Research Centre of the European Commission.[39]

2.5 Historical Hazard / Disaster Event Data

Knowledge about the locations of historical hazards and disaster events and their impacts is crucial for understanding the disaster risks and taking appropriate risk reduction measures. Historical hazard information indicating where, when and what type of events occurred, is crucial for developing reliable hazard maps, based on the assumption, “the past is the key to the present”.

In addition, historical disaster data indicating the type and amount of losses per administrative area is essential for developing and validating risk models and their outputs (risk maps). Generally, there are different stakeholders involved in the collection of historical hazard data and in maintaining disaster databases.

2.5.1 Historical Hazard Data

Historical hazard events, such as earthquakes, landslides, floods and wildfires are mostly collected by expert organizations that analyse the particular types of hazards. Some examples are provided as follows:

- Global earthquake data can be obtained from USGS.[40]

- Flood events can be obtained from different sources. The Global Flood Monitor[41] detects flood events by automatically analysing social media (Twitter) in 11 languages. Both historical and real-time events are shown. Flood events mapped

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[37] A detailed description of the methodology can be found at Oak Ridge National Laboratory, "Documentation". Available at https://landscan.ornl.gov/documentation.
[38] WorldPop. Available at https://www.worldpop.org/.
[39] European Commission, "Global Human Settlement". Available at https://ghsl.jrc.ec.europa.eu/.
[40] USGS, "Earthquake Hazards". Available at https://www.usgs.gov/natural-hazards/earthquake-hazards/earthquakes.
[41] Global Flood Monitor. Available at https://www.globalfloodmonitor.org/.

from satellite images (e.g., Landsat and MODIS) can be found on a global flood observatory.[42]

- Wildfires mapped from satellite images can be found on GlobalForestWatch.[43]

- A global inventory of rainfall-induced landslides can be found on NASA's open data portal.[44] Global data on landslides that resulted in casualties can be found on the Global Fatal Landslide Database of the University of Sheffield.[45]

For many types of hazards, such global databases are not detailed enough for generating appropriate hazard maps, and national or local databases should be consulted. However, these are either missing, incomplete or difficult to access in many countries. A good example of a publicly-available national landslide database is the one from Colombia.[46]

There are not many examples of collaborative mapping of hazard events, where citizens can contribute voluntarily to collect disaster information. Some examples are provided as follows:

- **NASA Landslide Reporter** – Volunteers from any part of the world can contribute with landslide reporting in order to improve the models for landslide early warning.[47]

- **USGS Felt Report** – This is a tool where people can report the effects of earthquakes in order to make the earthquake intensity maps more accurate.[48]

2.5.2 Historical Disaster Data

The collection of historical disaster event data is generally the responsibility of the designated national agencies and therefore, the collected information and sources can be heterogeneous across a region. Nevertheless, there are a number of

[42] Dartmouth Flood Observatory. Available at http://floodobservatory.colorado.edu/WebMapServerDataLinks.html.
[43] GlobalForestWatch Fires. Available at https://fires.globalforestwatch.org/home/.
[44] NASA's Open Data Portal, "Global Landslide Catalog". Available at https://data.nasa.gov/Earth-Science/Global-Landslide-Catalog/h9d8-neg4.
[45] University of Sheffield, "Global Fatal Landslide Database". Available at https://shefuni.maps.arcgis.com/apps/webappviewer/index.html?id=98462998953c4f1fbd7caaa166373f63.
[46] Servicio Geológico Colombiano, "Sistema de Información de Movimientos en Masa". Available at http://simma.sgc.gov.co/.
[47] NASA, "Landslide Reporter: Crowdsourcing Landslide Data". Available at https://maps.nccs.nasa.gov/apps/landslide_reporter/.
[48] USGS, "Earthquake Hazards Program: Felt Report - Tell Us!" Available at https://earthquake.usgs.gov/earthquakes/eventpage/tellus.

organizations that collect information on historical disaster events, at different scales and with different objectives, as follows:

- **EM-DAT**[49] – Since 1988, the World Health Organization Collaborating Centre for Research on the Epidemiology of Disasters has been maintaining an emergency events database called EM-DAT. However, only disasters that fulfil a set of criteria is included in the database: they have to kill 10 or more people, affect 100 or more people, and result in a declaration of emergency or lead to a call for external assistance. Although the EM-DAT database is the most comprehensive globally and is being used by international organizations, it is less applicable at the local level as many smaller events that do not meet the inclusion criteria are missing.

- **DesInventar**[50] – Since 1994, a bottom-up approach has been established to develop local-level disaster databases called DesInventar. This initiative started in Latin America and was later expanded to other regions with support from the United Nations Development Programme (UNDP) and the United Nations Office for Disaster Risk Reduction (UNDRR). Now, similar systems have been implemented in countries in Asia, Africa and the Caribbean. The open source DesInventar is a conceptual and methodological tool for the generation of national disaster inventories and the construction of nationally-owned databases of damage, losses and the effects of disasters. DesInventar is now integral to the Sendai Framework Monitor that measures the implementation of the Sendai Framework.

- **GLIDEnumber**[51] – The Asian Disaster Reduction Center has established a database to provide a unique identification of major disasters using a globally-common unique ID "GLIDE", with information on the date, duration, location, magnitude, source and a description of the disaster event. The database, however, has gaps.

- **(Re)insurance companies** – (Re)insurance companies like MunichRe and SwissRe have been collecting data on disaster impacts. For instance, the Munich Re database for natural catastrophes, NatCatSERVICE, includes more than 23,000 entries on material and human loss events worldwide. However, the data is not publicly available, but MunichRe maintains a website providing general disaster information.[52]

[49] EM-DAT. Available at https://www.emdat.be/.
[50] DesInventar Sendai. Available at https://www.desinventar.net/.
[51] GLIDEnumber. Available at https://glidenumber.net/.
[52] Munich RE, "NatCatSERVICE". Available at https://natcatservice.munichre.com/.

Something To Do

The aim of this task is to compare and evaluate the completeness of the various disaster databases.

Choose a disaster event in your country or a disaster event in another country that you know about. Compare the data of the chosen disaster event in the following databases:

- EM-DAT database (https://www.emdat.be/). You need to register before you can login;
- DesInventar (https://www.desinventar.net/);
- GLIDEnumber (https://glidenumber.net/); and
- National and local disaster databases maintained by your country, if available.

Share the results from your evaluation of the completeness of the disaster databases with other training participants or your colleagues.

2.6 Hazard and Risk Data

Besides access to datasets that can be used for hazard and risk assessment, there is an increasing number of analysed hazard and risk information that can be consulted. However, their coarse spatial resolutions (e.g., in terms of 1-10km) may not be useful for DRM at national or subnational levels. Some examples of such readily-available hazard and risk information include the following:

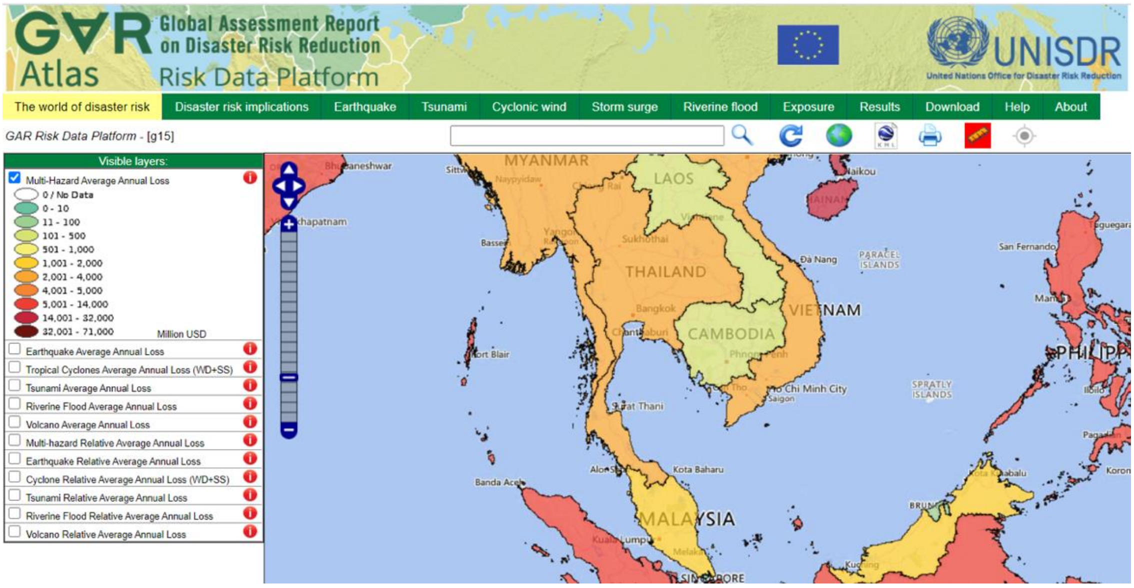
- **Think Hazard**[53] – This initiative provides a general view of the hazards for a given location that should be considered in project design and implementation to promote disaster and climate resilience. The tool highlights the likelihood of different natural hazards affecting administrative areas (very low, low, medium and high), provides guidance on how to reduce the impact of these hazards, and where to find more information. The hazard levels given are based on published hazard data provided by a range of private, academic and public organizations.

- **Global GAR data portal** – The Global Assessment Report on Disaster Risk Reduction (GAR) is the report of the United Nations on worldwide efforts to reduce disaster risk. The GAR is published biennially by the UNDRR, and is the product of contributions from nations, and public and private disaster risk-related science and research, amongst others. In 2015, the GAR was supported by a Risk Data Platform[54] in which all available data on past hazard events, human

[53] ThinkHazard! Available at https://thinkhazard.org/en/.
[54] UNDRR, "GAR Risk Data Platform". Available at https://risk.preventionweb.net/capraviewer/.

and economical hazard exposure, and risk from natural hazards is provided via an interactive platform for viewing and downloading. The software for the platform is a module of the Comprehensive Approach to Probabilistic Risk Assessment (CAPRA) software suite of products. But it can be used in stand-alone form as a spatial data infrastructure and web mapping service for a wide range of applications. Some of the source code have been taken from the DesInventar open source initiative and uses Tomcat, an Apache Software Foundation product.

Figure 11: Screenshot of the GAR Risk Data Platform

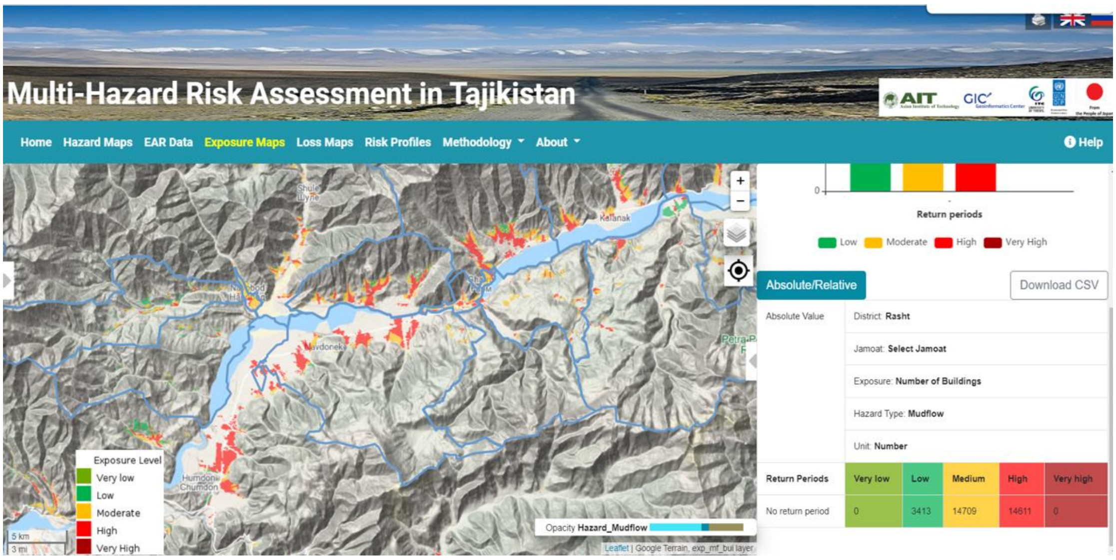


Source: UNDRR, "GAR Risk Data Platform". Available at https://risk.preventionweb.net/capraviewer/.

- **National data portal** – There are some national data portals for hazard and risk information. One example is the Multi-Hazard Risk Analysis per District Platform in Tajikistan, developed by AIT-GIC and ITC-UT with support from UNDP and the Japanese government in 2020.[55] This platform allows you to analyse the risk of seven types of hazards against three types of elements-at-risk at the district and *jamoat* (subdistrict) levels in Tajikistan. You can query the maps, generate custom-made risk profiles for the administrative units and save them as reports. The data is from national organizations and international data sources.

[55] Multi-Hazard Risk Assessment in Tajikistan. Available at http://tajirisk.ait.ac.th/.

Figure 12: Screenshot of the Multi-Hazard Risk Analysis per District Platform in Tajikistan



Source: Multi-Hazard Risk Assessment in Tajikistan. Available at http://tajirisk.ait.ac.th/.

2.7 Spatial Data Infrastructure

The sharing of geospatial information is challenging because the world's geography is diverse, dynamic and complex. What geospatial data captures is influenced by our professional discipline, our culture and/or our view of the world in light of the subject we are addressing at a particular time.

The purpose of a national spatial data infrastructure (NSDI) is to facilitate and coordinate the useful exchange and sharing of geographic information and services. It is the means by which governments and organizations have developed interoperability for geographic information. The data produced according to the guidelines of the NSDI is as follows:

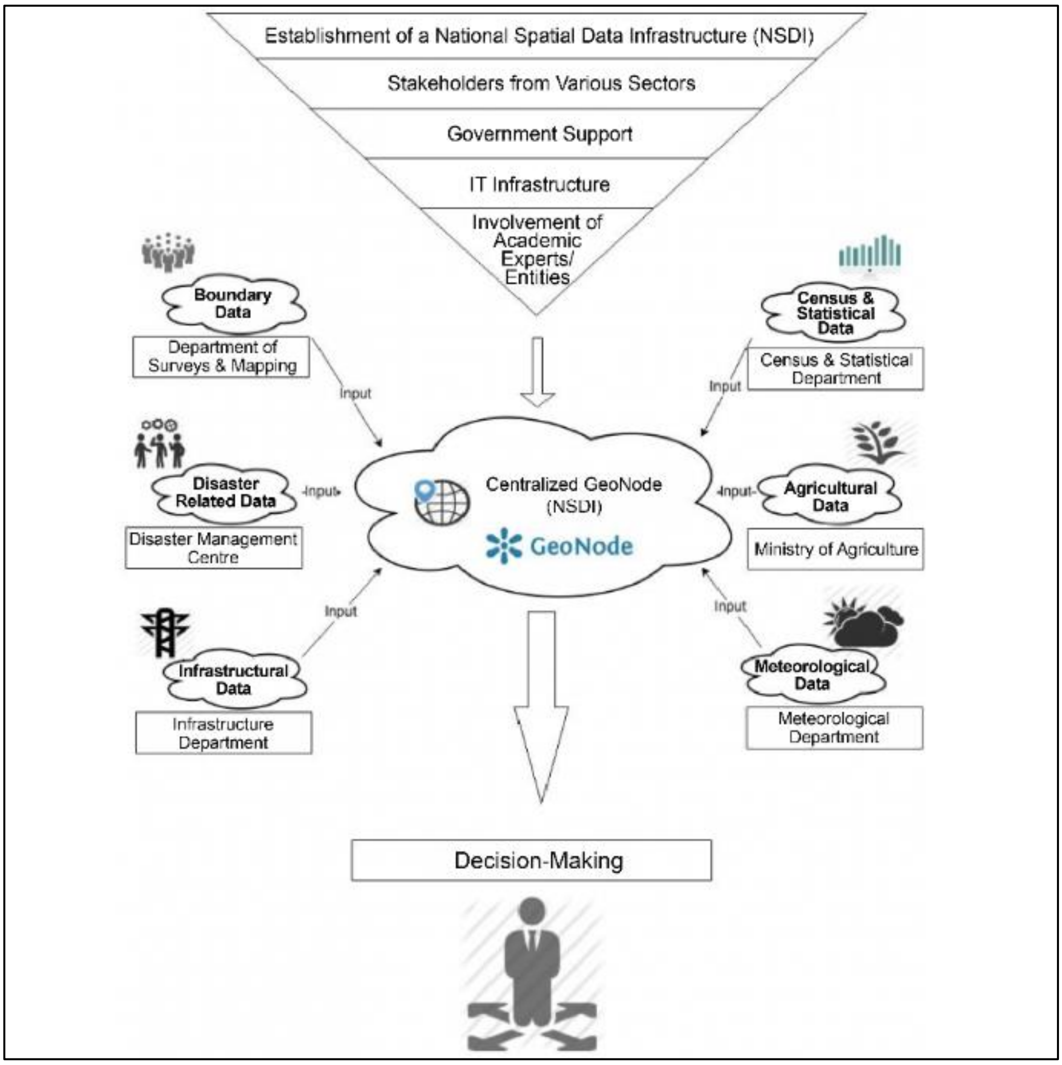
- Ready and available to be used in a GIS;
- Easily distributed for others to use;
- Can be worked on by two or more people or organizations at once;
- Can be applied in many different ways; and
- More efficient and cost effective to use.

In order to gain the maximum benefit from the NSDI, it is necessary to have a well-organized and carefully-coordinated framework and policies in place for data and infrastructure management. Coordination among the stakeholders and an enabling environment are also important. Unless there is proper understanding and coordination among the stakeholders, a sustainable geospatial data sharing system cannot be developed.

The NSDI is a key component of the geospatial framework for institutional collaboration. The NSDI has to manage the following aspects in order to provide a proper mechanism to facilitate collaboration and sustain the geospatial data sharing platform (Figure 13):

- Stakeholders from organizations and coordination among them;
- A supportive environment for the sharing and utilization of geospatial data;
- Technology and infrastructure; and
- Human resources involving academic experts and entities.

Figure 13: Example of a framework for country-level data sharing



These aspects of the framework are explained in turn:

- **Stakeholders** – Since data is often scattered in different departments and agencies across a country, the NSDI can be used to aid in the collection, processing, management, access, delivery and use of spatial data.

The process of establishing an NSDI varies from country to country. The involvement of policymakers of a country is certainly required to assess the departments and agencies that are actively developing spatial data, and appoint a focal point to coordinate the NSDI. For example, the Government of Belize appointed the Ministry of Natural Resources and Agriculture as the focal point for the NSDI.

The focal point needs to then identify and engage with relevant departments and agencies in setting up institutional agreements on data sharing. By bringing various stakeholders under the NSDI, it is possible to bring data to one place. For instance, the coordinating organization of the NSDI may assign the responsibility of maintaining census data to the country's Census Department. Then, based on the suggestions and recommendations of the Census Department, an agreement can be developed to set permissions allowing the public or a group of users, access to the census data.

- **Supportive environment** – For the NSDI to succeed, it is essential to receive continuous support from the national government, particularly in promoting coordination among the department and agencies, and creating an enabling environment for data sharing. The entity identified as the focal point for establishing the NSDI in a country can raise awareness on the importance of the NSDI to its national counterparts and seek their support, as well as establish and promote policies and legal frameworks to enable the efficient sharing of spatial data.

  A major challenge in inter-agency data sharing is the perceived loss of authority and power over the data. However, this challenge can be addressed through reassurance to the data-holding departments and agencies that the sharing of data benefits both the government and citizens, especially in humanitarian assistance during disasters. Moreover, they need to be assured that sensitive data, such as those that may cause a threat to national security, for example, can be restricted based on the NSDI data access rights. In order to facilitate and encourage open data sharing, the development and adoption of policies and agreements between departments and agencies are important.

- **Technologies and infrastructures** – Technologies and their standards are important for the NSDI. A standard is a documented agreement between a producer and a consumer. It is a reference document to be used in contracts and international trade that specifies definitions of characteristics, technical design and content, precise criteria, rules, and guidelines. Standards ensure that material products, processes and services are fit for purpose.

  The ICT infrastructure—normally a centralized system that can host a large amount of data with many concurrent connections to the servers—is also critical for establishing the NSDI. Since high network traffic is expected, it is essential to have a reliable and persistent Internet connection such as a leased line. The system should operate 24x7 and requires redundant power supplies and system backups.

- **Human resources** – The NSDI will be successful only if the data is provided, accessed and used by knowledgeable people and organizations. Users of the spatial data must have the necessary training and knowledge to understand and use it properly. Users must know, for example, the type of resources that can be used for a specific analysis. Efficient and proper application of spatial data requires education and knowledge in ICTs and databases, and in some cases, web applications, geodesy and coordinate reference systems, remote sensing, statistics, and spatial theory. Involvement of academic and research institutes will help in creating a knowledge hub as they provide undergraduate and postgraduate education and advanced research programmes.

In order to provide an ICT platform for stakeholders to collect, store, analyse and present geospatial data, a GIS system is required. Conventional GIS systems include all components of a GIS, such as data management, data analysis or application, and data presentation in one single platform or tier. They have a non-distributable software design, meaning that all components are in the same system. This makes it difficult to share results with other users located in different places.

Therefore, to be able to visualize and analyse data that is located elsewhere physically, and do that with many different clients, another design is needed. In a web-based GIS all the individual layers are separated (multi-tier). This allows many users (or clients) to access and visualize the data at the same time. It offers the possibility to connect different client platforms (e.g., personal computers, tablets, mobile phones) to the same information system.

A WebGIS is a special GIS tool that uses the Internet as a means to access and transmit remote data, conduct analysis and present GIS results. Other terms for WebGIS include Internet GIS, Distributed GIS, Online GIS and Networked GIS. In a WebGIS, a client-server approach is used with clients requesting information and servers responding to individual requests.

In a simple case, a client (browser) requests a Hypertext Markup Language (HTML) document from a web server (HTML server). However in a WebGIS, the transferred document is not a simple copy of a previously stored HTML document. Based on the request parameters, the output is dynamically generated as a map. Therefore, the WebGIS system uses other languages, referred to as Extensible Markup Language (XML), such as Geographical Markup Language for geographical data and Scalable Vector Graphics for two-dimensional graphics.

The systems should be interoperable, meaning that they should be able to transfer data and metadata seamlessly and access functions seamlessly. This requires interfaces and standardization. For WebGIS applications, the standardization is done by the Open Geospatial Consortium, a non-profit organization that aims to deliver spatial interface specifications that are openly available for global use. There are several Open Geospatial Consortium web service specifications, such as the Web Coverage Service for raster data and satellite imagery, and the Web Feature Service for vector data.

GeoNode is an example of a web-based application and platform for developing geospatial information systems and deploying spatial data infrastructures. It brings together mature and stable open-source software projects under a consistent and easy-to-use interface allowing non-specialized users to share data and create interactive maps.

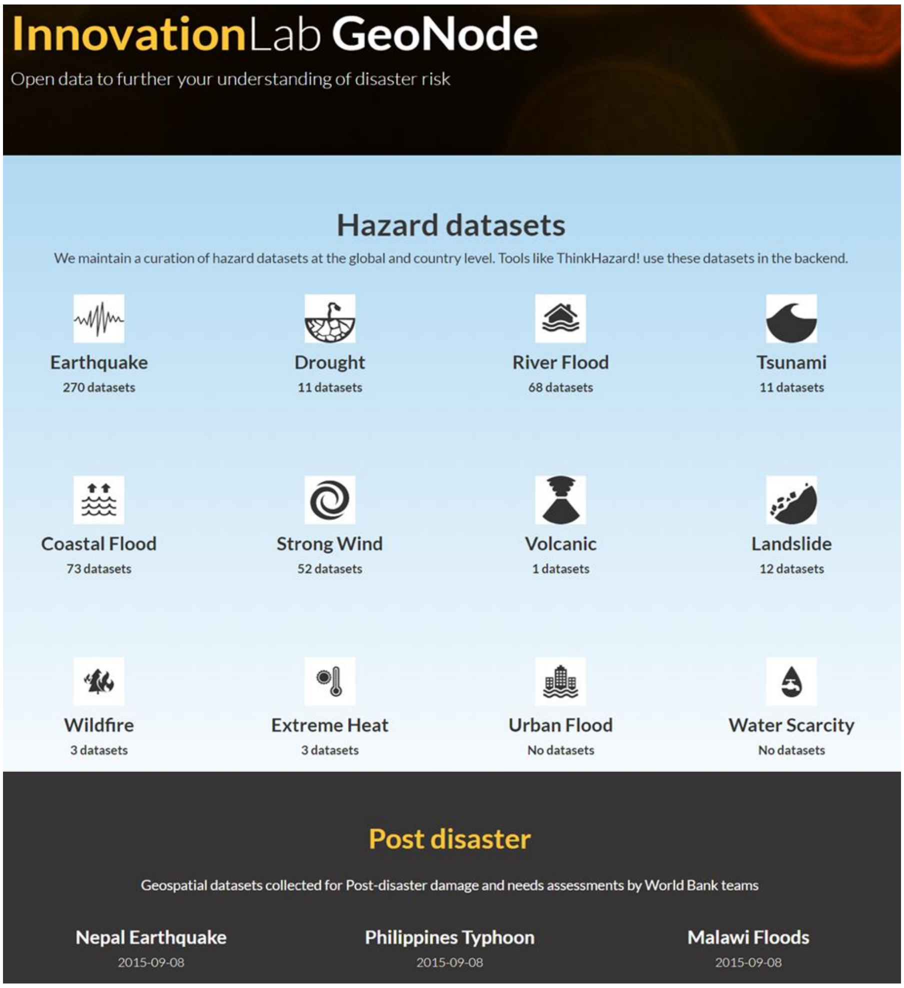
Data management tools built into GeoNode allow for the creation of data, metadata and map visualizations. Each dataset in the system can be shared publicly or restricted to allow access to only specific users. Features like user profiles, commenting and rating encourage the development of communities around the platform to facilitate the use, management and quality control of the data.

GeoNode is also designed to be a flexible platform that software developers can extend, modify or integrate to meet requirements in their own applications. Once the data is uploaded, GeoNode allows users to search for it geographically or via keywords. All the layers are automatically projected to Web Mercator for maps display, making it possible to use popular base layers like OSM, Google Map and Bing Map layers.

GeoNode comes with helpful cartographic tools for styling and composing maps graphically. Once data layers are uploaded and saved, it is possible to overlay them for visualization or make a PDF copy for printing. Cartographic tools make it easy for anyone to create and share maps with functionality traditionally found in desktop GIS applications. Organizations such as the World Food Programme[56] and the World Bank's Global Facility for Disaster Reduction and Recovery[57] have created GeoNode platforms to create and share geospatial data and maps (Figure 14).

[56] WFPGeoNode. Available at https://geonode.wfp.org/.
[57] Global Facility for Disaster Reduction and Recovery Innovation Lab GeoNode. Available at https://www.geonode-gfdrrlab.org/.

Figure 14: Screenshot of the Global Facility for Disaster Reduction and Recovery Innovation Lab GeoNode



Source: Global Facility for Disaster Reduction and Recovery Innovation Lab GeoNode. Available at https://www.geonode-gfdrrlab.org/.

Case Study 2: The Asian and Pacific Centre for the Development of Disaster Information Management

The Asian and Pacific Centre for the Development of Disaster Information Management (APDIM) was inaugurated in December 2018 as a regional institution of ESCAP. Located in Tehran, Islamic Republic of Iran, APDIM aims to reduce human losses, material damages and the negative impacts of natural hazards through enhancement of disaster information management in Asia and the Pacific.

APDIM provides its services to countries and organizations of Asia and the Pacific in three areas: (1) developing a regional platform on disaster risk data and information; (2) providing capacity development support on disaster information management; and (3) providing services for transboundary disaster risk reduction and management.

One of APDIM's objectives is to bridge information and knowledge gaps and support evidence-based risk sensitive decision-making by establishing a regional platform that pools data, information and statistics on disaster risk. The regional platform will be developed in collaboration with ESCAP divisions and regional institutions such as the ICT and Disaster Risk Reduction Division, Statistics Division, APCICT and the Statistical Institute for Asia and the Pacific, as well as with UNDRR, UNDP, Global Centre for Disaster Statistics and other partners.

This open and free platform will contribute to reporting on the implementation of the Sendai Framework and will help member States and stakeholders collect, analyse and understand data. The platform will allow users to access data, tools and techniques from various sources, process them to develop information management products, and include their own datasets to create an information repository.

In addition, APDIM plans to develop the Asia-Pacific Disaster Risk Atlas, a regional information and knowledge portal that will act as a gateway to regional disaster risk databases, especially for cross-border disaster risks. This online portal will contain geospatial datasets relating to natural hazards and exposure of energy, telecommunications and transport infrastructure. It will enable users to view layers on a base map to determine how exposure varies throughout the region, and will provide a basic analysis of the selected data through the dashboard (Figure 15).

The portal will be used for short-term impact-based safety data sheets, risk forecast and long-term risk and loss assessment. The portal will also encourage data sharing between United Nations agencies.

Figure 15: Screenshot of the Asia-Pacific Disaster Risk Atlas

Sources: APDIM. Available at https://apdim.unescap.org/; APDIM Brochure. Available at https://apdim.unescap.org/docs/APDIM-brochure-2019.pdf; Mostafa Mohaghegh, "Sand and Dust Storms at Regional Scale: Opportunities for Partnership and Cooperation", presentation made at the Asian Conference on Disaster Reduction 2019, Ankara, Turkey, 25-27 November 2019. Available at https://www.adrc.asia/acdr/2019/documents/S4-04_APDIM.pdf; and Yuki Mitsuka, "Impact Based Forecasting and Early Warning System", presentation made at the Second KMA / WMO Workshop on Impact-based Forecasts in Asia, Seoul, Republic of Korea, 19-21 November 2018. Available at https://www.wmo.int/pages/prog/amp/pwsp/documents/Presentation_KMA_YMitsuka.pdf.

3. ICT FOR RISK ASSESSMENT AND RISK VISUALIZATION

3.1 Introduction

Figure 16: Risk can be classified as low, moderate and high

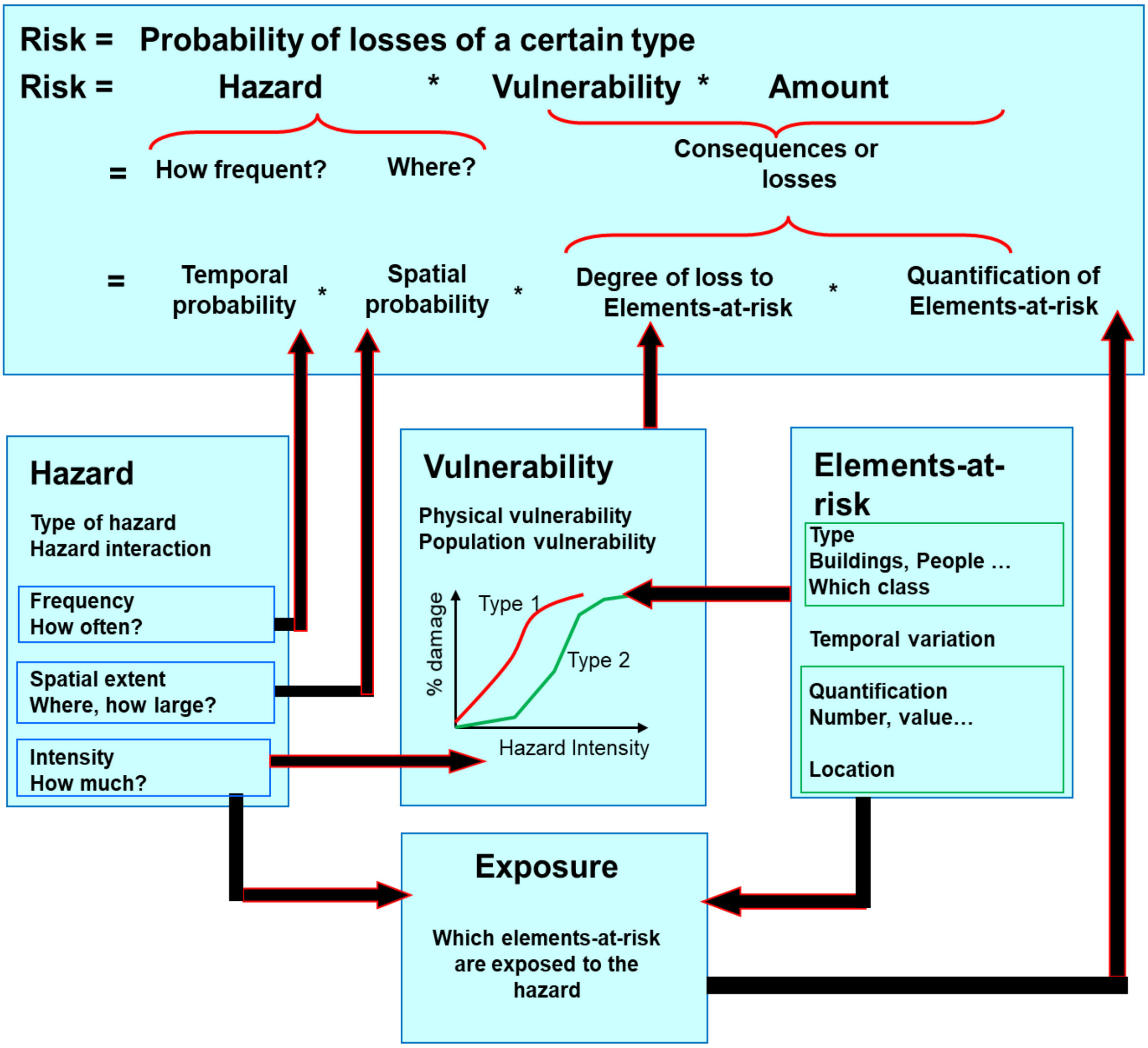
In order to effectively reduce disaster risk, it is important to first understand the risk. This section introduces the risk concept and the approaches used for risk assessment (Figure 17). Disaster risk assessment includes: (1) the identification of hazards; (2) a review of the technical characteristics of hazards such as their location, intensity, frequency and probability; and (3) the analysis of exposure and vulnerability, including the physical, social, health, environmental and economic dimensions. Conceptually, disaster risk can be presented using the following equation:

Risk = Hazard X Vulnerability X Amount of exposed elements-at-risk / Capacity

The equation can be used with spatial data in a GIS environment to quantify or calculate risk, with a focus on (direct) physical, population and economic losses.[58]

[58] Disaster risk is commonly depicted as Hazard x Vulnerability x Exposure, divided by Capacity. The spatial interaction between elements-at-risk and hazards, which is often referred to as "exposure" in the risk formula, is an integral component of GIS-based risk assessment.

Figure 17: Basic framework for risk assessment



Source: C.J. Van Westen and others, “Multi-Hazard Risk Assessment: Distance education course – Guidebook”, United Nations University – ITC School on Disaster Geo-information Management, 2011. Available at http://ftp.itc.nl/pub/westen/Multi_hazard_risk_course/Guidebook/Guidebook%20MHRA.pdf.

3.2 Disaster Risk Analysis

Disaster risk analysis requires a number of components, as indicated in the equation, which include: hazard, elements-at-risk, exposure, vulnerability and capacity.

Hazard is a process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation.[59] Hazards are characterized by their:

[59] UNDRR, "Terminology". Available at https://www.undrr.org/terminology.

- **Temporal probability** – Frequency;
- **Magnitude** – Size of the event (e.g., earthquake magnitude, flood discharge); and
- **Intensity** – The spatial distribution of the potential harmful characteristics (e.g., earthquake intensity, height of flood). Hazard intensity results from modelling the hazard spatially (e.g., earthquake acceleration, flood depth, debris flow impact pressure, concentration of toxic gas).

The hazard component in the equation refers to the probability of occurrence of a hazardous phenomenon with a given intensity within a specified period of time (e.g., year).

The hazard also has a spatial component, related to the initiation of the hazard (e.g., a volcano) and the spreading of the hazardous phenomena (e.g., the areas affected by volcanic products such as lava flows).

Thus, the hazard probability has two components—spatial and temporal. The temporal probability refers to the chance that a given hazard event occurs within a certain time period (i.e., how often). The spatial probability indicates the chance that a particular location in the area (e.g., a building) would be impacted if the hazard event occurs. Either temporal or spatial probability can be used to develop hazard maps.

Some hazards are modelled and therefore the chance is very high that the modelled areas will be impacted. For other hazards, it is sometimes only possible to indicate zones with more or less chance that the event may happen (e.g., for landslide susceptibility zones) and only an estimation can be made of the expected density of the hazard event (i.e., the spatial probability).

There have been many developments in recent years in the types and complexities of hazard analysis, which have been driven by improvements in computing power, the availability of data and the emergence of various high-quality physical models. These models are often data driven and hence, the quality of the input data plays a large role in the quality of the final result. New technologies, such as remote sensing and GIS are also revolutionizing our capacity to analyse hazards.

Table 2 shows the major hazards in Bhutan and the data required for hazard assessment.

Table 2: Hazard data requirements, types, sources and assessment methods for selected hazard types

Hazard	Data required	Data type and source	Assessment method
Flood	• Extent and location of flood-prone areas • Depth and duration of flood • River water level or discharge • Frequency and timing of occurrence • Rainfall volumes and intensities	• Historical records of frequency and location • Meteorological data: rainfall records and monitoring (e.g., rain gauges) • DEM • Land-use mapping • Hydrological data (river flows)	• Flood frequency analysis • Hydrologic modelling • Hydraulic modelling
Landslide	• Natural conditions affecting slope stability • Triggering factors: rainfall, earthquake • Vegetation and other land use • Number and type of landslides that may occur • Potential initiation and runout areas	• Identification of location, extent and frequency of previous landslides • Maps of rock formations and characteristics, surface geology, soil deposition, geomorphology, hydrology (especially groundwater and drainage) • DEM • Vegetation / land cover mapping	• Surveying, mapping, remote sensing • Historical records of characteristics and impact of past events • Dynamic or statistical modelling • Runout modelling
Windstorm and extreme rainfall	• Locations and extent of areas likely to be affected • Frequency of occurrence and directional patterns • Velocity and direction of wind (wind severity scales) • Associated pressure conditions, rainfall	• Historical and climatological records of frequency, location, characteristics (including cyclone paths) • Meteorological records of rainfall, wind speeds and directions • Topography and geomorphology of affected areas (where there is risk of flash flooding from heavy rainfall)	• Impact of past events • Weather forecasts
Earthquake	• Locations and extent of known seismic hazard zones, epicentres, faults • Magnitude and intensity • Frequency of events • Geological, geomorphological, hydrological features that influence ground shaking and deformation • Potential secondary effects: landslides, mudslides, avalanches, floods from dam failures	• Maps of seismic sources (faults, fault systems) • Geological, geomorphological maps and surveys • Data on past occurrence of earthquakes, their locations, characteristics (e.g., magnitude, intensity) and effects • Attenuation relations • Overburden characteristics (geotechnical characterization) • DEM	• Calculations of maximum ground accelerations • Zoning and micro-zoning (mapping / recording seismological, geological, hydro-geological parameters)

Source: Adapted from Charlotte Benson and John Twigg, *Tools for Mainstreaming Disaster Risk Reduction: Guidance Notes for Development Organisations* (Geneva, ProVention Consortium Secretariat, 2007). Available at https://www.preventionweb.net/files/7511_toolsformainstreamingDRR.pdf.

Elements-at-risk are the population, properties and economic activities, including public services and any other defined values exposed to hazards in a given area. They are also referred to as "assets". Elements-at-risk have spatial and non-spatial characteristics. There are many different types of elements-at-risk and they can be classified in various ways. A common classification is presented in Table 3.

Table 3: Classification of elements-at-risk

Physical elements • Buildings: Urban land use, construction types, building height, building age, total floor space, replacement costs • Monuments and cultural heritage	**Population** • Density of population, distribution in space, distribution in time, age distribution, gender distribution, disability distribution, income distribution
Essential facilities • Emergency shelters, schools, hospitals, fire brigades, police	**Socioeconomic aspects** • Organization of population, governance, community organization, government support, socioeconomic levels • Cultural heritage and traditions
Transportation facilities • Roads, railway, metro, public transportation systems, harbour facilities, airport facilities	**Economic activities** • Spatial distribution of economic activities, input-output table, dependency, redundancy, unemployment, economic production in various sectors
Lifelines • Water supply, electricity supply, gas supply, telecommunications, mobile phone network, sewage system	**Environmental elements** • Ecosystems, protected areas, natural parks, environmentally-sensitive areas, forests, wetlands, aquifers, flora, fauna, biodiversity

The way in which the elements-at-risk is characterized (e.g., as number of buildings, number of people, economic value or the area of qualitative classes of importance) defines the way in which the risk is presented.

The interaction between the elements-at-risk and the hazard defines the exposure and vulnerability of the elements-at-risk.

Exposure indicates the degree to which the elements-at-risk are exposed to a particular hazard. The spatial interaction between the elements-at-risk and the hazard footprint is depicted in a GIS by overlaying the hazard map with the elements-at-risk map.

Vulnerability refers to the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.[60]

Vulnerability can be divided into physical, social, economic and environmental vulnerabilities. The vulnerability of communities and households can be based on a number of criteria, such as age, gender and source of income, which are analysed using qualitative methods. The physical vulnerability is the degree of loss that a particular type of element-at-risk (e.g., a particular building type such as one-floor masonry) will experience if it is exposed to a certain intensity of the hazard. Physical vulnerability is often represented as a vulnerability curve.

The vulnerability of a particular element-at-risk is multiplied with the quantified value of the element-at-risk, which can be represented as a simple number (e.g., number of buildings or people) or economic value (e.g., of the structure and/or content). This value is usually calculated for the administrative units (e.g., neighbourhood, census tracks) and multiplied with the spatial probability to estimate the losses. The temporal probability of the hazard event is then combined with the losses in order to obtain the specific risk. The specific risks of hazard events are summed up to obtain the total risk.

Table 4: Summary of definitions used in disaster risk analysis

Term	Definition
Hazard	A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation.
Exposure	The situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas. Measures of exposure can include the number of people or types of assets in an area. These can be combined with the specific vulnerability and capacity of the exposed elements to any particular hazard to estimate the quantitative risks associated with that hazard in the area of interest.
Vulnerability	The conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.
Capacity	The combination of all the strengths, attributes and resources available within an organization, community or society to manage and reduce disaster risks and strengthen resilience.
Disaster Risk	The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity.

[60] UNDRR, "Terminology". Available at https://www.undrr.org/terminology.

Annual Average Loss	The long-term expected loss per year averaged over many years. While there may actually be little or no losses over a short period of time, the annual average loss accounts much larger losses that may occur more infrequently. In other words, it is the weighted average of expected loss from every event conditioned on the annual probability of each loss occurrence.
Probable Maximum Loss	The value of the largest loss that could result from a disaster in a defined return period such as 1 in 100 years. The term is always accompanied by the return period associated with the loss.

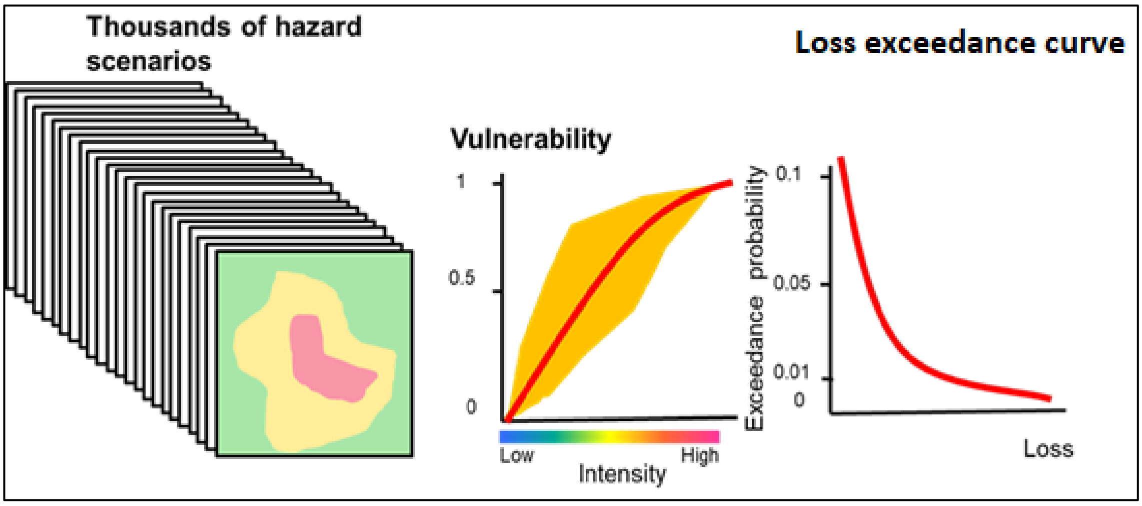
Source: UNDRR, "Terminology". Available at https://www.undrr.org/terminology.

3.3 Risk Assessment Approaches

For the assessment of risk, a number of approaches can be used, depending on the objective of the project and the amount of data available. The main approaches are highlighted as follows:

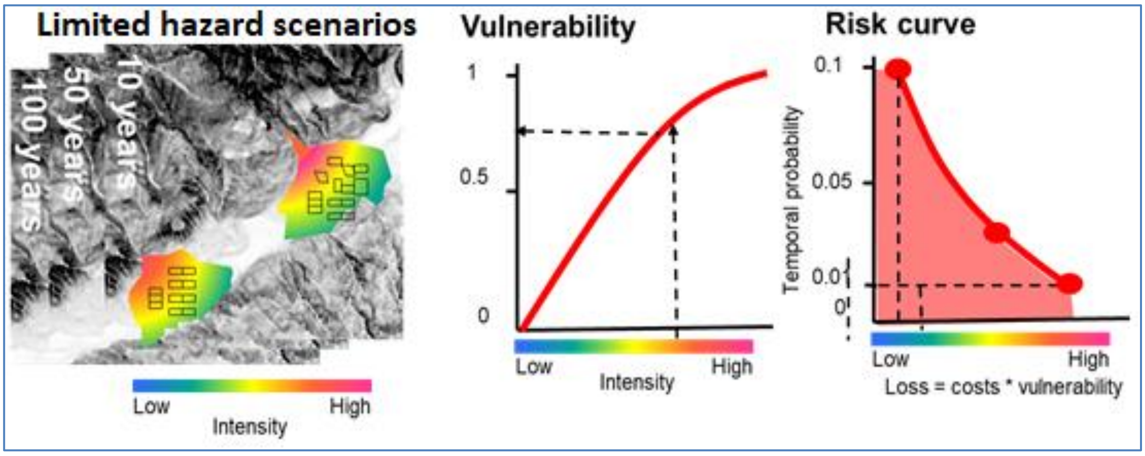
- **Probabilistic method** – This method uses a combination of probabilistic hazard scenarios, exposure and vulnerability that are produced through modelling. Probabilistic risk assessment takes into account all the disasters that could occur in the future, including very intensive losses over long return periods, and thus overcomes the limitations associated with estimates derived from historical disaster loss data. The method requires the modelling of all possible hazard events that may occur in the future. These scenarios are usually generated using specific software tools that combine statistical data on the frequency / magnitude of the events with empirical models for the expected results. Such models are particularly suited for hazards such as earthquakes and tropical storms.

Figure 18: Probabilistic risk assessment with thousands of hazard scenarios that incorporate uncertainty in risk components, resulting in a loss exceedance curve



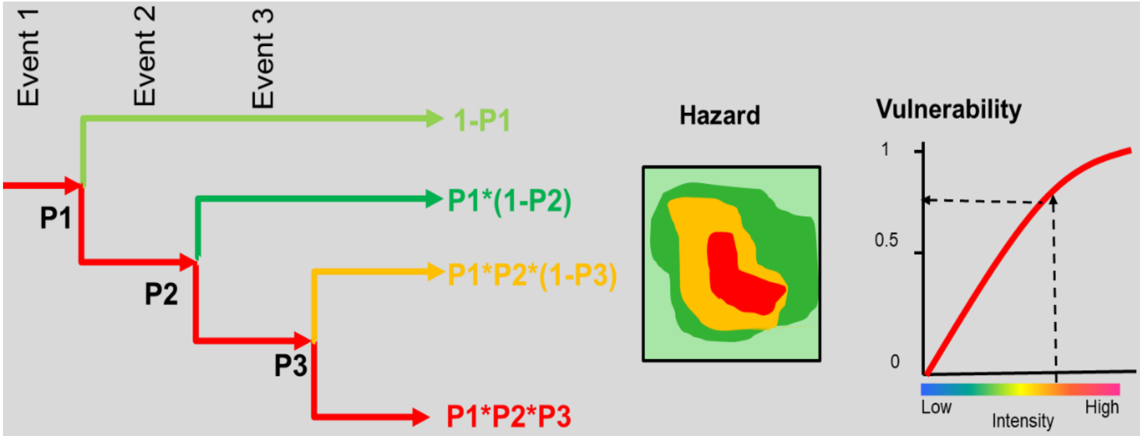
- **Quantitative deterministic method** – This method analyses the risk quantitatively using a limited number of hazard scenarios that have been modelled for different frequency. This method is often used for hazards that require extensive modelling to derive the hazard intensity (e.g., flood depth modelling). GIS operations are used to analyse the exposure as the intersection between the elements-at-risk and the hazard footprint area for each hazard scenario. The intensity values are used in combination with the element-at-risk type to find the corresponding vulnerability. The multiplication of exposed amounts and vulnerability gives the losses for the same hazard scenario, which are plotted against the temporal probability of occurrence in a risk curve. This is repeated for all available hazard scenarios. The area below the curve is the average annual loss that can be expected.

Figure 19: Quantitative deterministic method in which limited hazard scenarios are used for loss estimation, and the losses are plotted against temporal probability to obtain the risk



- **Event-tree analysis** – A number of hazards may occur in chains where one hazard triggers the next (e.g., an earthquake triggering a landslide that blocks the river and causes a dammed lake, which at some point will cause a dam-break flood). These are called domino effects or concatenated hazards, which are the most problematic types of hazards to analyse in a multi-hazard risk assessment. The best approach for analysing such hazard chains is to use an event-tree analysis. An event tree is applied to analyse all the combinations (and the associated probability of occurrence) of the parameters that affect the system under analysis. The analysed events are linked to each other by means of nodes. All possible states of the system are considered at each node and each state (branch of the event tree) is characterized by a defined value of probability of occurrence.

Figure 20: Schematic representation of an event-tree analysis of the probability of occurrence at each node of the tree



- **Semi-quantitative methods** – Risk assessments are often complex and do not allow for a full numerical approach, since many aspects are not quantifiable or have a very large degree of uncertainty. This may be related to the difficulty in defining hazard scenarios, in mapping and characterizing the elements-at-risk, or defining the vulnerability using vulnerability curves. In order to overcome these problems, the risk can be assessed using risk matrices or consequences-frequency matrices, which are diagrams with frequency and impact classes on the axes (Figure 21). They permit the classification of risk based on expert knowledge with limited quantitative data. The risk matrix is made of classes of frequency of the hazard events on one axis, and the impact (or expected losses) on the other axis. This approach permits the visualization of the effects and consequences of risk reduction measures and provides a framework for understanding the risk.

Figure 21: Risk matrix approach in which risk is determined by a combination of frequency and impact classes

		Impact			
		None	Small	Moderate	High
Frequency	Very High		High	Very High	Very High
	High		Moderate	High	Very High
	Moderate		Low	Moderate	High
	Low		Low	Low	Moderate
	None	No Risk			

- **Exposure-based methods** – Disaster risk assessment does not have to be data intensive. A basic form of risk is the exposure. In some instances, the location of a hazard event and the number of people or buildings exposed to that hazard event can be useful information for decision-making.

  For example, data on past hazard events (e.g., the location and depth of floods) can be collected using satellite images, community-based maps or mobile apps to determine the intensity and extent of floods. This can involve: (1) conducting a survey among the local residents on their experiences in recent memory; and (2) collecting characteristics and values of the exposed buildings.

Figure 22: Simple representation of elements-at-risk and the area that may be potentially affected by the hazard

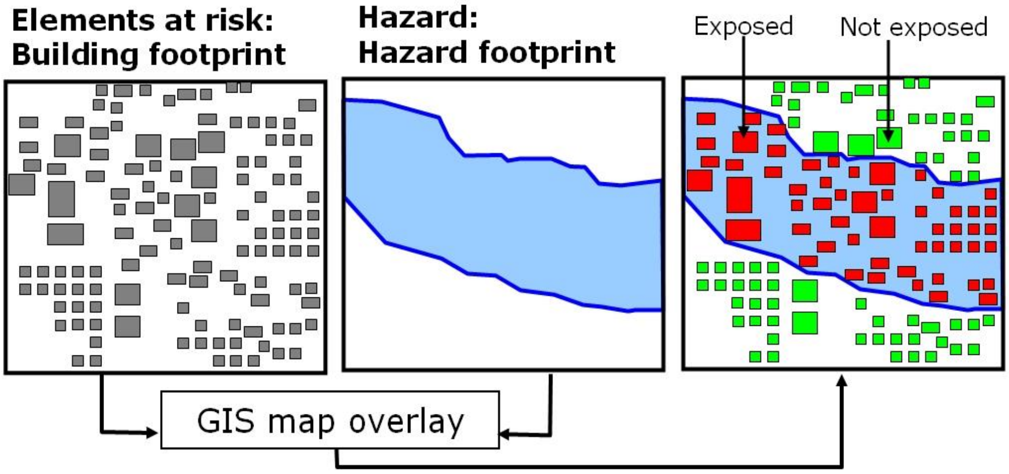


Figure 23: Flood depth and risk to buildings in Hue, Viet Nam

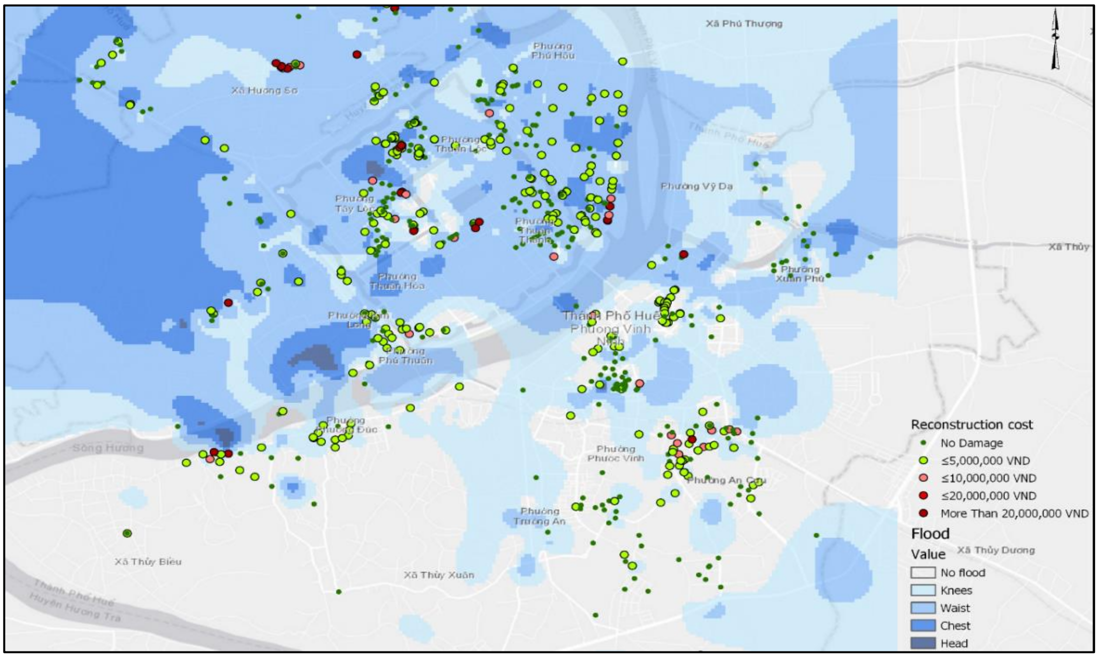


Figure 23 shows a case study from Viet Nam, where a field survey was conducted using a mobile app. While it may not be possible to obtain a detailed flood risk map, a hazard map with exposure levels of buildings and infrastructure can be developed for risk mitigation and prevention.

- **Qualitative methods** – There are many situations where the semi-quantitative method for risk mapping is not appropriate. This can be due to a lack of sufficient data available to quantify the components. Another reason is the need to take into account a number of different components of vulnerability that are not incorporated in the semi-quantitative method, such as social vulnerability, environmental vulnerability and capacity. In these cases, it is common to follow an indicator-based approach to measure vulnerability and risk through selected indicators to quantitatively compare different areas or communities.

  The spatial multi-criteria evaluation of disaster risk assessment is divided into a number of components, such as hazard, exposure, vulnerability and capacity, using a criteria tree, which lists the subdivision into objectives, sub-objectives and indicators. Data for each of these indicators are collected at a particular spatial level (e.g., by administrative units). These indicators are then standardized (e.g., by reclassifying them between 0 and 1), weighted internally within a sub-objective and then the various sub-objectives are also weighted amongst themselves.

Figure 24: Qualitative risk approach with indicators that are combined to provide a relative ranking

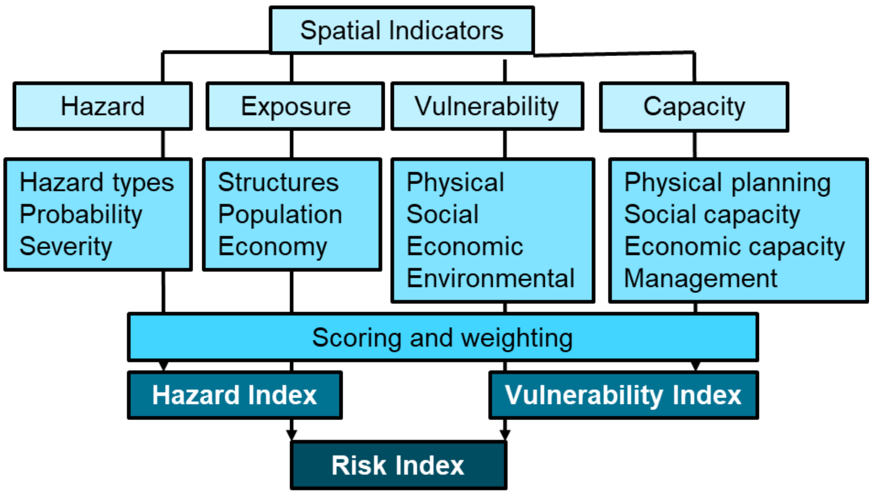


Table 5: Advantages and disadvantages of risk analysis methods

Method	Advantage	Disadvantage
Probabilistic risk assessment	Provide complete analysis of average annual losses as basis for financial decision-making.	Require specialized software and is not applicable for all types of hazards (e.g., landslide, volcano, flood). Very data demanding.
Deterministic quantitative risk assessment	Provide quantitative risk information that can be used in cost-benefit analysis of risk reduction measures.	Very data demanding. Difficult to quantify temporal probability, hazard intensity and vulnerability.
Event-tree analysis	Allow modelling of a sequence of events and works well for domino effects.	The probabilities for the different nodes are difficult to assess and spatial implementation is very difficult due to lack of data.
Risk matrix approach	Allow the expression of risk using classes instead of exact values, and is a good basis for discussing risk reduction measures.	Do not give quantitative values that can be =used in cost-benefit analysis of risk reduction measures. The assessment of frequencies and impacts is difficult, and one area may have different combinations of frequencies and impacts.
Simple exposure analysis	Simplest way to quantify data as basis for decision-making. Provide basis for preparedness planning.	Do not incorporate vulnerability and actual losses. Do not consider different events / frequencies.
Spatial multi-criteria evaluation	Only method that conducts a holistic risk assessment, including social, economic and environmental vulnerabilities and capacities.	The resulting risk is relative and does not provide information on actual expected losses.

3.4 Tools for Risk Analysis

Risk assessment is computationally intensive. It can be carried out using conventional GIS systems, although it is advisable to use specific software tools. Loss estimation has been carried out in the insurance sector since the late 1980s using dedicated systems for catastrophe modelling, developed by private companies resulting in a range of proprietary software models (e.g., AIR, RMS, EQECAT).[61] Unfortunately, most of these models are not publicly available, which is a major obstacle for risk assessment in many parts of the world.

[61] For an overview of the models see: Insurance Development Forum Oasis Hub. Available at https://catrisktools.oasishub.co/records/.

The best initiative for publicly-available loss estimation thus far is **Hazus**,[62] developed by the United States Federal Emergency Management Agency together with the National Institute of Building Sciences. The first version of Hazus was released in 1997 that focused on seismic loss estimation. This was extended to multi-hazard losses in 2004, incorporating losses from floods and windstorms. Hazus was developed as a software tool under ArcGIS. Several countries have adapted the Hazus methodology to their own situation. The Hazus methodology has also been the basis for the development of other software tools for loss estimation, such as **SELENA**.[63]

An interesting example is **RiskScape**[64] developed in New Zealand. The software combines hazard, asset and vulnerability layers through a data selection process to quantify a range of economic and social consequences. This helps practitioners make informed decisions on natural hazard management activities.

A simple tool for the analysis of exposure is **InaSAFE**.[65] It is a free software that produces realistic natural hazard impact scenarios for better planning, preparedness and response activities. It provides a simple but rigorous way to combine data from scientists, local governments and communities to provide insights into the likely impacts of future disaster events.

Another interesting development is in stand-alone software modules for multi-hazard risk assessment that are not running as a component of an existing GIS. A good example of this is **CAPRA**[66] for the World Bank Global Facility for Disaster Reduction and Recovery. The methodology focuses on the development of probabilistic hazard assessment modules for earthquake, hurricane, extreme rainfall and volcanic hazards, and the hazards triggered by them, such as floods, windstorms, landslides and tsunamis.

Another recent development is towards open source web-based modules for multi-hazard risk assessment. A tool that is currently under development as part of the Global Earthquake Initiative is **OpenQuake**.[67] This is most probably going to be the standard for earthquake loss estimation, and there are plans to expand it into a multi-hazard risk assessment tool.

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[62] United States Department of Homeland Security, "Hazus". Available at https://www.fema.gov/hazus/.
[63] NORSAR/ICG, "The SELENA-RISe Open Risk Package". Available at http://selena.sourceforge.net/index.shtml.
[64] RiskScape. Available at https://www.riskscape.org.nz/.
[65] InaSAFE. Available at http://inasafe.org/.
[66] CAPRA. Available at https://ecapra.org/.
[67] OpenQuake Platform. Available at https://platform.openquake.org/.

3.5 Types of Risk

Risk is defined as the probability of losses. The losses can be expressed in a number of different ways and can be direct or indirect:

- **Direct losses** are the losses that are directly caused by the hazard event (e.g., damaged or destroyed buildings); and

- **Indirect losses** are the longer-term losses as a consequence of the direct losses (e.g., loss of employment). Indirect losses can sometimes be much larger than the direct ones and they are more difficult to model.

Losses can be tangible (quantifiable) or intangible (e.g., losses to cultural heritage or environment). Table 6 gives an overview of the types of risk.

Table 6: Types of risk

Group	Type	Method	Risk is expressed as:
Qualitative	Relative risk	Spatial multi-criteria evaluation	A relative score or classified into classes (high, moderate, low)
	Classes	Risk matrix approach	Classes characterized by combination of frequency and impact
Semi-Quantitative	Exposed number	Simple exposure analysis	Exposed amount (buildings, roads, people, etc.) without probability and losses
	Exposed value	Simple exposure analysis	Exposed value of elements-at-risk in monetary terms, without probability or actual losses
Quantitative	Loss number	Deterministic quantitative risk assessment	Number of buildings, length of roads, area of agriculture destroyed
	Monetary losses	Probabilistic risk assessment, deterministic quantitative risk assessment, event-tree analysis	Monetary value of the losses
	Individual risk	Probabilistic risk assessment, deterministic quantitative risk assessment, event-tree analysis	Probability of being killed by one type of hazard for one person in the exposed area
	Societal risk	Probabilistic risk assessment, deterministic quantitative risk assessment, event-tree analysis	Number of people that may be killed in the area resulting from a hazard happening and the respective probabilities

The types of risk provide different types of information on the basis of which decisions are taken in different phases of the DRM cycle, as will be demonstrated in the next sections.

3.6 Risk Visualization

In order to make appropriate decisions on the basis of risk information, it is important to select the appropriate method to visualize and communicate the risk. Since risk is a spatially varying phenomenon, GIS is now the standard tool for the production and presentation of risk information. Risk can be presented in the following forms:

- **Statistical information per administrative unit** (country, province, municipality or neighbourhood), such as –
  - A risk index value resulting from qualitative risk assessment (e.g., spatial multi-criteria evaluation); or
  - Probable maximum loss or average annual loss.

- **Risk curves**, such as –
  - Loss exceedance curve for economic risk; or
  - F-N curve for societal risk.[68]

- **Maps** showing the spatial variation of risk over an area, such as –
  - A hazard map with an overlay of elements-at-risk;
  - Qualitative classification of risk classes by high, moderate and low; or
  - Quantitative estimation of building, economic or population losses per administrative unit.

- **Animations** showing the spatial and temporal distribution of hazards and risk, such as –
  - Flood animation showing the development of a flood over time, including the flood height and water velocity shown per time step as a movie file, overlain with elements-at-risk information; or
  - Fly-through, three-dimensional display of risk information over a high-resolution satellite image. For example, Google Earth can be used to develop such animations by overlaying the risk maps in GIS and KML files in Google Earth.

- **WebGIS applications** that allow users to combine and display different types of information, such as –
  - Hazard maps of individual hazard types;
  - Elements-at-risk information;

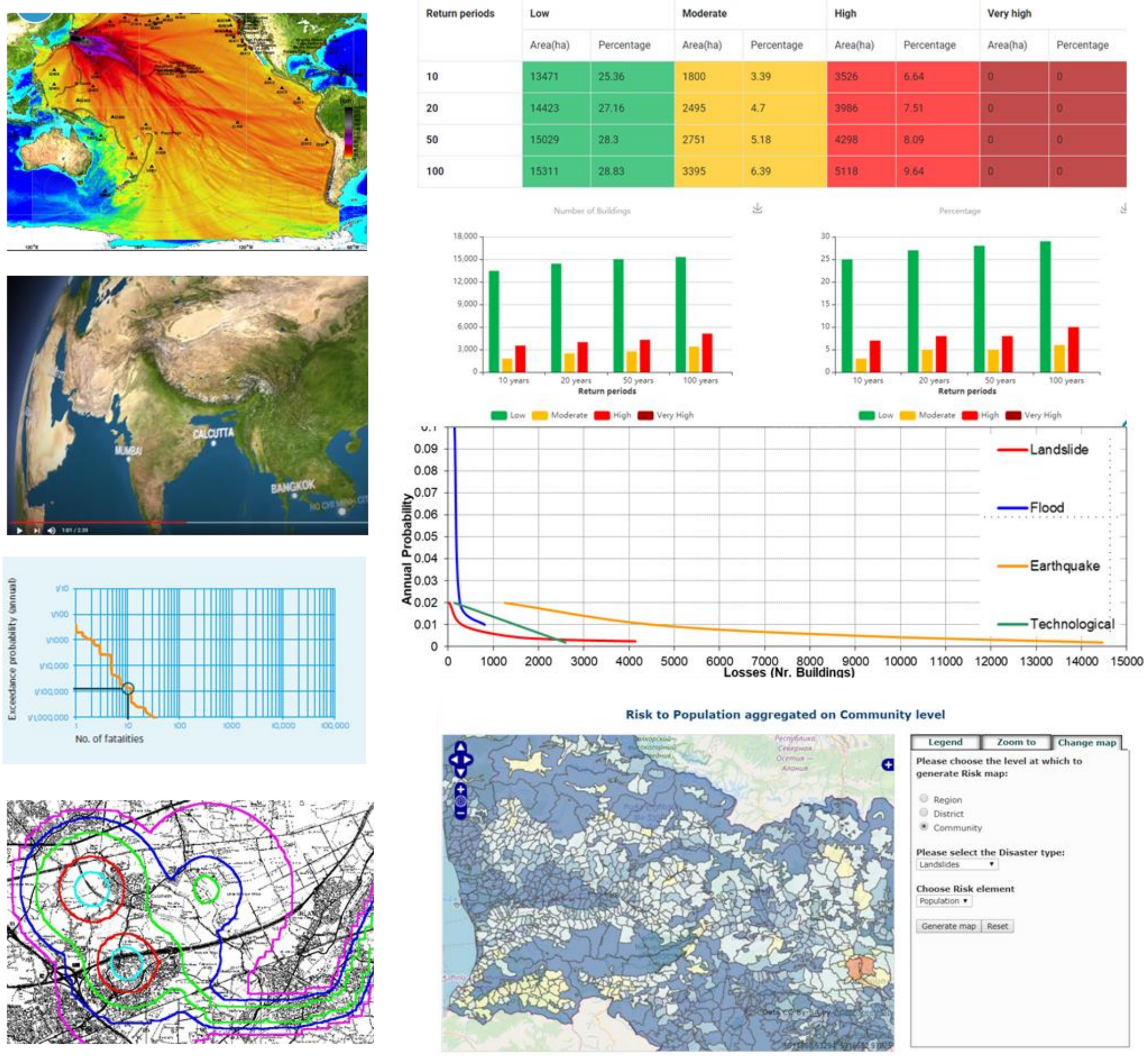
[68] An F-N curve provides a result of likelihood or frequency (F) of fatal events occurring causing a certain number of fatalities (N), within a given period of time, usually set for one year.

- Maps of individual risk types for different return periods; or
- Multi-hazard risk maps.

- **Spatial data infrastructure / clearinghouses that** allow users to share basic GIS data online among different technical and scientific organizations involved in hazard and risk assessments.

- **Decision-support systems** in which the risk data can be used in combination with other types of information to compare various decision alternatives and decide upon the optimal choice.

Figure 25: Examples of risk visualization for communicating risk



Notes: From bottom left in clockwise direction – individual risk contours, societal risk graph, video animation, model animations, exposure tables, exposure bar graphs, risk curves and spatial decision-support system.

Risk visualization needs more attention to ensure that the key results from the risk assessments conducted by a group of thematic experts are effectively communicated to targeted stakeholders, decision makers and end users, allowing them to make informed decisions.

Table 7: The relationship between stakeholders in risk management and risk visualization options

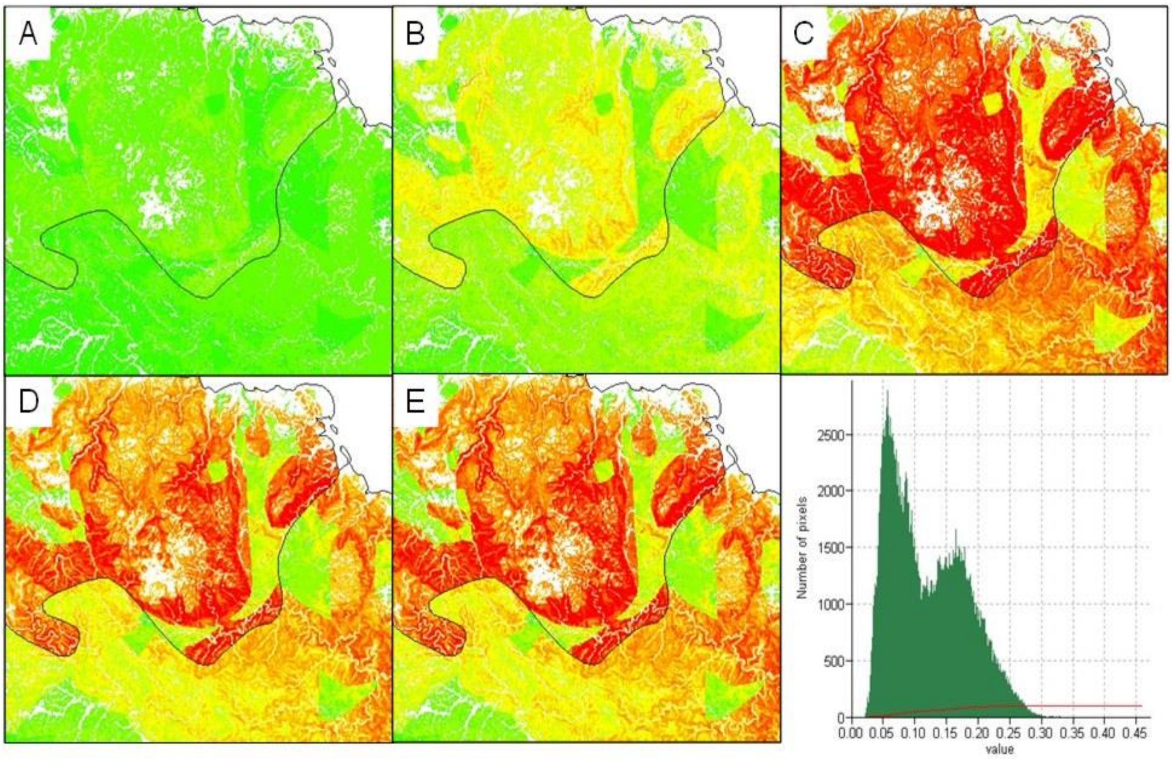
Stakeholder	Purpose	Type of risk visualization
General public	General information on risk over large areas	Basic WebGIS applications to overlay the location of major hazard types with high-resolution imagery or topographic maps
	Awareness raising	Animations (what-if scenarios)
	Community-based DRM projects	Simple maps of the neighbourhood with risk class, buildings and other features
Businesses	Investment policies and location planning	General information about hazards and risks in both graphical and map formats
Technical staff of (local) authorities	Land-use regulation / zoning	Maps with simple legend in three classes: construction restricted, construction allowed, further investigation required
	Building codes	Maps indicating the types of building allowed (building type, number of floors)
	Spatial planning	Hazard maps with simple legend related to probabilities and possible consequences
	Environmental impact assessment	Maps and possible loss figures for future scenarios
	Disaster preparedness	Real-time simple and concise web-based information in both graphical and map formats
Decision makers / local authorities	Decision-making on risk reduction measures	Statistical information, loss exceedance curves, F-N curves and maps
	Investments	Economic losses and projected economic losses for future scenarios
	Strategic environmental assessment	General statistical information for administrative units
Non-governmental organizations	Influence political decisions in favour of environmental and sustainable development	This can vary from simple maps to web-based applications, depending on the objectives of the non-governmental organization
Scientists / technical staff of hazard data producers	Hazard information exchange to public and other agencies	WebGIS applications to access basic information
	Exchange of basic information for hazard and risk assessment	Spatial data infrastructure / clearinghouse for exchanging information
Insurance industry	Development of insurance policy	Loss exceedance curves of economic losses or F-N curves
Media	Risk communication to public	Animations of hazard phenomena that clearly illustrate the problems

Most risk maps employ traffic-light colours (i.e., green-yellow-red) to convey areas with different levels of risk. The proper definition and representation of risk classes is important. With traffic-light colours, green should represent safe areas with negligible or zero risk.

When colour gradients or ramps are used, the minimum and maximum values of risk should be given in the map legend. While national and provincial level risk maps can be presented using continuous values or classes, the risk of individual objects at the municipal and local level needs to be visualized.

When the risk has been estimated quantitatively or semi-quantitatively and it is represented by a colour gradient or ramp, there are various options by which the risk values can fit between the minimum and maximum intensity colour. Figure 26 shows the visual effect of different risk representation options for the same area of a risk index map using the traffic-light representation. The differences in visualization for the same risk values are quite remarkable, therefore, choosing the appropriate option for risk representation is critical to communicating the risk effectively.

Figure 26: Risk representation of the same area using various stretch options and map histograms



Notes: A = risk values stretched between 0-1; B = risk values between minimum and maximum risk values; C = risk values between two times standard deviation; D = risk values between 0.5 percentage of the histogram; and E = risk values between 1 percentage of the histogram.

Source: Castellanos, 2008.

In risk maps with classes, similar challenges arise in deciding the number of classes and the break values for each class. The use of simple classifications with three classes is preferred for end users such as local authorities. However, for physical planners or researchers, a higher number of classes may be required. For selecting the break values among classes, current GIS systems can select from many methods (e.g., equal intervals, defined intervals, standard deviation and natural breaks).

Something To Do

Explore some good examples of risk visualizations. Take a look at:

- The Geoportal of Natural Hazards and Risks in Georgia (http://drm.cenn.org/index.php/en/). Check the options for disaster reporting, disaster database, hazards and risk map, and hazards and risk profile.
- The web atlas at https://issuu.com/levan.natsvlishvili/docs/binder1.
- The Multi-Hazard Risk Assessment in Tajikistan website (http://tajirisk.ait.ac.th/). Display and query hazard, elements-at-risk, loss and risk, and generate a risk profile.
- The Caribbean Handbook on Risk Information Management (http://www.charim.net/). This online handbook supports the generation and application of landslide and flood hazard and risk information to inform the planning and infrastructure sectors, and specifically targets small countries in the Caribbean.

3.7 Policy Considerations

Communicating risk information to people living in disaster prone areas will lead to more effective outcomes at all stages of the DRM, but more importantly, it will allow communities to take greater control of their own lives by providing them with valuable information that can be used to adopt risk mitigation measures and improve coping strategies.

While traditional media such as television and newspapers continue to play a prominent role in communicating risk to a mass audience, the advancement of ICTs provides wider access to information via web-based communication media, such as social media and websites. Moreover, advancement in WebGIS technology has enabled the visualization of complex information such as exposure, vulnerability and risk in an intuitive manner that can be widely shared online.

Policymakers are encouraged to consider the following issues to ensure effective risk visualization and communication:

- **Communicating with at-risk communities** – ICTs provide a great opportunity to reach out to at-risk communities even in remote areas. ICT interventions should focus on understanding and communicating their vulnerabilities and capacities for effective DRM.
- **Increasing ICT accessibility** – Universal access to ICT services is important for effective risk communication, which will require favourable policies and regulations that are supported by resources dedicated to reaching users located in underserved areas. While expanding the ICT infrastructure, its resilience to disasters should be considered, incorporating backup services, as well as diverse and redundant communication channels.
- **Advancing information accessibility** – There is currently an abundance of information available globally on DRM, but that does not necessarily translate into its widespread accessibility or utility. Information accessibility is limited by literacy, poverty, disability etc., which need to be addressed. In many places and cultures, there is a lack of relevant information conveyed in local languages or suited to the actual living conditions of people exposed to natural hazards. Language barriers must be addressed for existing information to be accessible.

4. ICT FOR DISASTER MITIGATION AND PREVENTION

4.1 Introduction

Disaster mitigation and prevention comprises a very important pre-disaster phase, which is the "business-as-usual" situation when there is no imminent threat.

This phase is difficult to implement because there are often more pressing issues that need stakeholders' attention, and efforts spent on disaster prevention can be seen as a "waste of time and resources". However, it is in this phase where the main benefits can be achieved that will reduce the cost of disasters in the long term.

Figure 27: Pictorial explanation of the terms "risk perception", "risk analysis", "mitigation" and "prevention"

The phase is called mitigation and prevention, because of the activities and measures that are taken to reduce existing and avoid new disaster risks. Mitigation[69] refers to the lessening or minimizing of the adverse impacts of hazard events, while prevention focuses more on completely avoiding potential adverse impacts of hazard events.[70]

Examples of prevention include, construction of dams or embankments that eliminate flood hazards, land-use regulations that eliminate exposure in flood zones, and seismic engineering designs that ensure the survival and function of a critical building in any likely earthquake.

The adverse impacts of hazards, in particular natural hazards, often cannot be fully prevented, but their scale or severity can be substantially lessened (mitigated) by various strategies and actions. Mitigation measures include engineering techniques and hazard-resistant construction (structural measures), as well as improved environmental and social policies and public awareness (non-structural measures).

[69] It should be noted that in climate change policy, "mitigation" is defined differently and is the term used for the reduction of greenhouse gas emissions that are the source of climate change.
[70] UNDRR, "Terminology". Available at https://www.undrr.org/terminology.

ICTs can contribute to mitigation and prevention, and decisions on the types of structural and non-structural measures, as well as their locations, are best determined by conducting a thorough risk assessment. Acquisition of geographically-registered information on hazards and the vulnerability of the elements-at-risk, and analysis of consequent risks are essential.

4.2 Stakeholders and Objectives at Various Geographic Levels

Central to the whole process are the stakeholders and their roles in mitigation and prevention. Table 7 presents the stakeholders in risk management and the optimal risk visualization options for them. The stakeholders can apply different options for disaster risk reduction, and their requirements for risk information in this process will be different.

At the international level, the main stakeholders are the national governments, multilateral development banks (e.g., Asian Development Bank, World Bank), United Nations agencies (e.g., ESCAP, UNDRR, UNDP, UNEP, UNESCO, UNHCR, UNOCHA),[71] the International Federation of Red Cross and Red Crescent Societies,[72] international development agencies (e.g., USAID, JICA, DFID, EuropeAID, GTZ) and international non-governmental organizations (e.g., Care, Oxfam, Tearfund, Caritas).

In Asia, for example, 30 non-governmental organizations are part of the Asian Disaster Reduction & Response Network[73] to promote coordination and collaboration for effective and efficient disaster risk reduction and response in the Asia region. Important Asian intergovernmental organizations involved in capacity building and DRM activities are the Asian Disaster Preparedness Center[74] and the Asian Disaster Reduction Center.[75]

At the national level, the main stakeholders involved in mitigation and prevention are government departments responsible for the construction, monitoring, maintenance and protection of critical infrastructure (e.g., the Ministry of Public Works), national planning agencies with the mandate to create development plans for different sectors and levels, and national emergency management organizations.

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[71] United Nations, "Funds, Programmes, Specialized Agencies and Others". Available at https://www.un.org/en/sections/about-un/funds-programmes-specialized-agencies-and-others/index.html.
[72] International Federation of Red Cross and Red Crescent Societies. Available at https://media.ifrc.org/ifrc.
[73] Asian Disaster Reduction & Response Network. Available at https://www.adrrn.net/.
[74] Asian Disaster Preparedness Center. Available at http://www.adpc.net/.
[75] Asian Disaster Reduction Center. Available at https://www.adrc.asia/.

Many countries have established dedicated DRM agencies for risk assessment, early warning, disaster preparedness and response. Some of these are civil defence organizations linked to ministries of internal affairs or the military, whereas in other countries, they are independent agencies. National governments are responsible for establishing DRM legislation, norms and codes, including the establishment of risk acceptability criteria that form the basis for risk evaluation.

At the provincial level, the stakeholders are provincial governments and organizations that coordinate planning and DRM at the provincial level, especially in regions with relatively small municipalities, to form an overarching support for local authorities in terms of capacity building, resources and logistics.

At municipal and community levels, the local authorities play a major role in DRM in consultation with other stakeholders, including the private sector, local non-governmental organizations and the public.

The objectives of disaster risk reduction planning for different geographic levels are presented in Table 8. The scales at which risk information is generated may vary from local community to international levels.

Table 8: Mitigation and prevention decisions at different geographic levels for which risk information plays an important role

Geographic level	Mitigation and prevention decision for which risk information is required
International / Regional	Prioritization of countries/ regions for investments in DRM by donor organizations
	International risk transfer mechanisms
	Risk mitigation related to global-scale disasters (e.g., pandemics)
	Design of early warning for large-scale disasters (e.g., cyclones, tsunamis, drought, large river flooding)
National	Prioritization of provinces / districts for investments by national government, non-governmental organizations and donor organizations
	Strategic environmental assessment analysing the impact of climate change
	Risk financing and transfer mechanisms (e.g., investments, trust funds, CAT insurance, bonds)
	Risk communication strategies (e.g., national campaigns)
	Development of legislation, organizational set-up and codes (e.g., building standards, risk acceptability thresholds)
	National early warning systems, impact-based forecasting, forecast-based financing

	Design of risk mitigation measures for large-scale disasters (e.g., storm surges, drought, flooding)
	Design and management of national-scale critical infrastructure (e.g., energy, transportation, health)
Provincial	Prioritization of municipalities for investments in DRM
	Analysing effects of climate change, land-use change and population change
	Spatial planning (e.g., regional development plans, sectoral plans)
	Critical infrastructure planning
	Environmental impact assessment of new (infrastructural) projects
	Disaster response planning (e.g., organization, logistics, support of individual municipalities, capacity building)
	Development of early warning systems and spatial decision-support systems
	Preparedness planning (e.g., shelters, logistics, resources, communication)
Municipal	Spatial planning (future scenarios translated into plans for infrastructure, land-use types, population, critical facilities)
	Regulatory zoning (land-use allocation at plot level), relocation planning of at-risk communities
	Building control (e.g., building permits, cadastral applications) and issuing permits for commercial activities (e.g., hazardous or polluting activities)
	Design, implementation and management of structural mitigation measures for specific areas
	Design, implementation and management of non-structural mitigation measures (e.g., local risk transfer tools, awareness, communication)
	Implementation of municipal early warning systems for specific hazards types
Community	Community-based disaster risk reduction, collaborative risk identification, risk communication
	Local disaster preparedness planning
	Local planning and execution of structural mitigation measures
	Community-based risk transfer tools (e.g., informal risk pooling)
	Community-based early warning systems (e.g., for flashfloods, debris flows)

Some key activities where risk information is important for decision-making include the following:

- **Spatial planning**, which are methods used by national and local governments to influence the future allocation of activities. Typically, it is a public sector activity with both regulatory and development functions. Through spatial planning, authorities make choices between various types of development that should take place in a given location and time. These choices imply that stakeholders in the planning process have a shared understanding of the issues at hand, of the need for action and of the desired spatial outcomes, and the stakeholders collectively have the means to reach their goals. In many countries and localities, spatial planning is a challenge as many of the issues being considered are shrouded in uncertainty, and the creation of spatial plans entails many wicked problems.

- **Planning of risk reduction measures**, which can be structural or non-structural. Structural measures refer to any physical construction to reduce or avoid possible impacts of hazards, such as engineering measures and construction of hazard-resistant and protective structures and infrastructure. Non-structural measures refer to policies, awareness, knowledge development, public commitment, and methods and operating practices, including participatory mechanisms and the provision of information that can reduce risk and related impacts.

- **Design and management of critical infrastructure.** The location of facilities like schools, hospitals, and networks for energy, transportation, water and communication is a strategic spatial planning decision. Its strategic importance lies in its long-term impact, not only on the facility itself, its viability and its use, but also on its surroundings and the urban system as a whole. Facility location is a typical planning issue that needs to be looked at in an integrated manner, incorporating aspects related to the demand for the service the facility offers, its characteristics (functions, area requirement, etc.) and the suitability of possible locations. These aspects also need to be examined in light of broader issues regarding land and infrastructure development, which adds complexity to the planning process.

- **Risk transfer**, which is the process of formally or informally shifting the financial consequences of particular risks from one party to another, whereby a household, community, enterprise or State authority will obtain resources from the other party after a disaster occurs, in exchange for ongoing or compensatory social or financial benefits provided to that other party.[76] There are various options for financing DRM, known as disaster risk financing instruments. These instruments are commonly classified as *ex post* (e.g., budget re-allocations, loan conversations, borrowing) and *ex ante* (e.g., accumulated reserves, precautionary savings, contingent credit, risk transfer / insurance). Insurance is a type of *ex ante* financing where coverage of a risk is obtained from an insurer in exchange for ongoing premiums paid to the insurer.

Even when effective disaster risk reduction measures are in place, there is always a residual risk for which emergency response and recovery capacities must be maintained. The presence of residual risk implies a continuing need to develop and

[76] UNDRR, "Terminology". Available at https://www.undrr.org/terminology.

support effective capacities for emergency services, preparedness, response and recovery, together with socioeconomic policies such as safety nets and risk transfer mechanisms, as part of a holistic approach.

4.3 Risk Perception, Communication and Evaluation

Risk can be divided into two distinct dimensions: (1) the "factual" dimension, which indicates the actual measured level of risk that can be expressed in probability of losses (e.g., number of people and buildings, monetary values); and (2) the "sociocultural" dimension, which includes how a particular risk is perceived and viewed when values and emotions come into play.

4.3.1 Risk Perception

Risk perception is about how individuals, communities or governments perceive, judge, evaluate or rank the level of risk. It deals with questions, such as: Do they know? Are they worried? Are they prepared to act? Who they think should act? What are the elements-at-risk worth to them?

Figure 28: High-risk coastal areas can be perceived as ideal locations for living

Risk perception plays an important role in DRM as it influences the actions that people will take to increase or reduce their risk. When people have poor or no perception of a particular risk, their actions may be inappropriate or even harmful (as shown in Figure 28).

The ways people perceive risk are related to their cultural and religious background (e.g., they may accept disasters as "acts of God"). Risk perception is also influenced by socioeconomic level. People living in squatter areas may perceive the same objective level of risk as being much lower than people living in more developed areas, as it is rated against other socioeconomic problems.

The political background of countries plays an important role in risk perception and DRM. For instance, in countries with a centralist political system, disaster risk is often perceived as an issue that the government can deal with more easily than in a country where individual actions and decisions are rated more important. The level of awareness is also important as people may not perceive a certain risk as high if they are not aware of it. Risk communication through different media therefore plays a major role in risk perception.

Another factor that influences the perception of risk is the frequency of hazard events. The risk of more frequently occurring events, for instance flooding, is generally perceived as more problematic than the risk of infrequent events such as earthquakes. Also, the time that has passed since the last major hazard event determines the level of awareness.

4.3.2 Risk Communication

An important component that influences the perception of risk is the communication between stakeholders on the types and severity of risk. Government organizations should actively involve multiple stakeholders in the consultation process, informing them about the actual levels of risk and working together to identify risk reduction measures.

Risk communication is the interactive exchange of information about risks among risk assessors, managers, news media, interested groups and the general public. Communication should be analysed in terms of **who** (source) says **what** (message), via **what medium** (channel), to **whom** (receiver) and directed at what kind of **change** (effect).

Risk communication may focus on the imminent threat of a hazard event, give a warning intended to produce an appropriate emergency response, or convey information about how to cope with a disaster. In such cases the message is clear, and the receiver is in need of the information that will lead to direct benefits (saving lives and properties).

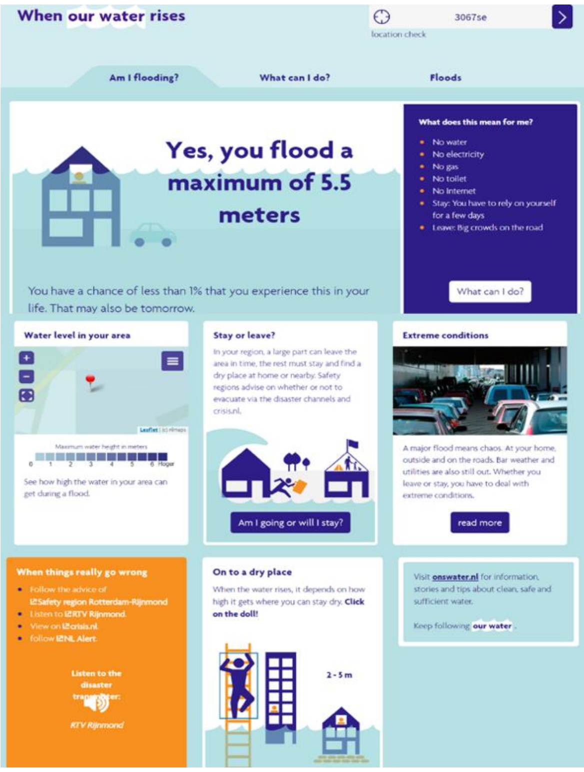
Risk communication in the mitigation and prevention phase focuses on the long-term potential for a hazard event to occur, and is intended to create awareness and lead to choices that will reduce the risk. However, to convey such information in a time when risk is not at the centre of people's attention, is a difficult task.

Risk communication has traditionally been a one-way, top-down transfer of information from authorities to the public. Risk has been communicated via mass media (television, radio, newspaper, websites). The national campaigns to raise public awareness and enhance disaster preparedness have not always been successful due to lack of trust or interest, and lack of involvement from the public.

More recently, instead of providing generalized information about "what to do in case of a disaster", governments have adjusted their national campaigns to focus on a variety of disaster types, each with different preparedness and response actions. In the Netherlands, citizens are able to obtain relevant risk information based on their postal code or global positioning system (GPS) coordinates (Figure 29).

Innovative ways have been used to communicate disaster risk through movies and soap operas featuring disaster-related issues. Recent developments in ICTs have also allowed for risk communication through games, where users can actively participate in decision-making. In the Stop Disasters! game, players can learn about risk management by building schools, hospitals, housing and defences to protect the local community in multiple disaster scenarios, including tsunamis, wildfires and earthquakes (Figure 30). Radio-television programmes such as the Philippine DZMM Red Alert that actively engages with listeners and viewers nationwide on emergency and disaster preparedness issues, is another example of innovative risk communication.[77]

Figure 30: Targeted risk information by postal code or GPS in the Netherlands



Source: Als ons water stijgt. Available at https://www.overstroomik.nl/.

Figure 29: Screenshot of Stop Disasters! game

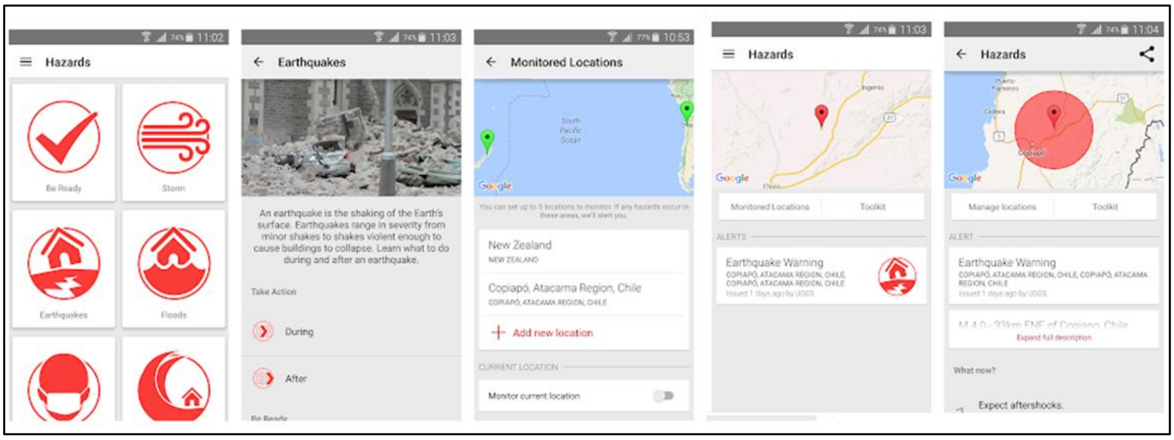
Source: UNDRR, “Play and learn to Stop Disasters!” Available at https://www.stopdisastersgame.org/.

[77] ABS-CBN News, "TeleRadyo". Available at https://news.abs-cbn.com/dzmm/.

There is growing awareness that two-way communication is more effective and increases the involvement of the general public as stakeholders in the decision-making process. Mobile phones, mobile applications[78] and social media platforms[79] have become popular for such two-way communication. They can be used to send specific information to people based on the location information of their mobile phones. In case of an emergency, only those people located within a certain distance of the hazard event will receive information that is relevant to them at that moment.

For example, the New Zealand Red Cross has developed a Hazard App for smartphones to help people prepare for and respond to hazards (Figure 31).[80] The app is pre-loaded with information about floods, earthquakes, tsunamis, fires, and weather and biosecurity risks. Users of the app can receive alerts from New Zealand's participating alerting authorities via the app. Alerts are targeted to specific geographic locations and users can control the locations, types of hazard and level of alerts they wish to receive through the app.

Figure 31: Risk communication through Hazard App in New Zealand



At the local level, risk communication can be even more focused on the stakeholders involved in a risk assessment and on the approaches for risk reduction that can be adopted. Risk communication at the local level is aimed at:

- Making people aware of the risk in their neighbourhood;
- Improving their knowledge on possible disasters and how they can be prepared;
- Changing their attitude towards disaster preparedness;

[78] A mobile application, also referred to as a mobile app, is a computer program or software application designed to run on a mobile device such as a phone, tablet or watch. Wikipedia, "Mobile app". Available at https://en.wikipedia.org/wiki/Mobile_app.
[79] Social media is a collective term for websites and applications which focus on communication, community-based input, interaction, content-sharing and collaboration. TechTarget, "Social Media". Available at https://whatis.techtarget.com/definition/social-media.
[80] New Zealand Red Cross, "Hazard App". Available at https://www.redcross.org.nz/what-we-do/in-new-zealand/disaster-management/hazard-app/.

- Changing eventually their behavior towards disaster risk reduction and building disaster resilience; and
- Creating dialogue on disaster risk reduction alternatives.

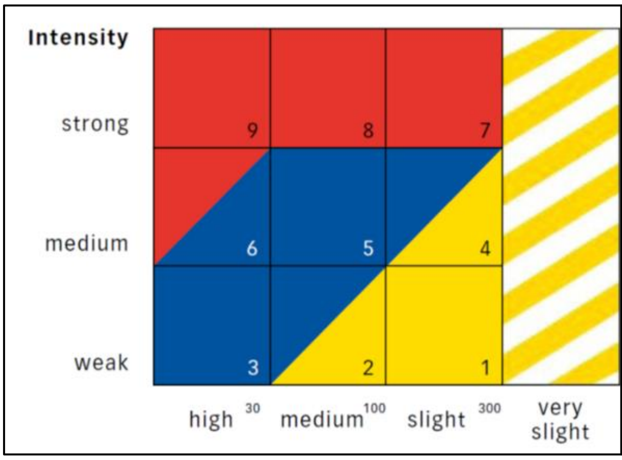
4.3.3 Risk Evaluation

Risk evaluation is the stage at which values and judgment enter the decision-making process, explicitly or implicitly. This stage includes consideration of the importance of the estimated risks and the associated social, economic and environmental consequences, in order to identify a range of alternatives for managing the risks.

The definition of acceptability levels is a responsibility of the national or local government in a country, as it greatly affects decisions on the zoning of areas by risk level and the amount of investment needed to reduce risk to an acceptable level.

Risk acceptability depends on many factors (including the factors discussed in the risk perception section) and differs from country to country. Many countries have not formally adopted a risk acceptability standard. Some countries, however, have implemented hazard acceptability criteria as the basis for spatial planning, where the probability and intensity of the hazard determine the hazard level. See an example from Switzerland in Figure 32.

Figure 32: Hazard acceptability matrix used in Switzerland for restrictive zoning



Probability

Process	Low intensity	average intensity	high intensity
Rockfall	E < 30 kJ	30 kJ < E < 300 kJ	E > 300 kJ
Landslide	Vs < 2 cm/year	Vs: dm/year	Vs > dm/day; Displacement > 1 m per event
Debris flow	--	D < 1 m and v < 1 m/s	D > 1 m and v > 1 m/s
Static flooding	h < 0.5 m	0.5 < h < 2 m	h > 2 m
Dynamic flooding	q < 0.5 m²/s	0.5 < q < 2 m²/s	q > 2 m²/s
Bank erosion	t < 0.5 m	0.5 < t < 2 m	t > 2 m
Snow avalanche	P < 3 kN/m²	3 kN/m² < P < 3 kN/m²	P > 30 kN/m²

E = kinetic energy; Vs = mean annual velocity of landslide; D = thickness of debris front; v = flow velocity (flood or debris flow); h = flow depth; q = specific discharge (m³/s/m) = h x v; t = extent of lateral erosion; P = avalanche pressure exerted on an obstacle

Source: Olivier Lateltin and others, "Landslide risk management in Switzerland", *Landslides*, vol. 2 (2005), pp. 313-320. Available at https://doi.org/10.1007/s10346-005-0018-8.

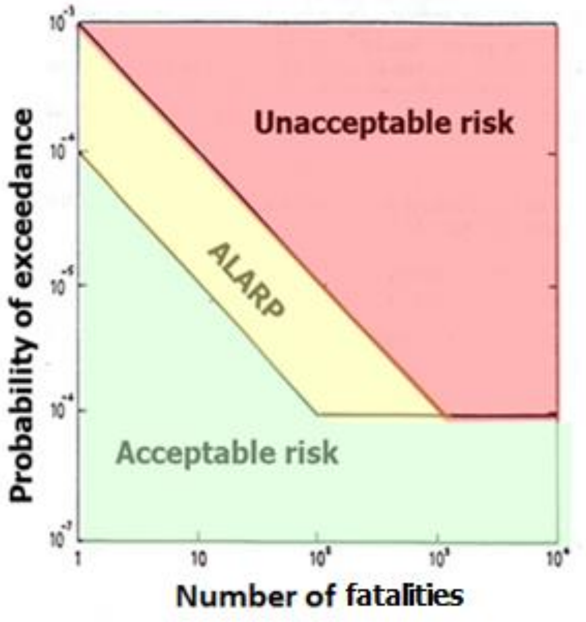
Risk evaluation determines whether the risk level is:

- **Acceptable** – A risk that the society or impacted individuals are prepared to accept. Actions to further reduce such risk are usually not required unless reasonably practicable measures are available at low cost in terms of money, time and effort; and

- **Tolerable** – A risk within a range that society can live with so as to secure certain net benefits. It is a range of risk regarded as non-negligible, and needing to be kept under review and reduced further if possible. The intermediate zone is called the “as low as reasonably practicable” (ALARP) zone. Risks lower than the limit of tolerability are tolerable only if risk reduction is impracticable or if its cost is grossly disproportionate (depending on the level of risk) to the improvement gained.

Risk acceptability levels are generally determined on the basis of individual risk levels (e.g., 10^{-5}, also represented in maps as risk contours) or societal risk levels (using F-N curves), of which an example is shown in Figure 33.

Figure 33: Risk acceptability principle based on societal risk or F-N curves



Notes: An F-N curve provides a result of likelihood or frequency (F) of fatal events occurring causing a certain number of fatalities (N), within a given period of time, usually set for one year; and ALARP = As low as reasonably practicable.

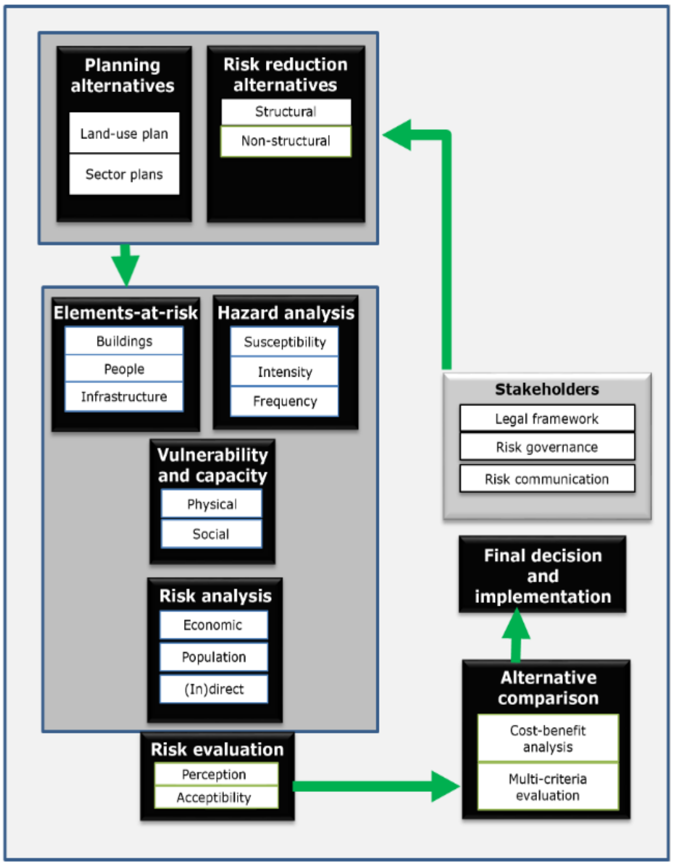
4.4 Analysing Risk Reduction Alternatives

If the risk for the current situation is considered unacceptable, stakeholders can decide to plan for risk reduction alternatives, which involves:

- **Planning alternatives** – Focusing on where and what types of activities are planned and preventing those future development areas from being exposed to natural hazards; and

- **Planning of risk reduction measures** – Including structural measures (such as dikes, check-dams, sediment catchment basins) and non-structural measures (such as relocation planning, strengthening / protection of existing buildings).

Figure 34: Risk management framework for analysing and evaluating optimal risk reduction measures based on their benefits in reducing the risk, and costs for implementation and maintenance



The implementation of certain structural and non-structural risk mitigation measures may lead to a modification of the hazard, exposure and vulnerability. Some measures will modify the hazard, in terms of the probability (or return period) of specific hazard events, the spatial distribution of the hazard and the intensity of the hazard. Some measures may affect the exposure of elements-at-risk, as these may change, for instance by relocation of exposed buildings. Also, the vulnerability of the elements-at-risk may change, for instance when retrofitting is considered. Finally, it may change the quantification of the elements-at-risk, such as the economic value or the number of people.

Therefore, experts should evaluate together with stakeholders, the effects of the proposed risk reduction alternatives on the hazard, elements-at-risk location and characteristics, and vulnerability. If needed, new hazard modelling should be carried out, or new elements-at-risk maps should be made representing the new situation.

There are many different risk reduction alternatives that can be formulated, and each of them have advantages and disadvantages. A simple example to illustrate the use of risk assessment in the evaluation of optimal risk reduction measures is shown in Figure 35.

Figure 35: Simplified hypothetical example of the use of risk assessment for the evaluation of optimal risk reduction measures

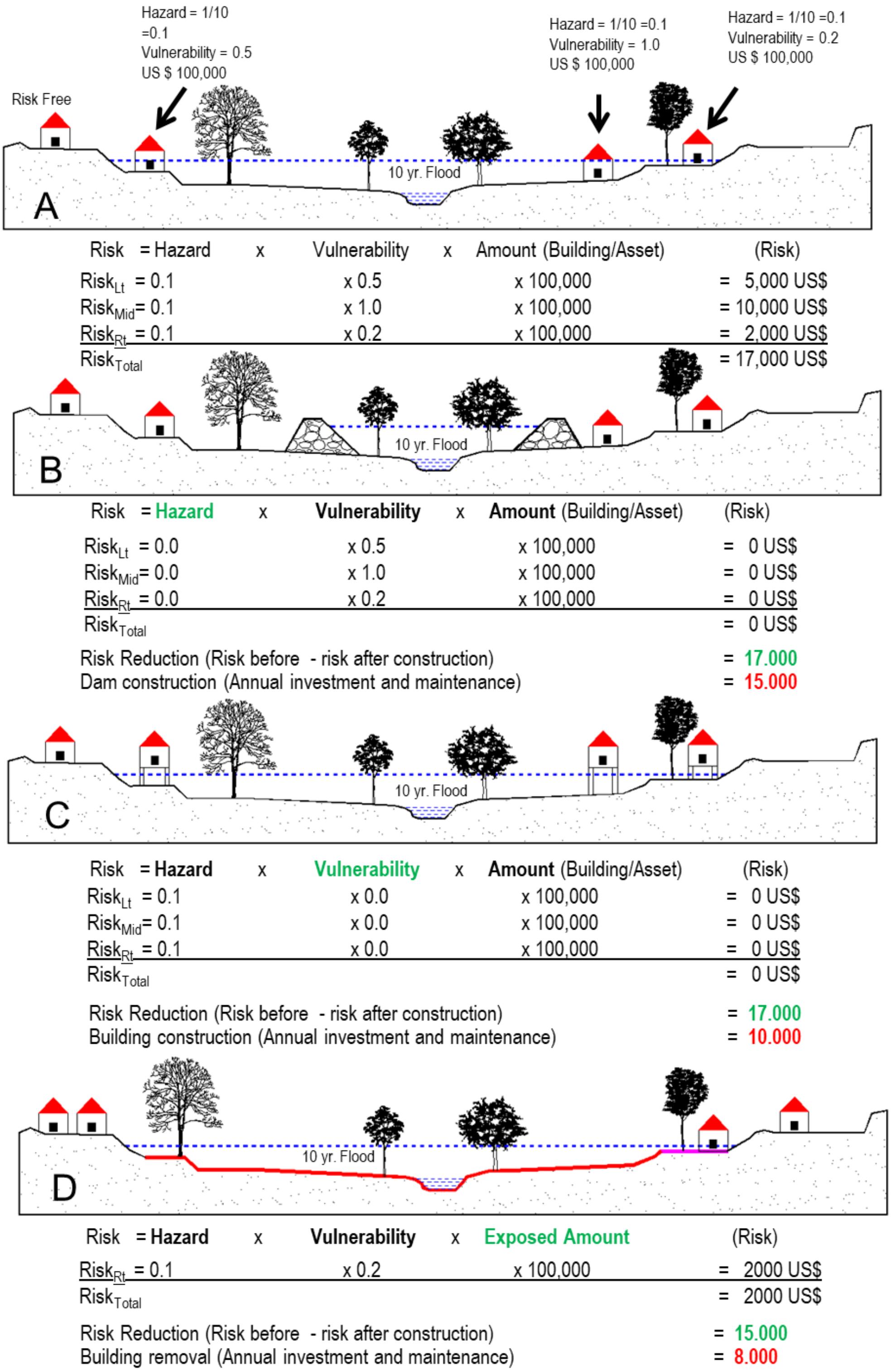


Figure 35 shows a cross section through a river valley and the 10-year flood level. In reality, such analysis will take into account the different flood levels and their frequencies.

Figure 35A shows the existing situation in which three buildings are exposed to the 10-year flood. The risk is calculated by multiplying the annual probability of the flood hazard occurring (marked as “hazard” in the diagram) with the vulnerability of each building to the flood hazard (vulnerability) and the value of the exposed elements-at-risk (building / asset).

Figure 35B illustrates the changing risk situation for the alternative of constructing a dam or an embankment. This will affect the hazard, as the 10-year flood will not affect the buildings. Note that for a real case study, higher (and less frequent) flood levels should be considered that may overflow the proposed embankment.

Figure 35C illustrates the changing risk situation for the alternative of flood proofing the exposed buildings. This will affect the vulnerability level of the elements-at-risk (i.e., the buildings), as they will no longer be vulnerable to the 10-year flood level. The number of elements-at-risk exposed to the 10-year flood remains unchanged.

Figure 35D illustrates the changing risk situation for the alternative of relocating two of the three exposed buildings. This will affect the two buildings and their vulnerability, thus, the number of exposed elements-at-risk will decrease, whereas the extent and intensity of the 10-year flood occurring remain unchanged.

Based on these risk reduction alternatives, a re-analysis of the hazard, elements-at-risk and vulnerability is required, followed by a comparison of the resulting level of risk with the current level of risk. The difference between the average annual losses before and after the implementation of the risk reduction alternatives provides information on the extent of risk reduction. This should be done for all the risk reduction alternatives, and the extent of risk reduction should be assessed in terms of economic risk reduction (reduction in the average annual losses in monetary values) and in terms of population risk reduction (reduction in the expected casualties or people exposed).

Once the effects of the various risk reduction alternatives are analysed in terms of their risk reduction potential, the next step is to compare and decide which alternatives to implement. This can be done using several methods:

- **Cost-benefit analysis** – The analysis quantifies the benefits and costs of the risk reduction alternatives by representing the annual risk reduction in monetary values. For example, the costs of the risk reduction alternative include the investment and maintenance costs over the project lifetime. Cost-benefit analysis can be carried out by calculating relevant indicators, such as the net present value, internal rate of return or cost-benefit ratio.

- **Cost-effectiveness analysis** – This is carried out when the risk reduction costs can be quantified and compared in monetary values, but the benefits cannot. This is the case when population risk is calculated, as it is generally considered unethical to represent human lives in monetary values.

- **Multi-criteria evaluation** – When both the risk reduction costs and benefits cannot be quantified in monetary values, or when non-quantifiable indicators are used in addition to cost-benefit or cost-effectiveness, a (spatial) multi-criteria evaluation is generally considered the best option. In such analysis social, ecological, cultural and other criteria can be incorporated in the decision-making process.

The comparison of alternatives is normally carried out in a multi-stakeholder process before a decision is taken on the optimal alternative that will be implemented. This involves consultation with the various stakeholders involved, and public hearings with the population, private sector, non-governmental organizations and various civil society groups.

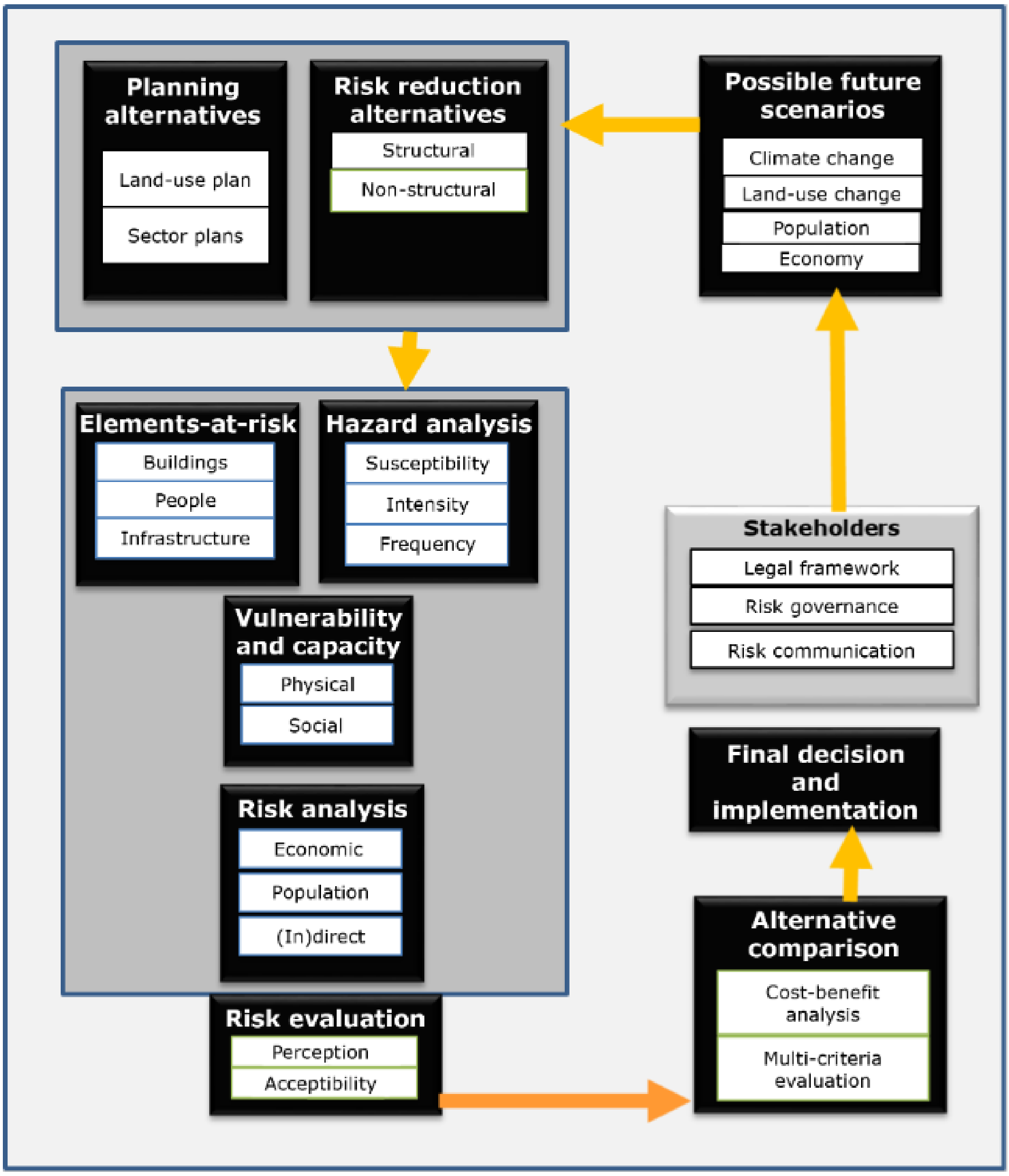
At this stage, the stakeholders have the opportunity to request adjustments to the proposed plan of action, and if these adjustments are agreed upon, a new round of evaluation may be needed especially if the adjustments are likely to result in substantial changes to the hazard, elements-at-risk and vulnerability. Once the plan is approved, implementation will begin, and monitoring will be required.

4.5 Analysing Possible Future Scenarios

Risk is changing continuously, as specific hazards, elements-at-risk and their vulnerability change. Over a longer period of time this may result in considerable changes to the risk of multiple hazards. Figure 36 illustrates the workflow for analysing the changing risk from possible future scenarios and the selection of optimal risk reduction measures.

The scenarios are related to possible global and regional changes to climate, land-use, population and the economy. By following the workflow, stakeholders can evaluate how these trends have an effect on the hazard and elements-at-risk and how these will translate into different risk levels.

Figure 36: Framework for analysing and evaluating optimal risk reduction measures with different future scenarios



4.5.1 Climate Change Scenarios

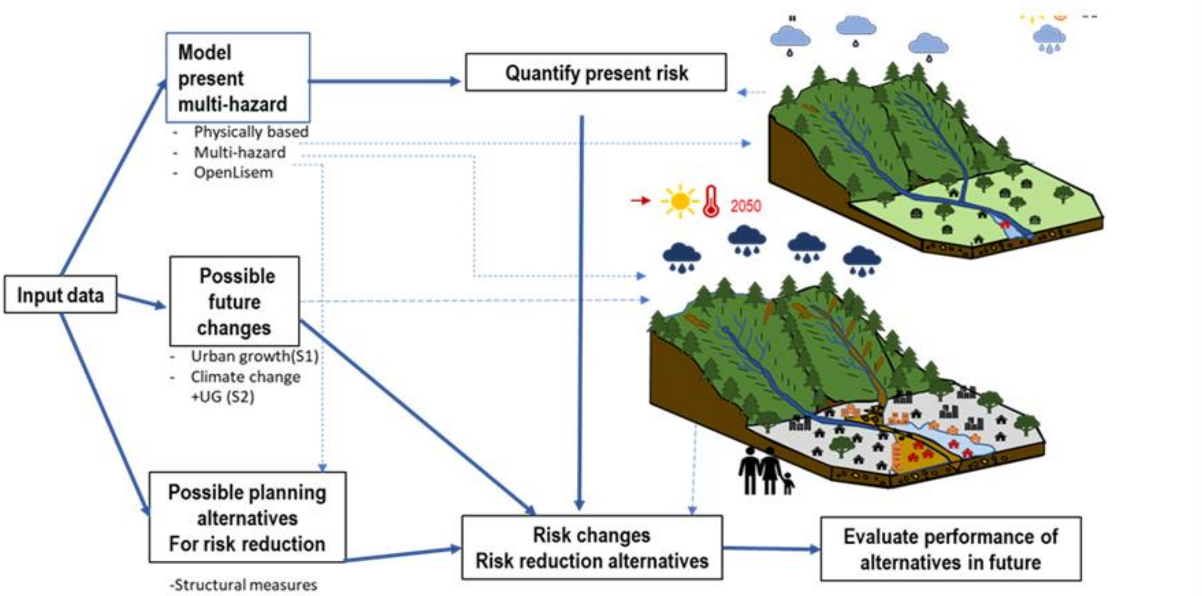
In evaluating the impact of climate change on multi-hazard risk, the involvement of climate experts is needed in developing and applying climate change scenarios. The expected effects in terms of changes in frequency and magnitude of hydro-meteorological triggers should be analysed, but also possible new hazards that results from climate change (e.g., increased landslide activity in areas with permafrost decline), or other feedback loops (e.g., increased forest fire activity leading to more debris flows).

The IPCC reports that heavy precipitation events have increased in frequency, intensity and/or amount since 1950, and further changes in this direction are very likely during the 21st century.[81] A more recent IPCC report indicates that climate projections of precipitation are less robust than for temperature as they involve processes of larger complexity and spatial variability.[82] However, there is evidence that the number of heavy rainfall events is increasing, while the total number of rainfall events is decreasing.

4.5.2 Land-Use Change Scenarios

In evaluating the impact of land-use changes on multi-hazard risk, the involvement of land-use experts is needed to indicate possible land-use changes based on macroeconomic and political developments, which can then be translated into local changes. For instance, scenarios can be envisaged where an economic crisis leads to the future expansion of low-class residential areas. The combination of climate change and land-use change scenarios with risk reduction alternatives should be developed, and the possible changes should be expressed for a certain year in the future (e.g., for 2050). Figure 37 provides an example.

Figure 37: Workflow for analysing changing multi-hazard risk using climate change and land-use change scenarios to identify risk reduction alternatives for an urban area in Colombia



Source: Felipe Fonseca, Institute for Geo-Information Science and Earth Observation, University of Twente.

[81] IPCC, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (New York, Cambridge University Press, 2012). Available at https://www.ipcc.ch/report/managing-the-risks-of-extreme-events-and-disasters-to-advance-climate-change-adaptation/.

[82] IPCC, *Special Report on Climate Change and Land* (2019). Available at https://www.ipcc.ch/srccl/.

The possible future scenarios may lead to modification of the hazard, exposure and vulnerability in certain future years. If needed, new hazard modelling should be carried out, or new elements-at-risk maps should be made representing the new situation, and the risk analysis for the new situation carried out.

The difference between the current average annual losses and those in a future year under a given change scenario provides information for decision makers on the possible consequences of climate change and land-use change scenarios. Stakeholders should analyse these changes carefully in terms of:

- **Spatial location of changes in risk** – Some areas may be more affected by these possible future changes than others. Based on the outcomes of the analysis, stakeholders can then prioritize certain areas for critical interventions;

- **Critical sectors** – Changes in risk can be analysed for different sectors of society, such as economy, agriculture, tourism, education, transportation, etc.; and

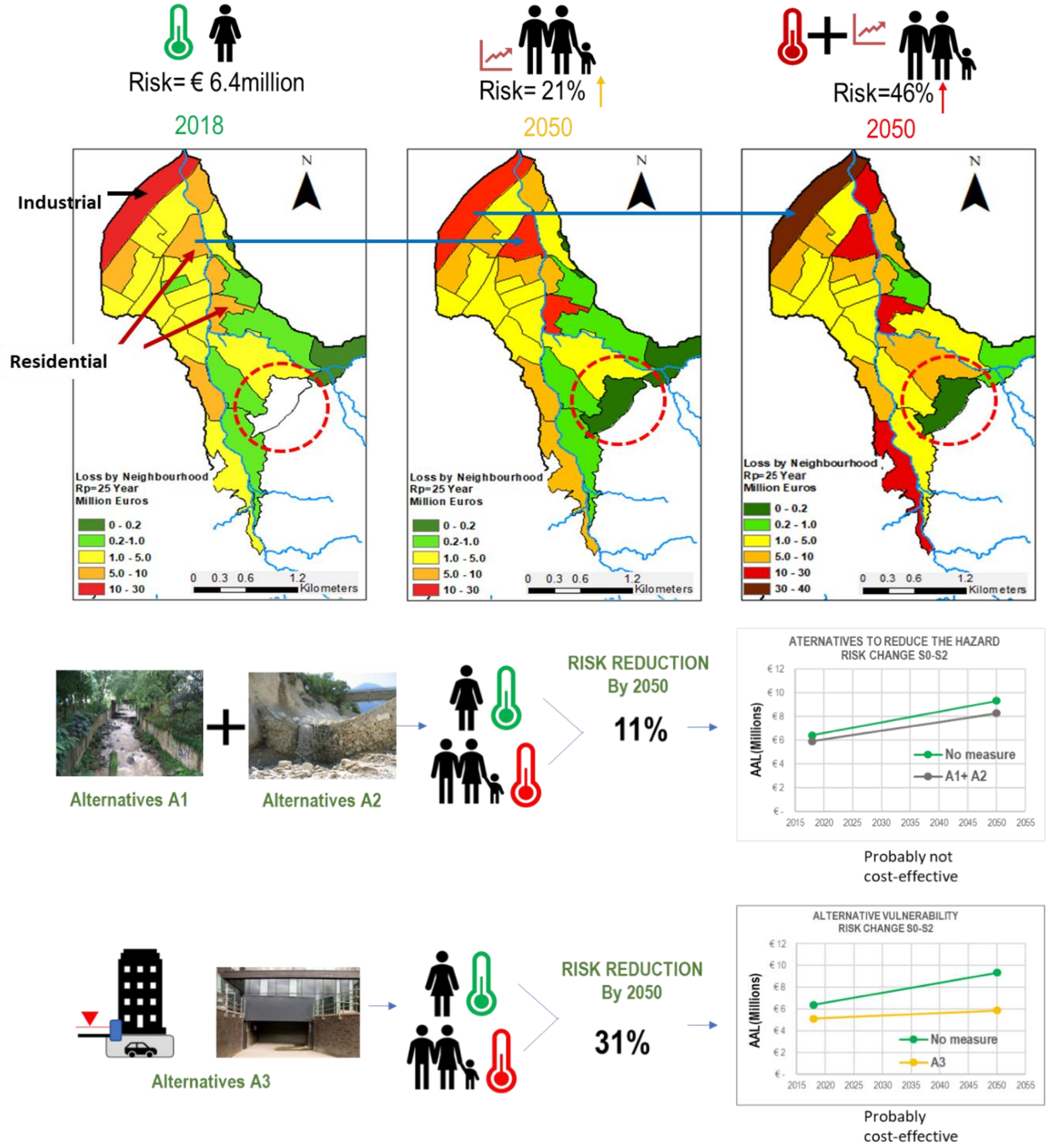
- **Development of adaptation strategies** – In areas where an increase in risk is expected according to the possible scenarios, adaptation strategies should be formulated to reduce possible impacts through risk reduction alternatives that can be implemented now.

4.5.3 Comparing Mitigation Alternatives Using Different Scenarios

Once the effects of the various risk reduction alternatives have been analysed using different future years and future scenarios, the next step is to compare them and decide which of the alternatives will be the best to implement. Again, the cost-benefit analysis, cost-effectiveness analysis and multi-criteria evaluation can be used to compare the risk reduction alternatives (see Section 4.4).

When possible future changes are taken into account, the cost-benefit ratio of the various alternatives may be quite different than if no future changes are considered. By considering future scenarios, stakeholders will be able to select a risk reduction alternative that is the most “change proof”, which means the risk reduction measure continues to be useful in the future, even when scenarios change (Figure 38).

Figure 38: Example of analysing changing multi-hazard risk using climate change and land-use change scenarios to identify risk reduction alternatives for an urban area in Colombia



Notes: The analysis compares the risk level in 2018 with the expected risk level in 2050 under two scenarios: (1) a population growth scenario that increases the risk level by 21 per cent; and (2) a combined climate change and population growth scenario that increases the risk level by 46 per cent. Next, three risk reduction alternatives (A1, A2 and A3) are assessed by applying the combined climate change and population growth scenario. Results show that the structural mitigation measures (A1 and A2) lead to an 11 per cent risk reduction in 2050, while combining flood proofing of large buildings with structural mitigation measures (A3) leads to a 31 per cent risk reduction in 2050.

Source: Felipe Fonseca, Institute for Geo-Information Science and Earth Observation, University of Twente.

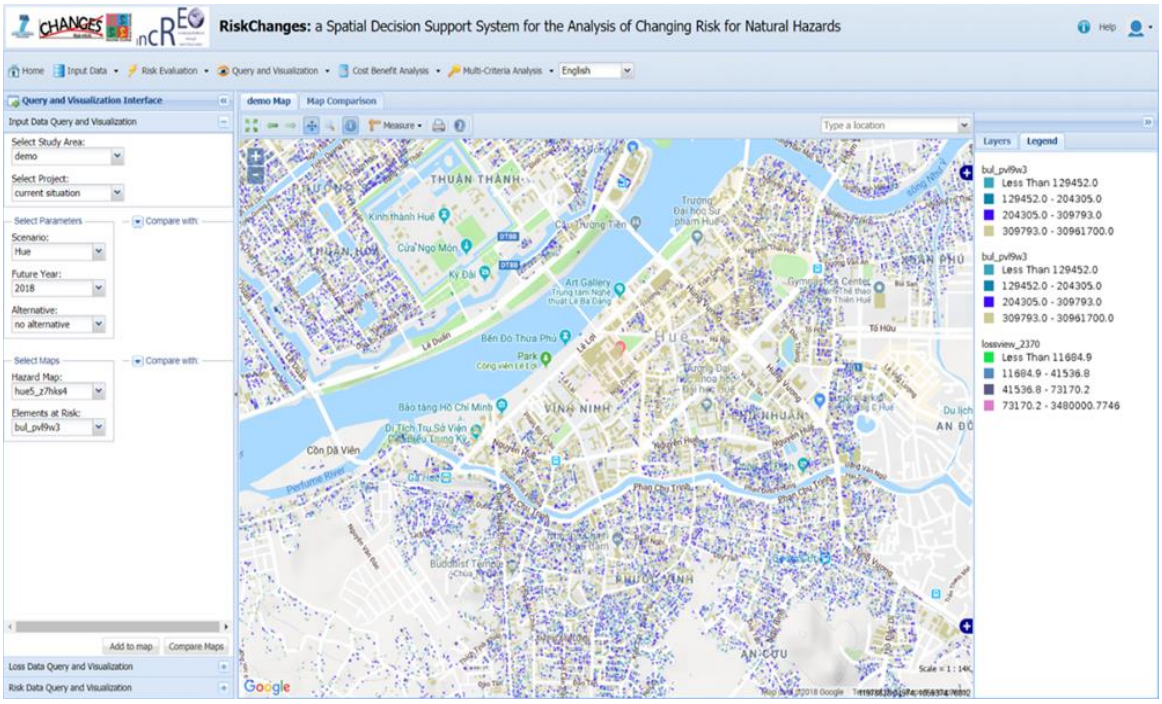
4.6 Decision-Support Systems

The analysis of risk requires a repetitive procedure for each hazard scenario (different hazard types and return periods) in combination with various elements-at-risk types, and then for each possible risk reduction alternative and future scenario.

This requires the use of automated procedures using GIS and spatial decision-support tools. An example of this is the open source software, **Climada**,[83] which integrates hazard, exposure and vulnerability to compute the necessary metrics to assess risk and quantify socioeconomic impact of hurricane-related hazards at a general scale.

Another example is the **RiskChanges Spatial Decision-Support System**[84] that is composed of a number of integrated components (Figure 39). The risk assessment component allows the conduct of spatial risk analysis with different degrees of complexity, ranging from simple exposure (overlay of hazard and assets maps) to quantitative analysis (using different hazard types, temporal scenarios and vulnerability curves) resulting in risk curves.

Figure 39: Application of the RiskChanges Spatial Decision-Support System to analyse changing flood risk in Hue, Viet Nam



83 Climate-ADAPT, "Climada (2015)". Available at https://climate-adapt.eea.europa.eu/metadata/tools/climada.
84 RiskChanges: A Spatial Decision Support System for the Analysis of Changing Risk for Natural Hazards. Available at http://sdss.geoinfo.ait.ac.th/. Examples of the application of RiskChanges are available at Caribbean Handbook on Risk Information Management, "4.6 RiskChanges Spatial Decision Support System". Available at http://www.charim.net/use_case/46.

The second component includes the definition of risk reduction alternatives and links back to the risk assessment module to calculate the new level of risk if the measure is implemented, and a cost-benefit component compares the alternatives for decision-making.

The third component is a temporal scenario component that allows the definition of future scenarios. This platform is suitable for organizations involved in planning risk reduction measures that have staff capable of visualizing and analysing spatial data.

4.7 Policy Considerations

Understanding disaster risk in all its dimensions of vulnerability, capacity, exposure of populations and assets, hazard characteristics and the environment is the first priority for action underlined in the Sendai Framework.

ICT innovations that enhance measurement tools and the collection, analysis and dissemination of data have an important role in the implementation of the framework. Some relevant recommendations related to ICT for disaster mitigation and prevention at the national and local levels highlighted in the Sendai Framework are to:

- Promote the collection, analysis, management and use of relevant data and practical information and ensure its dissemination, taking into account the needs of different categories of users, as appropriate;
- Develop, periodically update and disseminate, as appropriate, location-based disaster risk information, including risk maps, to decision makers, the general public and communities at risk of exposure to disaster in an appropriate format by using, as applicable, geospatial information technology;
- Promote real-time access to reliable data, make use of space and in situ information, including GIS, and use ICT innovations to enhance measurement tools and the collection, analysis and dissemination of data;
- Promote investments in innovation and technology development in long-term, multi-hazard and solution-driven research in DRM to address gaps, obstacles, interdependencies, and social, economic, educational and environmental challenges, and disaster risks; and
- Promote national strategies to strengthen public education and awareness in DRM, including disaster risk information and knowledge, through campaigns, social media and community mobilization by targeting specific audiences and their needs.

Policymakers are encouraged to consider the following issues when developing strategies and plans for identifying and using ICT for disaster mitigation and prevention:

- **Incorporate ICT for DRM as part of sustainable development efforts** – ICT for DRM needs to take into consideration potential impact on society, the environment and the economy, and ensure that interventions do not increase people's exposure to hazards. There is also a growing momentum towards the integration of climate change mitigation as well as disaster mitigation into sustainable development policies. In this case, ICTs are indispensable and should be incorporated in policies and strategies for climate change mitigation and disaster mitigation;

- **Provide an enabling policy environment** – National governments play a vital role in providing an enabling environment for leveraging the potential of ICT for DRM through appropriate policies and institutional arrangements. Coherent policies and legislations need to be in place to promote disaster mitigation and prevention by developing innovative solutions; and

- **Promote risk-informed policies and investments** – Policies and investments must be risk-informed, tailored to local circumstances and coupled with environmental protection. It is also crucial to encompass disaster resilience in all sectors, including health, education, social protection, agriculture and infrastructure, by developing a comprehensive portfolio of sectoral investments and policies for taking appropriate disaster mitigation and prevention measures.

5. ICT FOR DISASTER PREPAREDNESS

5.1 Introduction

Disaster preparedness is defined as the knowledge and capacities developed by governments, response and recovery organizations, communities and individuals to effectively anticipate, respond to and recover from the impacts of likely, imminent or current disasters.[85]

Figure 40: Magical multi-hazard forecasting stone

Preparedness is based on a sound analysis of disaster risks and good linkages with early warning systems. It includes such activities as contingency planning, the stockpiling of equipment and supplies, the development of arrangements for coordination, evacuation and public information, and associated training and field exercises. These must be supported by formal institutional, legal and budgetary capacities. The related term “readiness” describes the ability to quickly and appropriately respond when required. During the preparedness phase, the coordination among governments, civil organizations and citizens is promoted to get ready for an upcoming emergency. In this phase, the involvement of communities is crucial since they can provide actionable real-time information using social media platforms or mobile apps.

A disaster preparedness plan establishes arrangements in advance to enable timely, effective and appropriate responses to specific potential hazard events or emerging disaster situations that may threaten society or the environment.[86] An ICT-enabled disaster preparedness plan facilitates the timely receipt of weather forecasts and early warnings from the designated national / regional agencies and their dissemination to the public.

ICT applications can contribute to several systems that are important in the disaster preparedness phase:

[85] UNDRR, "Terminology". Available at https://www.undrr.org/terminology.
[86] Ibid.

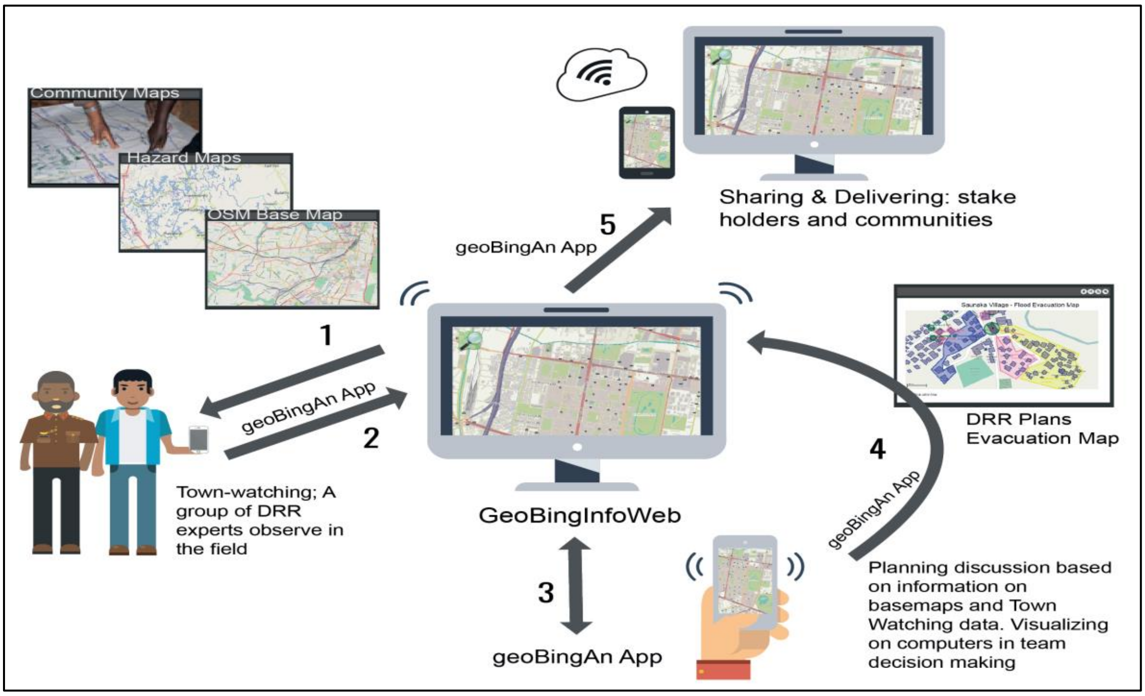
- **Forecasting system** – Predicts the level of danger based on indicators at regional scale and regular intervals;
- **Monitoring system** – Increases the understanding of natural processes but can also be utilized to plan further actions; and
- **Warning system** – Detects significant changes in the environment (as precursors for mass movements) before the event occurs.

5.2 ICT for Community-Based Preparedness Planning

ICTs have emerged as important tools for disaster preparedness through the collection and dissemination of disaster-related data and information. Advances in ICTs, especially the latest generation of mobile phones and their applications, have made it possible for community members to collect and share local data in real-time, linking reports, photos and other multimedia data to their respective locations.

ICTs have been used in community-based DRM to strengthen resilience and support disaster preparedness. In Fiji, for example, ICT tools have been successfully used by communities for disaster preparedness (Figure 41). A community-led mapping in collaboration with the local government was organized to map the elements-at-risk, such as buildings, roads, waterbodies and other critical infrastructures, in OSM. A mobile app was developed to download and view these elements-at-risk on mobiles phones, and community members were trained to add attributes to the elements-at-risk through field surveys to develop a community-based OSM base map for disaster preparedness planning.

Figure 41: Activity flow of using ICTs in community-based preparedness planning in Fiji



The general activity flow for developing these maps was as follows:

- Identify the area and select community members for the task;
- Community members register for an OSM account and carry out OSM mapping to add the elements-at-risk of the selected locality after a basic training on OSM;
- Community members download the updated OSM map to their mobile phones using the mobile app;
- Community members go to the selected localities to add attributes to the elements-at-risk in offline mode following the naming conventions of the OSM; and
- Upon completion of the field survey, community members connect to the Internet and upload the collected data and information to a local or cloud server.

This community-based DRM methodology, known as town watching, was adopted to collect hazard, exposure and risk information, as well as identify possible evacuation routes and emergency shelters. Town watching was done by the community members in Fiji under the guidance of a DRM expert. The DRM expert guided community members as they walked around the community to record the level of hazard, exposure and risk against each element-at-risk using a pre-defined dropdown menu available in the mobile app. At the same time, geotagged photos of elements-at-risk were added to the app.

The level of hazard, exposure and risk recorded was based on the community's perception of past hazard events. While carrying out the field survey, the community recorded potential evacuation routes and emergency shelters, taking into account the hazard and risk situation in the locality.

At the end of the field survey, the data and information was uploaded to a server to update the community map, which could then be viewed and edited online using a web browser. The DRM expert again discussed the updated map with the community and further edited it in online mode, based on the local knowledge of the community.

While such kind of community-level maps are often prepared in hardcopies, which are static and not easily accessible or usable by the communities, the use of remote sensing data, GIS tools and ICTs can help communities easily prepare maps for effective preparedness planning and DRM. These maps can be easily accessed and updated anytime by the community themselves using the mobile app.

Case Study 3: Safety Sinmungo – Republic of Korea's ICT-based smart civil complaint processing service

Launched in 2014 by the Ministry of Public Safety and Security and ranked second in the nation's "Top 30 Innovative Administrative Services", the web-based and mobile-based Safety Sinmungo app allows people to report unsafe or hazardous conditions. The reports can vary from at-risk conditions such as sunken roads and aging facilities to any hazards near construction sites that may have a considerable impact on people.

Its mobile app enables people to easily and directly report hazards by uploading pictures or video clips anytime, anywhere, including but not limited to the deployment of drones for responding to forest fires and smart controls for road hazards. Users can check the status of their reported matters and also view safety-related news.

When a user files a report, it is immediately sent to the person in charge of the relevant incident, and a response must be given to the user within seven days after the report is made, so authorities cannot delay the conduct of an inspection.

To encourage proactive reporting of unsafe and hazardous conditions, those who file a report are rewarded after their cases are reviewed by a safety committee consisting of four to five experts and civil servants.

As of February 2015, 3,600 cases were reported through the mobile app, 3,300 of which were resolved.

Sources: Arirang TV, "Bizline Ep103: Issue, Interview, Science & Technology, ICT, Zoom, North Korea", 5 March 2015. Available at https://youtu.be/4SdM4gPnNsM; and 100ResilientCities.org, "Resilient Seoul: A strategy for urban resilience 2019", Seoul Metropolitan Government, 23 September 2019. Available at http://www.100resilientcities.org/wp-content/uploads/2019/09/Resilience-Strategy-Seoul-English-compressed.pdf.

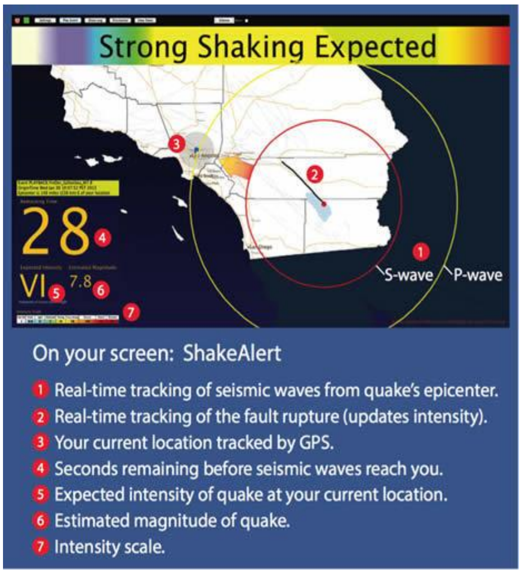
5.3 ICT Systems for Alerting and Evacuating

One of the logical developments of ICT for disaster preparedness is the design of apps to assist citizens in the preparedness phase, either to raise their awareness of the risks in their area, inform them about what to do in case of an emergency, alert them of possible hazard events, or guide them to evacuate.

5.3.1 Alerting

Even though earthquake early warning systems can only give a warning seconds before the actual earthquake happens, they are useful for citizens to seek cover, switch off vulnerable equipment and initiate vital response actions. There are now several earthquake early warning systems in the testing phase.

Figure 42: ShakeAlert – An app for earthquake warning



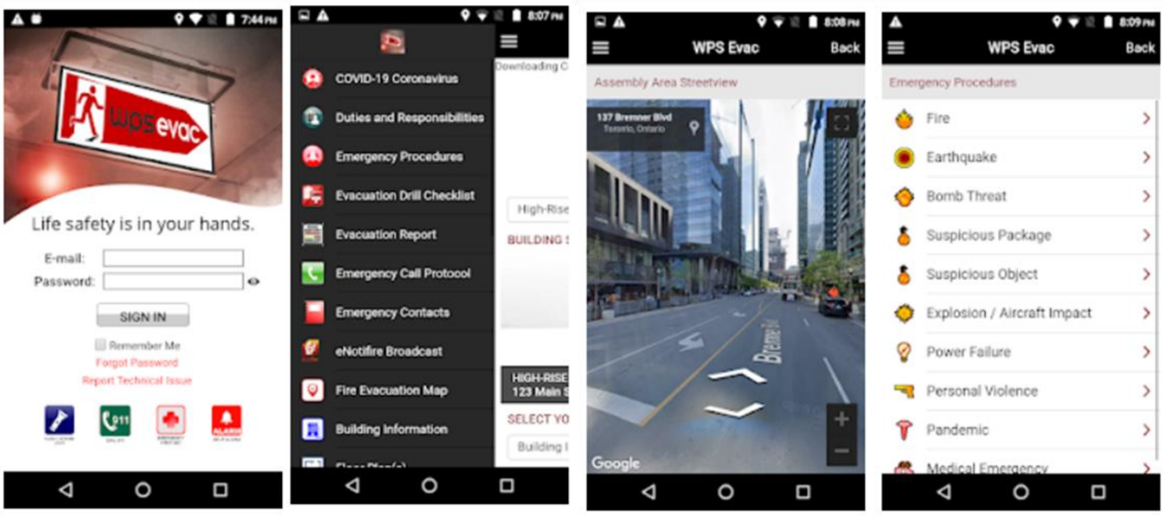
Source: USGS, "Earthquake Hazards: Early Warning".
Available at https://www.usgs.gov/natural-hazards/earthquake-hazards/early-warning.

In California, USA, users of the ShakeAlert App will receive a message like the one shown in Figure 42 when an earthquake is expected. The message alerts the user to how many seconds before the shaking waves arrive at their location and the expected intensity of shaking at that site. The shaking intensity follows the Modified Mercalli scale. An intensity of VI, as shown in Figure 42 means the shaking is felt by everyone, people find it difficult to stand and structures may suffer some damage. The warning message also displays a map with the location of the epicentre, the magnitude of the earthquake, and the current position of the primary and secondary waves.

5.3.2 Evacuating

An example of an app developed to help with evacuation is the WPS Evac App (Figure 43). During an emergency situation, the app can help building emergency personnel and occupants respond by following the procedures found on the mobile app. If evacuation is necessary emergency personnel and occupants can quickly access the evacuation map that will lead them to a recommended location away from the building. Once they safely reach the recommended assembly area, the floor warden can conveniently send an “all clear” or “alert status” directly from the app to building personnel.

Figure 43: WPS Evac App to assist with evacuating a building



Source: Google Play, "WPS Evac". Available at https://play.google.com/store/apps/details?id=com.mark.buildingevac&hl=en_US.

5.4 ICT for Shelter Planning

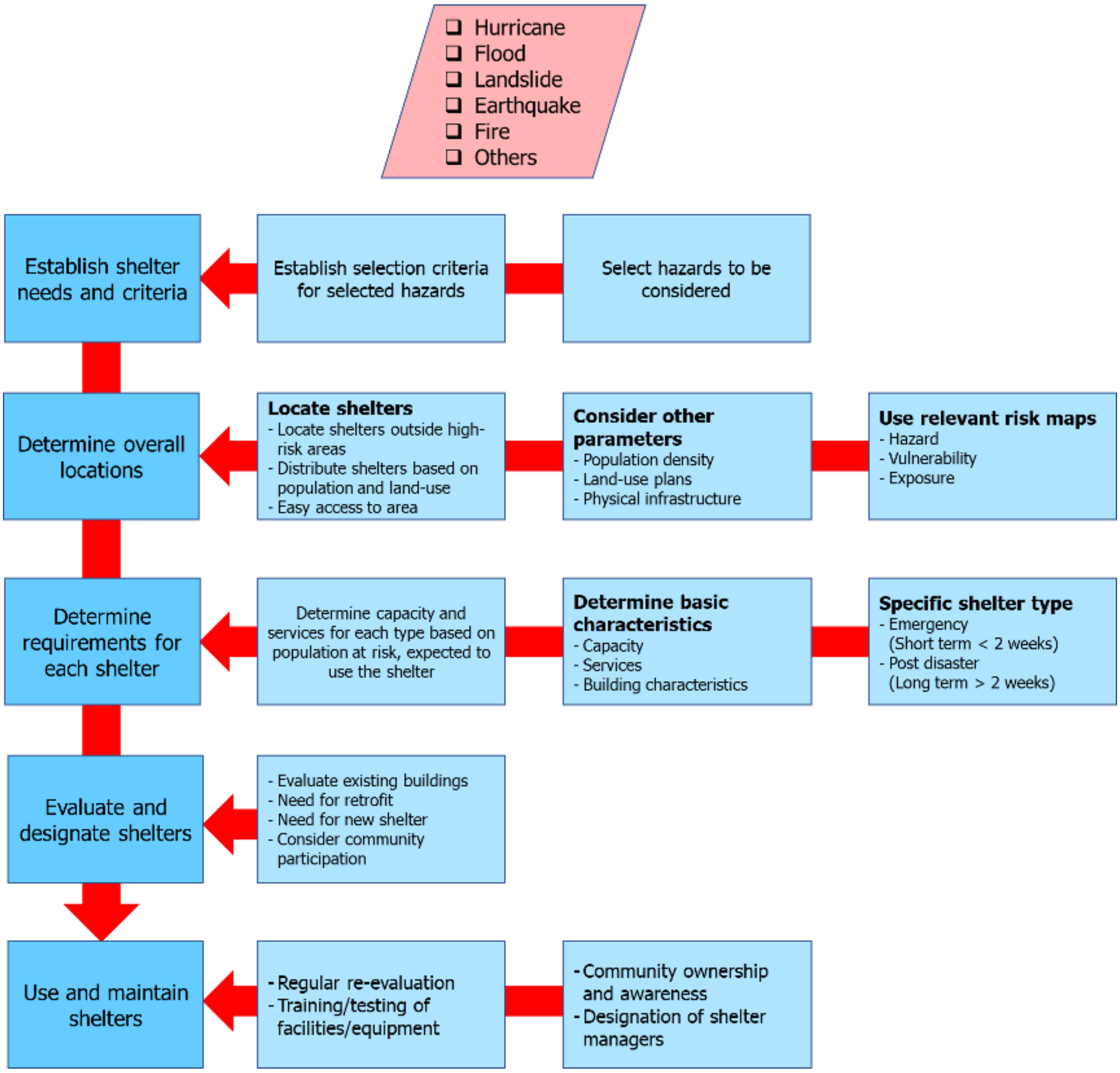
Emergency shelters provide an interim replacement for the basic needs of people affected by disasters and emergencies until they or their communities are able to support a return to normalcy. A shelter facility can either be designed and constructed solely as an emergency shelter or have multiple uses (e.g., as a community centre, school or religious institution). The shelters may be used during an emergency when a hazard warning is issued or a hazard is imminent, and they act as safe places away from floods or are built to withstand strong winds, for example. Shelters may also be used post disaster to accommodate people who have lost their homes after a disaster. Emergency shelters provide a safe, sanitary and secure environment for people to live temporarily.

Shelters must be designed at higher standards than regular buildings as they need to withstand extreme events. These shelters need to not only remain intact, but they must also be operational and serviceable, and have the capacity to accommodate a large number of people packed together along with their belongings.

The preferable solution to providing protection to residents is to build a new and separate building specifically designed and constructed to serve as an emergency shelter. The potential advantage of a stand-alone shelter is the safe location away from potential hazards. However, incorporating the shelter into an existing building or a planned renovation or building project may reduce the shelter cost and may be more easily accessible to residents in the locality.

Shelters must be evaluated in a systematic way in terms of safety, functionality and criticality to reduce vulnerability and disaster risk. Figure 44 summarizes the procedures for the various phases of shelter planning.

Figure 44: Procedures for the various phases of shelter planning



The key steps for shelter planning are as follows:[87]

- **Establish shelter needs and evaluation / analysis criteria** – The first step of the shelter evaluation process is to gather primary information related to hazard type, including past events information and community knowledge. Shelter

[87] For information on hurricane shelter planning, see: Hawaii Emergency Management Agency, "Hurricane Evacuation Shelter Planning and Operations Guidelines", December 2017. Available at https://dod.hawaii.gov/hiema/files/2018/02/State-Guidelines-for-Hurricane-Evacuation-Shelters.FINAL_.December-2017.pdf.

analysis criteria are established based on selected hazard type and information, and include shelter safety, functionality and criticality.

- **Determine shelter location** – This step involves determining the approximate location and distribution of possible shelters according to the community and population to be served. This needs to be based on the exposure of the community to multiple hazards, the types of hazards, the safety of the shelter surroundings and the structural vulnerability of the shelters to the hazards. Other parameters that should be considered are population density, which relates to shelter capacity, the availability and number of access roads / paths, warning time and travel time (i.e., distance from the surrounding community). Primarily, shelters should be located outside of the high-risk areas. Where not possible, the shelters should be located in the least hazardous portion of the high-risk areas.

Figure 45: Use of GIS for identifying gaps in shelter distribution

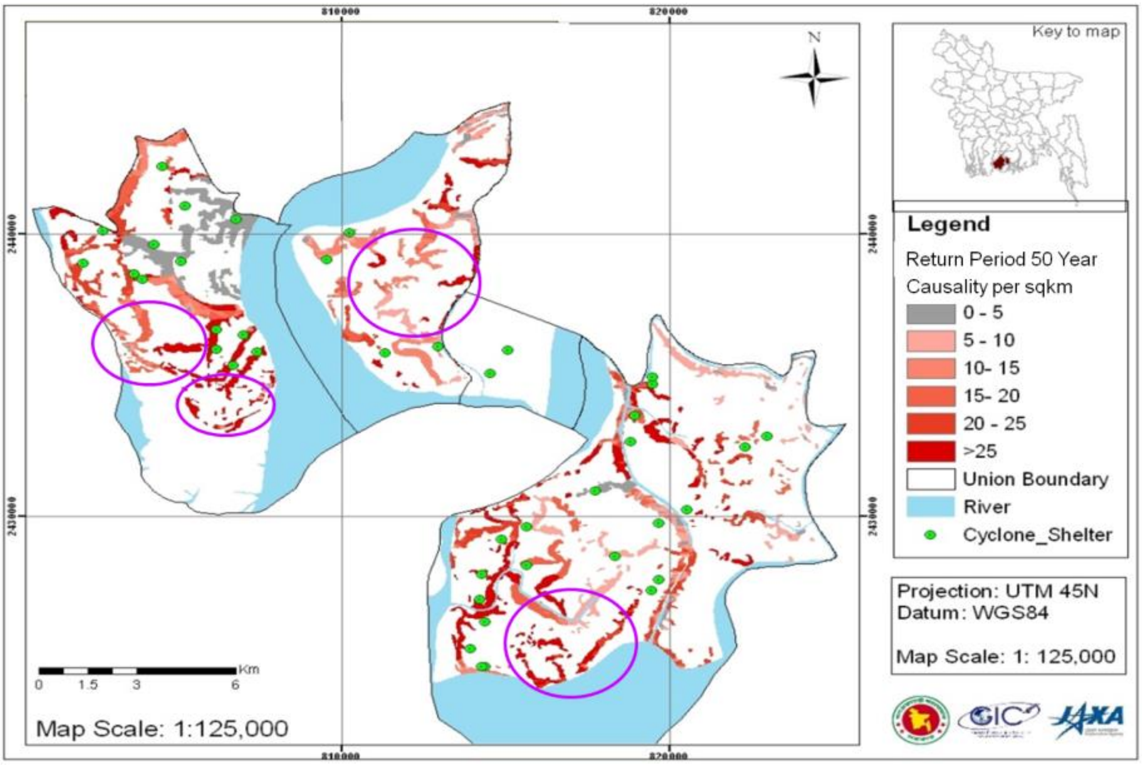


Figure 45 shows a storm surge risk map for a 50-year tropical cyclone along with the distribution of existing cyclone shelters in Barguna district of Bangladesh. The risk map is based on storm surge inundation depth and the vulnerability of buildings and populations exposed to the storm surge, and shows the expected human casualties per square kilometre. Examining the existing cyclone shelter locations, the risk map clearly shows that there are several high-risk areas in the Barguna district where no shelters are available, while a number of shelters are found in other areas of lower risk. Such an uneven distribution of shelters can be clearly identified by modelling and analysing the relevant digital data in the GIS environment, and additional shelters may be constructed to fill the existing gaps and reduce the risk.

- **Determine requirements for each shelter** – This step focuses on developing the requirements and selection criteria for the particular shelter to be provided or designated. For example, flood shelters need to be at higher elevation, or have liveable floors well above the expected flood level and are strong enough to withstand the water currents and debris flow. For windstorm and hurricane shelters, buildings must have strong roofs, cladding walls, and doors and windows with proper locking and shutters. The shelter criteria may include requirements for multiple hazards. Other considerations include accessibility to communities, duration of occupancy, security, proper ventilation, emergency exits, and storage provisions for food, water and first-aid kits.

- **Evaluate and designate shelters** – Based on the selection criteria, either the community or the local government can propose a list of buildings in close proximity to the optimum location of the shelters for consideration. These can be schools, religious buildings or other suitable buildings. If no such suitable building can be found, a new dedicated shelter may be proposed as a community centre.

  The designated shelters are normally based on recommendations from the evaluation agency. This may involve using the building as it is, or with recommended retrofits or modifications. If the proposed buildings are not suitable, the evaluation agency may recommend selecting an alternative building. This evaluation can be carried out using a site survey and multiple considerations. The evaluation process can also be formalized using the analytic hierarchy process[88] to reduce subjectivity.

- **Use and maintain shelters** – It is important to properly maintain the shelters in order to keep them ready for an emergency event. This can be done through creating awareness and community ownership, as well as designation of shelter managers. Regular re-evaluation, training, and testing of facilities and equipment should be planned and scheduled.

5.5 ICT for Early Warning

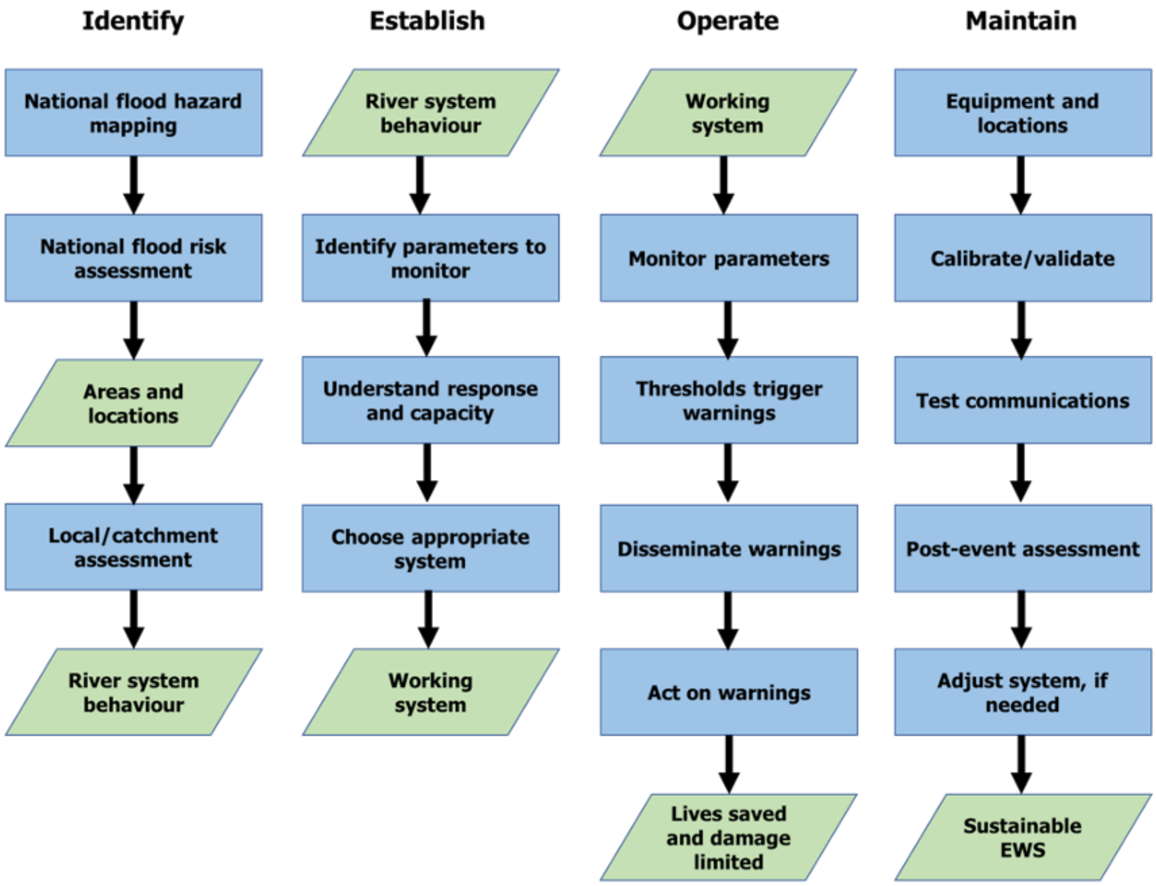
Early warning systems are one of the important elements of disaster preparedness and they are designed to provide early warning to people with as much lead time and certainty as possible, in order to allow individuals and communities threatened by hazards to act in time and in an appropriate manner to reduce the possibility of

[88] The analytic hierarchy process is a multi-criteria decision-making approach that can be used to solve complex decision problems. It uses a multi-level hierarchical structure of objectives, criteria, subcriteria and alternatives.

injury, loss of life, and damage to properties and livelihoods. In 2006, the United Nations[89] identified four elements in natural hazard early warning systems:

- **Risk knowledge** – The systematic assessment of hazards and vulnerabilities, and mapping of their patterns and trends;
- **Monitoring and warning service** – Accurate and timely forecasting of hazards using reliable, scientific methods and technologies;
- **Dissemination and communication** – Clear and timely distribution of warnings to all those at risk; and
- **Response capability** – National and local capacities and knowledge to act correctly when warnings are communicated.

Figure 46: Schematic representation of the components of a flood early warning system



Note: EWS = early warning system.

[89] United Nations, *Global Survey of Early Warning Systems* (2006). Available at https://www.unisdr.org/2006/ppew/info-resources/ewc3/Global-Survey-of-Early-Warning-Systems.pdf.

The process diagram in Figure 46 shows how various components are used in the set up and operation of an early warning system. These are divided into four simple stages for clarity and it should be noted that some of these stages may occur in parallel, and they are not necessarily sequential.

The example of a flood early warning system is used to understand how ICTs can contribute to an effective early warning system. Most of the following principles apply equally to other hazards:

- **Identify the need for an early warning system** – The first step in designing an early warning system is to identify if and where there is a need for one. Since an early warning system can cater to multiple hazards, it is always better to look at the overall hazard, exposure and risk in the area of interest in order to design a robust system.

- **Conduct hazard and risk assessment** – If there are existing maps on flood hazards, this can be used as an ideal starting point. If hazards maps are not available, then a hazard assessment should ideally be undertaken as described in Section 3. The national hazard map will show general areas where there is a high probability of the hazard occurring (rather than just recent historical events). This can be used in a national flood risk assessment that takes into account infrastructure, property and human exposure to floods, and quantifies the severity. The outcomes from this risk assessment can then be used to objectively identify where an early warning system will bring the most benefit in terms of reducing the flood risk. Usually, these will be urban centres and infrastructures, as well as low-density urban areas. Depending on the objectives of the early warning system, the risk assessment may also include agricultural areas and undeveloped areas (Table 9).

Table 9: Flood impact zones

Flood risk	Flood Impact Zone			
	Undeveloped area (low)	Agricultural land (medium)	Low density urban (high)	Urban centres & key infrastructure (very high)
High	High/low	High/medium	High/high	High/very high
Medium	Medium/low	Medium/medium	Medium/high	Medium/very high
Low	Low/low	Low/medium	Low/high	Low/very high

The colour codes, green-yellow-orange-red, are indicative of the importance/benefit of flood forecasting and warning

Source: World Meteorological Organization, Integrated Flood Management Tools Series, Issue 19, 2013.

- **Catchment or location assessment** – Once the location for the early warning system is identified, it is necessary to look in more detail at the location-specific context of the chosen area. This means establishing how the hazard is most likely to occur with a detailed description of its characteristics. This will allow an appropriate early warning system to be established.

The location-specific context is established through a catchment or location assessment. Undertaking this assessment requires a skilled specialist with good technical understanding of meteorological, hydrological and hydraulic processes in order to thoroughly assess how the river system works and the detailed mechanisms that occur during a hazard event. It should be noted here that although there may be similarities between catchments, local conditions and characteristics often make flood hazard a particularly local phenomenon, which means this level of assessment is essential, otherwise there is a risk that the early warning system will be poorly implemented, perhaps warning the wrong people / areas or setting inappropriate warning thresholds.

This local assessment should cover hazard events from start to finish, beginning with climate and weather conditions that give rise to the flood events (e.g., high intensity rainfall from tropical storms), the catchment conditions and characteristics that give rise to particularly dangerous river conditions (e.g., steep slopes and impervious soils in the upper catchment), and finally how the high river levels lead to out-of-bank flows and the consequential flood flow paths through populated areas.

Understandably, this level of assessment requires a reasonably large amount of geophysical and exposure data of an appropriately fine resolution, some of which may be available already, but it is likely that some specific local surveys may be required to collect suitable data (e.g., details of population and buildings at risk in floodplain areas in order to know who to warn). It is likely that catchment or fluvial (river) computer modelling will be undertaken as part of the local assessment to establish catchment and flood behaviours. A critical component of this local assessment will be in the form of local knowledge, making up for data limitations and feeding in stakeholders' first-hand experience of what happens in an event. The technical specialist often collects this through a catchment walk-through and interviews with stakeholders.

The outcomes of the local assessment form the basis for the design and implementation of the early warning system. In summary, the local assessment should identify:

- What conditions give rise to an event? There may be more than one mechanism that gives rise to risk. This will make it clear what should be monitored in order to get an early indication that an event is imminent;

- What explicit parameters to monitor, where to measure them and how frequently to measure them; and

  - The physical flow paths and timings of events, possibly with intensity (e.g., depths and velocities). This will make it clear who will need warning and how quickly. The understanding of the timing is crucial for an early warning system.

- **Monitoring parameters and thresholds for an early warning system** – Once an understanding of the river system and what is likely to occur in an event has been ascertained, it is possible to design and build an appropriate system. It should be clear from this knowledge, which specific locations will be best for monitoring relevant parameters, for example, rainfall higher up in the catchment, and upstream and local water levels. Measuring rainfall and river levels form the core monitoring system for flood early warning. Furthermore, speedy and reliable delivery of data from the field to the monitoring centre is critical. ICTs play an important role here in taking measurements through electronic sensors and transmitting the data to the monitoring centre.

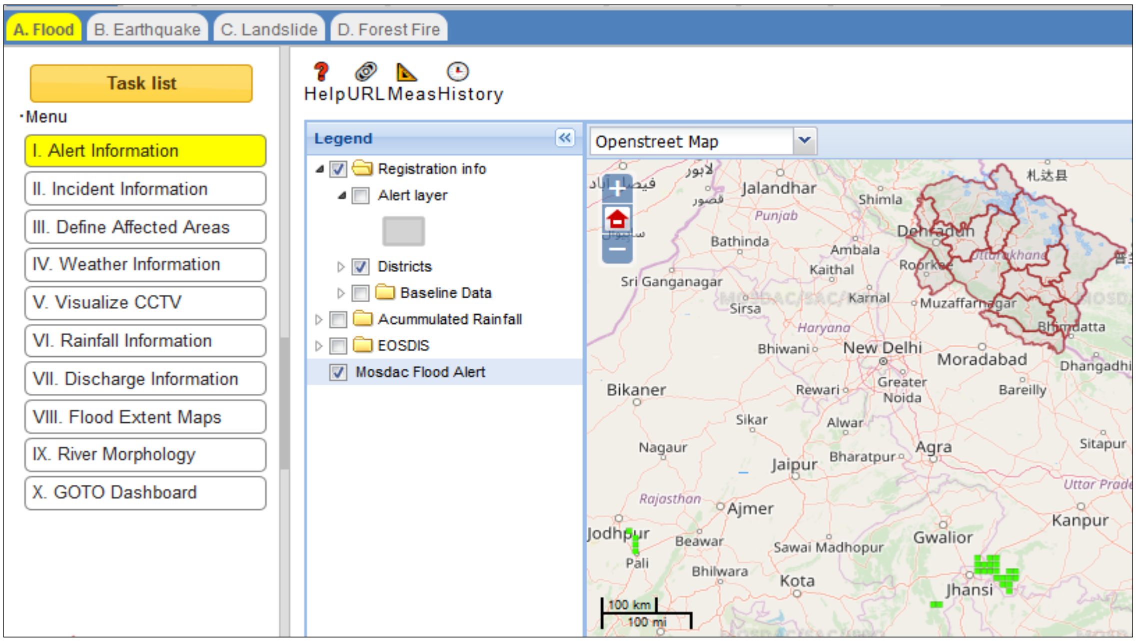
  The basic types of instruments used for flood monitoring are: (1) tipping bucket rain gauges; (2) water level recorders; (3) ultrasonic flow measurement devices; and (4) automatic weather stations. While complex automated systems may seem an ideal solution, they can be challenging to maintain, and can limit contribution and involvement of relevant communities, which may limit the sustainability of the early warning system. It is generally better to use a measurement method that involves the community to encourage engagement, and in the long run, promote a sense of ownership for the very people that the system is designed to warn.

- **Information dissemination** – Typically for an early warning system, when monitored parameters exceed predetermined thresholds (determined from local assessment described above), this triggers the next stage of the system. This next stage involves informing a designated person that the threshold has been exceeded, and puts into action the predetermined plan of disseminating warnings and acting on those warnings.

  The responsible parties for disseminating warnings can vary depending on local capabilities and legal responsibilities. If there is a strong and well-supported institutional capability, the monitoring and dissemination may be undertaken by local government institutions. However sometimes, for similar reasons to community monitoring of parameters, it may be better to involve local communities in this role, particularly if the community already has a strong collective sense of responsibility.

  How messages and warnings will be practically disseminated is of critical importance and should be studied in detail, including having alternative forms of communication in case the primary system fails. A physical system with a user-friendly interface is necessary to monitor and communicate warnings (Figure 47), and it is important that clear procedures are established so that responsible parties understand what they need to do at each stage of an event. These procedures should be documented in a clear, easy to understand way, and need to be easily available, ideally posted in clear view (not in a report on a shelf).

Figure 47: Example of an interface for a flood monitoring and early warning system



It is common for an early warning system to use several levels of increasingly urgent warnings, with each level raising the urgency and escalating the warning to more people to take further actions. This multi-tiered approach is sometimes referred to as the "Ready, Set, Go" concept that conveys the severity and timing of a forecast hazard and the level of forecaster confidence. This is typically to allow for the fact that an early warning system is most effective if warnings are given as early as possible but offset by the fact that very early warnings can be unreliable due to uncertainties of an event actually happening. False warnings can have a counterproductive effect in that too many will lead communities to ignore future warnings with potentially disastrous consequences.

An example of a multi-tiered approach is an early warning of impending high rainfall from the meteorological services being communicated by short message service (SMS) or voice to designated volunteers who are put on alert of a possible event. The volunteers can then monitor the weather system to see if it triggers a threshold or passes by without consequences.
While implementing an early warning system, it is desirable to follow a standard and an international standard called the Common Alerting Protocol (CAP) is

already available for making the system compatible locally, regionally and nationally, as explained in Box 1. The CAP is being promoted by the International Telecommunication Union and the World Meteorological Organization.

Box 1: The Common Alerting Protocol

The CAP is an international standard for emergency alerts and public warnings. It is an open, non-proprietary XML-based digital data interchange format that can be used for alerts and warnings locally, regionally and nationally for input into a wide range of information management and warning dissemination systems. It is designed for **all hazards** related to weather events, earthquakes, tsunamis, volcanoes, public health, power outages and many other emergencies. It is also designed for **all media**, including sirens, mobile phones, faxes, radio, television and various digital communication networks based on the Internet. The CAP allows a consistent warning message to be disseminated simultaneously over many different warning systems, thus increasing the warning's effectiveness while simplifying the warning task.

The CAP is the first step in developing an integrated and seamless alert and warning system by replacing single-purpose interfaces between alert or warning sources and dissemination media to serve as a "universal adaptor". With CAP, an alert sender can activate multiple warning systems with a single input, and emergency managers can compile diverse alert sources for situational awareness. It provides a template for effective warning messages based on the best practices identified in academic research and real-world experience. The implementation of CAP can integrate all stakeholders through a common information exchange hub for better coordination at the time of a disaster.

Some of the important CAP features are:

- Flexible geographic targeting using latitude / longitude boxes;
- Multilingual and multi-audience messaging;
- Enhanced message update and cancellation features;
- Template support for framing complete and effective warning messages;
- Digital encryption and signature capability;
- Facility for digital images, audio and video; and
- Enhanced situational awareness at local and regional levels.

The final stage in the warning process is action based on the warnings. This can include individual responsibilities to prepare or evacuate, but also involves those who ensure action is taking place and further reinforces the message for people who may not have received the initial warnings. This can involve responsible officials and/or community members.

While dissemination of early warnings up to the last mile has been improved to a great extent with the expansion of mobile networks and increase in bandwidths in recent years, there are still gaps especially in remote areas of the developing countries. However, efforts are being made to reduce such gaps through development of satellite-based communication systems for delivering early warning messages. The satellite-based early warning system has another advantage of continuity and reliability even at the time of a catastrophic disaster when traditional communication systems may not be available.

One of the satellite-based early warning systems is the Quasi Zenith Satellite System (QZSS), which is one of the GNSS that supports SMS facilities for early warnings.[90] While primary functions of the QZSS is to provide precise positioning of objects, it has an additional capability to send SMS to a designated point or a polygon. This system belongs to Japan, but the Japanese government is considering making the early warning facility freely available to countries in Asia and the Pacific from where the satellites are visible.

Figure 48: Information flow in QZSS

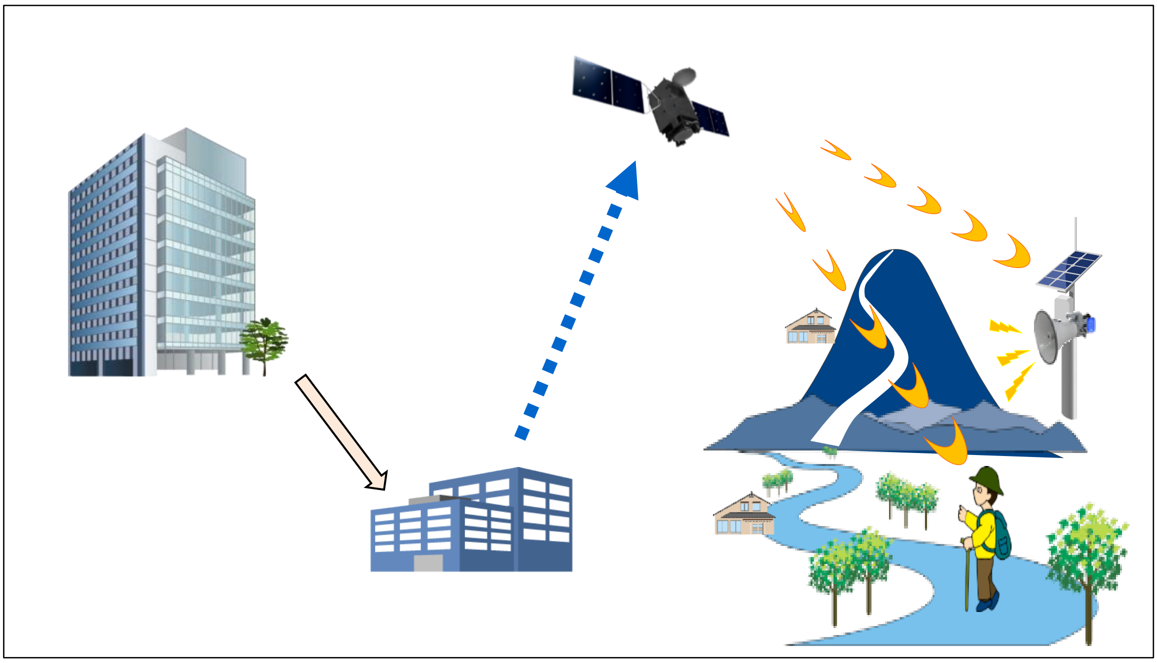


Figure 48 shows the flow of information in QZSS. An early warning message coming from the source (meteorological agency) first goes to a control station, which is

[90] Koji Suzuki, "QZSS Application to Early Warning Information Platform", *Modern Environmental Science and Engineering*, vol. 5, no. 10 (2019), pp. 901-908.

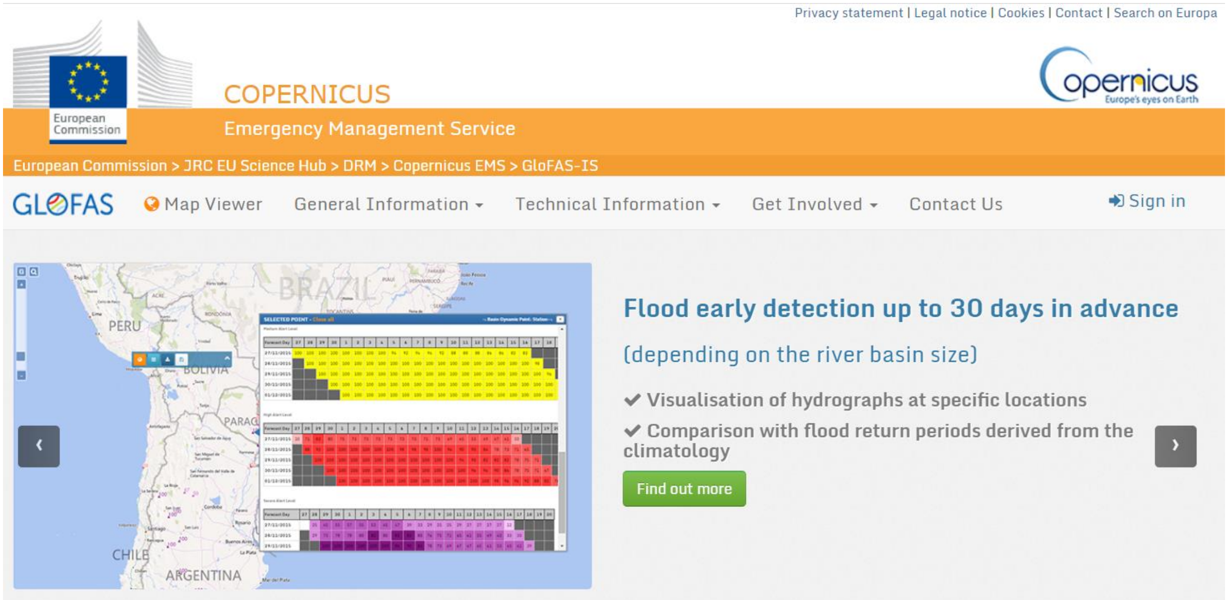
uplinked to a QZSS satellite. The satellite system then broadcasts the early warning message that can be received at the ground through a compatible receiver.

5.6 Examples of Early Warning Systems for Different Hazard Types

5.6.1 Global Flood Early Warning System

The Global Flood Awareness System (GloFAS)[91] is the global flood monitoring and forecasting service of the European Commission Copernicus Emergency Management Service. GloFAS provides a daily hydrological forecast with an overview of upcoming flood events for the next 30 days (GloFAS 30-day). It also provides a monthly hydrological forecast with river flow outlooks highlighting unusually high or low river flow up to 16 weeks ahead (GloFAS Seasonal). The aim of GloFAS is to complement national and regional authorities and services, and support international organizations in decision-making and preparatory measures before major flood events (particularly in large transnational river basins). GloFAS only focuses on rivers, and does not provide real-time forecast information on flash flood risk, coastal flooding or inundated areas.

Figure 49: Screenshot of GloFAS



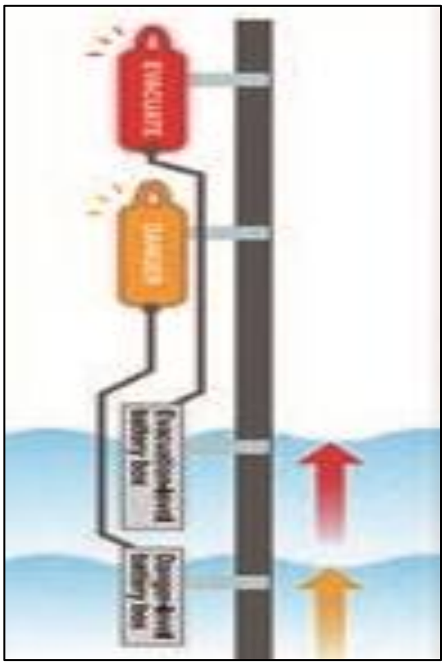
Source: European Commission Copernicus, "GloFAS". Available at https://www.globalfloods.eu/.

[91] European Commission Copernicus, "GloFAS". Available at https://www.globalfloods.eu/.

5.6.2 Local Flood Early Warning System

Water batteries have been invented for providing automated early warnings for flood.[92] These batteries are activated when immersed in water and generate electricity. This characteristic of the batteries is used to provide early warnings when batteries placed at a marked flood level in a river gets soaked. The electricity generated turns on the lights of different colours (Figure 50), indicating different level or intensity of floods so that the community can take appropriate action, such as evacuation to higher and safe places. There is also a provision for data transmission to the concerned agencies or authorities.

Figure 50: Water battery for flood early warning



This is a low-cost solution for providing timely early warning to local communities and authorities, particularly in areas where an early warning system is not in place.

5.6.3 Earthquake Early Warning System

Despite many attempts, there are still no operational systems that can warn populations with enough lead time for full evacuation from earthquakes. There are, however, tools that give a warning with enough lead time (seconds to tens of seconds) to seek immediate shelter or shut off vulnerable equipment. One example is the ShakeAlert App shown in Figure 42.

Another example is the Earthquake Guard (Figure 51) that detects “P” (primary) wave before the arrival of the “S” (secondary) wave that causes shaking.[93] The Earthquake Guard has a specialized software to distinguish between earthquake and living noises, which prevents the issuing of false alerts. The Earthquake Guard can issue alerts in multiple languages in accordance with the estimated seismic intensity level of an earthquake. The Earthquake Guard can also automatically shut down critical infrastructure like elevators, power and gas supplies, and stop the production line at factories to prevent the occurrence of cascading hazards and their impacts. At the community level, the Earthquake Guard provides citizens a short

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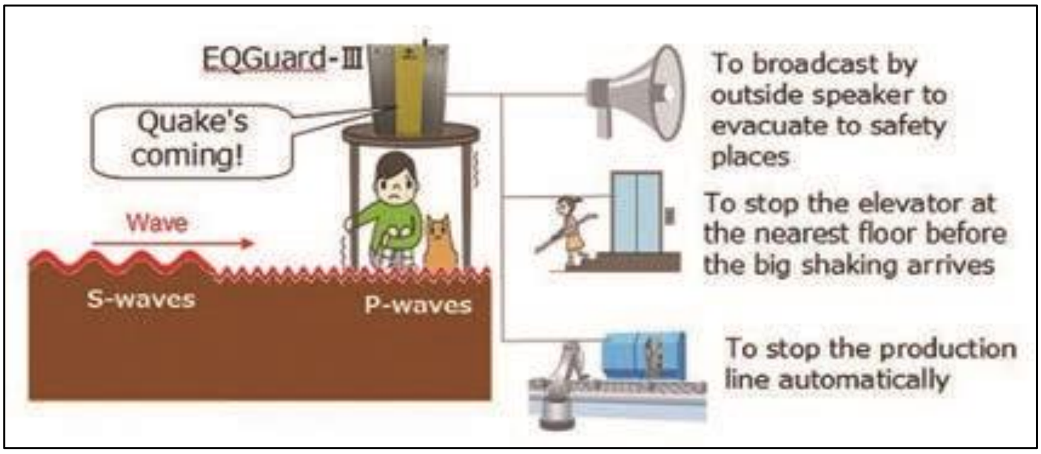
[92] Takako Izumi and others, "30 Innovations for Disaster Risk Reduction", International Research Institute of Disaster Science, March 2019. Available at https://apru.org/wp-content/uploads/2019/03/30-Innovations-for-Disaster-Risk-Reduction_final.pdf.
[93] Ibid.

window to take actions for safety, thus helping to create a culture of safety and informed decision-making.

Figure 51: Overview of the Earthquake or EQ Guard



5.6.4 Global Drought Early Warning System

The Global Drought Observatory is an initiative of the European Commission Copernicus Emergency Management Service (Figure 52).[94] It provides drought-relevant information such as maps of indicators derived from different data sources (e.g., precipitation measurements, satellite measurements, modelled soil moisture content). Different tools, like graphs and compare layers, allow for displaying and analysing the information.

Figure 52: Screenshot of the Global Drought Observatory

Source: European Commission Copernicus, "GDO – Global Drought Observatory". Available at https://edo.jrc.ec.europa.eu/gdo/php/index.php?id=2001.

[94] European Commission Copernicus, "GDO – Global Drought Observatory". Available at https://edo.jrc.ec.europa.eu/gdo/php/index.php?id=2001.

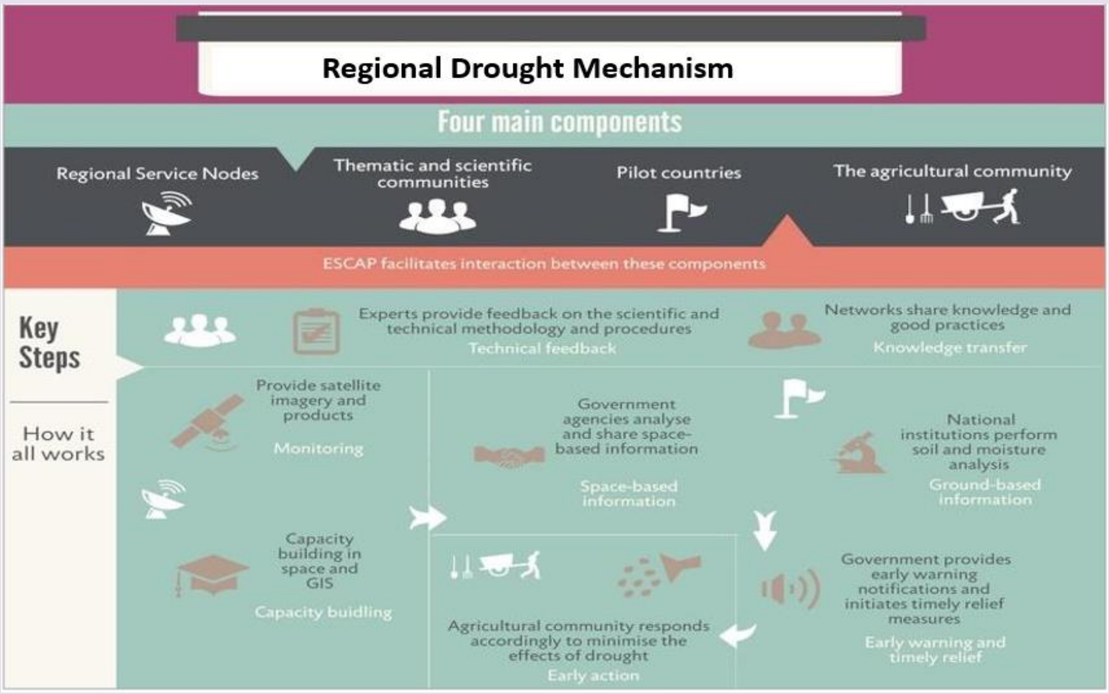
Case Study 4: The Regional Drought Mechanism for Monitoring and Early Warning

The Regional Drought Mechanism was initiated in 2013 to address the scarcity of resources and capacity to analyse data in many drought-prone developing countries in Asia and the Pacific. It is a flagship programme of ESCAP under RESAP (see Case Study 1) designed to enhance the capacity of governments in the use of space-based data for effective drought monitoring and early warning. The mechanism has four components (summarized in Figure 53):

1. **Regional service nodes**, currently in China, India and Thailand, provide satellite data and services as well as capacity development activities in the pilot countries in the region;
2. **Thematic and scientific communities** where diverse groups are networked together under specific thematic areas to advise on drought monitoring and early warning, preparedness and action;
3. **Pilot countries** are selected upon their request to participate in the mechanism as beneficiaries of the cutting-edge science and technology to better prepare for drought; and
4. **Agricultural community** that directs the beneficiaries on the ground to proactively reduce the impacts from droughts, based on sound knowledge and timely warning information from government institutions.

ESCAP facilitates interactions among these components through an iterative process adapted to each country's context to build their resilience to drought.

Figure 53: Components and steps of the Regional Drought Mechanism



For example, through the RESAP network, ESCAP facilitated the matching of Mongolia's drought monitoring needs with the ability, in particular from China, to provide customizable tools and expertise. Following a five-year development and learning process, DroughtWatch-Mongolia was officially handed over to Mongolia on 17 September 2018 in full operation with the ability to provide real-time drought monitoring for DRM.

The Mongolian National Remote Sensing Centre under the Information and Research Institute of Meteorology, Hydrology and Environment is now collaborating with the regional service node in China to expand the capabilities of the system to include the monitoring of *dzud*, which is an extreme weather event causing livestock mortality due to the summer drought and subsequent harsh winter conditions.

Such multi-year and multi-partner investments reveal how the Regional Drought Mechanism can be successfully tailored to local needs, with sustainability and future use in mind.

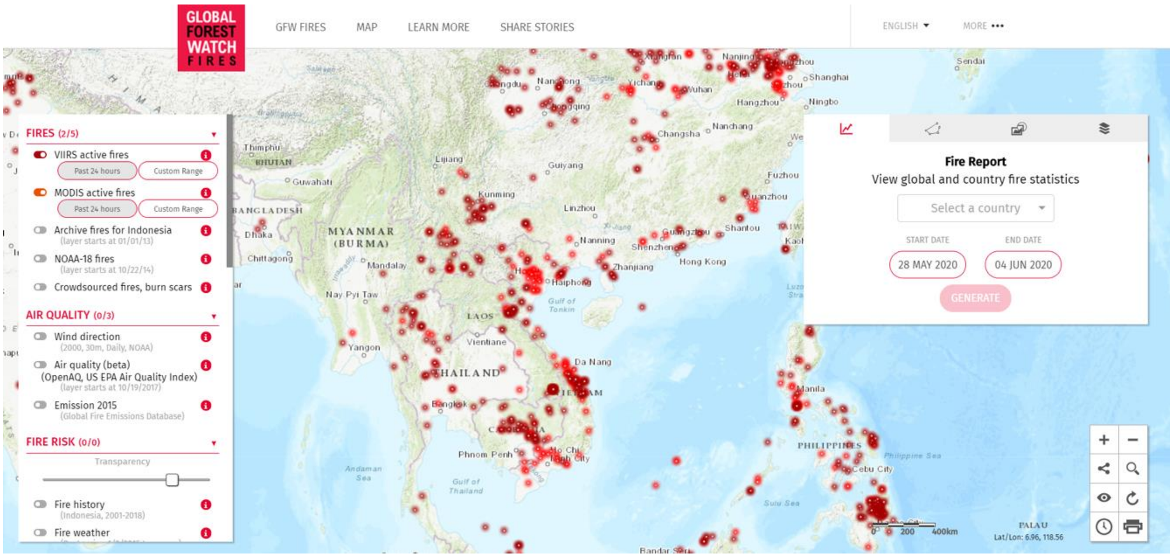
Sources: ESCAP, "ESCAP's Regional Cooperative Mechanism for Drought Monitoring and Early Warning". Available at https://www.unescap.org/our-work/ict-disaster-risk-reduction/regional-cooperation-in-disaster-risk-reduction/rcm-drought-monitoring-early-warning; and ESCAP, "DroughtWatch System in operation in Mongolia", video, 11 February 2019. Available at https://www.unescap.org/sites/default/files/Regional%20Drought%20Monitoring%20Mechanism%20REV%204_rev.mp4.

5.6.5 Forest Fire Early Warning System

Global Forest Watch Fires[95] (Figure 54) is an online platform for monitoring and responding to forest and land fires using near real-time information. The platform combines real-time satellite data from NASA's Active Fires System, high-resolution satellite imagery, detailed maps of land cover and concessions for key commodities such as palm oil and wood pulp, as well as weather conditions and air quality data to track fire activity and related impacts. Global Forest Watch Fires provides analysis to show where fires occur and help understand who may be responsible. The platform aims to empower people to better combat harmful fires before they burn out of control and hold accountable those who may have burned forests illegally.

[95] Global Forest Watch Fires. Available at https://fires.globalforestwatch.org/home/.

Figure 54: Screenshot of the Global Forest Watch Fires

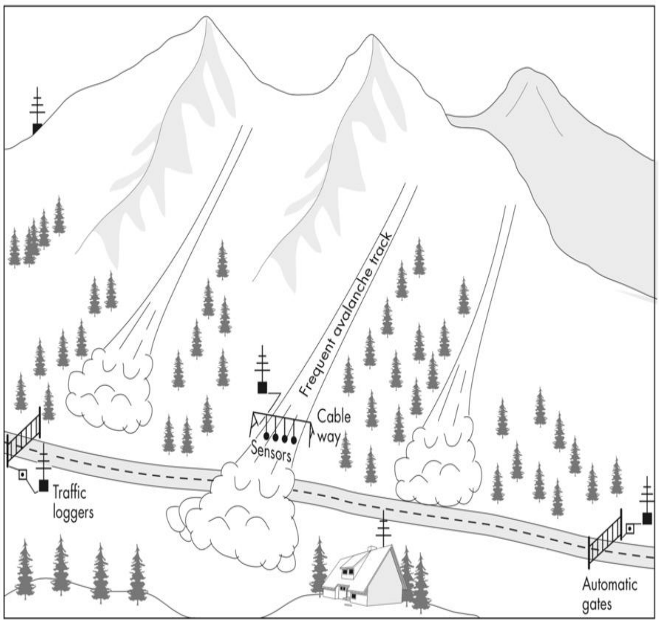


Source: Global Forest Watch Fires. Available at https://fires.globalforestwatch.org/home/.

5.6.6 Snow Avalanche Early Warning System

Avalanches occur in mountain areas if snow is deposited on slopes steeper than 20°. Figure 55 shows an avalanche early warning and management system deployed on a mountain highway in western USA.[96] A set of automatic avalanche detectors using tilt switches has been deployed near the road over the most active avalanche track. When these switches exceed a pre-set threshold, the system initiates an early warning by radio telemetry to alert the highway authority of the avalanche and advises road users of the blockage immediately, either by activating flashing warning signs or by closing snow gates at each end of the corridor.

Figure 55: Avalanche monitoring and management system



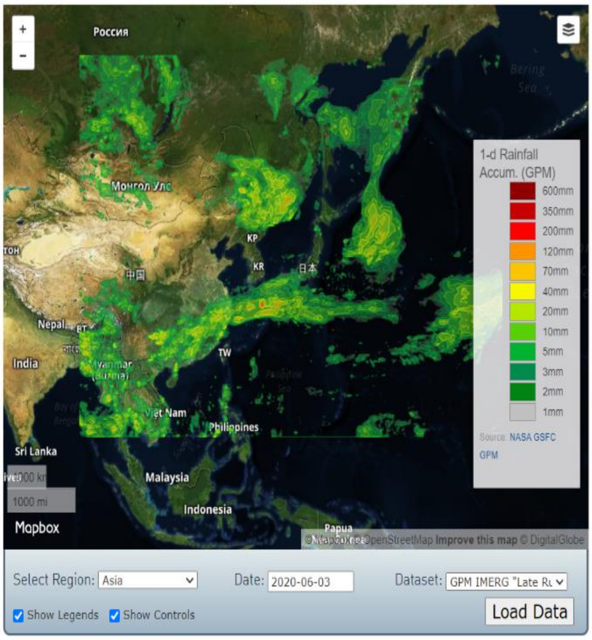
Source: Robert Rice Jr. and others, "Avalanche hazard reduction for transportation corridors using real-time detection and alarms", *Cold Regions Science and Technology*, vol. 3, no. 1 (February 2002), pp. 31-42.

[96] Robert Rice Jr. and others, "Avalanche hazard reduction for transportation corridors using real-time detection and alarms", *Cold Regions Science and Technology*, vol. 3, no. 1 (February 2002), pp. 31-42.

5.6.7 Landslide Early Warning System

Landslide early warning is more complicated than other types of natural hazards as landslide initiation locations are difficult to predict. Current initiatives of landslide early warning mostly focus on establishing a regional threshold for landslide warning, which does not include a spatial prediction of the types, numbers and volumes of landslides needed for risk assessment. For rainfall-induced landslides, NASA has been working for some time on the Landslide Hazard Assessment for Situational Awareness method that incorporates a global landslide susceptibility map with rainfall estimates from satellite data (Figure 56).[97]

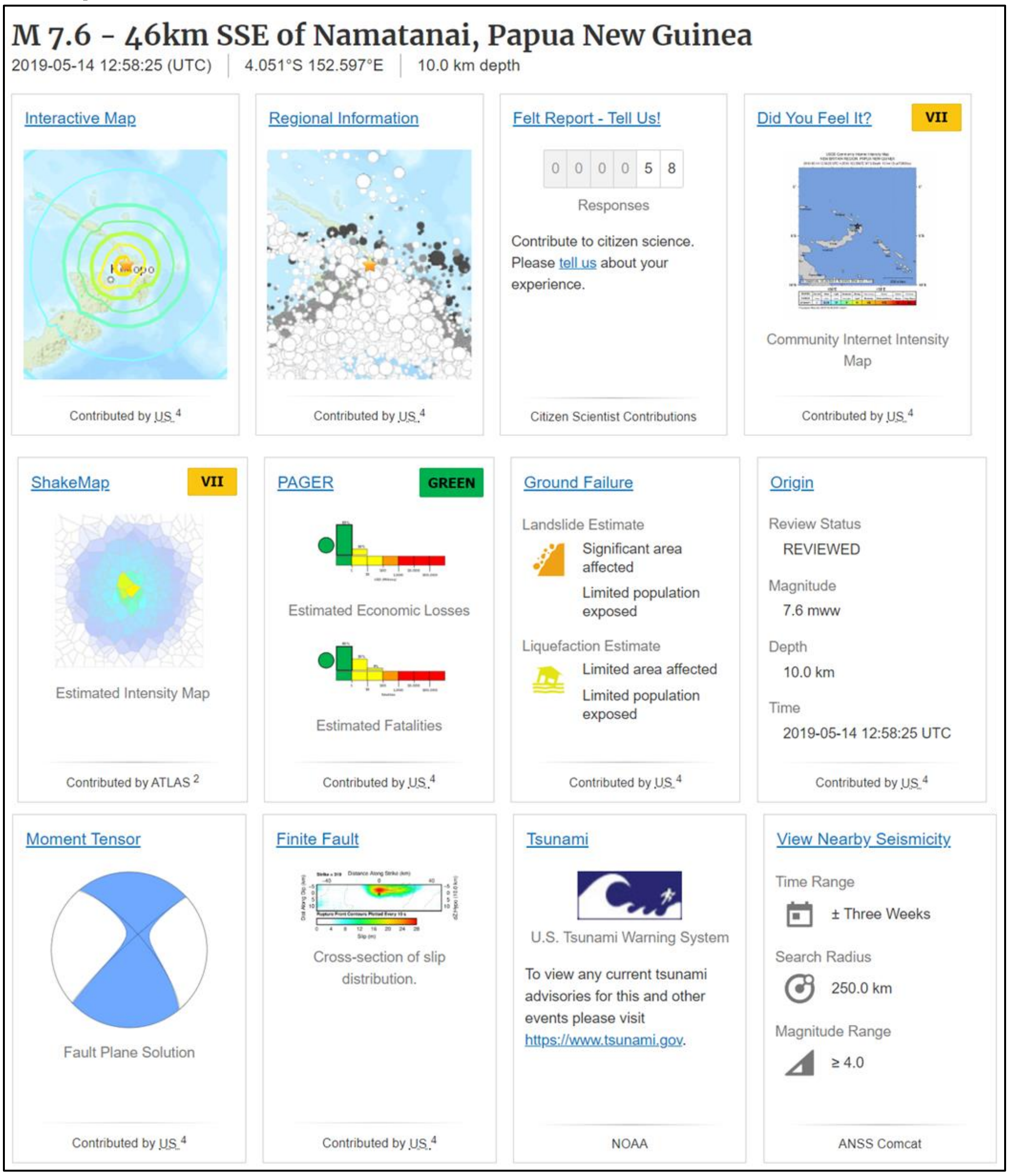
Figure 56: NASA's effort to establish a landslide early warning system using satellite data



In the field of earthquake-induced landslides, there have been attempts to generate rapid information on expected landslide distribution following an earthquake to support rescue planning. The earliest attempts were made by Godt and others (2008) using a hybrid model that included a basic Newmark model approach. Statistical models, however, proved to be more effective as demonstrated by Nowicki Jesse and others (2018) and Tanyas and others (2019). The model developed by Jesse and others is being used by the USGS in combination with population data to give an estimation of the number of people that may be affected by earthquake-induced landslides (Figure 57).

[97] NASA Global Precipitation Measurement, "Modeling and Reporting Landslides". Available at https://gpm.nasa.gov/applications/landslides#modelingandreportinglandslides.

Figure 57: Example of information for an earthquake provided by USGS that includes warnings for landslides, liquefaction, tsunamis and number of people exposed



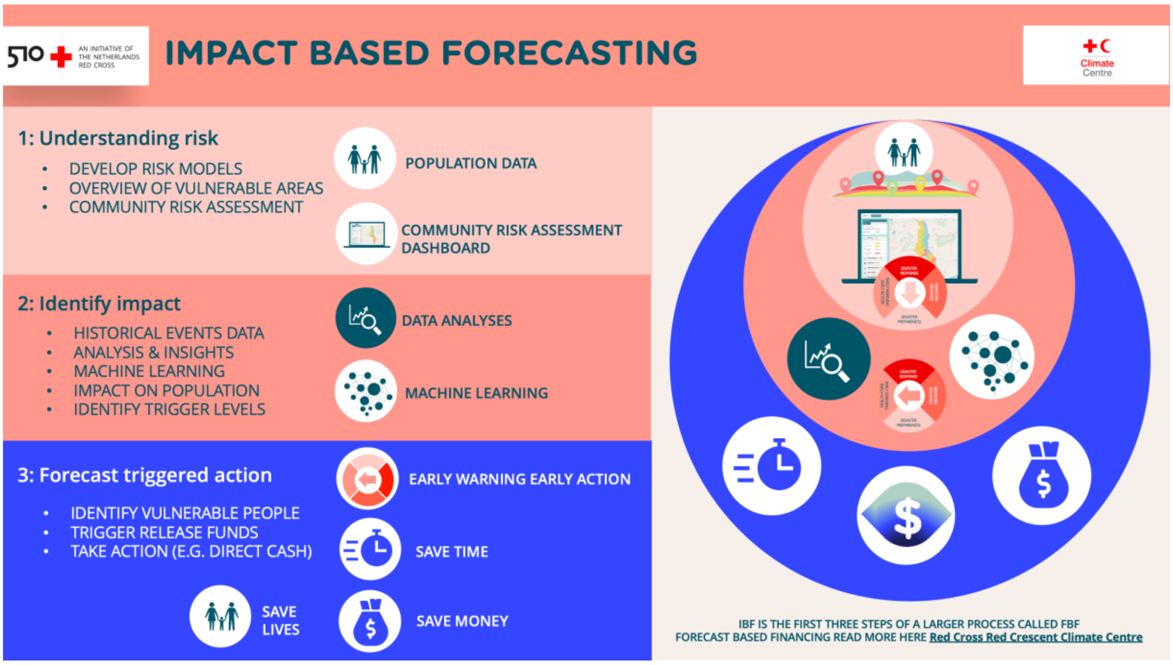
Source: USGS, "Earthquake Hazards Program: M 7.6 - 46km SSE of Namatanai, Papua New Guinea", 14 May 2019. Available at https://earthquake.usgs.gov/earthquakes/eventpage/us70003kyy/executive.

5.7 ICT for Impact-Based Forecasting

Impact-based forecasting is a procedure for providing predictions on the possible impact of disasters based on forecasts of measurable precursors in an early warning system. This impact is analysed using a combination of available data (e.g., population distribution, agricultural areas, infrastructure) and continuously changing data (e.g., weather forecasts).

Impact-based forecasting is part of forecast-based financing that enables access to humanitarian funding for early action based on in-depth forecast information and risk analysis.[98] The International Red Cross and Red Crescent Movement is aiming to change humanitarian assistance with forecast-based financing by directing resources to those area where they will be needed, based on the modelling of the losses and impact of a disaster during the early warning phase. While traditional disaster response is based on damage-limiting reaction to weather-related hazards, finance-based forecasting focuses on anticipating them with the help of scientific data and research.

Figure 58: The principles of impact-based forecasting



Source: Netherlands Red Cross, "IBF: Impact-Based Forecasting". Available at https://www.510.global/impact-based-forecast.

Impact-based forecasting consists of three stages: (1) understanding risk, (2) identifying impact and (3) forecasting triggered action (Figure 58).

For understanding the risk, risk models are developed using relevant geographic data, including population distribution, in order to identify the most vulnerable communities, and the community risk data can be accessed through a dashboard.

For identifying the future impacts of disaster risk on communities, the community risk data is then combined with historical disaster events, and suitable machine learning techniques are used to determine the trigger levels. This helps aid workers

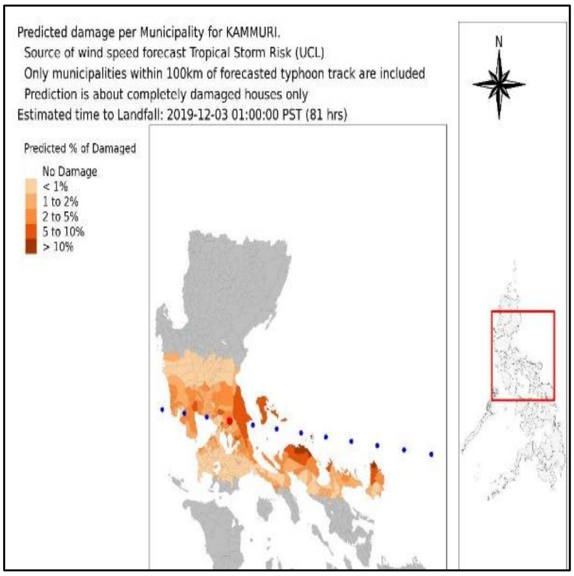
[98] International Federation of Red Cross and Red Crescent Societies and German Red Cross, "Forecast-based Financing". Available at https://www.forecast-based-financing.org/.

in disaster prone areas take necessary actions in the event of a disaster being predicted.

The forecasting of triggered action allows early actions, and when triggered, funds will be released, enabling people in the impending disaster areas with the means to protect themselves.

Figure 59 shows an example of impact-based forecasting. From the forecast, the Red Cross volunteers in the Philippines carried out several activities to reduce the impact of the typhoon, such as the strengthening of houses, securing vulnerable assets, early harvesting of crops and evacuation of livestock from the areas where the impact was expected to be the highest.[99]

Figure 59: Example of impact-based forecasting for Typhoon Kammuri approaching the Philippines



5.8 Policy Considerations

ICTs are effective in enhancing global, regional and national cooperation in early warning. Particularly, ICTs can support national and local early warning systems by facilitating communication between national and local authorities and the communities, as the role of communities in early warning is increasingly being recognized.

Policymakers are encouraged to consider the following issues when developing strategies and plans for identifying and using ICT for disaster preparedness:

- **Unlock the potential of regional cooperation** – Regional cooperation is the key for disaster preparedness. The Asia-Pacific Disaster Resilience Network, an initiative of ESCAP, can strengthen existing knowledge and capacities in disaster preparedness through three interrelated pillars: (1) the regional platform for multi-hazard early warning systems; (2) the regional space applications for disaster risk reduction; and (3) the regional hub of knowledge and innovations.

[99] International Federation of Red Cross and Red Crescent Societies and German Red Cross, "Typhoon Kammuri (Tisoy) approaching the Philippines". Available at https://www.forecast-based-financing.org/2019/12/02/typhoon-tisoy/.

- **Capitalize on new technologies** – The application of ICTs in handling and analysing very large and complex data (big data) to reveal patterns, trends and associations are gaining increasing attention. Taking advantages of big data, governments may initiate forecast-based disaster risk financing and social protection as part of disaster preparedness.
- **Strengthen early warning systems** – Countries are advised to strengthen their early warning systems by integrating geospatial data and satellite data to monitor hazards and assess location-specific impacts. Investment should be made in end-to-end early warning systems, including supporting infrastructure and regulatory framework. Disseminating early warning messages to the last mile, though difficult, may be achieved by embracing ICTs and relevant applications.
- **Encourage standardization** – Standardization is an important component for seamless and wider dissemination of early warnings. The CAP, the international standard for emergency alerts and early warnings, is being promoted by the International Telecommunication Union and the World Meteorological Organization among their member countries.

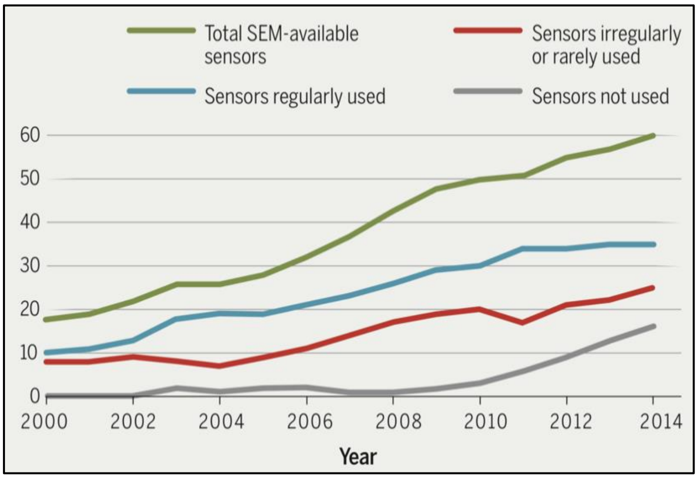
6. ICT FOR DISASTER RESPONSE AND RELIEF

6.1 Introduction

Disaster response refers to actions taken directly before, during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected.[100] Disaster response is mainly focused on immediate and short-term needs and is sometimes called disaster relief.

ICTs can play a major role in effective, efficient and timely response. In recent years, the number of Earth observation satellites has increased and these satellites are equipped with imaging sensors in the visible and near- to mid-infrared part of the electromagnetic spectrum or in the radar frequencies (Figure 60). These sensors with a spatial resolution in the range of 0.3m to more than 300m are useful for disaster impact mapping.[101]

Figure 60: Increasing trend of optical and radar satellite sensors for satellite-based emergency mapping



At the time of a disaster, the situational awareness is very important for directing response efforts, and mobile phones can provide location-specific real-time information through crowdsourcing. High-risk areas, as well as highly vulnerable groups such as the elderly and women-headed households, can be captured in a GIS platform for efficient emergency response. GIS maps along with a navigation system empower emergency authorities to better respond to disasters.

6.2 ICT for Disaster Alerts

One of the main disaster alert systems is the Global Disaster Alert and Coordination System (GDACS),[102] which is a cooperation framework between the United Nations, the European Commission and disaster managers worldwide to improve alerts,

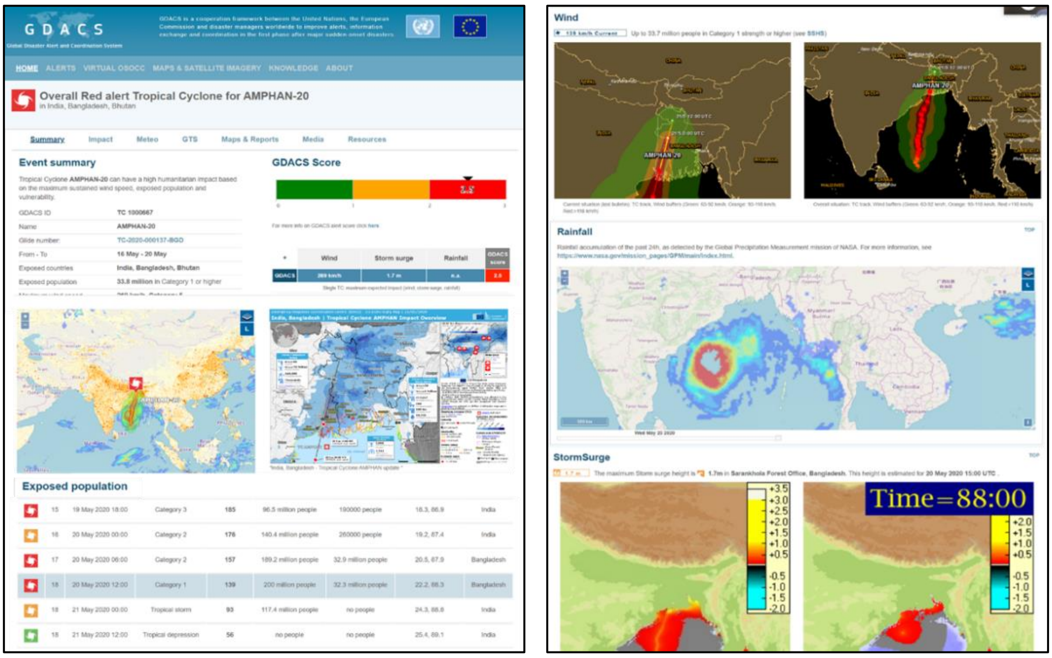
[100] UNDRR, "Terminology". Available at https://www.undrr.org/terminology.
[101] Stefan Voigt and others, "Global Trends in Satellite-based Emergency Mapping", *Science*, vol. 353, no. 6296 (2016).
[102] GDACS. Available at https://www.gdacs.org/.

information exchange and coordination immediately after major sudden-onset disasters.

GDACS integrates various information systems worldwide to facilitate international information exchange and decision-making. The selection and alert level of natural hazards in GDACS is based on automatic impact assessment models. GDACS software continuously monitors and receives scientific data on natural hazards in order to run analytical models. Information about the location, hazard intensity and other characteristics is then used to calculate the affected area and the expected impact. Different models are used for different hazard types. Subsequently, the potential consequences of the event are assessed by calculating the population within the affected area and their vulnerability.

Currently, GDACS alerts are issued for earthquakes and possible subsequent tsunamis, tropical cyclones, floods and volcanic eruptions. For earthquakes, tsunamis and tropical cyclones, all calculations and assessments are done automatically, without human intervention. Studies are under way to include floods and volcanic eruptions in this list, which are currently manually introduced. Research and development is continuous to improve global monitoring. Figure 61 provides an example of the wealth of information available on GDACS for disaster responders on Tropical Cyclone Amphan that affected India, Bangladesh and Bhutan in 2020.

Figure 61: Example of the wealth of information for disaster responders on GDACS



Source: GDACS, "Overall Red Alert Tropical Cyclone for AMPHAN-20", 20 May 2020. Available at https://www.gdacs.org/Cyclones/report.aspx?eventid=1000667&episodeid=18&eventtype=TC.

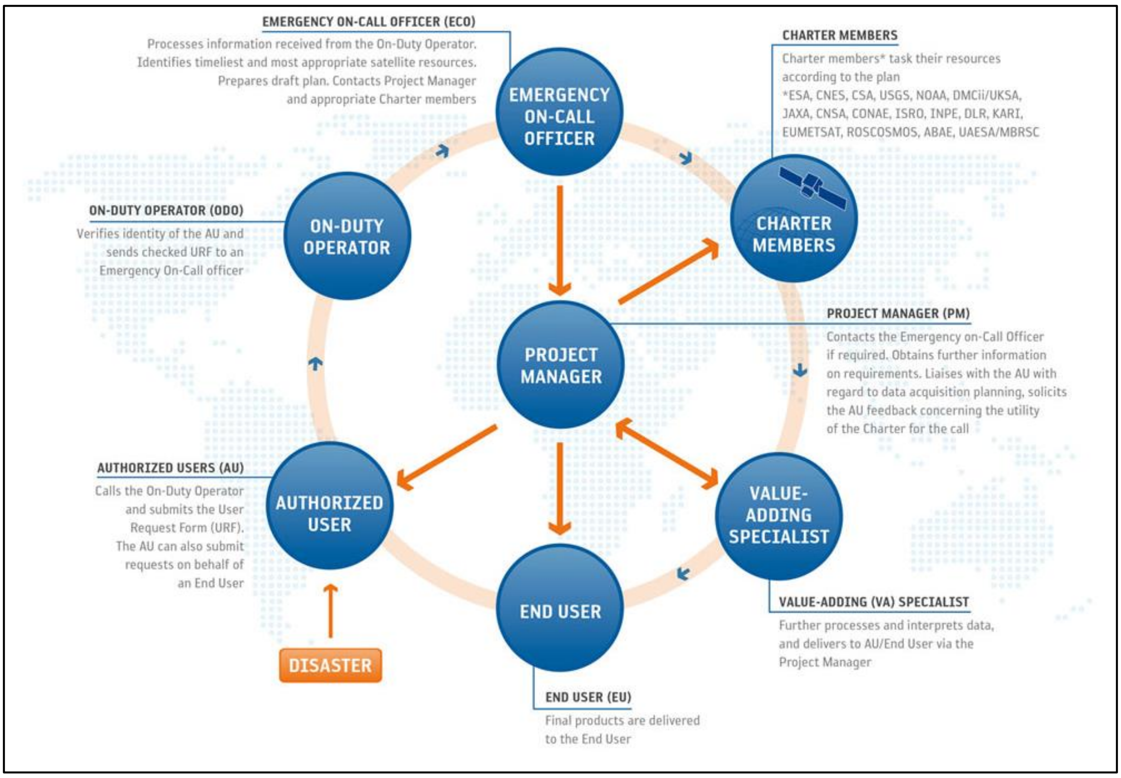
6.3 Post-Disaster Response Using Satellite Data

Space agencies and multilateral forums have established a number of regional and international mechanisms for making satellite data and products available for emergency response purposes.

At the international level, the **International Charter on Space and Major Disasters**[103] promotes collaboration among space agencies around the world to make satellite data available to the DRM authority in an affected country during an emergency. The Charter combines Earth observation assets from different agencies, including high-resolution satellite images from commercial operators.

Although any national DRM authorities can submit requests to activate the Charter for satellite data on a disaster, a set of procedures need to be followed (Figure 62). Members countries of another regional initiative called, “Sentinel Asia” (there are 31 member countries as of 2019) can also activate the Charter through Sentinel Asia.

Figure 62: Procedures for activating the International Charter on Space and Major Disasters



Note: The diagram illustrates the sequence of events that occur once the Charter is activated, beginning with the authorized user (bottom left).

Source: International Charter on Space and Major Disasters, "How the Charter Works". Available at https://disasterscharter.org/web/guest/how-the-charter-works.

103 International Charter on Space and Major Disasters. Available at https://disasterscharter.org/.

For the Asia-Pacific region, the **Sentinel Asia**[104] initiative provides free satellite images for emergency responses during a major disaster in the region. Sentinel Asia is a voluntary-based initiative among the regional space agencies and DRM agencies for humanitarian assistance purposes through the application of remote sensing and WebGIS technologies.

Sentinel Asia was activated on 28 September 2018 after an earthquake struck off the central Indonesian Island of Sulawesi triggering a tsunami with wave height of 3m. Given the catastrophic damages caused by the earthquake and tsunami, the activation was escalated to the International Charter on Space and Major Disasters in order to secure high-resolution satellite images from a greater number of data providers around the world. One of the worst affected areas was the city of Palu, where liquefactions were reported in three areas. Figure 63 shows one of the areas called Balaroa where 3,556 buildings were damaged—the left image shows status of the buildings before the earthquake and the right image shows damaged buildings after the earthquake.

Figure 63: Example of the use of satellite data for mapping the impact of liquefaction in Palu, Indonesia in September 2018

Source: International Charter on Space and Major Disasters.
Available at https://disasterscharter.org/.

The Charter has an agreement to support United Nations agencies. The United Nations Office for Outer Space Affairs and the United Nations Institute for Training and Research's Operational Satellite Applications Programme (UNOSAT) can submit requests to activate the Charter on behalf of users from the United Nations.

104 Sentinel Asia. Available at https://sentinel-asia.org/.

The UNOSAT Rapid Mapping Service[105] provides satellite image analysis during humanitarian emergencies caused by both natural disasters and conflict situations. Besides satellite images from the Charter, UNOSAT also receives satellite images from other sources, including free and open sources, commercial vendors and in-kind donations. With 24/7 availability to process requests, a team of experienced analysts ensures timely delivery of satellite maps, GIS-ready data, statistics and reports. This service is free for United Nations agencies and humanitarian entities operating in line with United Nations policies.

There are other organizations providing rapid mapping services. In Europe, the Copernicus Emergency Management Service, which is a collaboration between the European Commission and the European Space Agency, provides information on different types of disasters for emergency response, including meteorological hazards, geophysical hazards, deliberate and accidental human-induced disasters, and other humanitarian disasters. The service has an on-demand mapping component, providing rapid maps for emergency response. In addition, it has a risk and recovery component that provides disaster information to support recovery, mitigation, prevention and preparedness, as well as an early warning and monitoring component that continuously observes and forecasts floods, droughts and forest fires.

Something To Do

Watch the following video explaining the UNOSAT rapid mapping service with examples from different humanitarian crises: https://youtu.be/91-X0Mclbqs.

6.4 Participatory Mapping for Disaster Relief

Participatory or collaborative approaches to mapping often involve volunteers coming together to develop maps to support response and relief activities. There are a number of initiatives in this area:

- **MapAction[106]** – This is a UK-based charity, staffed by specialist volunteers, whose core role is to support humanitarian operations through provision of spatial data collection and mapping capabilities in the field. Their products and services include large-scale maps for specific relief requirements through sectoral overlays, maps formatted to specific needs of aid agencies, interactive GIS technology on web-based servers, enabling online queries, and enhancing existing baseline maps through computer-linked GPS and GIS systems.

[105] United Nations Institute for Training and Research, "UNOSAT Rapid Mapping Service". Available at https://www.unitar.org/maps/unosat-rapid-mapping-service.
[106] MapAction. Available at https://mapaction.org/.

- **GISCorps**[107] – This programme has been operating entirely on a volunteer basis since 2003. GISCorps volunteers reside in different states across the USA and use a Twiki site to work collaboratively in providing GIS services to support humanitarian relief as well as sustainable development, including the strengthening of spatial data infrastructure and developing the capacity of local spatial expertise around the world.

- **Global MapAid**[108] – This non-profit organization was initiated to develop specialist maps for emergency and humanitarian aid workers. The organization consists of experienced aid workers, GIS analysts, web developers and volunteers from Stanford University. The focus is to provide mapping services for slow-onset disasters and crises such as food insecurity, drought, human immunodeficiency virus monitoring and orphans in refugee camps. However, the organization does provide assistance in rapid onset disasters such as floods, if needed.

- **Humanitarian OSM Team**[109] – This is an international team dedicated to humanitarian action and community development through open mapping. When a major disaster strikes, volunteers come together online and on the ground to create open maps to enable disaster responders to reach those in need.

- **Missing Maps**[110] – This initiative supports the Humanitarian OSM Team in developing technologies, skills, workflows and communities so that local organizations and individuals can use the OSM maps and data to better respond to disasters and crises.

Figure 64: Steps for voluntary mapping after humanitarian crises

107 URISA's GISCorps. Available at https://www.urisa.org/giscorps.
108 MapAid. Available at https://www.globalmapaid.org/.
109 Humanitarian OSM Team. Available at https://www.hotosm.org/.
110 Missing Maps. Available at https://www.missingmaps.org/.

Source: Missing Maps. Available at https://www.missingmaps.org/.

Something To Do:

You can also contribute to the Humanitarian OSM Team. Watch this video to find out how: https://youtu.be/9MW8-yCRTYw.

6.5 Use of Mobile Apps for Reporting Disaster Incidents

Mobile apps are becoming popular communication channels for disaster incident reporting by allowing interactions between communities and the relevant authorities. Disaster incidents reported via mobile apps can be received by relevant authorities and viewed in a web interface of a decision-support system. This is especially useful if a disaster occurs in a remote area. Upon registration of a disaster incident in the decision-support system, it can be further disseminated to all responsible stakeholders via SMS or email.

Figure 65: Example of a disaster incident report from a mobile app and displayed in a decision-support system

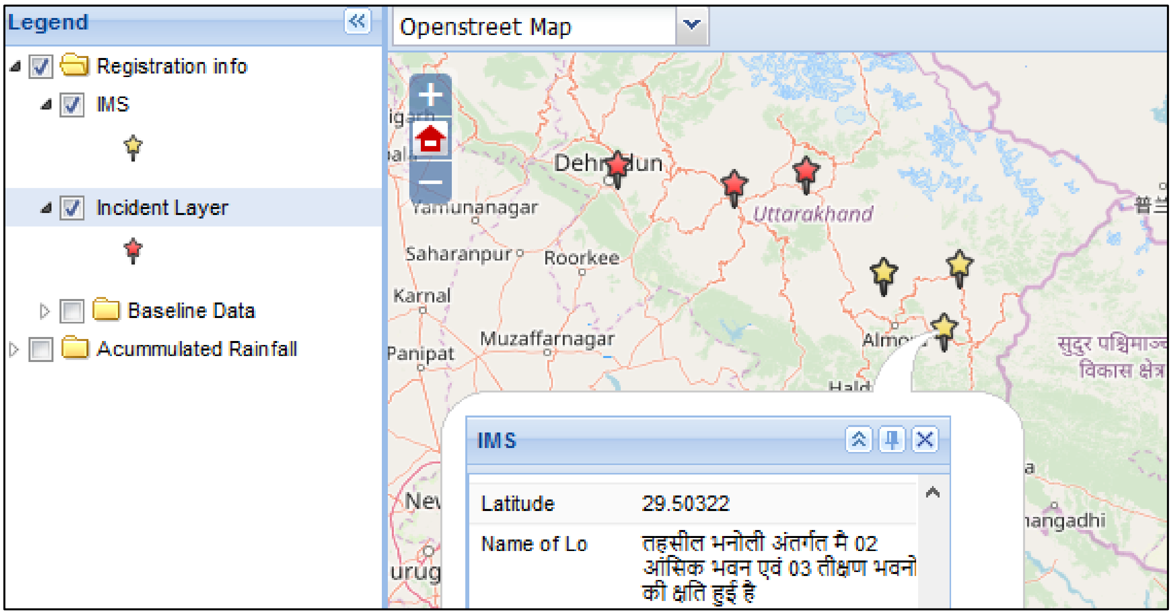
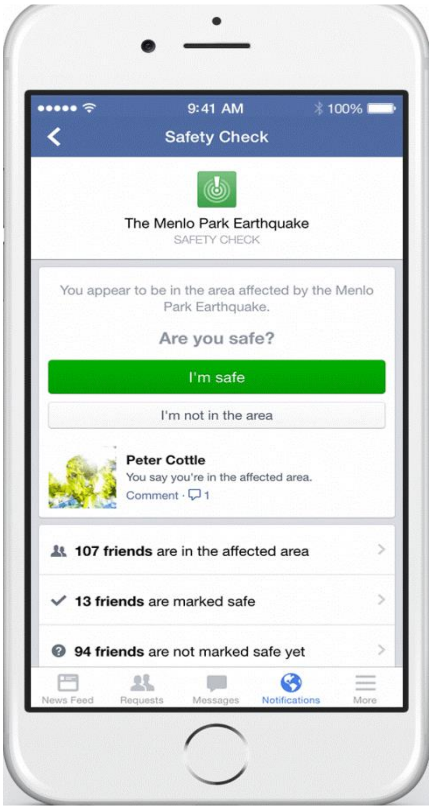


Figure 65 shows an example of a disaster incident report coming from the field through a mobile app and displayed in a decision-support system. Using the mobile app, community members can report about a disaster quickly and accurately, with videos, photos and location details. The reported disaster incident will be immediately displayed in the decision-support system, which can help to reduce delays in disseminating information to the public.

Figure 66: Facebook's Safety Check tool



In times of disaster or crisis, people often turn to social media platforms to check on family and friends, and obtain updates on the situation. Facebook has a Safety Check tool (Figure 66) that allows users to mark themselves safe, mark their friends as safe and check the safety of others in affected areas. Other useful features for response and relief on Facebook include the ability to connect directly with other people nearby to give or find help with resources like food, supplies or shelter; and support those affected by crises by fundraising or donating.[111]

Another example is the "Did You Feel It App"[112] that collects information from people who felt an earthquake and creates maps that show what people experienced and the extent of damage.

MyShake[113] is a citizen science project that brings users together to build a global earthquake early warning network. The app monitors earthquakes using data from users' phone sensors and keeps users informed about earthquakes.

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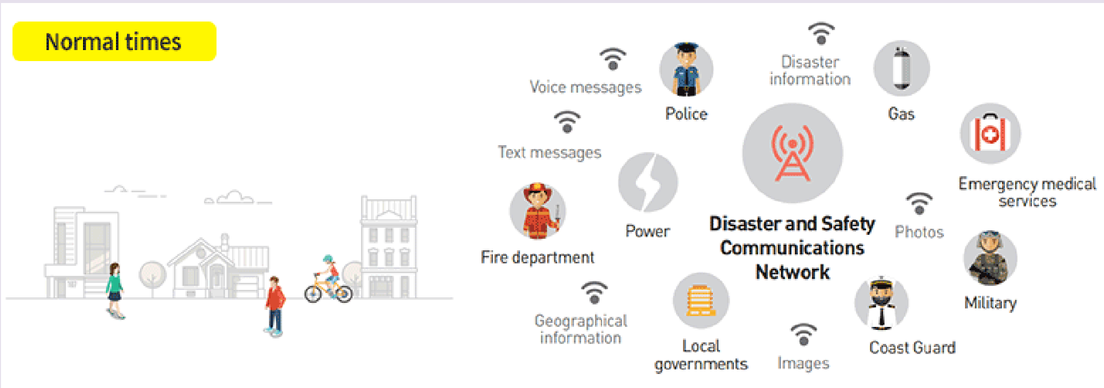
[111] Facebook, "Crisis Response". Available at https://www.facebook.com/about/crisisresponse/.
[112] USGS, "Earthquake Hazards Program: Did You Feel It?" Available at https://earthquake.usgs.gov/data/dyfi/.
[113] MyShake, "Developing an early warning network for everyone". Available at https://myshake.berkeley.edu/about-us.html.

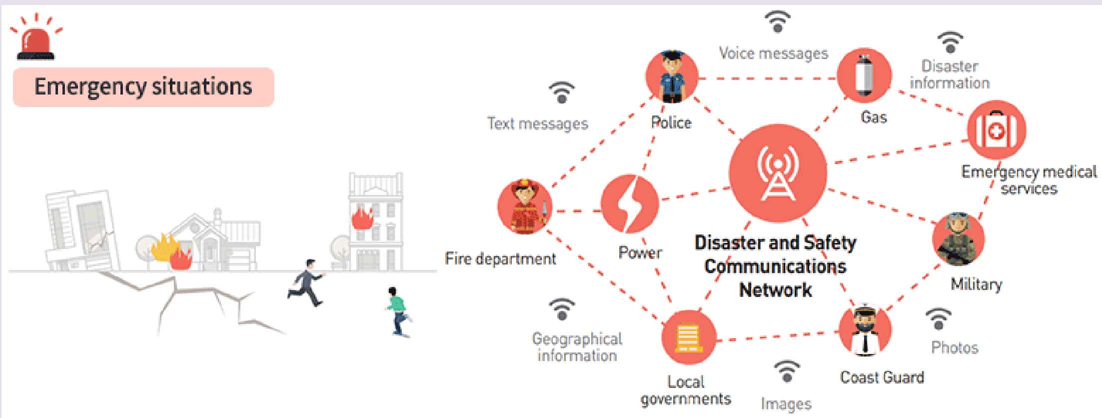
Case Study 5: The Republic of Korea's disaster and safety communication network

The Government of the Republic of Korea has built a nationwide network for disaster and safety communication. Managed by the Ministry of Interior and Safety, the network serves 200,000 users from 330 institutions in eight areas, including police officers, firefighters, public officials, and electricity, gas and forest services, enabling them to communicate and promptly support rescue efforts using dedicated terminals both in normal times and emergencies (Figure 67).

This unified command and collaboration system adopts fourth-generation Long-Term Evolution wireless technologies and uses the base stations built by national mobile carriers. The nationwide network has been built for full geographic coverage and emphasizes network stability so that there will be no interruptions in communication during disaster events.

Figure 67: The Republic of Korea's disasters and safety communication network during normal times and emergency situations





Sources: Ministry of Interior and Safety, "Disaster and Safety Communications Network (Korea Safe-net)". Available at https://www.mois.go.kr/eng/sub/a03/bestPractices7/screen.do; and Jin-young Cho, "National Disaster Safety Communications Network Project to be Built Using PS-LTE", *Business Korea*, 26 February 2015. Available at http://www.businesskorea.co.kr/news/articleView.html?idxno=9252.

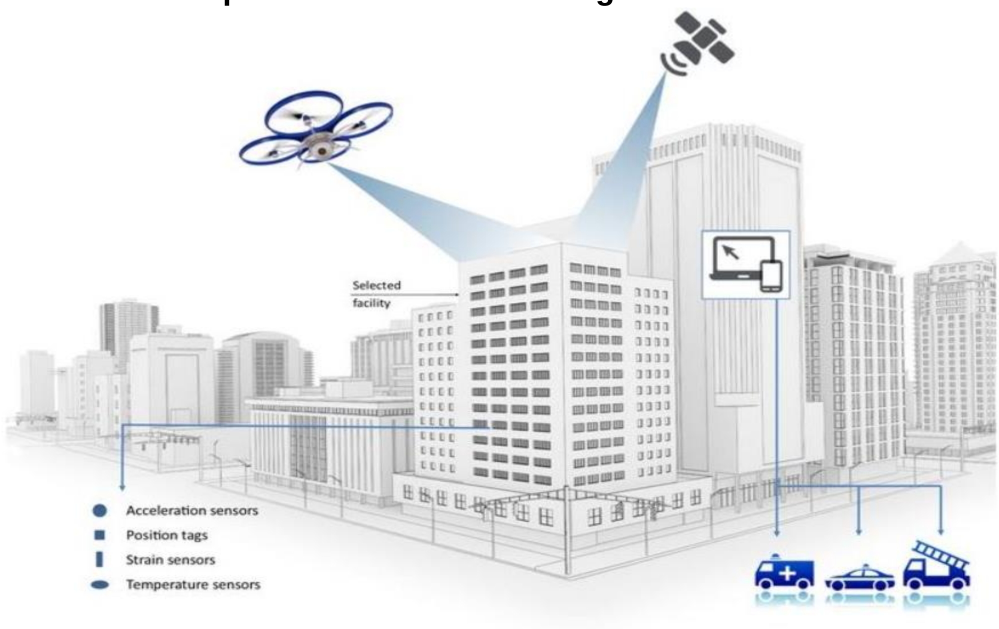
6.6 Use of Robots in Search and Rescue Operations

Robots are very useful for conducting search and rescue operations in collapsed buildings after a disaster, especially after a catastrophic earthquake. People trapped inside collapsed buildings must be rescued within 48 hours, otherwise there is very little chance of survival due to lack of food, water and medical treatment.

One of the challenges for rescue workers is locating survivors, assessing the physical risks in the area and protecting themselves during search and rescue operations as the weight and movement of rescue workers can trigger a further collapse of the structures. Collapsed structures also create confined spaces that are difficult to access by rescue workers, limiting the search to no more than a few metres from outside. However, robots can be risked in searching for survivors in unstable structures and confined spaces, and they can easily enter into confined spaces and assist rescue workers in the following four ways:[114]

1. Reduce the risk of rescue workers by entering unstable structures;
2. Increase speed of response by accessing otherwise inaccessible areas;
3. Extend the reach of rescue workers by accessing otherwise inaccessible areas; and
4. Increase efficiency and reliability by methodically searching areas with multiple sensors and using algorithms to provide a complete search in three dimensions.

Figure 68: Integrated set-up using drones, sensors and robots for improved relief and rescue operations in urban settings



Source: RECONASS. Available at http://www.reconass.eu/.

[114] Binoy Shah and Howie Choset, "Survey on Urban Search and Rescue Robots", *Journal of the Robotics Society of Japan*, vol.22, no.5 (2004), pp. 582-586. Available at https://www.jstage.jst.go.jp/article/jrsj1983/22/5/22_5_582/_article/-char/en.

Case Study 6: The use of ICTs to flatten the COVID-19 curve in the Republic of Korea

ICTs played a vital role during the COVID-19 pandemic in the Republic of Korea. Mobile devices were used to support early testing and contact tracing. Mobile apps were particularly useful in disseminating emergency information on the virus, flagging infection hotspots and helping to maintain social distancing among the citizens (left image in Figure 69).

The cellular broadcasting service of the Republic of Korea enabled government agencies to transmit emergency alert text messages on COVID-19-related information to the public through their mobile phones. Text messages included movement paths taken by confirmed patients and other related information. Residents who received COVID-19 emergency texts could quickly check if their movements overlapped with those of a confirmed patient, allowing them to get tested quickly if necessary. In this way, the cellular broadcasting service contributed to slowing the spread of the virus across the nation.

GIS was extensively used to prepare a comprehensive situation map for COVID-19 (https://coronapath.info), which provided the following information in Korean and English:

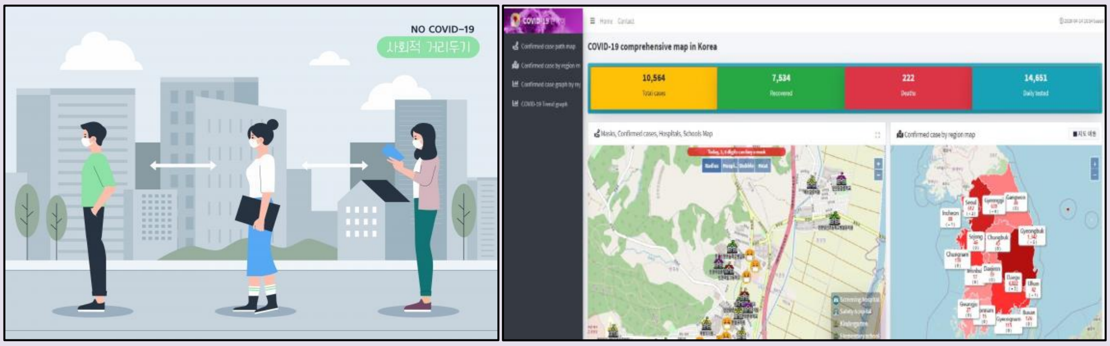
- A comprehensive situation map marking patient routes, screening centres, COVID-19 safe health clinics, mask vendors, educational institutions, etc.;
- A map of patient counts for cities and provinces;
- A graph of patient counts for cities and provinces; and
- A graph of the COVID-19 situation.

Key information such as the accumulated count by region and number of tests performed was summarized and provided as visualization data on the main page of the website (right image in Figure 69). Real-time data of publicly-distributed face masks was provided to people through both the website and mobile apps, reducing confusion and inconvenience while raising distribution efficiency.

The Korean government also used ICTs to prevent the spread of COVID-19 via travellers entering the country. A self-diagnosis mobile app was developed to monitor symptoms of inbound travellers and provide them with prompt medical advice. The mobile app connected users directly to the call centre and social media channels for medical answers against suspected symptoms and allowed early treatment.

ICT applications informed the Korean government about the overseas travel history of its citizens, and enabled early-detecting of patients and isolating the close contacts of patients. Key information collected by location helped government officials take location-specific and targeted actions to contain the COVID-19 pandemic in the Republic of Korea. Thus, taking the advantage of ICT tools and applications, the Korean government was successful in flatteing the COVID-19 curve and came out from the crisis at an early date.

Figure 69: Use of mobile app for social distancing and situation map for COVID-19



6.7 Policy Considerations

ICTs are essential tools for disaster response activities and are widely used during a disaster. Satellite-based mapping coupled with GIS data (either from archived data or crowdsourced data) provide a quick assessment on the extent of a disaster and damages caused, which is always helpful in supporting humanitarian response activities on the ground. In addition, web-based communication media such as social media and websites have proved very useful for disaster response activities. Policymakers are encouraged to consider the following issues when developing strategies and plans for identifying and using ICT for disaster response:

- **Improve communication and ICT infrastructure** – This includes strengthening the resilience of the ICT infrastructure, which is critical during the disaster response phase. Telecommunications authorities should establish policies and response arrangements as part of their disaster risk reduction strategies, including strengthening the ICT infrastructure’s resilience to disasters.

- **Engage network operators in disaster response** – Most countries now have mobile phone networks even in remote areas. Thus, network operators play a critical role in disaster response by channelling relevant information to rescue workers and to those affected. Network operators should be part of the development of policies and plans for disaster response.

- **Unlock the potential of regional cooperation** – Disasters do not occur in isolation. National policies should consider the need for regional and international collaboration, especially in the event of a large-scale disaster. The International Charter on Space and Major Disasters and the Sentinel Asia initiatives provide satellite-based value-added products at the time of a disaster upon request from an affected country. However, countries must plan in advance and designate a national agency to activate these initiatives and maximize the benefits.

7. ICT FOR DISASTER RECOVERY

7.1 Introduction

Disaster recovery is the restoring or improving of livelihoods and health, as well as economic, physical, social, cultural and environmental assets, systems and activities, of a disaster-affected community or society, aligning with the principles of sustainable development and “build back better”, to avoid or reduce future disaster risk.[115]

Figure 70: Comic strip on ICT for disaster recovery

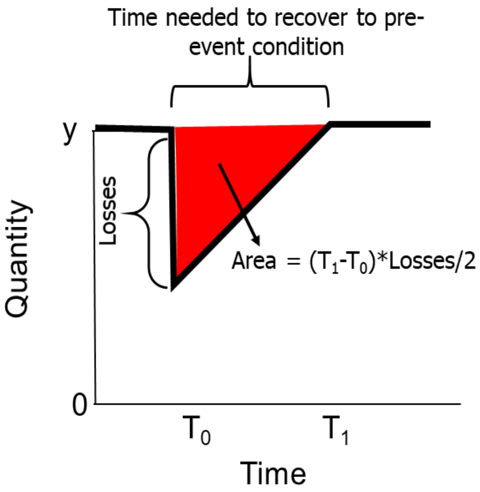
Remote sensing technology can be helpful in the disaster recovery phase through extraction of reference (pre-event) and crisis (post-event) data from satellite images. With its synoptic coverage and frequent acquisition time, remote sensing satellite can cover a large disaster-affected area in near real time. High-resolution satellite images provide visual information and make it easy to extract useful information like building damages. Satellite data-derived mapping products are useful in quantifying post-disaster damage and monitoring recovery after catastrophic disasters.

[115] UNDRR, "Terminology". Available at https://www.undrr.org/terminology.

7.2 Resilience and Recovery

Resilience is defined as the ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform 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 through risk management.[116]

Figure 71: Schematic representation of resilience

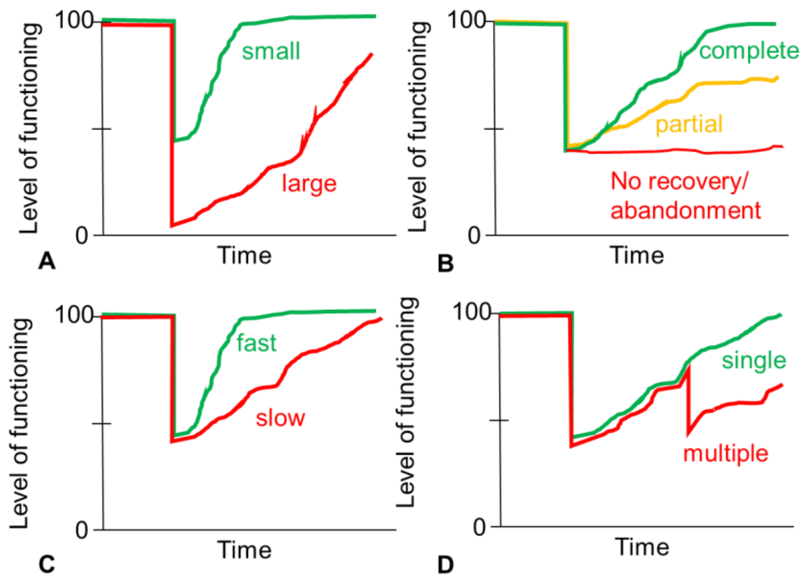


Resilience can be visualized and modelled as a triangle (Figure 71), with time as x-axis, and a predefined quantity as y-axis. This quantity can be many things, such as the number of intact buildings, length of operating water pipelines, economic production, biodiversity etc. When a disaster occurs this quantity will be reduced due to the losses. These losses can be estimated in a risk assessment. After the disaster event it will take a certain amount of time before the quantity returns to pre-disaster level. The triangles in Figure 72 represent resilience as time to recovery multiplied by the losses, divided by half. The figure shows different scenarios for post-disaster recovery and resilience.

ICT tools can be used to model the losses and recovery beforehand, in order to design measures to strengthen resilience. ICTs can also be used after disasters to monitor recovery.

[116] Ibid.

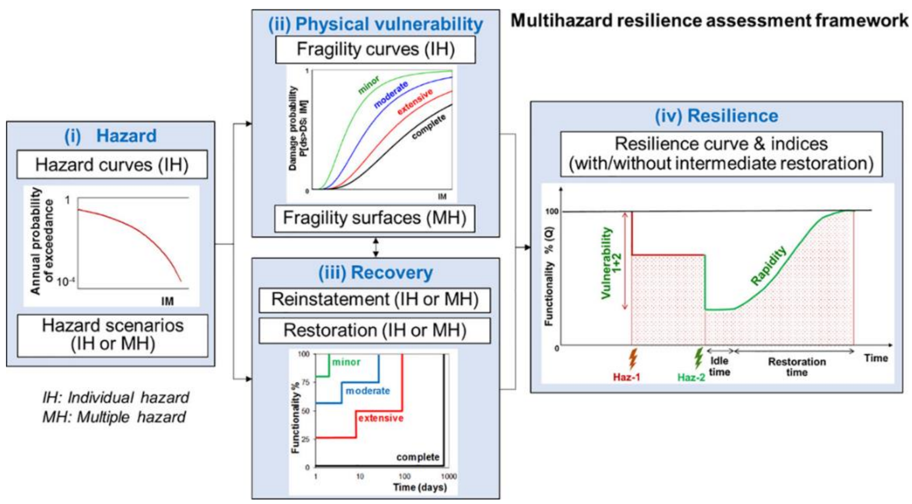
Figure 72: Graphs showing scenarios of recovery and resilience



Notes: A = Recovery from large or small impacts; B = Complete, partial or no recovery after a disaster; C = Fast or slow recovery; and D = Recovery from multiple disaster events occurring in sequence.

A framework for resilience modelling of transportation networks is shown in Figure 73. For resilience modelling, detailed information is needed on the hazard, vulnerability and exposure in order to estimate losses. The restoration is modelled using a number of curves.

Figure 73: Framework for modelling the resilience of transportation networks



Source: Sotirios A. Argyroudis and others, "Resilience assessment framework for critical infrastructure in a multi-hazard environment: Case study on transport assets", *Science of the Total Environment*, vol. 714 (April 2020).

7.3 Post-Disaster Building Damage Assessment Using Satellite Data

The extent and intensity of damage, and the type of damage are essential information for planning recovery efforts. Remote sensing data is very useful for providing a quick assessment of the status of buildings when a disaster strikes. The monitoring of newly-built buildings during reconstruction in the disaster recovery phase is another important utilization of remote sensing data.

Post-disaster damage assessment from remote sensing images are being used by government organizations, international agencies and insurance industries. The increased availability of this type of data and the frequently updated data archives make the high-resolution optical images well-suited as a pre-event reference data source for building damage assessments.

7.3.1 Visual Interpretation for Building Damage Assessment

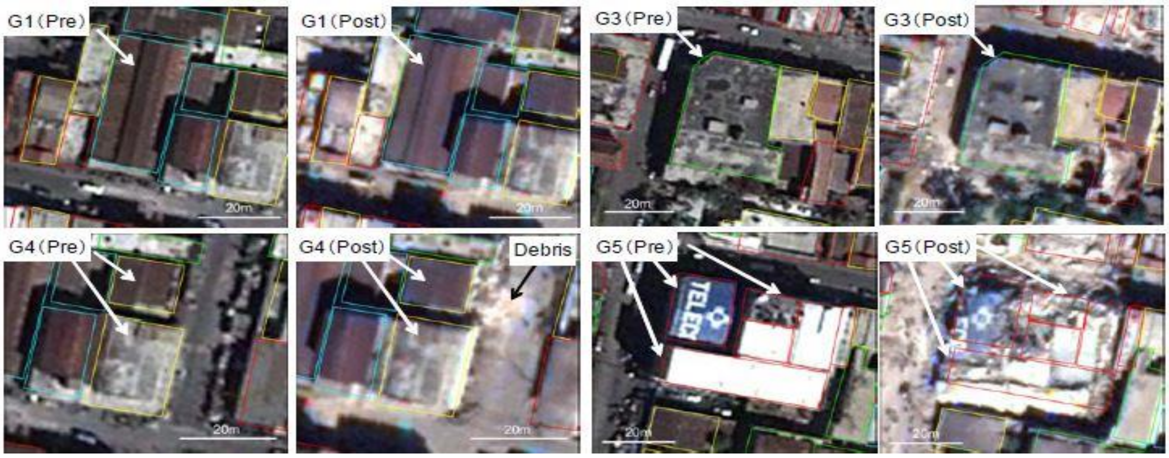
Visual interpretation and change detection using both pre- and post-disaster remote sensing images are the most commonly-used methods for building damage assessment. Change detection approaches identify the differences in the state of a building before and after a disaster using pre- and post-disaster images. Change detection can be implemented using shape analysis, brightness value comparison and image differencing by thresholding the colour difference. The differences between colour, spectra, texture and other features extracted from the remote sensing images can be used to detect damaged and undamaged buildings. Automatic change detection using images acquired before and after a disaster is faster than visual interpretation.

Collapsed buildings are often observed as being much brighter than the surrounding buildings, and in many cases, have rough textures. Changes in relative shadow heights may indicate possible soft-storey failures or “pancaking.” This type of damages occurs in case of earthquakes when the bottom or lower storey of a building is less stiff than the uppers storeys, and thus collapses completely. Examples of some of these failures can be viewed on Google Earth (Figure 74).

Figure 74: Pre- (left) and post-event (right) imagery of "pancaked" and "stair-step" damage patterns

A study to develop a methodology for detecting damaged buildings from satellite images was carried out using pre- and post-earthquake satellite images of the 2010 earthquake in Haiti.[117] The study showed that a texture analysis can be applied to satellite images for detecting collapsed buildings (Figure 75).

Figure 75: Building damage assessment using pre- and post-earthquake images



Source: H. Miura, S. Midorikawa and H. C. Soh, "Building Damage Detection of the 2010 Haiti Earthquake Based on Texture Analysis of High-Resolution Satellite Images", paper presented at the 15th World Conference on Earthquake Engineering, Lisbon, Portugal, 2012. Available at https://www.iitk.ac.in/nicee/wcee/article/WCEE2012_1816.pdf.

Figure 75 shows no difference between the pre- and post-earthquake images in the G1 building. Similarly, in the G3 building, significant differences on the roof and its surroundings cannot be found between the images. For the G4 building, damages in some parts of the building and debris around the building can be identified in the post-earthquake image. However, changes to the roof of the G4 building are almost indiscernible between the images. In the case of the G5 building, the post-earthquake image clearly shows the roofs completely destroyed, and debris from the collapsed building scattered in and around the building, indicating that it is feasible to identify collapsed buildings from satellite images. When details of the pre- and post-earthquake images for the G5 building are carefully examined, the building edges can be clearly identified. Moreover, homogeneous pixels can be found on the roofs in the pre-earthquake image, while bright and dark pixels are close to each other in the debris in the post-earthquake image. Thus, a texture analysis can be applied to satellite images for detecting collapsed buildings.

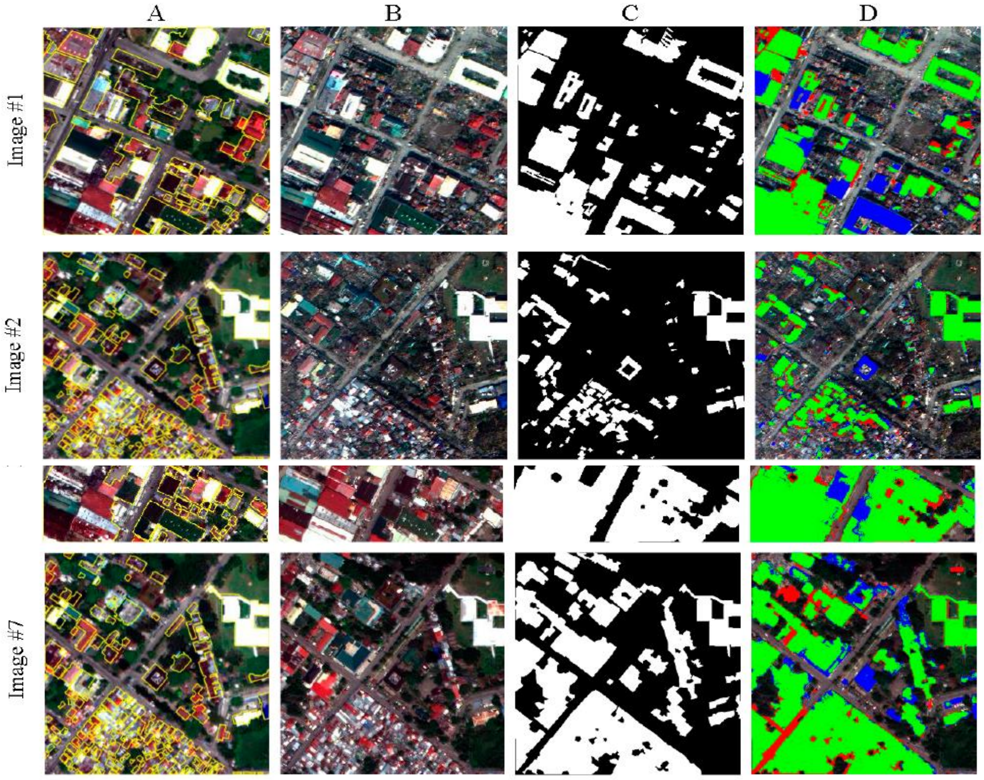
7.3.2 Deep Learning for Building Damage Assessment

Deep learning techniques, especially convolutional neural network-based approaches, can extract information from remote sensing images for image-based

[117] H. Miura, S. Midorikawa and H. C. Soh, "Building Damage Detection of the 2010 Haiti Earthquake Based on Texture Analysis of High-Resolution Satellite Images", paper presented at the 15th World Conference on Earthquake Engineering, Lisbon, Portugal, 2012. Available at https://www.iitk.ac.in/nicee/wcee/article/WCEE2012_1816.pdf.

structural damage assessment. An integration of multi-temporal satellite data, in particular, very-high-resolution satellite images and pre-disaster OSM data using an automated deep learning technique provides an excellent opportunity for updating post-disaster building database.[118] This technique was used to assess damage in Tacloban city in the Philippines after being hit by the Super Typhoon Haiyan (Yolanda) in 2013.

Figure 76: Results from the automated post-disaster building detection using a deep learning technique in Tacloban, Philippines after Typhoon Haiyan in 2013



Notes: Column A – Pre-disaster images (8 months before Typhoon Haiyan) with OSM building boundaries in yellow; Column B – Images #1-2 were taken 3 days after Typhoon Haiyan and Images #6-7 were taken 4 years after Typhoon Haiyan; Column C – The reference image for buildings, in which white and black colours represent the building and background pixels; Column D – Detected buildings for test images. Green, red and blue represent true positive, false positive and false negative detection results, respectively.

Source: Saman Ghaffarian and others, "Post-Disaster Building Database Updating Using Automated Deep Learning: An Integration of Pre-Disaster OpenStreetMap and Multi-Temporal Satellite Data", *Remote Sensing*, vol. 11, no. 20 (2019). Available at https://www.mdpi.com/2072-4292/11/20/2427/htm.

For the Tacloban study, multi-temporal WorldView-2 satellite images were used that included images acquired one month before the disaster (one pre-disaster image),

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[118] Saman Ghaffarian and others, "Post-Disaster Building Database Updating Using Automated Deep Learning: An Integration of Pre-Disaster OpenStreetMap and Multi-Temporal Satellite Data", *Remote Sensing*, vol. 11, no. 20 (2019). Available at https://www.mdpi.com/2072-4292/11/20/2427/htm.

and images three days and four years after the disaster (two post-disaster images). The OSM data was used as the reference building layer after co-registration with the satellite image to automatically generate training samples for deep learning. The data provided global coverage of building datasets through crowdsourcing, although data quality varied. The deep residual U-net approach was adapted as the classifier, while the change detection process was done based on two textural measurements—Variation-Histogram of the Oriented Gradients and Edge Density Index—to distinguish the damaged or demolished buildings and intact buildings in the post-disaster image.

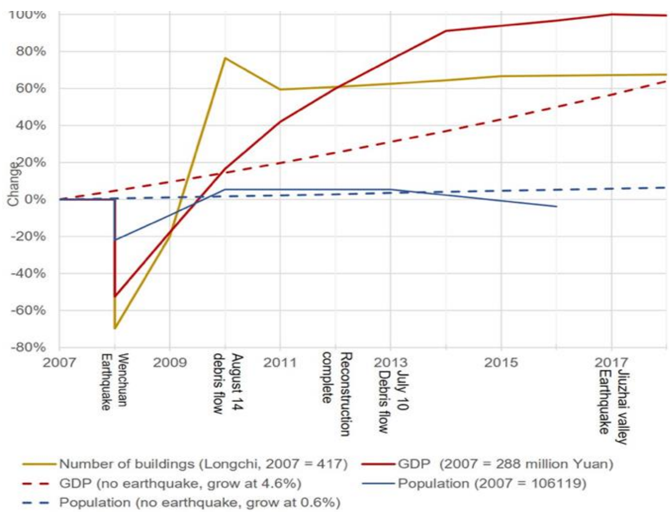
Figure 76 shows the results of a selected area in the satellite images. The overall accuracy of this deep learning technique in assessing building damage is 84.2 per cent. It demonstrates the robustness of the technique in updating the building database after a disaster in a complex area such as Tacloban (with a mixture of squatter settlements and formal buildings, and buildings with various colours and shapes).

7.4 Post-Disaster Recovery Monitoring

The recovery after major disasters is not limited to buildings. Post-disaster recovery monitoring has been carried out using a range of remote sensing tools (from satellite images to drone images) for vegetation, agriculture, transportation, landscape and other aspects.

Major disasters such as earthquakes damage societies in mountainous regions by intensive ground shaking, triggering co-seismic landslides, and resulting in loss in vegetation, weakened hillslopes and large volumes of co-seismic loose debris. This drastically raises the susceptibility of rainfall-induced landslides for a prolonged period.

Figure 77: Monitoring of recovery after the 2008 Wenchuan Earthquake in Longchi, China, based on analysis of multi-temporal satellite images and modelling



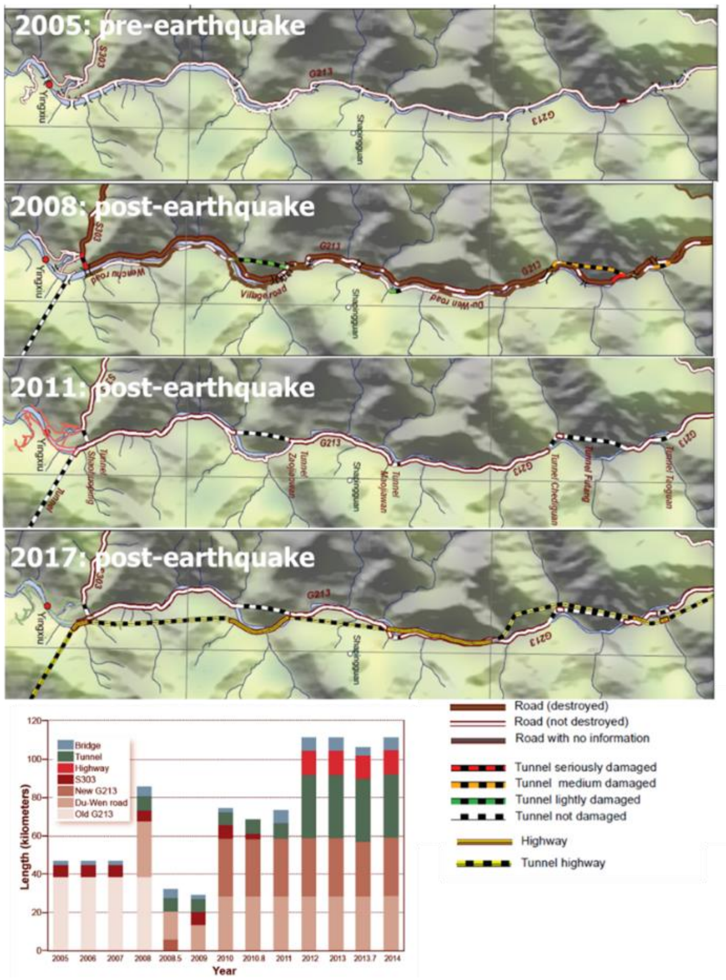
Source: Chuan Tang and Cees van Westen, *Atlas of Wenchuan-Earthquake Geohards: Analysis of Co-Seismic and Post-Seismic Geohazards in the Area Affected by the 2008 Wenchuan Earthquake* (Beijing, Science Press, 2018). Available at https://issuu.com/ceesvanwesten/docs/atlas_of_wenchuan_earthquake_geohaz.

Huge losses caused by post-seismic landslides were witnessed after the 1999 Chi-Chi Earthquake and the 2008 Wenchuan Earthquake as the hazard frequency and magnitude were underestimated. A study monitoring the changes in landslide activity over a period of seven years after the 2008 Wenchuan Earthquake using five multi-temporal landslide inventories, which were interpreted stereoscopically from high-resolution satellite images followed by field investigation, showed that most of the post-seismic landslide activities occurred within the first three years following the earthquake.[119]

Figure 78 shows quantitative changes in the road network in the recovery period after the Wenchuan Earthquake. The 2017 map shows that the current road network is much more extensive than before the earthquake, due to large investments by the Chinese government.

[119] Chuan Tang and Cees van Westen, *Atlas of Wenchuan-Earthquake Geohards: Analysis of Co-Seismic and Post-Seismic Geohazards in the Area Affected by the 2008 Wenchuan Earthquake* (Beijing, Science Press, 2018). Available at https://issuu.com/ceesvanwesten/docs/atlas_of_wenchuan_earthquake_geohaz.

Figure 78: Monitoring of post-earthquake recovery of the road network after the 2008 Wenchuan Earthquake using multi-temporal satellite images



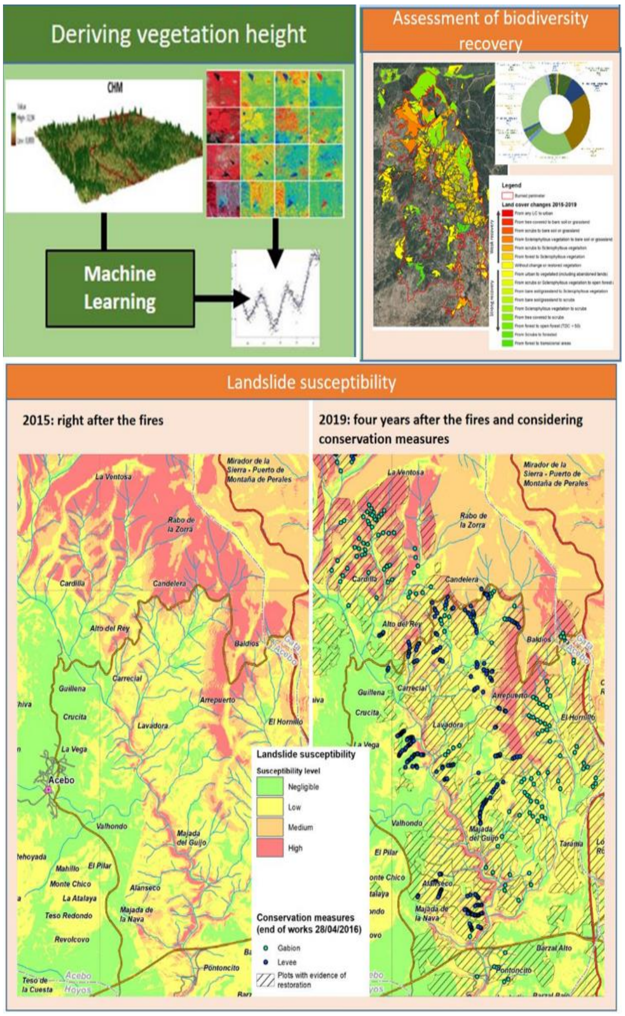
Source: Chuan Tang and Cees van Westen, *Atlas of Wenchuan-Earthquake Geohards: Analysis of Co-Seismic and Post-Seismic Geohazards in the Area Affected by the 2008 Wenchuan Earthquake* (Beijing, Science Press, 2018). Available at https://issuu.com/ceesvanwesten/docs/atlas_of_wenchuan_earthquake_geohaz.

7.4.1 Post-Fire Recovery Monitoring

Figure 79 shows an example of post-fire recovering monitoring from the Copernicus Emergency Management Service for the forest fire that took place on 6 August 2015 in Acebo, Spain, which burned 8,160 hectares of pine trees and shrub land.

Copernicus monitored the recovery of forests in terms of reduced soil erosion and the recovery of the flora. The products calculated and compared the situation just before the event (in 2014 and 2015), after the event (in 2015 and 2016), at the end of restoration activities (in 2016), and annually after that moment (in 2017, 2018 and 2019). Vegetation recovery for the years 2016 and 2019, compared with the pre-event situation in 2014-2015 was assessed using two variables—spectral recovery and vegetation height. Landslide susceptibility was estimated based on the Norwegian Geotechnical Institute model that considers several driving factors—topographic indices derived from DEMs, rainfall records, lithology and geology, soil moisture, and land cover maps.

Figure 79: Example of the use of ICTs to monitor post-fire recovery of vegetation, biodiversity and slope stability



Source: European Commission Copernicus, "EMSN072: Post forest fire recovery monitoring in Acebo, Spain". Available at https://emergency.copernicus.eu/mapping/list-of-components/EMSN072.

7.5 Policy Considerations

Ensuring that disaster recovery activities “build back better” requires strong management capacities of recovery institutions and enabling policies. ICTs offer innovative solutions and policymakers are encouraged to consider the following issues when developing strategies and plans for identifying and using ICT for disaster recovery:

- **Strengthen capacity building in the use of ICT for disaster recovery** – Countries should consider strengthening the knowledge and capacity in the use of spatial data, including Earth observation data and geospatial data along with available statistical and ground-truth data to assess the losses in order to prepare a good recovery plan. Furthermore, policies for using new imaging platforms such as drones may be adopted at an early date, which can take very-high-resolution images for accurate damage assessment at a very low cost.

- **Capitalize on new technologies** – With the advancement of new technologies, policymakers should utilize the innovations to promote empowerment and inclusions. The fourth industrial revolution includes innovations in deep learning (artificial intelligence), cognitive technologies, big data, analytics etc., and deep learning has demonstrated its usefulness for automating building damage assessment.

8. THE ROLE OF ICT IN ADDRESSING ISSUES RELATED TO GENDER AND DISASTER RISK MANAGEMENT

According to the Sendai Framework, DRM requires a multi-hazard approach and inclusive risk-informed decision-making based on the open exchange and dissemination of disaggregated data, including by sex, age and disability. DRM also requires easily accessible, up-to-date, comprehensible, science-based, non-sensitive risk information, complemented by traditional knowledge.[120]

Disaster data disaggregated by sex is important due to the fact that disasters affect women and men differently. Women tend to be more adversely affected than men and there tends to be more women casualties than men in disasters. When a disaster hits, a large proportion of women experience disadvantages compared with men because women have less access to resources, including finances, land and property, mobile phones and Internet connectivity, and less opportunities for education, skills building and employment. In the aftermath of a disaster, women are more likely to be exposed to threats to their safety, which include an increased risk of gender-based violence and loss of livelihoods.

Box 3: Statistics on the impact of disasters on women and children

- When the 2004 Asian tsunami struck, more than 70 per cent killed were women.
- In 2005, Hurricane Katrina hit New Orleans, USA, and affected predominantly African American women—already the region's poorest, most marginalized community.
- An estimated 87 per cent of unmarried women and 100 per cent of married women lost their main sources of income in Ayeyarwady Delta, Myanmar after Cyclone Nargis in 2008.
- The 1991 cyclone in Bangladesh killed 140,000 people, and within the age group 20-44, the women death rate was 71 per 1000, compared to 15 per 1000 for men.
- In the Philippines over the last two decades, 15 times as many infants have died in the 24 months following typhoon events as have died in the typhoons themselves. Most of them were infant girls.
- Disasters lower women's life expectancy more than men's, according to data from 141 countries affected by disaster between 1981 and 2002.
- Women and children are 14 times more likely to die than men from disasters.

Source: United Nations, "Gender Responsive Disaster Risk Reduction: A contribution by the United Nations to the consultation leading to the Third UN World Conference on Disaster Risk Reduction", version 2, 2014. Available at https://www.preventionweb.net/files/40425_gender.pdf.

[120] United Nations, *Sendai Framework for Disaster Risk Reduction 205–2030* (Geneva, 2015). Available at https://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf.

ICTs are powerful tools for empowering women, promoting gender equality and enhancing DRM. There is a need to address gender issues in DRM, which requires sex-disaggregated data and information that can be used for gender analysis at all stages of a disaster—before, during and after. In this regard, ICTs are not only useful for collecting data, but also for processing data to derive meaningful information and sharing information through communication media. Placing gender issues at the centre of disaster risk reduction policies and strategies is essential, and ICT tools offer innovative means to strengthen this inclusion. However, despite this recognition, the true potential of ICT for DRM to address gender issues is underutilized.

8.1 Mainstreaming Gender into Disaster Risk Management

A gender-sensitive approach to disaster risk reduction considers gender issues in the design of the policy, strategy and programme, and promotes the implementation of gender equality. Recently, there has been a critical shift in mainstreaming gender perspectives into DRM—from a women-focused approach to a gender-focused approach, based on the premise that the roles and relationships of women and men in DRM should be analysed within the overall gendered socioeconomic and cultural context. The strategic focus of DRM has also changed from a reactive response to a long-term proactive action, where gender considerations are necessary in achieving sustainable development.

At the global level, efforts to promote gender equality in disaster risk reduction have focused on advocacy and awareness raising, along with support for policy changes and gender mainstreaming in intergovernmental processes. Meanwhile, at the national level, an increasing number of governments are recognizing the importance of gender issues in their national disaster risk reduction strategies, although it is far from becoming a common practice. According to UNISDR (now UNDRR) in 2013, only 30 per cent of countries consider gender integration as a driver of progress, despite the increasing awareness of the importance of gender mainstreaming at the policy level.

Some of the challenges faced for mainstreaming gender into DRM are:

- Poor understanding of the linkages between gender and DRM at the policy and practitioner levels;
- Gender issues are often institutionally marginalized within organizations;
- Gender continues to be identified as an “add on” aspect, rather than an integral component;
- There is a lack of financial resources for global advocacy and action on gender and DRM;

- Gender events have not been adequately linked with intergovernmental DRM processes; and
- Lack of institutional and individual capacity and tools to mainstream gender into DRM.

Box 6: International commitments on gender equality

- The Convention of the Elimination of All Forms of Discrimination against Women
- The Beijing Declaration and Platform for Action
- Outcomes of the 23rd special session of the United Nations General Assembly
- Agreed conclusions of the 46th session of the Commission on the Status of Women on “Environmental management and the mitigation of natural disasters of 2002”
- Commission on the Status of Women resolution 49/5 of 11 March 2005
- The Hyogo Declaration and the Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters adopted by the World Conference on Disaster Reduction in Kobe, Japan on 18-22 January 2005
- The Beijing Agenda for Global Action on Gender-Sensitive Disaster Risk Reduction in Beijing, China on 22 April 2009
- Commission resolution 55/1 of 4 March 2011 entitled, “Mainstreaming gender equality and promoting empowerment of women in climate change policies and strategies”
- Outcome document of the United Nations Conference on Sustainable Development held in Rio de Janeiro, Brazil in June 2012 entitled, “The future we want”
- Commission on the Status of Women resolution 56/2 of 9 March 2012 on Gender Equality and the Empowerment of Women
- Commission on the Status of Women resolution 58/2 of 18 March 2014 on Gender Equality and the Empowerment of Women
- Relevant resolutions of the United Nations General Assembly, including resolutions 68/102 and 68/103 of 13 December 2013 and 68/211 of 20 December 2013, and Economic and Social Council resolution 2013/6 of 17 July 2013

Source: United Nations, “Gender Responsive Disaster Risk Reduction: A contribution by the United Nations to the consultation leading to the Third UN World Conference on Disaster Risk Reduction”, version 2, 2014. Available at https://www.preventionweb.net/files/40425_gender.pdf.

8.2 ICT for Women’s Empowerment

With a combination of factors such as low-cost smartphones, 4G / 5G roll-outs, increasing content generation and growing of people’s incomes, the smartphone is driving Internet penetration and reaching all section of societies. It offers promising solutions for bridging socioeconomic gaps, bringing in more inclusive delivery of services, and expanding opportunities in education, health and public services. Although the benefits are apparent, it also contributes to the triple divide—the digital, rural and gender divide (see Box 4).

According to a report by the International Telecommunication Union, the proportion of women using the Internet is 12 per cent lower than that of men worldwide. While the gender divide has narrowed in most regions since 2013, it has widened in Africa. In the least developed countries, only one out of seven women is using the Internet compared to one out of five men.

It is important to ensure that women's voice is heard so that technological developments can be leveraged in the way that prevents them from increasing inequalities. When used in a gender-sensitive way, ICTs can advance the processes of social inclusion with tangible results, including a narrowing of socioeconomic gaps between women and men.

Box 9: Less women than men own mobile phones

- Women are 14 per cent less likely than men to own a mobile phone.
- Nearly two-third of the unconnected (not owning a mobile phone) are women living in South Asia, East Asia and Pacific regions.
- 1.2 billion out of 2.9 billion women own a mobile phone in low- and middle-income countries (41 per cent), compared with 1.4 billion out of 3.0 billion men (46 per cent).

Source: GSMA in FAO, *Gender and ICTs: Mainstreaming Gender in the Use of Information and Communication Technologies (ICTs) for Agriculture and Rural Development* (Rome, 2018). Available at http://www.fao.org/3/i8670en/I8670EN.pdf.

8.3 ICT for Gender-Sensitive Disaster Risk Management

The use of gender-sensitive ICT solutions and applications, combined with traditional means of communication and information based on local needs and expectations, can make a significant contribution to improving gender equality and bridging the gender gap in DRM.

It is critical to enable "interactivity" to optimize the use of ICTs to promote gender-sensitive DRM. Women need to be part of the process to initiate, discuss, conceptualize and plan activities they will all do as a community. Active participation of women as "prosumers" in decisions are encouraged relating to what services, what content, where and how they are delivered, and how responsive governments are to the expressed, felt and unfelt needs of women.

Current ICTs address this "interactivity" by offering communication tools between the providers and users of services, where each individual can also become a generator of information. The individual is a consumer as well as a "prosumer" of content and services. In that sense, the interactivity in communication is at the heart of the use of ICTs to improve gender-sensitive policy.

8.4 Policy Considerations

The needs and concerns of women must be addressed while developing ICT and disaster risk reduction policies. A few policy considerations are listed below:

- Promote and facilitate the establishment of a Gender Unit within the ministry responsible for ICT and as an inter-agency effort;
- Incorporate gender-sensitive practices in the ministry by reviewing and developing new regulations, circulars and procedures to remove any gender bias, such as limited opportunities for training and advancement of women within the ministry;
- Develop capacity of policymakers and all those involved in the design and implementation of ICT policies, and make efforts for gender sensitization of technologists, and technology sensitization of gender specialists;
- Include gender specialists and women throughout the design, implementation and monitoring of all policies and strategies;
- Incorporate gender aspects in all stages of policy and programme formulation and budgeting, including allocation of resources, implementation, review and impact assessments, reprioritization, and reallocation of resources;
- Make collection and analysis of sex-disaggregated data mandatory in all data collections pertaining to ICTs and relevant sectors of development impacting on disaster risk reduction, in alignment with the Sendai Framework;
- Build the digital capacities of women so that participation in the knowledge society increases in terms of numbers as well as quality; and
- Promote ICTs and ICT-enabled services for women's economic empowerment to develop resilience to disasters.

9. SUMMARY

The world is confronted with rising trends in the frequency and severity of disasters along with their increasing impacts on lives and properties. Two major attributing factors to these trends are:

1. Increase in exposure of the elements-at-risk such as buildings and infrastructures, mainly due to rapid population growth and economic development during the last few decades; and
2. Increase in frequency and/or intensity of hydro-meteorological hazards, partly due to climate change.

In light of these trends, DRM has become an important instrument for reducing disaster risk, which requires the collecting and handling of enormous amounts of data and information, and some of these need to be collected in real time.

Advances in ICTs have made it possible to collect, analyse and manage this vast amount of data and information and use it across the key phases of the DRM cycle, namely, mitigation and prevention, preparedness, response, and recovery. Thus, the application of ICTs in DRM has increased many folds over the past decade or so. This module aims to highlight these applications by bringing best practices from different parts of the world and specifying the basic DRM principles for their application.

The first section provides an introduction to DRM and associated terminologies. Terminologies adopted by the United Nations are used in this module. Linkages between disasters and the SDGs are also briefly discussed in this section.

The second section describes the data necessary for DRM such as remote sensing data, digital elevation data, thematic data and historical disaster data. Each data type is discussed including their applications in DRM.

The third section provides an overview of disaster risk assessment, covering risk analysis, risk types and risk visualization. A basic framework for conducting risk assessment is explained and the importance of making risk information understandable to the relevant stakeholders through appropriate visualizations is emphasized.

The fourth section describes how ICTs can be used for adopting suitable disaster risk mitigation and prevention measures at the national and community levels. Terms such as risk perception, risk communication and risk evaluation are discussed. Relevant case studies on the use of ICTs to analyse and evaluate optimal risk reduction measures for decision-making are discussed.

The fifth section explores the use of ICTs in disaster preparedness, including the use of ICTs in community-based preparedness planning, alerting and evacuating, shelter planning, establishing early warning systems, and impact-based forecasting. Several real-world examples on the use of ICTs in monitoring and early warning for flood, earthquake drought, forest fire, snow avalanche and landslide are described.

The sixth section explores the use of ICTs in disaster response. One of the important requirements for disaster response is information exchange and coordination in the early stage of a disaster. Global and national systems that use ICTs to support disaster response and disseminate disaster alerts are highlighted. ICT applications are gaining popularity in participatory mapping for disaster relief activities and several major global initiatives are described. Specific applications such as use of mobile apps for reporting disaster incidents and use of robots in search and rescue operations are also mentioned.

The seventh section explores the use of ICTs in disaster recovery. To assist in disaster recovery, post-disaster building damage assessment using satellite data, including visual interpretation and change detection, as well as deep learning techniques are discussed. Examples of the ways in which ICTs are used for post-disaster recovery monitoring are also provided.

The eighth section highlights the role of ICTs in addressing gender-related issues for effective disaster risk reduction. Placing gender issues at the centre of disaster risk reduction policies and strategies is essential, and ICT tools offer innovative means to strengthen this inclusion. However, despite this recognition, the true potential of ICT for DRM to address gender issues is underutilized. The use of ICTs to empower women and pursue gender-sensitive disaster risk reduction are discussed.

Policy considerations are provided at the end of sections on: ICT for risk assessment and risk visualization (Section 3), ICT for mitigation and prevention (Section 4), ICT for disaster preparedness (Section 5), ICT for disaster response and relief (Section 6), ICT for disaster recovery (Section 7), and role of ICT in addressing gender issues in DRM (Section 8).

10. FURTHER READING

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