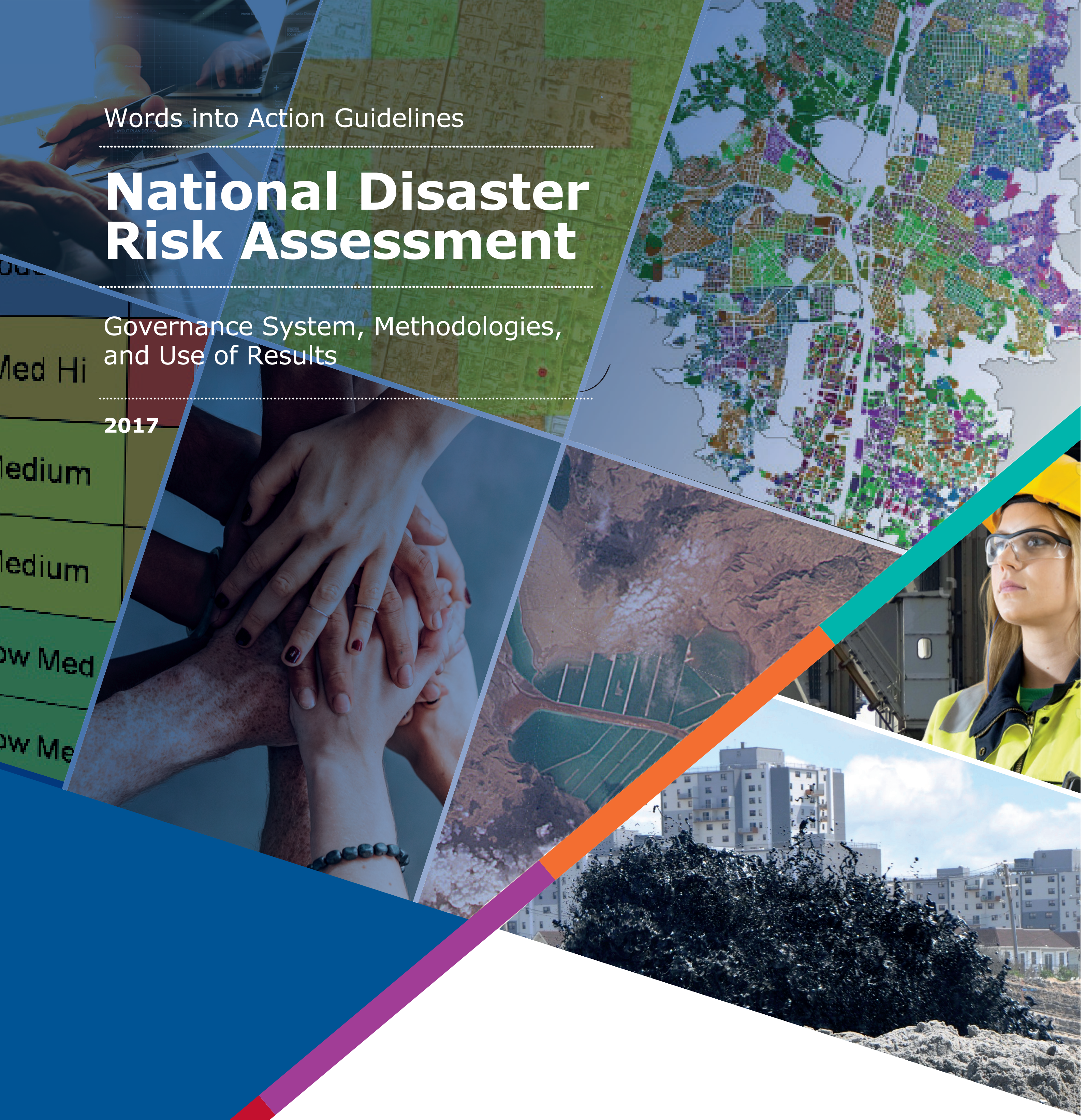


Words into Action Guidelines

National Disaster Risk Assessment

Governance System, Methodologies, and Use of Results

2017

In support of the Sendai Framework
for Disaster Risk Reduction 2015 - 2030

UNISDR
United Nations Office for Disaster Risk Reduction

Words into Action Guidelines

National Disaster Risk Assessment

UNISDR
2017

UNISDR
United Nations Office for Disaster Risk Reduction

Preface

The Sendai Framework for Disaster Risk Reduction 2015-2030, which was adopted by the Member States of the United Nations in 2015, is designed to support the reduction of existing level of risks and prevent new risks from emerging. In particular, it aims at substantially reducing disaster risk and losses of life, livelihoods and health, and losses of economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries.

The first priority for action of the Sendai Framework – understanding disaster risk – outlines a set of recommendations for ensuring that policies, measures and investments use risk information properly targeted towards reducing risk effectively. While the State has the primary role and responsibility in facilitating risk assessment and making risk information understandable and readily available to their peoples, the Sendai Framework also recognizes that all stakeholders and actors need to understand the risks they are exposed to and to be clear about the action they need to take to reduce those risks.

Challenges still remain in using risk information in policy design, planning and investments. In order to find good approaches to addressing this issue and share existing knowledge in an accessible format, the United Nations Office for Disaster Risk Reduction (UNISDR) commissioned the development of guidelines on national disaster risk assessment as part of a series of thematic guidelines under its "Words into Action" initiative to support national implementation of the Sendai Framework.

The Guidelines contribute to achieving the Sendai Framework target (g) on making disaster risk information available to people. They are also a testament to the great collaboration and partnerships among Member States and UNISDR technical partners in identifying good practices and sharing with others and so the Guidelines also contribute to achieving target (f) on enhancing international cooperation, by making good practice and know-how available to developing countries.

Embedding disaster risk assessment and integrating it into the very culture of governance and daily work are key to empowering all actors with an improved understanding of disaster risk. The Guidelines recommend that States establish a national system for understanding disaster risk that should be integrated with related policy and planning mechanisms.

The Guidelines attempt to make a contribution to the significant amount of work that is needed to develop tools and methods, to offer further guidance and to create partnerships to support countries in achieving this.

UNISDR looks forward to continuing this work in collaboration with UN Member States and numerous partners in improving understanding of disaster risk and building a safer future.

Robert Glasser, Special Representative of the United Nations Secretary-General for Disaster Risk Reduction, **UNISDR**

Contents

Acknowledgements

General Editor and Facilitator

Sahar Safaie (United Nations Office for Disaster Risk Reduction)

Part One: Main Body

Authors

Sahar Safaie (UNISDR); **Magda Stepanyan** (Risk Society); **Ruud Houdijk** (Houdijk Consultancy); **Tuna Onur** (Onur Seemann Consulting).

Peer reviewers

John Abrahams (World Health Organization); **Kelvin Berryman** (GNS New Zealand); **Andrew Bower** (European Civil Protection and Humanitarian Aid Operations); **Emily Clarke** (UK Civil Contingencies Secretariat); **Fadi Hamdan** (Disaster Risk Management Center); **Markus Hohl** (Swiss Federal Office for Civil Protection); **Ismail Khan** (NDMA Pakistan); **Robert Muirwood** (Risk Management Solutions); **John Rolfe** (Queensland Fire and Emergency Services); **Nestor Alfonso Santamaria** (UK Civil Contingencies Secretariat); **Alanna Simpson** (GFDRR); **Martine Woolf** (Geoscience Australia).

Case Studies

Authors

Emily Clarke (UK Civil Contingencies Secretariat); **Jo Horrocks** (New Zealand Ministry of Civil Defence and Emergency Management); **Sarah-Jayne McCurrach** (New Zealand Ministry of Civil Defence and Emergency Management); **Nestor Alfonso Santamaria** (UK Civil Contingencies Secretariat).

Part Two: Special Topics

Authors

Jonathan Abrahams (WHO); **David Alexander** (University College London); **Anne Anacia** (WHO); **Kevin Blanchard** (DRR Dynamics); **Ian Branagan** (Renaissance Re); **Massimo Ciotti** (ECDC); **Tarik Derrough** (ECDC); **Laura Espinosa** (ECDC); **Maureen Fordham** (University College London); **Stuart Fraser** (GFDRR); **JC Gaillard** (University of Auckland); **Jonathon Gascoigne** (Willis Towers Watson); **Maryam Golnaraghi** (The Geneva Insurance Association); **Anne Marie Gordon** (Renaissance Re); **Thorolfur Gudnason** (Directorate of Health, Iceland); **John Handmer** (IIASA); **David Hillson** (The Risk Doctor); **Stefan Hochrainer** (IIASA); **Adriana Keating** (IIASA); **Bijan Khazai** (CEDIM); **Reinhard Mechler** (IIASA); **Junko Mochizuki** (IIASA); **Virginia Murray** (Public Health England); **Ilan Noy** (Victoria University of Wellington); **Gianluca Pescaroli** (University College London); **Lisa Robinson** (BBC Media Action); **Ettore Severi (**ECDC); **Alanna Simpson** (GFDRR); **Catherine Smallwood** (WHO); **Robert Soden** (GFDRR); **Jonathan Suk** (ECDC); **Svetla Tsolova** (CEPS);

Chadia Wannous (UNISDR); **Martine Woolf** (Geoscience Australia).

Peer reviewers and contributors

Ali Ardalan (I. R. Iran Ministry of Health and Medical Education); **Robert Banick** (GFDRR); **Mark de Bel** (Deltares)**; Kelvin Berryman** (Institute of Geological and Nuclear Science); **Martha Liliana Carreño** (Ingeniar); **Diana Contreras** (GEM); **Venetia Despotaki** (GEM); **Ferdinand Diermanse** (Deltares); **Melanie Eckle** (Heidelberg University); **Darryl Glover** (Glover & Associates); **Cees van de Guchte** (Deltares); **Ellis Hazendonk** (Communication unit of the national crisis centre of the Netherlands); **Stephane Hallegette** (GFDRR); **Mark Harvey** (Resurgence)**; Paul Henshaw** (Global Earthquake Model Foundation); **Peter Hoppe** (Munich Re); **Roger Jones** (Victoria University); **Christian Kuhlicke** (Helmholtz-Centre for Environmental Research); **Owen Landeg** (Public Health England); **Gerry Lemcke** (Swiss Re); **Igor Linkov** (US Army Engineer Research and Development Center); **Paul Nunn** (SCOR SE); **Tyler Radford** (Humanitarian OpenStreetMap Team); **Ernst Rauch** (Munich Re); **Adam Rose** (University of Southern California); **Simone Ruiz-Vergote** (Allianz); **Sahar Safaie** (UNISDR); **Keiko Saito** (GFDRR); **Alanna Simpson** (GFDRR); **Robert Soden** (GFDRR & Co-Risk Labs); **Marjorie Sotofranco** (IFRC); **Claire Souch** (AWHA Consulting); **Peeranan Towashiraporn** (Asian Disaster Preparedness Center); **Emma Visman** (VNG Consulting Limited); **Zehra Zaidi** (Euro-Mediterranean Centre for Climate Change).

Part Three: Hazard specific Risk Assessment

Authors

Jonathan Abrahams (WHO); **Anne Anacia** (WHO); **Rebecca Beavers** (USA National Park Service); **Maria Caffrey** (University of Colorado); **Massimo Ciotti** (ECDC); **Tarik Derrough** (ECDC); **James Douris** (World Meteorological Organization); **Laura Espinosa** (ECDC); **Graham Fraser** (ECDC); Serkan Girgin (JRC); **Johann G. Goldammer** (Global Fire Monitoring Center); **Thorolfur Gudnason** (Directorate of Health, Iceland); **Zsuzsanna Gyenes** (JRC); **Alasdair Hainsworth** (World Meteorological Organization); **Elisabeth Krausmann** (JRC); **Susan Loughlin** (British Geological Survey); **Finn Løvholt** (Norwegian Geotechnical Institute); **Giorgos Mallinis** (Democritus University of Thrace); **Ioannis Mitsopoulos** (Global Fire Monitoring Center); **Farrokh Nadim** (Norwegian Geotechnical Institute); **Amos Necci** (JRC); **Roberto Rudari** (CIMA Foundation); **Ettore Severi** (ECDC); **Jane Sexton** (Geoscience Australia); **Vitor Silva** (Global Earthquake Model Foundation); **Catherine Smallwood** (WHO); **Jonathan Suk** (ECDC); **Svetla Tsolova** (CEPS); **Jonathan L. Vigh** (National Center for Atmospheric Research); **Claudia Villegas** (Ingeniar Ltda.); **Chadia Wannous** (UNISDR); **Graeme Weatherill** (Global Earthquake Model Foundation); **Catalina Yepes-Estrada** (Global Earthquake Model Foundation); **Martine Woolf** (Geoscience Australia).

Peer reviewers and contributors

Ignacio Aguirre Ayrebe (GTM/Univ. Cantabria); **Christa Andrade** (GTM/NOAA); **Ali Ardalan** (I. R. Iran Ministry of Health and Medical Education); **Tom Baldock** (University of Queensland); **Maria Ana Baptista** (GTM /IPMA); **Miquel Canals** (GTM/ University of Barcelona); **Nicola Casagli** (University of Florence); **Gareth Davies** (Geoscience Australia; Stuart Fraser (GTM/GFDRR); **Carmine Galasso** (University College London); **Eric Geist** (GTM/ USGS); **Frank Gonzalez** (GTM/University of Washington); J**onathan Griffin** (Geoscience Australia); **Bill de Groot** (Canadian Forest Service); F**austo Guzzetti** (Italian National Research Council); **Michel Jaboyedoff** (University of Lausanne); **Yasir Kaheil** (FM Global); **Bjørn Kalsnes** (NGI); **Utku Kanoglu** (GTM/METU); **Hamzah Latief** (GTM/ITB); **Stefano Lorito** (GTM/INGV); **Mohammed Mokhtari** (GTM/IIEES); **Gerassimos Papadopoulos** (National Observatory of Athens); **Raphael Paris** (GTM / LVM); **Dave Petley** (Sheffield University); **Jascha Polet** (GTM/Caltech); **Paola Reichenbach** (Italian National Research Council); **Fabrizio Romano** (GTM/INGV); **Stephanie Ross** (GTM/ USGS); **Mario Salgado Gálvez** (GTM/CIMNE); **Ernesto Salzano** (University of Bologna); **Paolo Scussolini** (Vrije Universiteit Amsterdam); **Hong Kie Thio** (GTM/ AECOM); **Matthew Thompson** (U.S. Forest Service); **Manuela Volpe** (GTM/INGV); **Andrew Williams** (University of Plymouth); **Martine Woolf** (Geoscience Australia).

Grateful for advice and support from:

Shoko Arakaki (UNISDR); **Fouad Bendimerad** (Earthquakes and Mega Cities Initiative); **Montserrat Marin Ferrer** (JRC); **Claudia Lally** (UK Go-science); **Mick Maghar** (Secretary IEC/TC 56)**; Karmen Poljansek** (JRC); **John Schneider** (GEM); **Catalina Jaime** (Red Cross-Red Crescent Climate Centre); **Sima Mostofi Javid** (Independent Consultant); **Andrew Krczkiewicz** (International Research Institute for Climate and Society); **Paolo Scussolini** (Institute for Environmental Studies, Vrije Universiteit Amsterdam);

With special thanks for support, enthusiasm and insights from:

Tuna Onur (Onur Seemann Consulting); **Ruud Houdijk** (Houdijk Consultancy); **Magda Stepanyan** (Risk Society); **Hasib Abdulrazaq** (UNISDR).

Editor

Christina O'Shaughnessy

Image Design

Hasib Abdulrazaq (UNISDR)

Graphic Designer

Valerio Lo Bello

Table of Contents

Summary

A holistic risk assessment that considers all relevant hazards and vulnerabilities, both direct and indirect impacts, and a diagnosis of the sources of risk will support the design of policies and investments that are efficient and effective in reducing risk.

During the decade of the Hyogo Framework for Action 2005-2015, substantial progress was made in advancing science and technology, developing tools for hazard and risk assessment, and producing risk information at different levels and scales across the world.

Nevertheless, major gaps still exist in risk information quality and availability for various applications. And more importantly, the challenge remains for decision makers to use the available information in policy design and investment.

In the Sendai Framework for Disaster Risk Reduction 2015-2030, understanding disaster risk is the first priority for action:

"policies and practices for disaster risk management should be based on an understanding of disaster risk in all its dimensions of vulnerability, capacity, exposure of persons and assets, hazard characteristics and the environment."

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

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

The Guidelines are intended to:

a) Motivate and guide countries in establishing a national system for understanding disaster risk that would act as the central repository of all publicly available risk information. This national system would lead the implementation and updates of national disaster risk assessment for use in disaster risk management, including for risk-informed disaster risk reduction strategies and development plans;

[1] UNISDR, 2015. Sendai Framework for Disaster Risk Reduction 2015 - 2030, The United Nations Office for Disaster Risk Reduction, Geneva, Switzerland.

b) Encourage disaster risk assessment leaders and implementing entities to aim for holistic assessments that would provide an understanding of the many different dimensions of disaster risk (hazards, exposures, vulnerabilities, capacities). The assessments would include diverse types of direct and indirect impacts of disaster – physical, social, economic, environmental and institutional. They would also provide information on the underlying drivers of risk – climate change, poverty, inequality, weak governance and unchecked urban expansion.

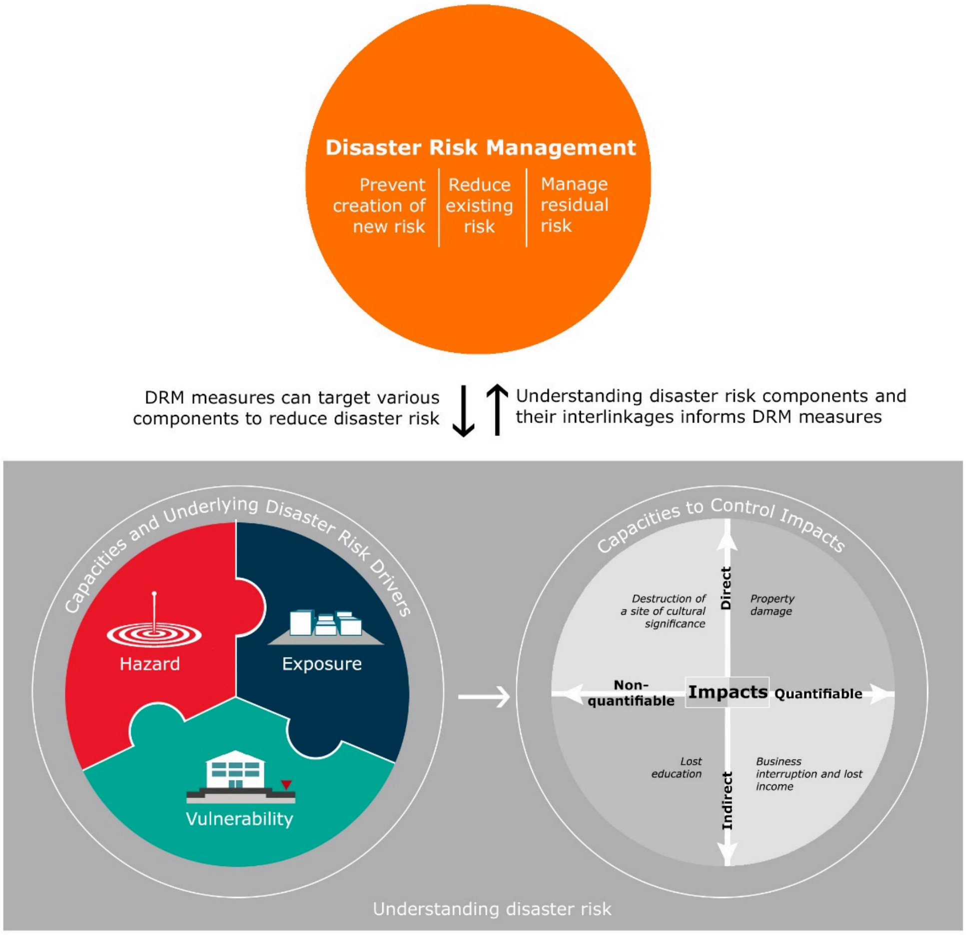


Figure i - Holistic understanding of disaster risk empowers effective and comprehensive disaster risk management (source: UNISDR)

Both of these outcomes may take many years and many iterations of the assessments, but as long as all the efforts have full national ownership by stakeholders and the scientific community and each update of the assessments is continuously improved, any country can achieve them.

Although the Guidelines focus on national disaster risk assessment, many of the concepts they contain are relevant and applicable to subnational and sector-specific assessments.

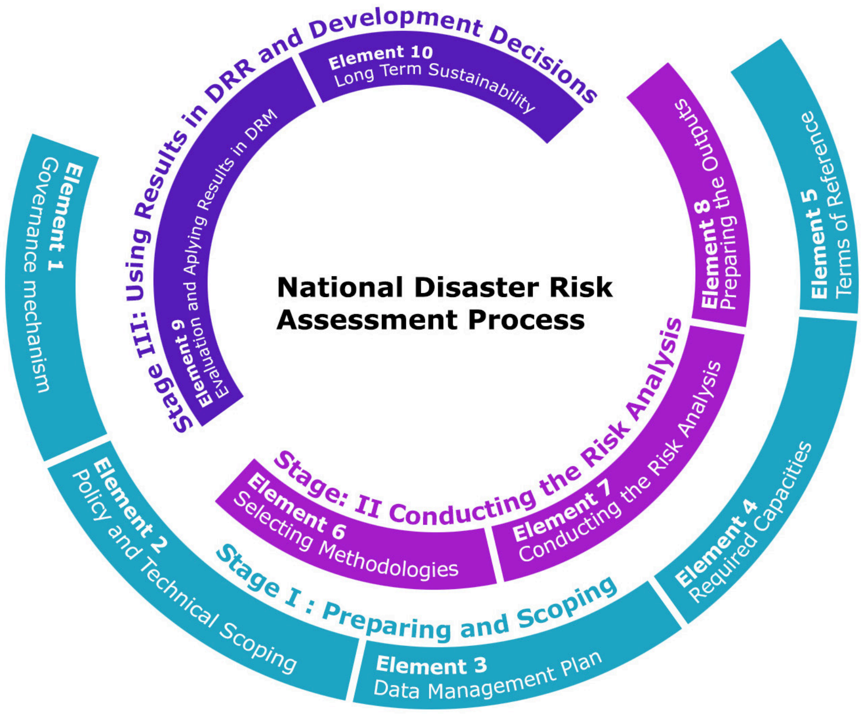


Figure ii Ten elements that enable success of a risk assessment are organized under three stages. The elements are interlinked and have some level of flexibility in sequencing and timing

The target audience of the Guidelines are disaster risk management practitioners and risk assessment experts who want to design and implement a risk assessment at global, regional, national, or subnational level for use in policy and investment.

Structure of the Guidelines

The *Guidelines* are designed to allow freedom in reading various sections according to the interests and needs of the users. They consist of three parts:

Part one - Main body

This part focuses on the three stages of the assessment process. All elements of the three stages are closely connected through feedback loops and have some flexibility in sequencing and timing:

- Stage I: Preparing and scoping
- Stage II: Conducting risk analysis
- Stage III: Using the results for disaster risk management and development decisions.

Part one provides policy guidance. Technical references for designing and implementing assessments are set out in parts two and three, as well as in footnotes and references.

Part two - Special topics

This part consists of modules on specific issues to be considered when designing and carrying out a national disaster risk assessment. Their relevance will depend on the country-specific context and national policy objectives. Each module can be read independently.

Part three - Hazard specific risk assessment

This part consists of modules covering more in-depth information on conducting risk assessment for specific hazards. The Sendai Framework calls for multi-hazard management of disaster risk based on understanding small-scale and large-scale, frequent and infrequent, sudden and slow-onset disasters caused by natural or human-generated hazards, as well as related environmental, technological and biological hazards and risks. Part three is a work in progress, which will gradually cover more hazards and assessment methods.

Ten elements that enable a successful risk assessment at any level and are key for establishing a central system for understanding risk

The ten elements that enable success of a risk assessment are organized under three stages of the risk assessment: (a) preparing and scoping, (b) conducting risk analysis and (c) using results for decisions in disaster risk management and sustainable development.

These elements have been developed based on common characteristics that were identified among many successful risk assessments conducted at various levels, as well as a few national central systems for understanding disaster risk, including in Mexico, the Netherlands, New Zealand, Switzerland and the United Kingdom.

Stage I / Preparing and scoping

This stage considers what needs to be done before embarking on an NDRA process, ensuring that outputs are fit for purpose. Five elements are introduced under this stage.

Element 1 - Establishing a governance mechanism

A successful NDRA requires a system of institutions, operational modalities, policies and a legal framework to guide, manage, coordinate and oversee implementation. It also requires consultations, engagement, ownership and contributions from a wide range of stakeholders.

Establishing a strong governance mechanism is the foundation for a successful risk assessment. Element 1 describes the rationale, objectives, structure and considerations for modalities of operation of such a mechanism. Three main aspects of the governance mechanism are introduced here: (a) the governance structure, which includes the lead agency, the multi-stakeholder coordination body and the technical committee, (b) the legal framework and (c) the process agreements.

Element 2 - Defining the policy scope and technical scope of NDRA

At the early stages of design, it is critical to be clear about the purpose and objectives of the risk assessment for producing relevant and usable information. Before conducting an NDRA, a feasibility study should be carried out.

The study should define the policy scope, the technical scope and the boundaries set by the technical, financial and political resources available for the assessment. The scope will depend on the complexity and scale of a country and its risks.

Element 2 provides an overview of the scoping process and issues for consideration to ensure the assessment is fit for purpose.

Element 3 - Developing an NDRA data management plan

Risk assessment is an extremely data-intensive process, and conducting a national risk assessment may involve accessing information from a wide range of stakeholders, including mapping agencies, scientific and technical ministries, universities, research institutions and the private sector. In addition, valuable new data and analyses are created during risk assessments.

Therefore a strategy needs to be developed to efficiently organize and manage the data as they become available, as well as for distributing the results to participants and key stakeholders. Element 3 describes both the rationale for having an NDRA data management plan and the critical issues that need to be included.

Element 4 - Developing required capacities

The NDRA process requires strong administrative, technical and financial capacities. Administrative capacities refer to the legal and institutional frameworks within the country and how inclusive they are for a multi-stakeholder NDRA. Financial capacities refer to the availability of funds for completing the NDRA.

Technical capacities refer to the type and level of technical expertise within the scientific community that are necessary for conducting risk analysis, as well as the technical capacities within the non-scientific community in understanding and using the results.

Element 5 - Developing terms of reference for NDRA

An NDRA is a project and needs to be managed as such. Its terms of reference guide the process and provide the basis for resource allocation. They should clearly indicate the timeline, milestones and deliverables, roles and responsibilities of the stakeholders, as well as the budget within which the process should be completed and results delivered.

They need to be endorsed by the designated national authority/authorities and supported by adequate resource allocation. Element 5 describes the importance of developing comprehensive terms of reference to manage NDRA implementation and delivery.

Stage II / Conducting risk analysis

This stage is the analytical risk analysis performed by a technical team, based on the terms of reference. It covers three elements.

Element 6 -Utilizing various risk analysis methodologies

Many different and complementary methods and tools are available for analysing risk. These range from qualitative – based on the subjective perceptions of experts – to semi-quantitative and quantitative methods: probabilistic risk analysis, deterministic or scenario analysis, historical analysis and expert elicitation.

Selecting the methods to use depends on the purpose the results should serve, the resources available and the significance of the risk. For effective disaster risk management, it is critical to have an understanding of risk from all hazards, interlinkages between hazards and vulnerabilities, and comparison of different types of risk.

Although various methods and tools are available for single hazard assessment, methods for aggregation and comparison of hazards, and cascading and interrelated hazards and vulnerabilities are far more limited. Element 6 briefly describes various risk analysis methodologies, risk comparison techniques and considerations for selecting the most suitable methodologies.

Element 7 - Key considerations in conducting risk analysis

This element describes key considerations in conducting a risk analysis, such as: (a) identifying and compiling existing input data, (b) assessing disaster risk management capacities and (c) determining the sources and drivers of risk, the direct and indirect impacts and the climate change impact.

Element 8 - Preparing the outputs of risk analysis for communication with stakeholders

Presenting the results in a format that is understandable, relevant and useful to the stakeholders is key to the success of an NDRA. Element 8 emphasizes the importance of using a variety of tools and methods such as geospatial tools and mapping, risk matrices, scenarios, loss exceedance curves, visuals and infographics to prepare the outputs of the analysis for communication and use by stakeholders for the purposes of the NDRA.

Stage III / Using NDRA results for disaster risk management and development decisions

Element 9 - Facilitating the process for evaluation and applying results in disaster risk management decisions

The outputs of risk assessment are inputs to decision-making on plans, actions and investments for managing disaster risk. Element 9 provides an overview of the necessary re-engagement between the technical team and the stakeholders to understand the NDRA results, evaluating the risks so as to prioritize them and applying the assessment to the original policy scope defined at the scoping and preparation stage.

This dialogue may lead to demand for further analysis to gain additional perspectives, such as greater understanding of the risk drivers, or the impact of certain disaster risk management policies or cost-benefit analysis of specific investments.

This step is by no means the end of disaster risk management or disaster management planning but simply an opportunity to evaluate options while interacting with the technical teams who conducted the national assessment.

At the end of this step, the final set of risk assessment outputs – as data sets, maps, reports or any other formats, customized for the stakeholders – is delivered to the NDRA lead agency, and this cycle of NDRA comes to an end.

Element 10 - Ensuring long-term sustainability of NDRA system

The vision of the Sendai Framework’s first priority for action, understanding disaster risk, and the approach presented in these Guidelines, is to have in every country a well-established central system for understanding disaster risk. The system should produce the risk information needed for prevention, mitigation, preparedness, response and recovery, in order to build a resilient future.

With a multi-stakeholder governance system, the central system updates the NDRA every few years, conducts specific risk assessment on demand and maintains the national clearinghouse of risk data and information. Element 10 describes the recommended long-term plan for the country NDRA system.

Conclusions and the way forward

The Sendai Framework calls for strong political leadership, commitment and involvement of all stakeholders, at all levels, to pursue the goal of preventing new and reducing existing disaster risk:

> **"through the implementation of integrated and inclusive economic, structural, legal, social, health, cultural, educational, environmental, technological, political and institutional measures that prevent and reduce hazard exposure and vulnerability to disaster, increase preparedness for response and recovery, and thus strengthen resilience".**

Such a complex task requires novel approaches and methods, and perhaps most importantly, new mindsets. Building resilience is largely a cross-cutting theme and starts from understanding disaster risk.

An NDRA can bring multiple sectors and stakeholders together to understand the risk and causes of risk from various hazards and vulnerabilities. A successful NDRA, embedded in development and DRR policy and planning, can be the foundation for successful disaster risk management – ranging from prevention and reduction to preparedness, response and recovery.

These Guidelines are a step forward in motivating countries to (a) establish national systems for understanding disaster risk to conduct risk assessments that they can integrate into their policy and planning mechanisms and (b) take a holistic approach to understanding the complexity of all dimensions of risk, including various hazards and vulnerabilities, direct and indirect impact – and most importantly, the sources and causes of risks.

Chapter 1. Background

About the Guidelines

Introduction

In 2016 the United Nations Office for Disaster Risk Reduction (UNISDR) commissioned the development of guidelines on national disaster risk assessment (NDRA) as part of a series of thematic guidelines under its "Words into Action" initiative to support national implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030.[2]

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

The Guidelines are intended to:

c) Motivate and guide countries in establishing a national system for understanding disaster risk that would act as the central repository of all publicly available risk information. This national system would lead the implementation and updates of national disaster risk assessment for use in disaster risk management, including for risk-informed disaster risk reduction strategies and development plans;

d) Encourage NDRA leaders and implementing entities to aim for holistic assessments that would provide an understanding of the many different dimensions of disaster risk (hazards, exposures, vulnerabilities, capacities). The assessments would include diverse types of direct and indirect impacts of disaster – such as physical, social, economic, environmental and institutional. They would also provide information on the underlying drivers of risk – such as climate change, poverty, inequality, weak governance and unchecked urban expansion.

Both of these outcomes may take many years and many iterations of the assessments, but as long as all the efforts have full national ownership by stakeholders and the scientific community and each update of the assessments is continuously improved, they are achievable in every country.

The Guidelines aim to be a policy guide and a practical reference to introduce the audience, especially practitioners of disaster risk reduction, to policy,

2 UNISDR, 2015. Sendai Framework for Disaster Risk Reduction 2015 - 2030, The United Nations Office for Disaster Risk Reduction, Geneva, Switzerland.

process and the high-level technical requirements for a holistic national disaster risk assessment. They provide an overview of policy objectives, effective governance, processes of design, implementation and use of assessment results in comprehensive disaster risk management.

They are based on the premise that any national disaster risk assessment needs to consider intensive and extensive risks, and that disaster risk management needs to be correlated with sustainable development and the effects of climate change[3,4].

The *Guidelines* are structured in three parts. The first part focuses on important elements in the NDRA process: preparation and scoping, implementation and use of results. The second part consists of modules on specific issues that should be considered depending on the objective and scope of the assessment. The third part covers more in-depth information on conducting risk assessment for various hazards.

Although the Guidelines focus on national disaster risk assessment, many of the concepts presented are relevant and applicable for subnational or sector-specific assessments.

Box 1. Understanding Disaster Risk is a requirement for achieving Sustainable Development Goals

• The 2030 Agenda for Sustainable Development outlines a vision for people, planet, prosperity and peace with the 17 Sustainable Development Goals (SDGs). Risk and resilience are at the heart of planning for achieving SDGs, because:
shocks and stresses can reverse years of efforts and investments in development achievements

• many of the SDGs are focused on issues that are underlying drivers of risk, for example: poverty and inequality, climate change, lack of peace, or weak institutions. Achieving these goals would lead to risk reduction.

• bad ‘development’ can be a source of risk for example: unregulated urban development or construction of vulnerable critical infrastructures.

Using holistic approach in understanding risk and applying it in development plans and investments ensure long term resilience of societies.

3 Natural climate variability and human-generated climate change influence the frequency, intensity, spatial extent and duration of some extreme weather and climate events. The vulnerability of exposed human society and ecosystems interacts with these events to determine impacts and the likelihood of disasters (IPCC, 2012). Besides natural hazards, climate change can also lead to change in exposure, for example in the case of climate refugees as a result of sea-level rise and draught.

4 IPCC, 2012. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA.

Methodology

The Guidelines are based on a detailed review of the methodologies, approaches and governance mechanisms practised in national disaster risk assessment across the globe, as well as on existing guidelines.

The selection of an approach for conducting the assessments takes account of a wide range of issues including the purpose of NDRA, available capacities and resources, quality of the available data, political will and engagement of the stakeholders and sectoral priorities. The design of the Guidelines permits the sharing of the findings from studying the most effective existing assessments. It also addresses the expected variability by offering information on a wide range of topics and hazards to be adapted to different national contexts.

With the objective of understanding the roots of the existing gap between the production of risk information and its actual use in decision-making in disaster risk management, the team working on the Guidelines held consultations both with national policy institutions and with technical experts. They did this to ensure that the recommended approach would be based on understanding both the policy and technical aspects of NDRA and use of the assessment in decision-making.

Target audience

The Guidelines advocate for an "all-of-government" and "all-of-society" approach for NDRA to ensure its legitimacy, comprehensiveness and effectiveness. This is an imperative given the multifaceted character of disaster risk, its causes and its need for interlinked action at all government levels, and across sectors and communities.

The Guidelines, therefore, address the following entities:

- Policymakers concerned with setting disaster risk management and sustainable development policy priorities and planning instruments across the entire public administration system at national and subnational levels.
- National, subnational and local practitioners of disaster risk management who will use the outputs from the assessment to guide the design and implementation of disaster risk management measures.
- Disaster risk management practitioners at regional and global development institutions financing or providing technical support to developing countries for conducting national risk assessments.
- Technical experts from a wide range of thematic specializations (e.g. hydrometeorology, geophysics, sustainable development, climate change,

public health, engineering, social protection, anthropology) who are involved in providing risk information for use in policy decisions.

- Academia and centres of research and knowledge creation that have a major role to play in providing a solid scientific basis for disaster risk assessment.
- Civil society representatives concerned with various aspects of building societal resilience at national and local levels or in a specific sector.
- The private sector – a key actor for reducing losses, prioritizing risk-proofed investments and the economic resilience of disaster-prone communities, as well as for providing data, methodologies and tools for NDRA.

How to read the Guidelines

The Guidelines are designed to allow freedom in reading various sections according to the interests and needs of the users. They consist of three main parts:

Part one - Main body (the present document)

This part focuses on the three stages of the assessment process. All elements of the three stages are closely connected through common issues to be addressed and feedback loops:

- Stage I: Preparing and scoping
- Stage II: Conducting risk analysis
- Stage III: Using the results for disaster risk management and development decisions.

Part one provides policy guidance. Technical references for designing and implementing assessments are set out in technical modules in parts two and three, as well as in footnotes and references.

Part two - Special topics

This part consists of modules on specific issues to be considered when designing and carrying out a national disaster risk assessment. Their relevance will depend on the country-specific context and national policy objectives. Each module can be read independently.

The topics addre ssed include the following:

- Risk communication
- Health aspects
- Direct and indirect economic impacts
- Data management

- Citizen participation
- Cost benefit analysis
- Benefits of probabilistic modelling
- Use of geographic information system
- Cross border issues
- Groups with vulnerabilities
- Cascading risk
- Use of the assessment for risk financing..

Part three - Hazard specific risk assessment

This part consists of modules covering more in-depth information on conducting risk assessment for specific hazards[5]. The Sendai Framework calls for multi-hazard management of disaster risk based on understanding small-scale and large-scale, frequent and infrequent, sudden and slow-onset disasters caused by natural or human-generated hazards, as well as related environmental, technological and biological hazards and risks. Part three is a work in progress and in the coming years will gradually cover more hazards and assessment methods.

The technical modules give an overview of concepts, methodologies and tools related to each special topic and hazard. They are aimed at an audience that understands risk assessment but is not expert in the topic. Each module offers resources and links to further information and guidance.

[5] For the interim version of the Guidelines, released in May 2017, parts two and three have not gone through editing to harmonize the writing style. This will be done for the final version.

Rationale for investing in national disaster risk assessment

Recent disasters dramatically affected millions of people, with hundreds of thousands of lives and US$ 1.5 trillion lost between 2005 and 2014 alone, a tenfold increase over the previous decade. Global economic loss from disasters varies on average from US$ 250 billion to US$ 300 billion each year[6]. This value is an underestimate as it only covers direct physical losses from five hazards. Figure 1 gives an overview of risk levels from only five hazards across the world. It is also important to note that loss values may not be too high in least developed countries but the impact of such losses would be significant for such fragile economies with weak social safety measures. This trend is set to continue undermining development gains and causing risks to people, the economy, the environment and culture.

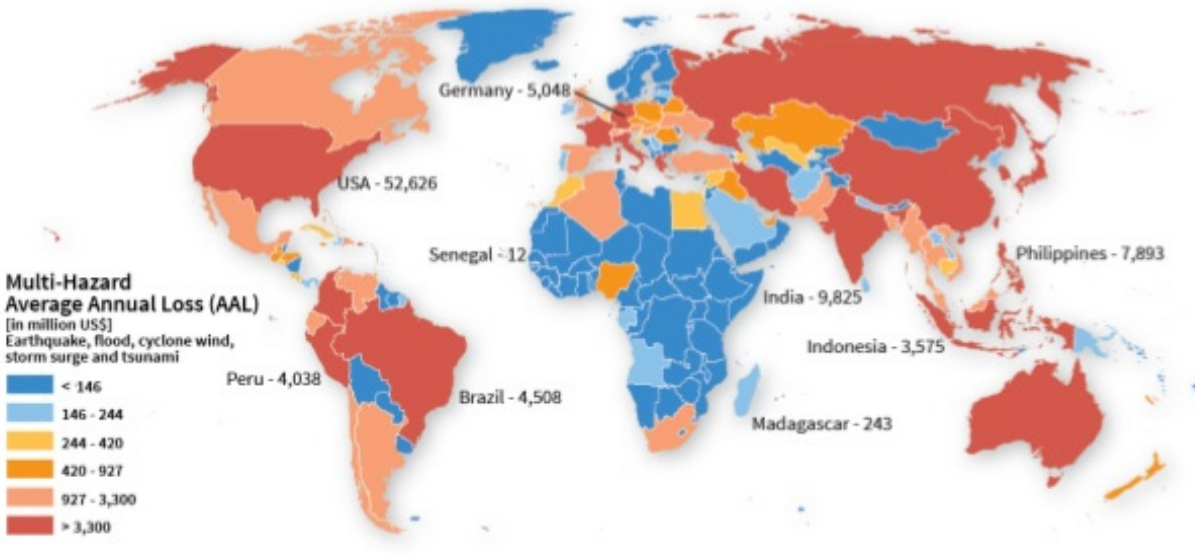


Figure 1 - Expected disaster losses annualized over the long term (average annual loss).

Results are from UNISDR global risk assessment of earthquake, flood, cyclone wind, storm surge and tsunami (in millions of US dollars).
Source: *UNISDR Global Assessment Report on Disaster Risk Reduction 15*

Changing climate, rapid urbanization, ongoing violence and conflicts in many

---

6 UNISDR, 2015. Global Assessment Report on Disaster Risk Reduction (GAR) 2015, The United Nations Office for Disaster Risk Reduction, Geneva, Switzerland.

parts of the world, changing demographics, technological innovations, increasing inequality and many other known and emerging changes with their inherent uncertainties have created an unprecedented context for disaster impact.

Apart from sudden large-scale disasters (intensive risks), the accumulation of impacts from small frequent events (extensive risks)[7] and slowly developing health, safety, security and environmental crises have a quiet but massive effect on society and on sustainable development. Investing in understanding disaster risk is therefore more important than ever if we want to understand its complexity and efficiently manage the resources required for managing disaster risk and designing interventions.

The Sendai Framework reinforces the crucial shift made in Yokohama and Hyogo from *managing disasters* to *managing disaster risk*, while resilience-building has grown into a shared ground for all international agreements made under the 2030 Agenda. Coherence and linkages between the implementation of the Sendai Framework, the 2030 Sustainable Development Goals, the Paris Agreement on climate change, the outcomes of the World Humanitarian Summit and the New Urban Agenda, and allied sectoral agreements such as the International Health Regulations (2005) are critical to ensure risk-informed development and resilience-building.

Resilience has been 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".[8] Resilience-building starts with understanding the risk that a society is facing, including disaster risk.

The outputs of an effective national disaster risk assessment inform disaster risk reduction efforts, including risk-informed sustainable development strategies, climate change adaptation planning, national disaster risk reduction across all sectors, as well as emergency preparedness and response.

The disaster risk management policy and planning applications of the outputs include:

- Informing national sustainable development plans so as to avoid the creation of new risk, reduce and manage existing risks, build resilience across various sectors and protect new and existing development from hazardous events.

---

[7] UNISDR, 2011. Global Assessment Report on Disaster Risk Reduction (GAR) 2011, The United Nations Office for Disaster Risk Reduction, Geneva, Switzerland.

[8] UNISDR, 2016. Open-ended Intergovernmental Expert Working Group on Indicators and Terminology relating to Disaster Risk Reduction: Report of the Second Session (Informal and Formal), The United Nations Office for Disaster Risk Reduction, Geneva, Switzerland.

- Informing national disaster risk reduction and climate change adaptation, including setting risk reduction goals and targets.
- Identifying strengths and gaps in national capacities, and resilience in relation to the risk levels.
- Identifying needs for more detailed sectoral or geographic risk assessments.
- Guiding disaster risk financial management and investment.
- Setting the basis (methods and data) for real-time prediction of exposure, vulnerability and impact in case of an unfolding disaster for the purpose of response and recovery planning
- Supporting public education and awareness activities.

National disaster risk assessments are costly exercises but the long-term benefits of risk-informed disaster risk reduction significantly outweigh the initial costs of the assessment. For most of the risk management measures that would benefit from a risk assessment, the financial cost of conducting an assessment is marginal in relation to the total cost of the investment.

Implementing national assessments, giving due consideration to the impact of climate change and to the correlation of disaster risk management with sustainable development creates a purposeful platform for communication and collaboration among stakeholders in disaster risk management, climate change adaptation and development, who, in many countries, are operating in silos. The approach to assessing and managing risks of different hazards and in different sectors (e.g. in relation to diseases) often occurs in isolation. Multi-hazard assessments help bring these actors together to study the relative risks of each type of hazard and find common ground for taking effective measures and using resources efficiently through an "all-hazards" approach.

Rationale for the approach presented in the Guidelines

A review of the achievement of the Hyogo Framework for Action 2005-2015 in risk identification and national disaster risk assessments has identified critical requirements for successful assessments, providing useful information for disaster risk reduction decision-making and practice. The review revealed that for an assessment to be successful, it needs the following:

- Inclusive governance mechanism
- Broad set of technical, financial, and administrative capacities
- Availability of reliable data and a solid methodology that meet the intended use of risk assessment results

- Political will to ensure that the outcomes are accessible, understandable and usable for the intended disaster risk management purposes.[9]

The approach presented in these Guidelines ensures that the following requirements for the success of an assessment are covered:

- **NDRA governance mechanism:** It is critical to ensure that the governance mechanism is well embedded in the disaster risk management governance mechanism and is inclusive. It should involve various sectoral ministerial portfolios, the national science and technology communities, the private sector and civil society.
  While national disaster risk assessment governance is primarily concerned with the assessment process itself, the national disaster risk management governance has a broader scope, including the design and implementation of disaster risk reduction strategies and enabling systematic integration of disaster risk considerations into development planning.
- **Purpose, methodology and outputs:** Clarity on the purpose of the risk assessment is needed to develop the scope, select the methodologies and tools, and the format of the outcomes. The methodology selected will define the sensitivity and robustness of the outcomes. While methods can vary significantly, it is essential to define the limitations of the chosen methodology to avoid false perception of precision, and define the confidence levels and uncertainties as well as the role of risk perception and risk acceptance that inevitably affects the decisions. For example, historical loss databases, which may cover data from few decades of disaster events, are excellent method for measuring impacts from high frequency and low impact events such as small floods. However, they can give false perception by masking less frequent floods with catastrophic impacts, which may not have happened in the past few decades but may happen in the future. Historical loss databases are not appropriate for assessing intensive events.
- **Capacities for conducting NDRA:** This refers to the technical, financial and administrative capacities required for effective implementation. An NDRA is often a complex and resource-intensive undertaking. Its scope is a trade-off between the full scientific depth of the assessment and the time and human resources that can be devoted to carrying it out while meeting the objective of using the assessment in disaster risk management.
- **Data management:** Availability of data is critical for a sufficiently grounded assessment. The assessment is made on the basis of validated sources of information and data on hazards, exposure, vulnerabilities and coping capacities. It might also be necessary to improve the existing data

[9] UNWCDRR, 2015. Risk Identification and Assessment (Priority 2) Multi-Stakeholder Working Session, United Nations World Conference on Disaster Risk Reduction, Sendai, Japan.

on hazard, exposure, vulnerability and capacities, as well as historical disaster loss data, the ongoing collection and recording of losses and damages, and the data management systems for NDRA.

- **Political commitment:** Political endorsement, leadership and the support of a high-level national authority, and ownership and commitment from all stakeholders are required to provide the necessary input data, understand the results and their limitations, and use the results in disaster risk management decision-making.

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

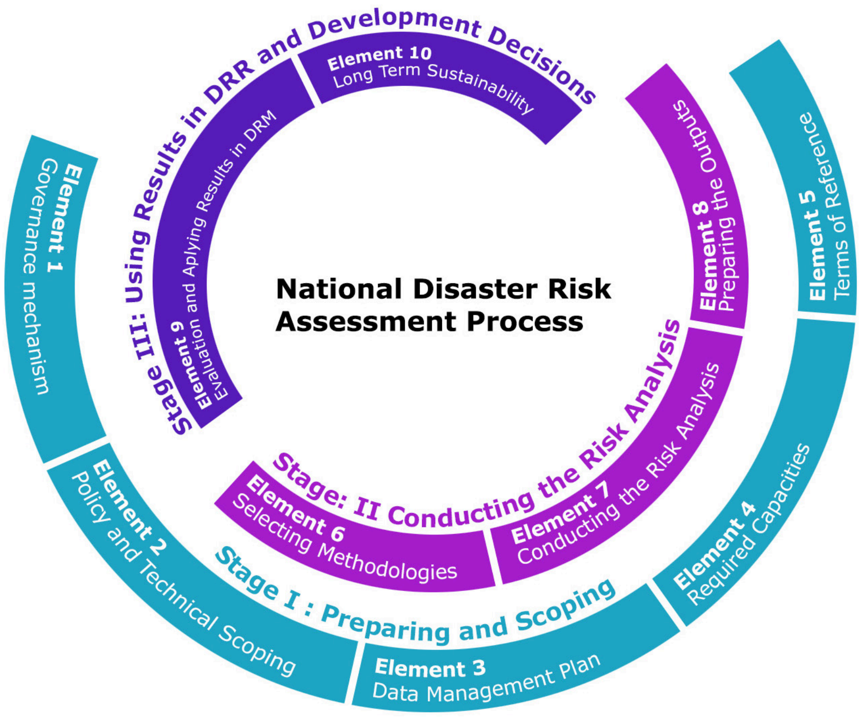


Figure 2 - Ten enabling elements in three stages of the NDRA process, interlinked through overlapping areas of concern and feedback loops

Understanding disaster risk components

Over time the conceptualization of disaster risk has undergone a transformation. These Guidelines use the classic disaster risk concept, which describes risk in terms of likelihood and impact, based on the interaction between hazard, exposure, vulnerabilities and capacities. To identify and evaluate the best measures for reducing risk, an assessment should also explain the underlying drivers of hazard, exposure, vulnerabilities and capacities, as well as the direct and indirect impacts.

Below are the definitions of these components from the Open-ended Intergovernmental Expert Working Group (OIEWG) report to the General Assembly on Indicators and Terminology, 2016.

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.

The definition of disaster risk reflects the concept of hazardous events and disasters as the outcome of continuously present conditions of risk. Disaster risk comprises different types of potential losses which are often difficult to quantify. Nevertheless, with knowledge of the prevailing hazards and the patterns of population and socioeconomic development, disaster risks can be assessed and mapped, in broad terms at least.

It is important to consider the social and economic contexts in which disaster risks occur and that people do not necessarily share the same perceptions of risk and their underlying risk factors.

Acceptable risk, or tolerable risk, is therefore an important subterm; the extent to which a disaster risk is deemed acceptable or tolerable depends on existing social, economic, political, cultural, technical and environmental conditions. In engineering terms, acceptable risk is also used to assess and define the structural and non-structural measures that are needed in order to reduce possible harm to people, property, services and systems to a chosen tolerated level, according to codes or "accepted practice" which are based on known probabilities of hazards and other factors.

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

National Disaster Risk: intensive and extensive Disaster Risks that either have a potential (cumulative) impact that is significant and relevant for the nation as a whole and/or require national DRM coordination.
Annotation: the boundaries of National Disaster Risk depend on the purpose and scoping of a NDRA process. This has to be defined in each country, taking into account existing governance and DRM policies. National Disaster Risks at least include all risks that cannot be sufficiently managed at sub-national level.

Extensive Disaster Risk: the risk associated with low-severity, high-frequency events, mainly but not exclusively associated with highly localized hazards.

Intensive Disaster Risk: the risk associated with high-severity, mid to low-frequency events, mainly associated with major hazards.

Disaster risk assessment: A qualitative or quantitative approach to determine the nature and extent of disaster risk by analysing potential hazards and evaluating existing conditions of exposure and vulnerability that together could harm people, property, services, livelihoods and the environment on which they depend. Disaster risk assessments include: the identification of hazards; a review of the technical characteristics of hazards such as their location, intensity, frequency and probability; the analysis of exposure and vulnerability, including the physical, social, health, environmental and economic dimensions; and the evaluation of the effectiveness of prevailing and alternative coping capacities with respect to likely risk scenarios[10].

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. Hazards may be natural, anthropogenic or socio-natural in origin. Natural hazards are predominantly associated with natural processes and phenomena. Anthropogenic hazards, or human-induced hazards, are induced entirely or predominantly by human activities and choices. This term does not include the occurrence or risk of armed conflicts and other situations of social instability or tension which are subject to international humanitarian law and national legislation. Several hazards are socio-natural, in that they are associated with a combination of natural and anthropogenic factors, including environmental degradation and climate change.

Hazards may be single, sequential or combined in their origin and effects. Each hazard is characterized by its location, intensity or magnitude, frequency and probability. Biological hazards are also defined by their infectiousness or toxicity, or other characteristics of the pathogen such as dose-response, incubation period, case fatality rate and estimation of the pathogen for transmission.

Multi-hazard means (1) the selection of multiple major hazards that the country faces, and[11] (2) the specific contexts where hazardous events may occur simultaneously, in a cascading manner or cumulatively over time, and taking into account the potential interrelated effects.

Hazards include (as mentioned in the Sendai Framework for Disaster Risk Reduction 2015-2030, and listed in alphabetical order) biological, environmental, geological, hydro-meteorological and technological processes and phenomena.

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

[10] In these Guidelines, assessment of coping capacity, underlying drivers of risk, direct and indirect impact are part of understanding disaster risk

[11] While OIEWG defined it with "and", in understanding of many experts contributing to this guideline the definition should use "or"

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. Capacity may include infrastructure, institutions, human knowledge and skills, and collective attributes such as social relationships, leadership and management.

Coping capacity is the ability of people, organizations and systems, using available skills and resources, to manage adverse conditions, risk or disasters. The capacity to cope requires continuing awareness, resources and good management, both in normal times as well as during disasters or adverse conditions. Coping capacities contribute to the reduction of disaster risks.

Underlying disaster risk drivers: Processes or conditions, often development-related, that influence the level of disaster risk by increasing levels of exposure and vulnerability or reducing capacity.

Underlying disaster risk drivers — also referred to as underlying disaster risk factors — include poverty and inequality, climate change and variability, unplanned and rapid urbanization and the lack of disaster risk considerations in land management and environmental and natural resource management, as well as compounding factors such as demographic change, non-disaster risk-informed policies, the lack of regulations and incentives for private disaster risk reduction investment, complex supply chains, the limited availability of technology, unsustainable uses of natural resources, declining ecosystems, pandemics and epidemics.

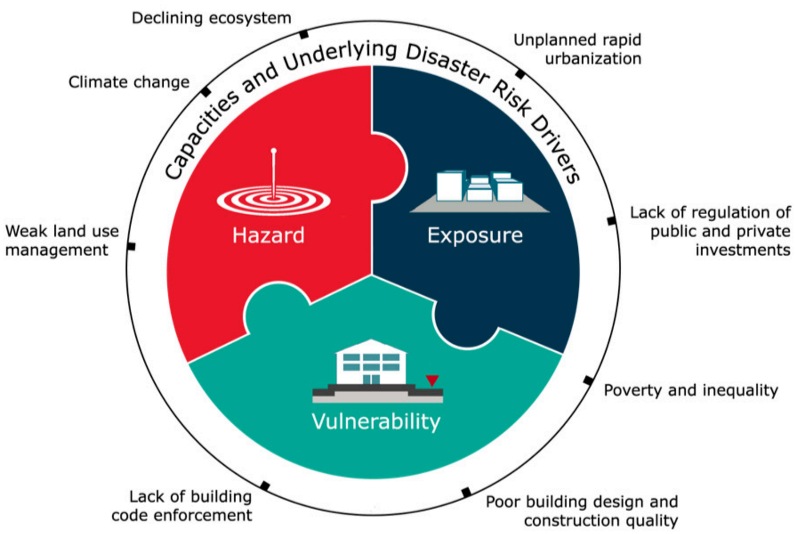


Figure 3 - Underlying drivers may influence more than one component of disaster risk

Disaster impact: is the total effect, including negative effects (e.g., economic losses) and positive effects (e.g., economic gains), of a hazardous event or a disaster. The term includes economic, human and environmental impacts, and may include death, injuries, disease and other negative effects on human physical, mental and social well-being.

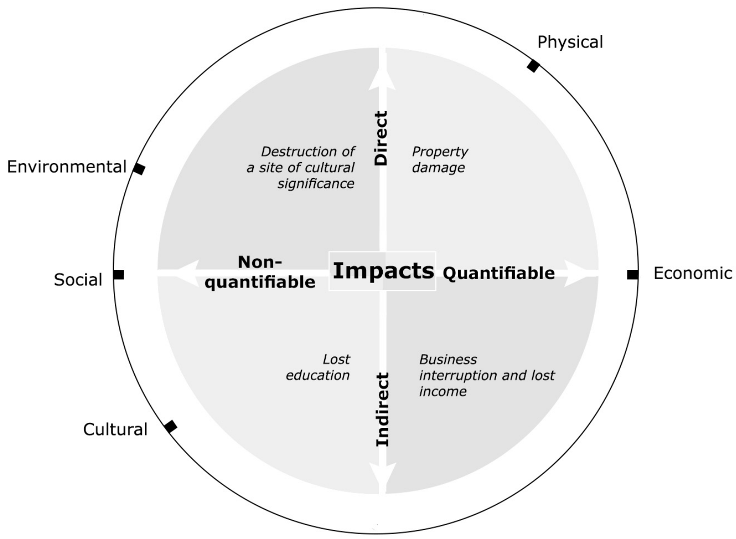


Figure 4 - There are direct and indirect impacts of disasters.
Not all types of impact can easily be quantified in monetary terms

---

Economic loss: Total economic impact that consists of direct economic loss and indirect economic loss.

Direct economic loss: the monetary value of total or partial destruction of physical assets existing in the affected area. Direct economic loss is nearly equivalent to physical damage.

Indirect economic loss: a decline in economic value added as a consequence of direct economic loss and/or human and environmental impacts. Indirect economic loss includes microeconomic impacts (e.g., revenue declines owing to business interruption), meso-economic impacts (e.g., revenue declines owing to impacts on natural assets, interruptions to supply chains or temporary unemployment) and macroeconomic impacts (e.g., price increases, increases in government debt, negative impact on stock market prices and decline in GDP). Indirect losses can occur inside or outside of the hazard area and often have a time lag. As a result they may be intangible or difficult to measure.

Hazard, exposure, vulnerabilities and capacities are dynamic and constantly changing as a result of changes, for instance, in land use and land cover, rapidly growing urbanization, construction practice and regulations and technological innovations. Other processes further impact the dynamics of hazard, exposure, vulnerability, capacity and their interactions, including underlying root causes such as climate change, population growth or changing demographic structures, and changing levels of inequality gaps and poverty. Therefore, understanding (through NDRA) and addressing (through disaster risk management) the root causes of all dimensions of risk is an essential consideration.

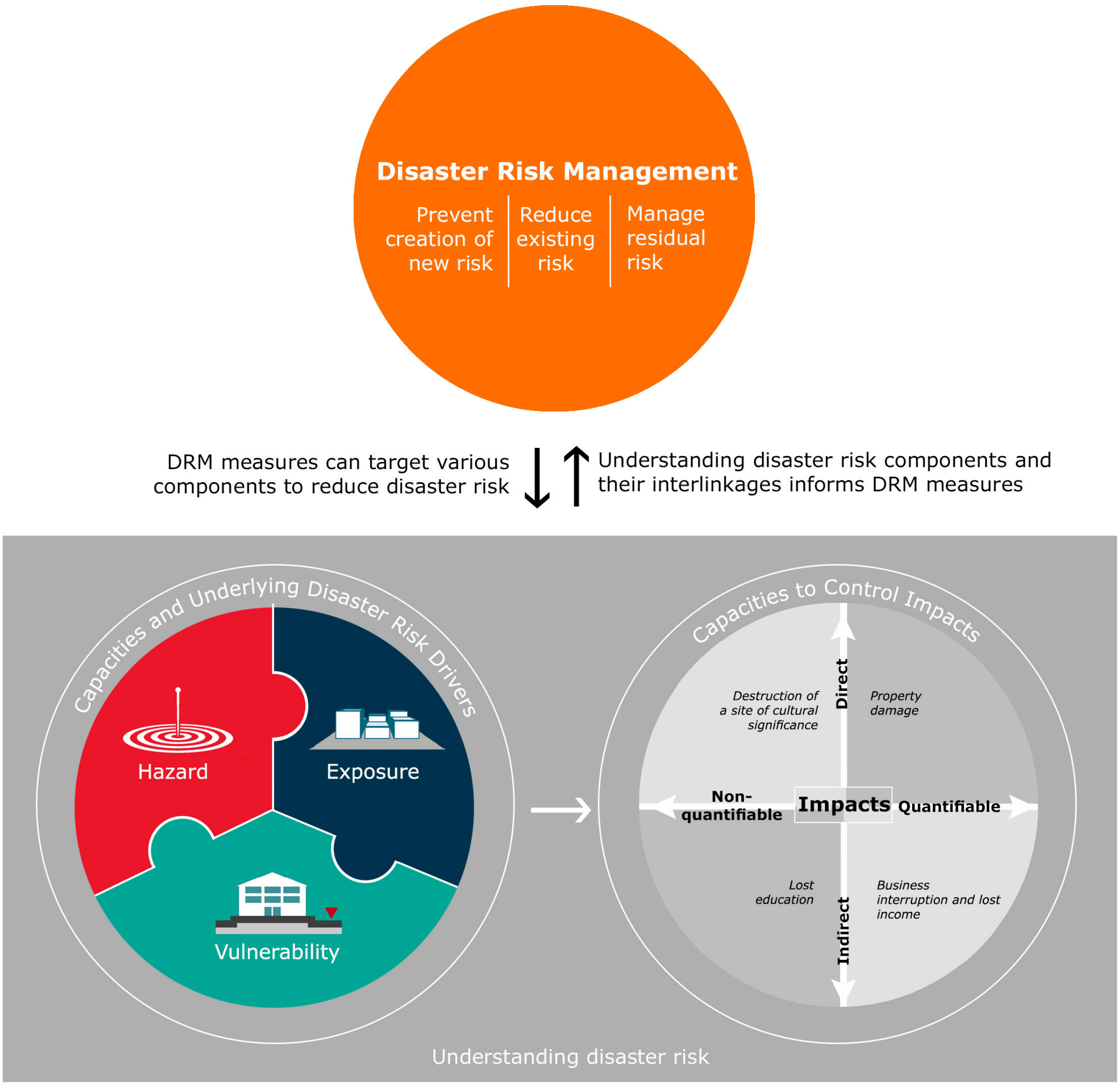


Figure 5 - Holistic understanding of disaster risk empowers effective and comprehensive disaster risk management

Box 2. Severity of disaster impact depends on exposure, vulnerability and coping capacity

In October 2016, hurricane Matthew caused severe devastation across the eastern Caribbean and south-eastern US claiming hundreds of lives. The level of impact varied significantly among different countries that were in the path of Matthew. This variation was due to intensity and path of the storm, area of landfall as well as the level of exposure, vulnerabilities, and coping capacity specially the capacity to evacuate people. In Cuba, more than 1million people were forced to evacuate before the storm arrives and there was no casualty. However, in Haiti where the hurricane had similar intensity, 175,500 people evacuated and around 550 people were killed. Six months later hundreds of thousands of displaced people were still living in shelters. In order to fully understand the potential impact from Hurricanes in these countries, the assessment should include socio-economic vulnerabilities, administrative and financial capacities, and longer term indirect impact of population displacement and infrastructure damage among other components of disaster risk.

Source: ON THE GRID: Global internal displacement in 2016
http://www.internal-displacement.org/global-report/grid2017/pdfs/2017-GRID-hurricane-matthew-spotlight.pdf

Process of national disaster risk assessment

The risk assessment process flow outlined in the international standards on risk management (ISO 31000:2009) and on risk assessment (31010:2009) is the most commonly used[12]. It starts with setting the context and then consists of three steps: risk identification, risk analysis and risk evaluation. This process flow is the basis for most European assessments and for the Australian national risk assessment guidelines and some others. Below is a description of each component of the process, cross-referencing the elements in the Guidelines that cover that step.

Establishing context: This step is concerned with understanding the risk management context in order to define the purpose and scope of the risk assessment. It includes engaging and consulting with stakeholders and defining criteria for decisions.
In the *Guidelines*, establishing context starts in element 1 and is then completed with policy and technical scoping in element 2.

Risk identification: From a national disaster risk assessment perspective, this step is concerned with a very high-level scoping of hazard, exposure and vulnerabilities to define the direction for the rest of the assessment process. It uses the knowledge and experience of stakeholders, data on past disasters and risk information to draw initial conclusions about the importance of a specific hazard, assets, known vulnerabilities and major impacts of concern for an NDRA. Consideration should be given to both extensive (frequent, low-impact) and intensive (occasional, high-impact) events, as well as potential

[12] Updated version of ISO 31000 and 310310 due for release in 2019.

cascading events and simultaneous events linked to the same cause (e.g. El Niño and La Niña).

In the *Guidelines*, disaster risk identification starts in element 2 and is then completed with more technical depth in element 6.

Risk analysis: This step is concerned with obtaining a more detailed understanding of the disaster risk: detailed hazard analysis, exposure analysis, vulnerability analysis and capacity analysis. The analysis provides insight into the interaction of a single hazard or a multi-hazard with the exposure and all dimensions of vulnerabilities (physical, environmental, social, economic and cultural). Each point of interaction of disaster risk components creates a unique coupling: a specific impact and its likelihood.

Another component of risk analysis is understanding and evaluating the effectiveness of the existing capacities (or the controls and measures in place for managing the risk, as this is called in ISO:31010). Understanding the effectiveness of capacities is critical for identifying targeted measures to manage the risk.

Risk analysis also includes assessing the confidence level or the level of uncertainty. This is relevant for both single-hazard and multi-hazard disaster risk analysis, with any time-horizon. Risk analysis is covered in elements 6 and 7.

Risk evaluation: This step allows for risk prioritization for the purpose of managing the risk. The multi-hazard disaster risks analysed for likelihood and impact could be presented in different ways to facilitate the visualization and prioritization process. The risk prioritization is further adjusted based on an understanding of capacities, risk perception[13] and risk acceptance of the whole of a country's society, and by the availability and level of resources to manage the risks. This requires input from those owning the risk and who are responsible for disaster risk management.

The whole of society is represented through stakeholder coordination and communication mechanisms to define the priority disaster risks. Only then is there a legitimate basis for disaster risk prioritization – defining the risks of high societal importance that require immediate attention, the risks that could be tolerated or neglected, and the risks that need to be closely monitored. Risk evaluation is covered in elements 8 and 9.

[13] Instead of considering risk perception and acceptance as part of the risk evaluation, another option is to perform an additional "societal risk assessment" to analyse societal risk considerations, as suggested by the International Risk Governance Council.

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

Table 1 - Mapping of ISO steps to the elements in the *Guidelines*

Chapter 2. Implementing a national disaster risk assessment

This chapter describes in detail each of the three stages of the assessment: preparing and scoping, conducting risk analysis and using the results for decisions in disaster risk management and sustainable development. Stage I covers the first five elements, stage II covers the next two and stage III the final two.

The elements reflect the logic of each stage, but many are interlinked. All the elements should be read in order to obtain a complete picture and better understand how they can enable a country to implement an effective NDRA process for producing information for use in disaster risk management.

Stage I Preparing and scoping

This stage considers what needs to be done before embarking on an NDRA process, ensuring that outputs are fit for purpose. It explains the importance of identifying the key stakeholders and shaping viable governance mechanisms for NDRA, including roles and responsibilities, defining the thematic scope of the assessment, agreeing on a data management plan, and assessing the technical capacities necessary for successful implementation of the NDRA and, if necessary, developing those capacities. The final product of this preparatory stage is the terms of reference to initiate the assessment process. The elements below detail each of these components.

Element 1 - Establishing a governance mechanism

This element describes the rationale, objectives, structure and considerations for modalities of operation of an NDRA governance mechanism.

Why a governance mechanism is needed?

The rationale for establishing a governance mechanism is based on the following:

a) An effective NDRA requires consultations, engagement and contributions from a wide range of stakeholders: governmental bodies including line ministries; civil defence; the private sector; civil society; the scientific community and the general public.
Many of these groups are owners of risk and in positions to manage that risk. As each has a different and often conflicting understanding of disaster risk, they communicate disaster risk information differently, have different institutional and legal requirements, and different

levels of financial resources to engage with a national disaster risk assessment.

b) A successful NDRA requires a system of institutions, operational modalities, policies and a legal framework to guide, manage, coordinate and oversee implementation. The principles of good governance – inclusiveness, transparency, accountability, efficiency and responsiveness – guide the implementation process. This is of particular interest, as the outcomes of an NDRA might in some cases show levels of risk that are not politically palatable and would therefore need a transparent and accountable risk evaluation.[14]

To function effectively, the NDRA governance structure requires:

- Clarity and agreement on the division of the roles and responsibilities of each involved actor
- Political legitimacy or mandate
- Adequate resources.

Obtaining long-term political commitment for a national disaster risk assessment is of great importance, because the assessment informs strategic decisions on risk management that require long-term political and financial commitment for their implementation. Besides, the assessment itself is an iterative process that can stretch across a political term of office and requires long-term sustainability.

Such a governance mechanism is defined based on the high-level objective of NDRA. For example, an assessment that is only supposed to provide inputs for national emergency preparedness and planning may have a different lead agency from an assessment that is meant to provide hazard and risk information for a comprehensive disaster risk reduction strategy, sustainable development planning or climate change adaptation.

Governance structure

While the context of NDRA governance is directly guided by the high-level objective of the assessment, and it can differ from country to country, there is also an emerging overall pattern of NDRA governance mechanisms defining roles and responsibilities of various entities:

- **Lead agency:** The lead agency, which coordinates and oversees the whole process and acts as the secretariat for the national disaster risk assessment, could be any of the following:
    - National civil protection agency/national disaster risk reduction agency

[14] For example, high-risk levels that could trigger concerns of scaring off investment, or low-risk levels that could limit chances of donor investment in disaster risk management projects.

    - Environmental protection agency
    - Ministry of Internal Affairs
    - Ministry of Planning and Development
    - Agency with a broad mandate related to disaster risk management
    - Office of the Prime Minister.

- **Multi-stakeholder coordination body:** Implementation of the national disaster risk assessment is carried out by a specially established coordination body that includes a variety of stakeholders (as the risk owners) and other actors who will use the outputs of the assessment for their disaster risk management measures. It is essential to include in this body stakeholders from the public and the private sector, from entities working on development planning and climate change adaptation, from civil society and the media, from national and sub-national levels, and general public representatives. If possible, it is best to give governance of the assessment to an existing intergovernmental coordination structure. This reduces the overheads and ensures long-term sustainability. The existing mechanism should be enhanced with the right technical entities and if needed other relevant stakeholders to ensure coverage of the full scope of the national disaster risk assessment.
  A variety of mechanisms and tools could be used for consultations, communication and collaboration depending on the objective. These could include in-person multi-stakeholder meetings and workshops, questionnaires, online collaboration platforms, social media and geospatial data platforms.

- **Technical committee:** A multisectoral technical committee provides scientific advice throughout the process, secures sufficient contributions from experts, and ensures an adequate level of scientific quality of the risk assessment. This committee has to ensure cooperation on the interface between science and policy. It should consist of a group of recognized experts with diverse backgrounds who understand both the technical and the policy implications of national risk assessments and how they are used in disaster risk management.
  Importantly, the technical committee should be of such a size and structure to allow access to a wide network of experts to quickly mobilize the expertise and advice required on specific technical matters. It may be necessary to set up additional thematic subcommittees on themes related to hazards, exposure, susceptibility, capacity, or cross-cutting themes. The technical committee might also decide to create subcommittees focusing on specific hazards. In the absence of the necessary expertise – for example, for conducting probabilistic risk modelling – a country should mobilize the capacities of the international scientific community.

Box 3 - Expert Advisory Council role in Georgia

In Georgia the involvement of science is enshrined in legislation. According to the Law on Public Safety, 'within the scope of the emergency risk reduction strategy, a national public consultative body — the Expert Advisory Council — is established under the Emergency Management Agency'. The Council consists of approximately 120 members, mostly scientists/experts from different organisations, academic institutions, official authorities and NGOs. The main task of the Council is to draw up analyses and recommendations for preventive measures which should be implemented by public authorities to mitigate emergencies.

Source: EU Peer Review Georgia, Risk Assessment and Early-Warning, 2015
http://ec.europa.eu/echo/sites/echo-site/files/georgia_peer_review_report_-_en.pdf

Whatever governance model is chosen, it should be suitable for implementing every step of the assessment from beginning to end, including:

- Identifying and engaging stakeholders
- Budgeting
- Undertaking quality control
- Holding multi-stakeholder consultations
- Defining needed capacities
- Defining the methodology
- Identifying data management requirements
- Overseeing delivery of outputs.

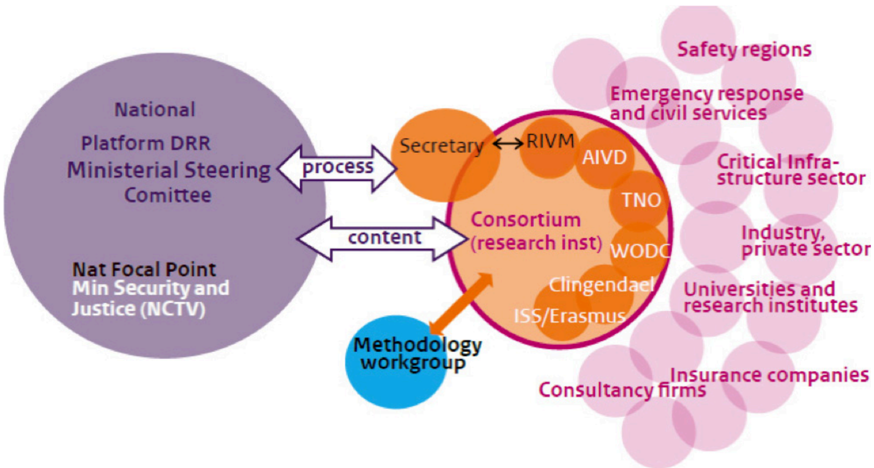


Figure 6 - Organizational structure of Netherlands national risk assessment.
Source: Words into Action Guidelines on National and Local Platforms (Consultative version), 2017.

Legal framework

The viability of a governance mechanism depends largely on the political endorsement of the national disaster risk assessment. Ideally, such political endorsement could be further formalized by a regulatory act prescribing the roles and responsibilities of the various institutions and the decision process concerning the outputs of the assessment.

Box 4 - South Africa's Act for disaster risk management makes risk assessment a requirement

Disaster Management Act, 2002 (Act No. 57 of 2002) of South Africa requires priority setting with respect to likely disasters affecting South Africa and emphasises the importance of disaster risk assessment to guide disaster risk reduction efforts including disaster risk management planning at national, provincial and municipal level.

Disaster risk assessment is the focus of Key Performance Area 2 (KPA2) in South Africa disaster risk management framework (2005) with the objective to "Establish a uniform approach to assessing and monitoring disaster risks that will inform disaster risk management planning and disaster risk reduction undertaken by organs of state and other role players."

Source: SA Disaster Risk Management Framework, 2005
https://www.westerncape.gov.za/text/2013/July/sa-national-disaster-man-framework-2005.pdf

Process agreements

For the effective functioning of the governance mechanism, some administrative or process-related agreements must be made and respected throughout the whole process, which in some cases may already be enshrined in legal bases or operational procedures:

- Roles and responsibilities of each partner.
- Budget and duration of the assessment.
- Conditions for including or excluding specific risks.
- Conditions for the risk-related data communication (including the assigning of confidentiality levels, if needed) during the assessment among its partners (internally) and among a larger group of stakeholders (externally).
- Agency responsibilities for holding and maintaining background data and results after the completion of the process and for the next rounds of the assessment, including privacy and security settings.
- The package of deliverables (e.g. geospatial platforms and maps, policy briefs, scientific research reports).
- Accountability of risk owners upon receiving the results.

Box 5- Stakeholders to be invited into the governance structure

The following is a non-exhaustive list of national entities (or equivalents) that should be considered for involvement in the process:

- Office of the Prime Minister (or similar level)
- National disaster risk management agency/ministry
- Ministry of Interior
- Ministry of Finance
- Ministry of Development and planning
- Ministry of Environment
- Ministry of Education
- Ministry of Health
- Ministry of Infrastructure and Public Utilities
- Ministry of Defence
- Ministry of Agriculture
- Emergency services – civil protection, fire and rescue, medical assistance, law enforcement
- National statistics office
- Public and private entities managing major lifelines such as telecommunication, water and sanitation, energy, transportation
- Representatives of local authorities
- National entity leading climate change adaptation efforts
- National entities leading scientific and data collection work related to various hazards: e.g. national hydro-meteorological agency, national geological agency
- Universities, think tanks and technical institutions from relevant fields (e.g. scientific departments relevant to various hazards, structural and civil engineering, social sciences, economics, geospatial data)
- National census department
- Civil society representatives, including representatives of women, children and other vulnerable groups
- Chamber of commerce (representing the private sector)
- Insurance sector.

The role of each stakeholder should be clear from the beginning so as to customize the communications and interactions accordingly. Depending on the roles, the stakeholders may be informed, consulted or solicited for data or technical advice, or fully involved to support implementation at different stages of the assessment.

Element 2 - Defining the policy scope and technical scope of NDRA

The objective of this element, scoping of NDRA, is to ensure NDRA is designed and implemented to be "fit for purpose".

Before conducting a national disaster risk assessment, it is important to conduct a feasibility study. The study should define the policy scope, the technical scope and the boundaries set by the technical, financial and political resources available for the assessment. The scope of the assessment will depend on the complexity and scale of a country and its risks.

The "policy scoping" is based on national disaster risk management policy objectives for preventing the creation of new risk, reducing existing risk, managing residual risk and developing resilience. Policy scoping may start with a political discussion at the higher level of government, such as a council of ministers, and then be continued by consultation with the stakeholders represented in the governance mechanism.

The "technical scoping" translates the policy scope into elements of disaster risk assessment (hazard, exposure, vulnerability and capacity), as well as the time-horizon for considering risk levels and the time cycle for updating the assessment.

The main mechanism for defining the scope is consultation with the stakeholders and users. The best modalities for this element are facilitated workshops for the technical committee and scientific stakeholders. Limitations posed by technical and financial resources would be considered in finalizing the scope.

The national disaster risk assessment is an iterative process whereby every element is built on the previous one, based on the results and decisions made, but may also demand updates or expansion of the previous element. Iterative scoping may lead to adjustments to the governance mechanism to ensure that the appropriate stakeholders are consulted and engaged within each element.[15]

Using existing risk information

Both policy and technical scoping benefit from existing loss and risk information:

- **Information on past losses:** Existing information on past disaster losses can provide valuable insights to guide the discussions in defining the scope. It should, however, be handled with care as it cannot predict the future. Records of historical disaster losses are known in most countries as a National Disaster Loss Database. These are especially helpful for understanding cumulative losses from high-frequency and low-intensity

15 Together, the policy scoping and technical scoping are similar to the step of "pre-assessment" of the IRGC Risk Governance Framework.

events, but do not provide information on low-frequency high-intensity events and extreme events.

- **Disaster risk information:** In every country, some level of information is already available on hazard and disaster risk. This might be extracted from lessons learnt, past risk assessment efforts, or regional or international efforts related to risk profiling. It is recommended that the lead agency should be accountable for the collation of all the available risk information and its use for discussions on scoping, in collaboration with the various data holders (also on the science/policy interface). Examples of existing risk information from international sources can be found in box 6.

Box 6 - Examples of existing hazard, risk, and historical loss information from global sources

Index for Risk Management (INFORM) tool (EU) - INFORM combines 50 different indicators related to the conditions that lead to crises and disasters. INFORM includes data on the area's human and natural hazard risks, the vulnerability of the communities faced with hazards, and the coping capacity of local infrastructure and institutions. http://www.inform-index.org/

Global Assessment Report (GAR) Atlas Risk Data Platform (UNISDR) - Online tool which shares spatial data information on global risk from natural hazards. It covers tropical cyclones and storm surges, earthquakes, riverine floods, and tsunamis. http://risk.preventionweb.net/capraviewer/main.jsp?tab=0

Think Hazard (GFDRR) - An online tool created by GFDRR to enable non-experts to consider natural hazard information in project design. Users can assess the level of river flood, earthquake, drought, cyclone, coastal flood, tsunami, volcano, and landslide hazard. http://thinkhazard.org/

EMDAT (CRED) - Online database that contains essential core data on the occurrence and effects of over 22,000 mass disasters in the world from 1900 to the present day. The database is compiled from various sources, including UN agencies, non-governmental organisations, insurance companies, research institutes and press agencies. http://www.emdat.be/

Global Assessment Report (GAR) disaster loss database (UNISDR) - Online database of detailed disaster loss database for 94 countries. These databases are developed at national level. http://www.desinventar.net/index_www.html

The Energy-related Severe Accident Database (ENSAD) managed by the Paul Scherrer Institute. https://www.psi.ch/ta/risk-assessment

Policy scoping

The following topics should be discussed in the n the policy scoping:

- **Societal functions/values, sustainable development and disaster risk reduction priorities:** What does a country want to protect against disaster risk? What are the "values to protect"? The Sendai Framework describes the main objectives as "reducing risk and losses in lives, livelihoods and health in economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries".[16] Individual countries may have specific priorities for disaster risk reduction – for example, protecting long-term economic growth or the safety and livelihoods of a low-income population. Defining risk reduction priorities gives direction to the selection and design of risk management measures[17].

Box 7- Sendai Framework global targets and indicators[18]

The Sendai Framework global targets and the set of indicators that were agreed upon by all countries in 2016 through an open-ended intergovernmental expert working group (OIEWG) can be used to guide the discussion on risk reduction priorities. The targets and indicators cover a wide range of impacts, such as:

- Number of people injured or illness attributed to disaster
- Number of people whose dwellings were damaged or destroyed
- Number of people displaced
- Direct loss of economic, agricultural and other productive assets, housing sector, or cultural heritage
- Disruption to critical infrastructure or basic services, health services, etc.

- **Disaster risk management measures**: The intended use of the outputs of the assessment should be clarified to the extent possible at an early stage as they have important implications for the technical scope. Consultation sessions with stakeholders from different policy fields are an important mechanism to elicit a range of potential management measures that draw on the outputs of the assessment. Regulations, initiatives and programmes relating to disaster risk reduction and disaster risk

16 UNISDR, 2015. Sendai Framework for Disaster Risk Reduction 2015 - 2030, The United Nations Office for Disaster Risk Reduction, Geneva, Switzerland.

17 J. Birkmann, et al., 2013. Framing Vulnerability, risk and societal responses: the MOVE framework

18 United Nations General Assembly, 2016. Report of the Open-Ended Intergovernmental Expert Working Group on Indicators and Terminology Relating to Disaster Risk Reduction, United Nations General Assembly, Geneva, Switzerland.

management should also be considered to see how those (or similar ones in the future) could be risk-informed by the assessment. Some questions are listed below as examples of the range of issues to be considered in relation to the national disaster risk assessment:

  - What kind of policy decisions will it inform, and how?
  - Will it serve the national disaster risk reduction strategy?
  - Will it serve climate change adaptation planning?
  - Will it serve national development planning?
  - Will it serve national business, sectoral or community resilience planning?
  - Is it focused on emergency preparedness and on saving lives, or will it serve holistic risk management planning to inform prevention, preparedness, response and recovery planning and practice?
  - Will it inform high-level disaster risk management investment planning or decisions on investing in risk reduction of key infrastructure? If so, which infrastructure for which hazards should it cover? And should it identify the most vulnerable infrastructure or just the most vulnerable sector as the basis for further assessment?
  - Will it form the basis for disaster risk financing and insurance?
  - Will it provide the basis for updating building codes?
  - Will it serve as the basis for financial support to subnational governments to invest in disaster risk reduction?
  - Will it provide insights on vulnerability of most common construction types?
  - Will it provide risk data disaggregated for low-income and vulnerable groups including women and children?

- **National versus nationwide:** Does the "N" in NDRA mean that the assessment has to inform disaster risk management decisions for the whole country, or is it limited to risks that are "of national importance (i.e. that the actual event would require national coordination)? If the latter is the case, the governance structure should delegate the separate assessment of non-national risks to the appropriate government level and sectors.

- **Current NDRA status:** The scope of the assessment might vary according to the status of existing national, subnational and sectoral risk assessments, as well as the current status and potential of a country's science/policy interface. If nothing exists, neither sectoral nor subnational risk assessments, the scope of a "first run of NDRA" might be limited to the main hazards that are most obvious from the experience of the stakeholders or from international information like the index for risk management (INFORM) or global/regional risk profiling conducted by international agencies. Alternatively, if sectoral assessments have already been completed, the scope should be as broad as possible and include existing work (where practical, and as long as it fits the NDRA objectives).

- **National versus local and sectoral disaster risk assessment**: An NDRA targets risks of national significance. This will also include disaster risks that only manifest themselves at provincial or community level, or in specific sectors. There is significant evidence of good practices across the globe of successful community-based disaster risk assessments. Careful balancing of bottom-up with top-down approaches in disaster risk assessment and establishing stronger linkages between the national assessment and local-level, community-level and sectoral disaster risk assessment practices could enrich both processes.[19]

Box 8- Fragmentary reports in Poland

In Poland ministries, national agencies and provinces are by law obliged to contribute to NDRA. Each sector and each province has to develop a so-called 'fragmentary report', according to the same national risk assessment methodology. In turn, the provinces ask for input from the municipalities. The national coordinating entity (the Government Centre for Security) gives feedback on all fragmentary reports, identifies gaps and connections and combines them into one overall 'Report on Threats to National Security' for the Council of Ministers. This kind of mechanism ensures that all sectors are involved in the NDRA process. The two-way risk-assessment process, from local, to provincial, to NDRA (and the feedback loop from national to provincial level) builds a strong decentralized information basis for NDRA, as well as a basis for the coordination of prevention strategies.

Source: EU Peer Review Poland, Risk Management Capacities, 2016http://ec.europa.eu/echo/sites/echo-site/files/poland_peer_review_report_-_en.pdf

A national risk assessment can provide a wealth of data and information for subnational and sectoral use. Examples include:

- Use in advocacy and awareness at the local/sectoral level
- Use for scoping step local/sectoral risk assessments
- Using hazard, exposure, vulnerability and capacity datasets as a starting point for developing higher resolution/local risk assessments
- Access to national and international technical experts
- Standardization of subnational and sectoral disaster risk information to enable local and cross-sectoral interconnections.

19 This depends on the governance system of a country. In some countries the responsibilities for disaster risk management (even for national disaster risks) are strongly decentralized, while in other countries the subnational level has no mandate whatsoever regarding national disaster risks. Furthermore, the level of autonomy of self-governing subnational bodies (e.g. federal States) can set limitations for a top-down approach to NDRA.

At the same time, representatives at the local and sectoral level can contribute with datasets that are available only to them (e.g. data on assets that are critical at local level). Arguably, NDRA could be a macro-level aggregation of subnational and sectoral risk assessments, so long as the interoperability of the methodologies is ensured. However, this will not always be reachable or optimal. In some countries, the governance mechanism and local/sectoral capacities may not be sufficient to guarantee coherence.

Depending on the size of the country, the nature of hazards and the national versus local disaster risk management governance mechanism, national guidelines for conducting risk assessment may be useful. These would help ensure that all risk assessments conducted at local and sectoral level adhere to a certain level of standards and benefit from common methodologies and relevant datasets.

- **National versus supranational disaster risk assessments**: Risks do not stop at administrative borders. For some risks it might be useful to carry out a cross-border[20] or supranational risk assessment in cooperation with other countries and international organizations (which might already have been done in the past). This is relevant for shared hazards (e.g. river basins) and hazards with potential cross-border impacts (e.g. industry and nuclear plants), as well as for potential cross-border cascading effects and interdependent assets (e.g. critical infrastructure).[21]
  Supranational disaster risk assessments will have a specific scope and specific objectives of their own; risk-informing, for example, cross-border disaster risk reduction strategies, critical infrastructure protection and international emergency response and humanitarian aid.

- **Time-horizon of NDRA:** It is important to define the time-horizon to be considered in the risk analysis, based on the understanding of the implications this has for the assessment of impact and likelihood. The selection of a time-horizon depends on the type of decisions that rely on the NDRA outputs. For example, disaster preparedness and emergency management often address a time-horizon of three to five years, which gives sufficient confidence for the disaster risks identified. An NDRA process that informs national development planning may use longer time-horizons, especially in the context of understanding longer-term risk trends from climate change, urbanization, sustainable development or changes in disaster risk reduction policies. A longer time-horizon is especially critical when it comes to evaluating the benefits of investment in new development and in reducing vulnerability of infrastructure.

---

20 This could be land borders or shared seas.

21 Taking into account, for example, the UNECE Convention on the Transboundary Effects of Industrial Accidents (unece.org/env/teia.html) and the Convention on the Protection and Use of Transboundary Watercourses and International Lakes (unece.org/env/water).

Scoring criteria for impact and likelihood

The scoping stage should define the criteria for scoring impact and likelihood. The choice of criteria is largely a political decision and should be part of the shareholder discussions. Scoring criteria include the following:

- **Impact criteria:** While the complexity of impact assessment varies significantly across countries, along with the risk assessment methodologies, a consensus on impact criteria should be reached as a part of the scoping process. Impact criteria should be defined across different types of impact critical for the country. In the current practices of national risk assessment, the impact criteria are based on a broader understanding of the main "values to protect", sometimes referred to as "vital or critical societal interests".

  The following types of impacts may be considered:

  - Human impact: Number of people affected – including deaths, severely injured or illness, displaced due to loss of home or livelihoods.
  - Economic impact: Includes damage and loss assessment in financial terms – the costs of the damage, the costs of the reparation and restoration, the costs of emergency measures, the costs of long-term recovery (costs of disruption of economic activities, unemployment, indirect social costs such as those for the restoration of education and health systems).
  - Environmental impact: Includes the loss of and structural damage to nature conservation areas, ecosystems and protected species, as well as general environmental pollution. The costs of environmental recovery are in most cases seen as part of the economic impact.
  - Political and social impact: Includes political implications of a disaster, social psychological impact, disruption of daily life, and violation of peace and rule of law. It could also include impact on development gains, (in)equality and social cohesion, as a separate "value to protect".

  The impact-level categories would be decided by the stakeholders and would vary from one country to another. Categories are defined for every type of impact and may be in different formats. For example, economic loss levels may be defined as an absolute financial loss or as a percentage of gross domestic product.

  The selection of labels associated with each category can become a sensitive issue, as this would be linked to the risk tolerance of a government and society. For example, one country might define as "insignificant" a human impact as being no more than 10 fatalities, more than 50 injured, and no need for evacuation; whereas another might define it as no fatalities or injured and no one or just a small number of people evacuated for a short period of time.

The following labels are commonly used for impact categories, although quantitative values should be assigned to each label and communicated to stakeholders:

1. Insignificant
2. minor/substantial
3. moderate/serious
4. significant/very serious
5. catastrophic/disastrous.

- **Likelihood criteria:** The selection of probability categories and their definition would also depend on the stakeholders and may have some different gradation in different countries. For example, one country may define the probability of >1 in 20,000 years as "very unlikely", whereas another might apply that label to the probability of one event in 100 years or less.
  It is recommended to use quantitative likelihood categories wherever possible and avoid emotive terms or terms that could be misunderstood by others. It is also recommended to select a likelihood scale that can effectively cover the analysis outcomes of intensive and extensive disaster risks.

Technical scoping

The technical scoping of NDRA goes hand in hand with the policy scoping. It considers available information on hazard, exposure, vulnerability and capacity in order to determine the relevant risk elements.

Identifying and scoping hazard allows the NDRA to narrow the focus from the full range of hazards faced by a country to those that present the greatest risk to its safety, security and development. Scoping hazard includes deciding whether NDRA should be focused on a limited number of significant risks or on multi-hazards. Understanding which hazards NDRA is to be focused on requires careful consideration of the following:

- Existing hazard data (e.g. historical loss data)
- Regional and global trends (e.g. impact of changing climate)
- Economic activities that can trigger natural hazards (e.g. in extractive industries or un-managed land use)
- Technical resources available for conducting risk analysis (e.g. input hazard data and expertise for modelling complex interdependencies of hazards)
- Financial resources available for conducting risk analysis.

It is particularly important to consider the balance between analysing intensive risks and extensive risks, and especially in relation to their respective potential impacts on sustainable development.

Potential hazards include the whole spectrum of hazards across the following hazard categories:

- Geophysical (earthquake, tsunami, volcanic eruption)
- Meteorological/hydrological (flood, storm surge, cyclone, hurricane, hail, heat wave)
- Climatological (drought, wildfires, frost)
- Biological (human epidemics, livestock pests and diseases, crop pests and diseases)
- Technological and human-generated hazards (increasing attention is being given to emerging risks from technological developments and the dependency of society on technology).

Identifying and scoping exposure provides an initial understanding of what should be the focus of NDRA to match both the policy and the hazard scope. This may include various assets in the social, physical, economic, environmental and agricultural categories. NDRA should be responsive to the protection of those sectors that have priority importance for sustaining a country's communities and ongoing development or those that are most susceptible to hazards. NDRA may be focused on impacts that threaten the whole country or significant areas within the national territory: major cities, major river basins, regions in proximity of volcanoes, coastal zones, nationally protected areas, public structures, cultural heritage, or critical infrastructure (including cyber).

Identifying and scoping vulnerabilities provides knowledge of the various types of vulnerabilities and interlinkages that should be considered in the assessment to match the policy scope. Categories of vulnerabilities include physical, economic, social, institutional, environmental, agricultural and health.

Identifying and scoping capacities provides an initial common understanding of the indicators that would be used for assessing capacities to manage the risk of disasters or coping capacity as defined by the Open-ended Intergovernmental Expert Working Group. Flaws in capacity, such as weak capacity in enforcing building codes, are among underlying drivers of risk. The scope of capacity should be assessed at an early stage and in consultation with the stakeholders, because of the wide range of views on the definition of capacity, the issues that can be considered, and the role of stakeholders in collecting the data for assessing capacity.

Some guidelines and methods are available, as well as many different sets of sectoral capacity (or resilience capacity) indicators, such as the following:

- European Commission *Risk Management Capability Assessment Guidelines*[22]
- INFORM indicators
- CADRI (Capacity for Disaster Reduction Initiative) methodologies
- Health-sector indicators for implementing the International Health Regulations.[23]

However, there is variability across sectors in the availability of me50 thodologies with a comprehensive list of indicators for disaster-coping capacity.

22 European Commission, 2015. Risk Management Capability Assessment Guidelines, Official Journal of the European Union, retrieved from site: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52015XC0808%2801%29

23 http://www.who.int/ihr/about/en/

Element 3 - Developing an NDRA data management plan

This element describes the rationale for having a data management plan for NDRA and what are the critical issues to be considered and covered in this plan.

Risk assessment is an extremely data-intensive process and conducting a national risk assessment may involve accessing information from a wide range of stakeholders including mapping agencies, scientific and technical ministries, universities and other research institutions, and the private sector. In addition, valuable new data and analyses are created during risk assessments. It is therefore necessary to develop a strategy to efficiently organize and manage the data as they become available, as well as distributing the results to participants and key stakeholders. A "gap analysis" (i.e. necessary data vs. available data) can be the starting point of such a strategy.

Data management plans govern the process by which data are gathered from participating entities, the technical and quality standards (including data resolution) to which new data will be produced, how data will be maintained during the risk assessment, and the means by which the output data will be shared and secured.

Data availability, accessibility and security are always major challenges in conducting risk identification and can have a significant impact on the credibility of the results. The quality of the results is directly related to the quality of the input data. Given the effort spent in collecting, preparing and maintaining all the necessary types of data, the return on investment can be maximized if the created datasets are shared and used many times.

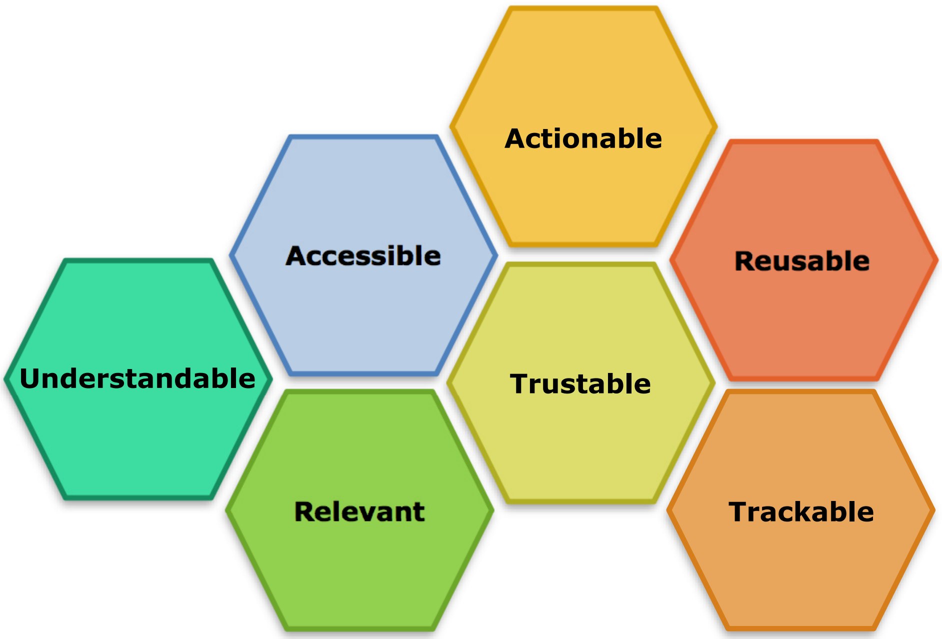


Figure 7 - Important qualifications of input and output datasets. These characteristics have technical, social, political, and financial implications for a risk assessment.

At the beginning of the scoping and the risk identification process, arranging for commitments from data owners and designing mechanisms to facilitate data-sharing both technically and administratively can maximize the quality of the risk identification. To this end the scoping stage of the assessment has to result in a data quality protocol, taking into account the required resolution of data to complete the NDRA in accordance with its set objectives and scope.

Open data and software standards and licensing options are now widely available for use by data providers and analysis software developers. These should be adopted where possible to ensure that information is developed, applied and maintained for multiple use and knowledge-sharing while still maintaining intellectual property interests and sufficient security for confidential information.

The following are some of the main recommendations for managing data and developing data management strategies:

- Assign a clear coordination role in data management to the lead agency, including provisions for central data storage and the mandate to define data standards.
- Incorporate stakeholders, both as potential contributors and users of risk assessment data, early in the planning process. Provide stakeholders with an understanding of the importance and value of their data for quality risk assessment. Give them an opportunity to make substantive contributions to the data management plan.
- Agree upon the data quality and resolution (based on the NDRA scope), licensing, metadata standards, acceptable formats and other protocols as early as possible.
- Whenever possible, release data under open licences that encourage wide use for many purposes.
- Develop a common repository for data during the risk assessment to facilitate sharing of the results and outputs when the assessment is completed.
- Document the data-sharing plan in a memorandum of understanding or other formal agreement that clarifies the expectations and responsibilities of participating stakeholders, including a non-disclosure agreement for restricted data.

Data availability for NDRA is best ensured by means of a legal basis that consolidates the key provisions of the data management strategy, such as obligatory data-sharing, transparent data ownership, lead agency coordination, data storage and restricted access to confidential data.

For further explanation of these concepts, see Module 9. Data Management throughout the National Risk Assessment Process Plan, in part two of the Guidelines.

Box 9 - More about open data policy for disaster risk assessment

To serve decision makers across a society, data need to be fully open, both legally and technically. By definition, a piece of data or content is open "if anyone is free to use, reuse, and redistribute it — subject only, at most, to the requirement to attribute and/or share-alike" (Open Knowledge Foundation Network).

This means that data must be:

1. Technically open: Many government datasets are locked in data formats that can only be read by proprietary software (and sometimes hardware, like obsolete magnetic tape backup drives). The data must be released in ways that allow any device or software to read them.
2. Legally open: The licence under which the data are released must permit redistribution and reuse.
3. Accessible: The data must be available at a public internet address (URL).
4. Interoperable: The data must follow open standards.
5. Reusable: The data can be redistributed and reused in ways that were not necessarily anticipated by the curator of the original data.

Source: *Open Data for Resilience Initiative: Field Guide, GFDRR, 2014*

Element 4 - Developing NDRA required capacities

This element describes the type of capacities that are required for implementing NDRA.

The NDRA process requires strong administrative, technical and financial capacities.[24] After the governance mechanisms are established and the scope of NDRA is defined, it is important to check whether the existing capacities are sufficient for the successful implementation of NDRA. If not, it is recommended that capacity improvement be part of the preparation stage.

Administrative capacities refer to the legal and institutional frameworks within the country and how inclusive they are for multi-stakeholder national disaster risk assessment. Characteristics that contribute to this include a clear division of roles and responsibilities across all stages of NDRA including communication, existence of required expertise or procedural possibilities of engaging external stakeholders in the NDRA process.

Financial capacities refer to the availability of funds for the completion of NDRA given the ambitions defined in its thematic scope.

Technical capacities refer to the type and level of technical expertise necessary for NDRA. The analysis of current technical capacities should

---

24 European Commission, 2015. Risk Management Capability Assessment Guidelines, Official Journal of the European Union, retrieved from site: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52015XC0808%2801%29.

include the current status of interaction, collaboration and communication between the scientific community and the policy process (science/policy interface).

The range of technical capacities that might be needed varies significantly according on the types of risk to be addressed, the level of detail/resolution expected, the complexity of multiple elements to be taken into consideration (both hazard-specific and non-hazard-specific) and the engagement of the different actors in the assessment process. Some important technical capacities could be highlighted to ensure their presence during the NDRA process:

- **Technical capacities within the scientific community** refer to the capacities required for the technical committee to ensure technical supervision, management, and facilitation of the NDRA process as well as the capacities of the technical teams conducting various forms of analysis. This encompasses a wide range of technical expertise that is necessary for understanding methodologies for hazard, exposure, vulnerability and capacity analyses and being able to conduct such analyses, whether they are qualitative, quantitative, or semi-quantitative. Some countries might need international technical support to address the capacity gaps in the short term.
- **Technical capacities within the non-scientific community** refer to the basic capacities of non-scientific experts (policy makers and decision makers) to better understand risk information in order to make informed decisions. The following provides some basic capacities for understanding risk information that will be beneficial before engaging in meaningful dialogue and discussion on national disaster risk assessment:
    - Understanding fundamental concepts of hazard and exposure, vulnerability, capacity, uncertainty and confidence level.
    - Understanding basic concepts of probability and return period of a hazard.
    - Understanding uncertainty and limitations of risk analysis methods
    - Importance of linking NDRA with comprehensive disaster risk management strategies and sustainable development

The comprehensive development of all disaster risk assessment capacities is often a long-term process that will be achieved through incremental improvements through each new round of NDRA. However, the critical capacities necessary for implementation the outcome of the assessment need to be addressed before the launch of the NDRA process.

Capacity	**Description**	**Level of effort (time)**	**Relevant entities**	**Suggested modalities for capacity development**
Technical capacities within the scientific community	To access available datasets and models, use modeling tools for further analysis and to prepare risk reports for decision makers.	High (few weeks to months)	Technical individuals or teams supporting decision makers or conducting relevant research	Hands-on trainings, courses on-line/in person or mixed to be run by qualified experts. This would allow recognition of individuals who gain a higher level of expertise who the decision makers can rely on their support in providing the risk information and explanations.
Technical capacities within the scientific community	To conduct quantitative hazard and risk analysis	Extensive (few years)	Technical teams that will conduct components of the NDRA that need fully quantitative assessment and modeling.	- University programs focused on different hazards and various aspects of risk modeling - Bilateral training-by-doing programs which are set up between two technical institutions in a developed and a developing country
Technical capacities among the DRR practioners / policy decision makers	To understand the results, the limitations, uncertainties, and use the results in planning and decision-making	Moderate (few days to weeks)	Decision makers in Disaster Risk Management	Technical trainings presented in person at workshops or online

Table 2 - Categories of technical capacities, amount of effort, and suggested methodologies for capacity development

Element 5 - Developing terms of reference for NDRA

This element describes the importance of developing a comprehensive terms of reference to manage the implementation and delivery of NDRA.

After the scope of the assessment has been determined, the terms of reference should be drawn up. These will guide the process and provide the basis for resource allocation. They should clearly indicate the timeline, milestones and deliverables, roles and responsibilities of various stakeholders, as well as the budget within which the process should be completed and results delivered. They need to be endorsed by the designated national authority/authorities and supported by adequate resource allocation.

A national disaster risk assessment is a project and must be managed as a project: i.e. with a project document, project management team, project board (part of the NDRA governance body), regular reporting and final evaluation. The evaluation is essential for identifying and documenting lessons learned so as to improve the next rounds of the assessment and future use of its results.

Ensuring sustainability of efforts should be a major consideration in the terms of reference. If the assessment is conducted with the assistance of international entities or the private sector, the terms of reference should include a requirement that knowledge for its updating and management is transferred to and built within national public authorities.

Stage II Conducting risk analysis

Risk analysis is performed by the technical team, based on the terms of reference developed at the end of the scoping and preparation stage. The process provides the tools for decision-making and engaging stakeholders in disaster risk management. It involves agreeing on a set of methodologies for analysing risk from various hazards and for merging the outputs into a common format for evaluating and comparing risks and communicating the results.

Element 6 - Utilizing various risk analysis methodologies

This element briefly describes various risk analysis methodologies, risk comparison techniques and considerations for selecting the most suitable methodologies.

Many different and complementary methods and tools are available for analysing risk. These range from qualitative – based on the subjective perceptions of experts – to semi-quantitative and quantitative methods, including probabilistic risk analysis, which is the most rigorous method.

The Sendai Framework encourages all-hazard disaster risk management. This requires an understanding of impact from multiple major hazards that a country faces, such as:

i) Single hazards

ii) Aggregation and comparison of risk from all hazards

iii) Sequential, simultaneous, cascading and interrelated effects of some hazards.

For single-hazard risk analysis, aggregation and comparison of risk analysis, a wide range of methodologies, approaches and tools are available, with varying levels of sophistication. For sequential, simultaneous and cascading risk analyses, however, fewer approaches and tools are available.

The selection of methodologies depends on what kind of decision the NDRA process has to support (see element 2). For example, investment decisions in DRR might require different methods than prioritization of national preparedness planning. In most cases, NDRA will be based on a combination of different kinds of methodologies that together provide appropriate results for the different decisions in the DRM governance process.

Selecting an analysis methodology also means striking a balance between the following:

1. Quality of the methodology and its appropriateness for the purpose the results should serve.
2. Resources it requires: technical (including data, tools and expertise), financial and time.
3. Significance of the risk and level of investment for managing the risk.

Some methodologies, such as probabilistic modelling, can provide a comprehensive view of hazard, risk and uncertainties that may be needed for certain decisions such as in relation to the design of high-cost structural disaster risk reduction measures. For example, investment decisions for certain structural measures may require a cost-benefit analysis to choose the most efficient design; whereas some non-structural measures, such as educating schoolchildren to evacuate, have lower costs associated with them or would not require comprehensive results from probabilistic modelling. Sometimes the cost of prevention is low enough that it is better to simply invest in prevention rather than a sophisticated analysis of risk.

Single-hazard risk analysis

A single-hazard risk analysis has the following components:

- **Hazard analysis**: Provides information on where, how big and how frequent the hazard events are, and on how severe their effects are (e.g. ground shaking for earthquakes, wind speed for cyclones, etc.).
- **Exposure analysis**: Provides information on the presence, attributes and values of assets that may be impacted by a hazard. The NDRA scope, including criteria selected for evaluating consequences (e.g. impact on people or the economy), guides the selection of assets to be included in this analysis.
- **Vulnerability analysis**: Provides information on how an identified asset reacts to the effects of the hazard. Identification of vulnerabilities is guided by the NDRA scope, including criteria selected for consequence evaluation, such as people, the economy, the environment and sustainable development gains. For many hazards, vulnerability assessment of structures and estimation of physical impacts is often the first step towards understanding downstream impacts on the population and the environment.
- **Uncertainty analysis**: For all the components of risk analysis, it is important to associate a level of uncertainty or confidence level in the calculations or estimates. This can be done by tracking the uncertainty or confidence level at every step where an estimate or judgement or calculation is made quantitatively or qualitatively.

Once these components are in place, a risk analysis can be carried out for each hazard. The following are the options for risk analysis methodologies, starting with the most sophisticated and resource-intensive one:

- **Probabilistic analysis**
- **Deterministic or scenario analysis**
- **Historical analysis**
- **Expert elicitation**

There are advantages and limitations in using each of these methods and each of them is good for certain purposes. However, all of them should be utilized throughout the process of conducting a multi-hazard risk assessment. Brief description of each method is below.

Probabilistic analysis: Probability is an inherent attribute of risk. All methodologies deal with probability either explicitly or implicitly but the probabilistic approach is a systematic and comprehensive methodology that quantifies these probabilities.

Probabilistic risk considers a large number of possible scenarios, their likelihood and associated impacts. In this method, a significant amount of scientific information on hazard, exposure and vulnerabilities, as well as insights from historical loss and damage data, is used to simulate (or model) the complex phenomenon of disaster risk.

Box 10- More about the probabilistic risk method and outputs

While probabilistic risk analysis is resource intensive, it has numerous advantages, including the following:

1. Ability to measure the risk costs (average annual loss (AAL) or return period losses) and consequently the ability to undertake cost-benefit analysis of alternative risk reduction measures.
2. Ability to aggregate risks from various hazards based on annualized losses (AAL).
3. Ease with which quantitative comparison of relative risk from various hazards can be undertaken.
4. Suitability for effectively capturing and quantifying uncertainties.
5. Tendency to reveal a more complete picture of risk in terms of both likelihood and impacts. (Scenario and historical approaches, on the other hand, tend to drift towards "known" and experienced risks, often leading to an underestimation of actual risk).

Some common terminology used in probabilistic risk analysis is described below:

Exceedance probability (EP) curve: The EP curve describes, for each level of dollar loss of interest, what the annual probability is for that level of loss or higher to happen. Figure 7 displays an example EP curve, where the annual probability of exceeding US$ 400 million is 0.3%.

Sometimes the annual probability of exceedance is plotted on the x-axis and the dollar loss on the y-axis, but the concept is the same.

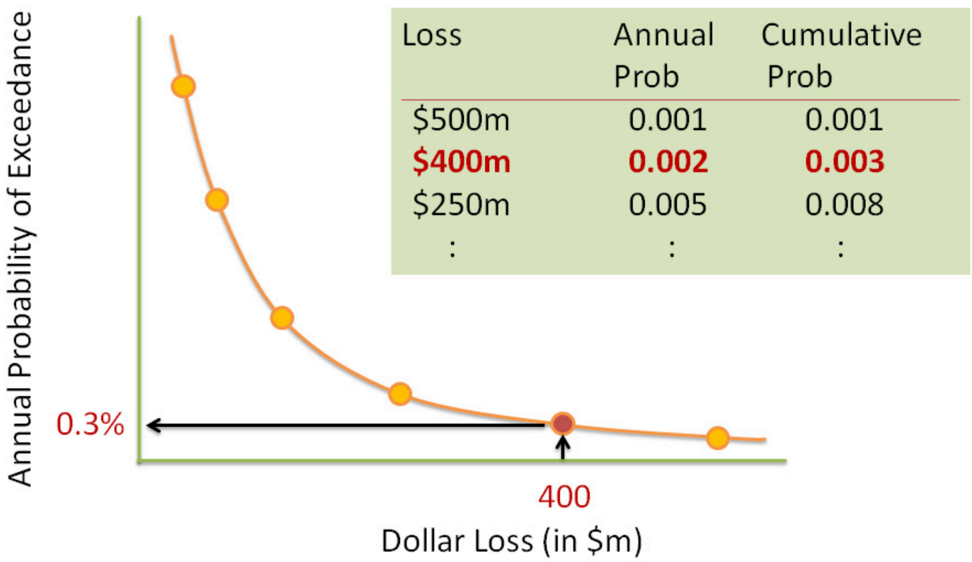


Figure 7 - Exceedance probability curve

The return period loss (sometimes referred to as the probable maximum loss or PML) is the loss corresponding to a certain likelihood, expressed in terms of annual probability of exceedance, or its reciprocal, the return period. Once the EP curve is constructed using probabilistic methods (or a number of scenarios with various likelihoods), loss can be obtained for any desired probability of exceedance (or return period). Similarly, the annual probability of exceedance can be obtained for any loss level of interest. For example, in Figure 8 the 250-year (or 1/250 = 0.004, i.e. 0.4% annual probability of exceedance) loss is $300million.

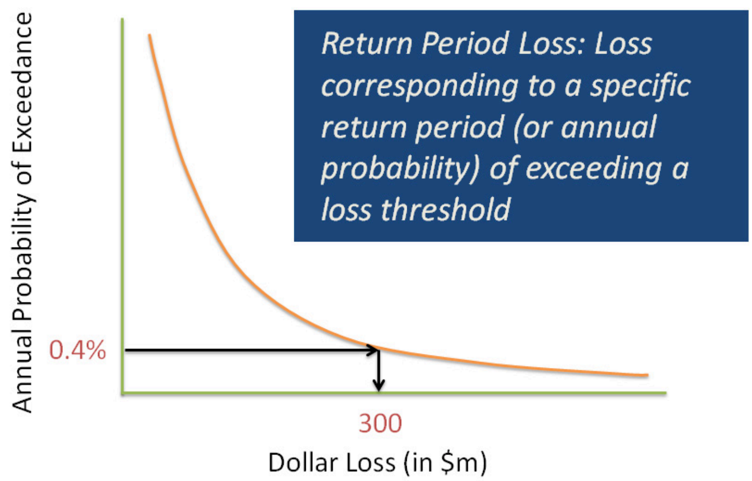


Figure 8 - Return period loss or probable maximum loss (PML)

Average annual loss (AAL): The long-term expected loss on an annualized basis, averaged over time. While there may actually be little or no loss over a short period of time, the AAL also accounts for much larger losses that occur less frequently. As such, AAL is the amount of funds that needs to be put aside annually in order to cumulatively cover the average disaster loss over time. AAL, in mathematical terms, represents the area under the EP curve.

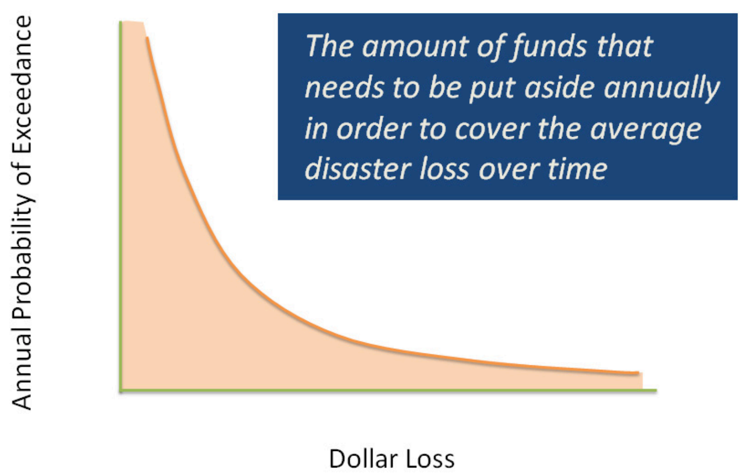


Figure 9 - Average annual loss (AAL)

Deterministic or scenario analysis: A deterministic or scenario analysis is the process of analysing the impacts or losses from a single event (scenario). This method characterizes possible event realizations in terms of size and location of events, but does not fully quantify the frequency of occurrence of these events or assess their impacts in a probabilistic manner.

Selection of the scenario and analysing the consequences may be supported by historical loss information or some level of scientific understanding of hazard, exposure and vulnerability in the region of interest. If when scenario or deterministic analysis is used in risk analysis, it is recommended that multiple scenarios with various likelihoods of occurrence (even if the likelihood is not explicitly quantified) be analysed to obtain a more complete picture of risk.

Box 11– Examples multi-criteria impact analysis

The impact analysis in the scenario-based approach should take into account all different kinds of societal impacts. As defined in the Sendai Framework, the societal impacts to be considered are impacts on human health and safety, the economy, the environment, the social and political stability, cultural heritage and education, as well as negative consequences for SDG's.

The impact on each of these societal values has to operationalized in one or more impact criteria, so the impact can be estimated in a transparent and comparable way for each risk. Examples of criteria in existing NDRA scenario based methods are[25]:

Human impact (health and safety)	• fatalities • severely injured or ill people • permanently displaced people • people with lack of basic necessities
Economic impact	• fatalities • severely injured or ill people • permanently displaced people • people with lack of basic necessities
Environmental impact	• disruption of ecosystems • environmental pollution • loss of ecological value
Social and political impact	• public outrage and anxiety/social-psychological impact • disruption of daily life • disruption of the education system • encroachment of the territory • infringement of the international position • violation of the democratic system • impact on public order and safety • loss of social cohesion
Impact on cultural heritage	• loss of cultural heritage and values

There are several ways to operationalise the criteria:

- **Quantitative indicators:** this can be a number (fatalities etc.) or amount (costs), but it can also be a combination of two quantitative dimensions, for example number and duration (in cases of displacement or lack of basic necessities).
- **Qualitative indicators:** this can be any kind of single indicator or combination of multiple indicators, that predict a certain level of impact.
- **Qualitative impact level descriptions:** if it is difficult or impossible to identify measurable indicators, each of the impact levels of a criterion could be operationalised by a qualitative description of "expected consequences". For example, a description of tangible collective behaviour for different levels of social unrest.

Each impact criterion needs to be operationalized in the same number of impact levels (for example 5 levels). There must be a consistency across criteria, as to assure that a certain level of impact on one criterion more or less fits with the same impact level on the other criteria. As the different societal impacts by nature are not interchangeable or comparable, the defining of such consistency requires both expert elicitation and a political decision.

The data for analysis of impact (and likelihood) levels can be drawn from sectoral and single hazard risk analyses. If those are not available, the expert elicitation of the scenarios should provide the required information on the impact criteria/indicators.

[25] See for example the methods of Germany, the Netherlands, Norway, Switzerland and the United Kingdom

Historical analysis: A database of damage and loss from past disasters, collected systematically over a reasonably long time, can provide a valuable understanding of extensive risks. Such databases can be used to conduct a historical analysis, providing information on frequency of occurrence, potential impacts and the overall risk associated with frequent events. A historical analysis cannot be used for infrequent hazards, such as earthquakes, and can be misleading by not revealing information about high-intensity events with low probability (e.g. a flood of one in a 100 year return period or 1% probability of occurrence in one year).

Box 12 - National disaster loss databases will be used for monitoring Sendai Framework progress

Besides being a data source to use in the historical analysis method, national disaster loss databases will be necessary for monitoring progress in Sendai Framework implementation at national and global level to report on Sendai Targets A to D, which measure loss, damage and impact from disasters. As of today, 105 countries have established national disaster loss databases. Many of these need to be updated and upgraded to comply with the Sendai Framework hazards coverage and monitoring requirements.

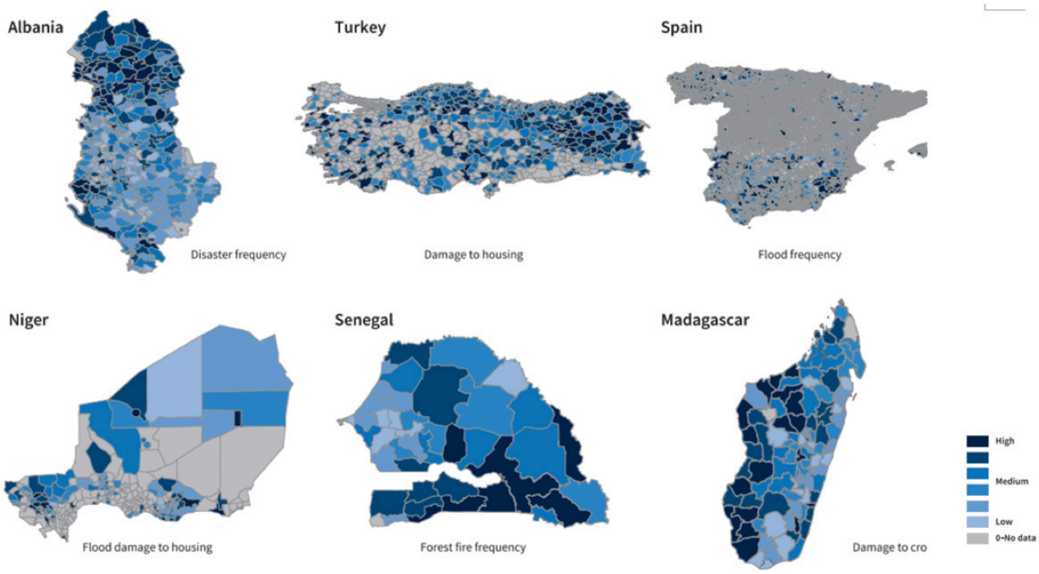


Figure 10 - Historical loss databases are established and used in many countries around the world. Source: Global Assessment Report (GAR) 2015.

Box 13 - Considerations in establishing a national historical loss database

The process of establishing or upgrading the national loss database is led by an appropriate national entity, although three scenarios may exist in the data collection process:

Scenario 1: Local civil protection collects and reports to national level

Scenario 2: National/regional assessment centres

Scenario 3: Hazard specific national authorities.

The choice of host institution is fundamental to the success and sustainability of the database. Hosting the database goes beyond the physical fact of having a computer or server where the database will be stored. The host institution is responsible for keeping the database up to date, coordinating efforts among different national and subnational entities who collect the disaster loss data, and producing output reports.

Experience from many countries shows that long-term sustainability of a national loss database is contingent on having the database maintenance and data collection embedded in the operations of the host agency. A national statistical office can be the host entity or can support another entity in hosting the database.

The following are the core activities for implementing this component:

1. Identifying key stakeholders and partners: host institution, data sources and end users.
2. Developing implementation plan with timelines, as well as roles and responsibilities for all actors involved.
3. Establishing recording methodology that should consider national legislation, context and existing practices. This includes deciding on the historical time frame and disaggregation level to collect data
4. Developing an official sustainability plan endorsed by the host agency and other relevant contributing agencies.
5. Setting up the computational environment for the database.
6. Recruiting data collectors and conducting training for the historical research.
7. Conducting training on day-to-day collection of loss data, which is done by permanent staff of designated entities at subnational and national level.
8. Developing and implementing an overall quality control strategy.
9. Starting day-to-day collection of losses.

Source*: UNISDR, 2015*

For further information see: Guidance for Recording and Sharing Disaster Damage and Loss Data, European Commission Joint Research Centre, 2015
http://drr.jrc.ec.europa.eu/Portals/0/Loss/JRC_guidelines_loss_data_recording_v10.pdf

Expert elicitation: If no other information or means to carry out risk analyses are available, individuals with good understanding of various components of disaster risk in the country can conduct the analysis using their expert judgement. While it is more common to conduct a qualitative analysis using the expert elicitation method, it is also possible for experts to provide a quantitative perspective on risk. This method has a significant amount of uncertainty for intensive risk and potential bias, particularly if a single expert is consulted. Consultation with multiple experts may reduce the potential bias.

Box 14. Swiss national risk assessment benefits from large number of experts and their judgements

The Swiss national risk analysis of disasters and emergencies identifies a spectrum of possible hazards, develops specific scenarios, analyses their impacts, and assesses the likelihood of their occurrence.

Hazard-specific workshops are held to assess the impact and likelihood of such scenarios. Five to ten experts from the public and the private sector, and academia, assess the extent of twelve defined damage indicators and the frequency of the scenario. Such assessments are carried out in structured group discussions, patterned on the Delphi approach.

In the first round, the experts individually estimate the frequency and the extent of damage for each indicator (e.g. the number of expected fatalities). To assess the impact and frequency associated with the various hazards, the experts refer to existing research and information such as studies, event analyses, exercise evaluations, statistics, field reports and other scenarios. On the basis of available data, they investigate and assess the impacts of the specific scenarios. If information is lacking or of insufficient quality, they will resort to well-founded assumptions.

In the second round, they discuss the variations of the individual expert estimations. The participants have the opportunity to explain their individual results. On the basis of this discussion, the experts reach a consensus on one value for each indicator and the frequency of the scenario.

More than 200 experts were included in the analytical process leading to the Risk Report 2015. Even though risk analysis is not a hard science, the methodological approach allows us to assess a broad range of hazards in a comparable, systematic and transparent way. This approach also ensures that all the important stakeholders can participate in the assessment.

Further documents:

FOCP (2015):
Disasters and Emergencies in Switzerland 2015: what risk does Switzerland face?, Bern.

FOCP (2013)
A Method for Risk Analysis of Disasters and Emergencies in Switzerland, edition 1.03, Bern.

Source: *Swiss Civil Defence, 2017,*
http://www.babs.admin.ch/en/aufgabenbabs/gefaehrdrisiken/natgefaehrdanalyse.html

Aggregation and comparison of risk from all hazards

One of the objectives of risk analysis is to provide a basis for adding and comparing risk from different hazards that may affect a country. Usually several single-hazard risk assessments are carried out first and then the outputs are used as input to tools and techniques that allow the various risks to be aggregated, compared and evaluated for decision-making. Such analysis provides a more complete understanding of risk from all hazards.

Aggregation of risks

Although this process may sound straightforward, various issues may need input from experts. Issues include the interlinkages of impacts and whether the risk outputs from all the hazards are presented in a common standard metric that can be simply added up. For example, if risk analyses for multiple hazards are all conducted probabilistically, loss results (e.g. dollar losses, life losses) can be combined probabilistically. However, to be additive, the risk from each hazard needs to be represented in an annualized form (see average annual loss in Box 10), which can then be summed up to give an idea of total risk.

In contrast, return period losses at a certain return period of interest (see Box 10) cannot be aggregated as easily. If a scenario approach is used to calculate risk from various hazards, aggregation is even more challenging since it is harder to find a standard loss metric that can be summed up. For example, if all the scenarios are worst case scenarios, there is little value in knowing the sum of all worst case scenario losses since it is improbable that all worst case events will happen at the same time.

Comparison of risks

Several techniques and methods exist for comparing risks from different hazards. ISO guidelines on risk assessment provide a variety of techniques. Although not all of these techniques are commonly used in disaster risk management, most can be adjusted to use in comparing risk for risk management decisions. The following are three of the most commonly used methods:

1. **Probabilistic risk analysis:** Various risk outputs – such as return period loss at various return periods of interest or average annual loss (see Box 10) – computed for each of the hazards can be compared from probabilistic risk analyses conducted for different hazards. The exceedance probability curve, one of the main outputs of probabilistic analysis, gives users the freedom to look into a variety of likelihoods or diverse values of impact from different hazards to compare, prioritize and make risk management decisions.

2. **Multi-criteria impact and likelihood scenario analysis**: In this approach, the different hazards within the scope of the national disaster

risk assessment are summarized into a set of “stress test scenarios” in the context of all relevant coping capacities of a country. The method allows the outcomes of single-hazard analyses (e.g. probabilistic, deterministic) to be compared.

The scenarios are selected as broad as possible so as to provide better insights to decision makers on the range of possibilities. Therefore, if the resulting capability gaps are resolved sufficiently, a country is more or less resilient to any existing or future risk. This approach has been most commonly used for emergency preparedness, recovery and reconstruction planning for which the “maximum credible” or “plausible worst case” scenario is of interest.

The method can also be used for other disaster risk reduction decisions, but to that end requires careful consideration of the scenario selection, as the use of worst case scenarios favours intensive risks over extensive risks.

The selection of scenarios is largely based on expert elicitation and requires the involvement of a wide range of stakeholders and experts to provide the scenarios for all kinds of risks and capacities. The scenarios are analysed on two dimensions of risk: impact and likelihood. And the final outcome of the analysis is represented in a risk matrix of likelihood and impact, as a basis for prioritizing risks (see also box 16). However, the resulting risk matrix does not provide an absolute ranking of risks. The acceptable risk appetite, the current coping capacity and new opportunities for risk reduction are among the other factors that might influence how the priorities are defined.

Box 16 – Risk matrix or multi-criteria impact and likelihood analysis

A risk matrix is the common template presenting the impacts, likelihoods of risks and confidence levels. This matrix projects the outcomes of the impact and likelihood analysis onto two axes. The visual tool helps decision makers see a clear distinction between impact and likelihood levels.

The actual impact and likelihood levels of different national risks represented in the risk matrix are the result of a single-hazard risk analysis.

	Consequence level				
Likelihood	**Insignificant**	**Minor**	**Moderate**	**Major**	**Catastrophic**
Almost certain	Medium	Medium	High	Extreme	Extreme
Likely	Low	Medium	High	Extreme	Extreme
Unlikely	Low	Low	Medium	High	Extreme
Rare	Very low	Low	Medium	High	High
Very rare	Very low	Very low	Low	Medium	High
Extremely rare	Very low	Very low	Low	Medium	High

Another aspect that needs to be presented is the confidence level or level of uncertainty. The confidence level is an additional level of information supporting decision-making. Various methods to add this element to the risk matrix have been used in different countries and national guidelines.

	Consequence				
Likelihood	**Insignificant**	**Minor**	**Moderate**	**Major**	**Catastrophic**
Almost certain	4	4	3	2	1
Likely	5	4	4	2	2
Unlikely	5	5	4	3	2
Rare	5	5	5	3	3
Very rare	5	5	5	4	3
Extremely rare	5	5	5	4	4

	Consequence				
Likelihood	**Insignificant**	**Minor**	**Moderate**	**Major**	**Catastrophic**
Almost certain	3	2	1	1	1
Likely	3	3	2	1	1
Unlikely	4	3	2	1	1
Rare	4	4	3	2	1
Very rare	5	4	3	2	2
Extremely rare	5	5	4	3	2

The image above shows two risk matrices with priority levels. The darker colour and number one denote the highest priority and the lighter colour and number 5 the lowest. On top the colouring for risks with the highest level of confidence and below for risks with the lowest level of confidence. The second one shows a broader range of high priority, as it cannot be ruled out that the risks should in fact be higher up in the matrix.

Source*: National Emergency Risk Assessment Guidelines, Australian Institute for Disaster Resilience*

3. **The index-based approach:** In this method, a wealth of information and data on hazard, exposure, vulnerability and capacity can be simplified to be represented with index scores (a number out of a full score) and then combined to present risk level with a single index score. The index-based approach provides actual risk values or likelihoods. Its main benefit, however, is the simplicity of using its output for comparing risk levels from various hazards or between regions of interest (e.g. subnational regions). Also subindices, if designed well and communicated transparently, can provide insight into the sources of risk from hazard, exposure, vulnerability or capacity.
   For example, the index for risk management (INFORM)[26], which has been developed at a global level to understand and measure the risk of a humanitarian crisis across various countries, assigns risks an overall score out of 10. It is a composite indicator combining 53 indicators. Figure 11 shows the INFORM multi-layer system. The elements in each layer are presented by an index value, which is calculated based on the contributing elements at the lower layer. Depending on the users' purpose and intent to target the disaster risk management measures, comparison and evaluation can be done using the indices at any layer.

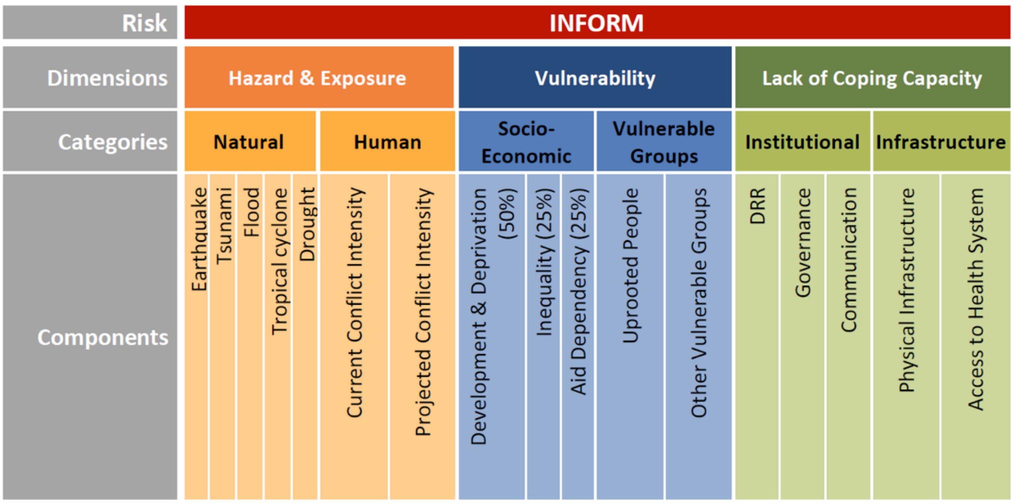


Figure 11 - INFORM model.
Source: INFORM methodology document (accessed March 2017)

[26] Inter-Agency Standing Committee and the European Commission, n.d. Index for risk management (INFORM), Joint Research Centre of the European Commission, retrieved from site: www.inform-index.org .

Sequential, simultaneous, cascading and interrelated effects of some hazards

The triple disaster in Japan on 11 March 2011 is a well-known case of sequential and simultaneous hazards with cascading effects. The disaster started with the Tōhoku earthquake, which killed about 100 people. The ensuing tsunami killed about 18,000, and there was uncertainty about the consequences of the radioactive contamination resulting from the Fukushima Daiichi nuclear meltdown.

The interaction between natural and technological hazards was amplified by local vulnerabilities, and the Fukushima nuclear accident was considered "a profoundly man-made disaster – that could and should have been foreseen and prevented".[27] Other critical infrastructure in the affected area was broadly compromised, thus constraining efforts to contain the cascading effects of the primary disruption.[28]

Cascading risks and disasters have serious implications for national risk assessment processes, especially when they disrupt the functioning of society and the economy due to their impacts on critical infrastructure. It is vital not only to understand and assess cascades in critical infrastructure, but also to know how to stop them from escalating.

Unfortunately, modelling such complex phenomena requires a significant amount of data and complex modelling tools and expertise, which can make it unfeasible to conduct quantitative modelling as common practice. Nevertheless, possible cascading effects of major hazards should be explicitly noted and quantified to the extent possible.

A complementary approach suggests that the paths of cascades can be understood in advance of the triggering events by identifying sensitive nodes that generate secondary events and rapidly scale up a crisis. Risk scenarios based on hazard can be integrated with corresponding vulnerability scenarios using escalation points to represent unknown triggers. The involvement of all stakeholders such as emergency managers, governmental and non-governmental organizations and representatives of the private sector could help determine which consequences of a disaster could become the principal drivers of cascades.

For more information, see part three, Module 3, on cross-sectoral and multi-risk approach to cascading disasters.

---

[27] The National Diet of Japan, 2012. The Official Report of the Fukushima Nuclear Accident Independent Investigation Commission: Executive Summary, The National Diet of Japan, Tokyo, Japan.

28 Pescaroli, G. and Ilan Kelman, I., 2016. How Critical Infrastructure Orients International Relief In Cascading Disasters. Journal of Contingencies and Crisis Management, 25(2), pp. 56–67.

Element 7 - Key considerations in conducting risk analysis

This element describes key considerations in conducting a risk analysis. More information on various methodologies and tools, and further resources relevant to conducting the risk assessment can be found in the modules on special topics and hazard specific risk assessment in part three.

Identifying and compiling existing input data

Identifying and compiling existing input data for various components of risk analysis are critical for the following purposes:

a) Further refining the technical scoping, including selection of analysis methodologies, since the level of detail in risk analysis is often driven by the resolution or quality of the available data;

b) Identifying data gaps and areas that require further data collection.

Data and information needed for analysing disaster risk often reside in a country's research institutions, government laboratories, statistics offices, etc. Sometimes private-sector studies are made public, especially when commissioned by government entities. On a broader scale, existing regional or international studies, though they may vary in resolution, can be used to supplement other available data.

Further considerations are described in element 3 on data management strategy of NDRA in this document and more details can be found in Module 9 on data management in part two of the Guidelines.

Assessing disaster risk management capacities

Understanding capacities is one of the main components of disaster risk assessment. It adds perspective when prioritizing and evaluating risks for decision-making. It is essential to understand capacities in order to quantify the total impact. Consideration needs to be given to how capacity assessment fits best in the process of NDRA and, more broadly, in disaster risk management. The concept of "lack of capacity" is often considered to be part of risk analysis itself, as it is one of the risk elements, besides hazard, exposure and vulnerability.

Box 17 – Categorization of capacity

The following list sets out the different ways in which countries categorize "capacity" in the context of disaster risk:

- By phase of the risk management cycle: prevention, preparedness, response and recovery.
- By the structural nature of the capacity: structural versus non-structural. Structural means actual, physical structures (e.g. dams, dikes); non-structural means "softer" measures (e.g. policy instruments and community resilience).
- By "target" within a holistic approach: human, human-made environment (built and technical) and natural environment.
- From the perspective of the "built environment": (in descending order) spatial planning, building construction, technical systems within a building, usage of the building, human behaviour.
- Based on natural/psychological mechanisms: "coping" versus "adapting". Coping focuses on tactical measures, based on the current risk level and previous events. Adaptation focuses on strategic measures in anticipation of future changes in risk.
- By institutional capability: administrative, technical, and financial.
- By element of risk: capacities to reduce hazard, exposure, and vulnerability.
- By element of impact: capacities to reduce human, economic, environmental and political-social impact.

Determination of sources and drivers of risk

The risk analysis phase provides the opportunity to better understand the underlying causes of risk. The risk assessment may highlight that a risk is dominated largely by the element of hazard due to climate change, exposure due to unchecked urban expansion, vulnerability due to lack of building code enforcement, poverty and inequality or capacity due to weak governance.

And cross-cutting themes can be identified that influence several components of risk at the same time, such as climate change and rapid technological development. If there is a specific risk that can be reduced by a change in policy or practice that eliminates or diminishes the root cause of the risk, this should be noted in the assessment.

Climate change impact

Climate change is one of the underlying drivers of risk and it impacts both slow-onset events such as: sea level rise, increasing temperatures, ocean acidification, glacial retreat, salinization, land and forest degradation, loss of biodiversity and desertification and extreme weather events such as: floods, cyclones, or extreme temperatures[29]. Some disaster risks have a direct relationship with the increase in frequency and magnitude of extremes in climate variables (temperature and precipitation) and low capacity to

29 Inter-Governmental Panel on Climate Change (IPCC) Fifth Assessment Report, 2014

adjustment. In particular, the policies and investments in climate change adaptation and disaster risk management should be fully aligned to benefit from measures that address both and ensure an efficient and coherent use of resources. Therefore, it is critical that NDRA incorporates the impacts of climate change on the relevant hazards and risks. At national level, convergence of climate change adaptation and disaster risk management is with national institutions and common stakeholders, financial and operational mechanisms, knowledge and capacity, and data and analysis processes. For example, the government of Laos has recently formed a Department of Disaster Management and Climate Change (DDMCC) at the Ministry of Natural Resources and Environment to manage the resources and processes for effectively for managing climate change impact and disaster risk[30].

While it is clear that the climate is changing, there is significant amount of uncertainty about exactly how it will change and by how much. Future changes in climate variables depends on the future level of greenhouse gas in the atmosphere and the response of global and local average surface temperatures to the increase in greenhouse gases.

One way to address future uncertainty is to use climate change scenarios and projection models to describe possible changes to climate variables which are then used as input into hazard and risk assessments and provide a range of risk levels for different climate change scenarios. This would empower decisions in design of policies and investments to ensure for example, future infrastructure will withstand future extreme events.

30 http://www.monre.gov.la/

Element 8 - Preparing the outputs of risk analysis for communication with stakeholders

This element emphasizes the importance of using various tools and methods to prepare the outputs of analysis for communication and use by stakeholders for the purposes of NDRA.[31]

Presenting the results in a format that is understandable, relevant and useful to the stakeholders is key to the success of a risk assessment. A review of current risk assessment efforts shows that more innovation and collaboration with experts in communications and other disciplines is necessary to improve the translation of technical information into transferable and useful information for decision makers and practitioners. For example, presenting the risk and loss values in an economic or social context, or expressing probabilities within the political timeframe or human lifetime, especially for low-likelihood but high-consequence events, helps convey the risk message clearly.

The final consolidated report of a risk assessment, communicating risk information to the general public or a local community, requires a different strategy from that for communicating the same information to economists or policymakers. It is recommended to pay close attention to the development of a communication strategy that breaks down the full risk assessment results into digestible pieces for different target audiences. Consider the goals for each target audience, varying from decision-making on risk prioritization and disaster risk reduction measures (NDRA stakeholders), disaster risk awareness and education (general public), to incentives for follow-up research (scientific community) and use of information for other risk assessments (subnational governments, sectors).

The following tools and formats can be used to report the results for different purposes:

- Geospatial tools and mapping for hazards and risk information. For further information, see Module G on the use of geospatial data.
- Risk matrices for comparison and showcasing prioritization of risk levels to decision makers are a common format to use for all risks. See Box 16 in Element 6.
- Scenario information depicted in maps and infographics, as well as preparation of exercises,
- to raise awareness among the general public.
- Brief snapshots of risk values, trends, with and without possible disaster risk reduction policies (if identified in the scoping step) and main findings for communicating with high-level decision makers.

31 Risk communication is a two-way process. This is reflected in element 9. Element 8 focuses only on the preparation of the results for two-way communication.

- Exceedance probability curves to communicate the concept of risk layers for disaster risk reduction actions.
- Sector reports to explain the assumptions, methodologies, findings and relevance of the information produced to the identified disaster risk management actors.
- Simple and clear formats, such as infographics, to present hazard and risk information accompanied by simple actions and decision-making considerations for use in communicating with the general public.

Stage III Using NDRA results for disaster risk management and development decisions

Element 9- Facilitating the process for evaluation and applying results in disaster risk management decisions

This element provides an overview of the necessary re-engagement between the technical team and the stakeholders to understand the NDRA results, evaluating the risks so as to prioritize them and apply the assessment to the original policy scope defined at the scoping and preparation stage.

The outputs of risk assessment are inputs to decision-making on plans, actions and investments for managing disaster risk. Understanding of disaster risk through an NDRA provides a scientific and evidence base for decision-making and planning. Once the technical team prepares NDRA outputs, the results and findings are presented to the key stakeholders to ensure the outputs are understandable and are usable for the purpose that was originally defined in the scoping phase. This closes the loop between the phase of conducting risk assessment and the scoping phase.

It is important to use the governance system of stakeholders that was designed at the early phases of the project to bring together all the key stakeholders involved in the scoping phase. This includes the scientific teams who conducted the risk assessment, the experts and the disaster risk management policy teams.

The following are some key issues that must be discussed and decided upon through engagement with stakeholders:

Evaluating and prioritizing the risks identified in the assessment. This process can be enhanced by setting transparent risk evaluation criteria or prioritization perspectives in advance (in stage I). The end result of the risk evaluation is a decision by the authorities (preferably the council of ministers or the national parliament), after stakeholder consultations and if possible public participation, on the "prioritization of risk".

- This means defining the risks of high societal importance that require immediate attention: priority hazards, priority exposed elements, priority vulnerabilities and priority capabilities to then decide on and design various disaster risk reduction measures. It is recommended to record the decision rationale regarding the prioritization of risks, as well as decisions regarding treatment options, and whether or not the "risk owner" has the option of accepting, treating or transferring the risk.

- Acceptable levels of risk.
- Uncertainties in results, as these will affect DRM policy decisions.
- The stakeholders discuss disaster risk management solutions based on risk prioritization, and further understanding of causes and sources of risk and identifying and perhaps addressing the underlying causes of risk and other considerations such as the following:
    - Large potential (indirect) consequences for Sustainable Development Goals.
    - Need for synchronization with other policy fields such as climate change adaptation, critical infrastructure protection and other sectoral needs.
    - Balanced mix between prioritization measures to avoid new risks, reduce existing risks and manage residual risks by means of all stages of the disaster risk management cycle: prevention, preparedness, response and recovery.
    - Need for continuity of existing disaster risk management policies.
    - Potential for quick wins.
    - Use of NDRA results for development planning, perspective planning and land-use planning.

This dialogue may lead to demand for further analysis to gain additional perspectives, such as further understanding of risk drivers[32,33] , or impact of certain disaster risk management policies or cost-benefit analysis of specific investments.

This step is not by any means the end of disaster risk management or disaster management planning, but only an opportunity to evaluate options while interacting with the technical teams who conducted the national assessment.

At the end of this step, the final set of risk assessment outputs – as datasets, maps, reports or any other formats, customized for the stakeholders – is delivered to the NDRA lead agency, and this cycle of NDRA comes to an end.

Relevant to this element are Module A: public communication, Modules F: data management, Module G: use of geospatial data.

---

32 UNISDR, 2015. Global Assessment Report on Disaster Risk Reduction (GAR) 2015, The United Nations Office for Disaster Risk Reduction, Geneva, Switzerland.

33 United Nations General Assembly, 2016. Report of the Open-Ended Intergovernmental Expert Working Group on Indicators and Terminology Relating to Disaster Risk Reduction, United Nations General Assembly, Geneva, Switzerland.

Element 10 - Ensuring long-term sustainability of NDRA system

This element describes the recommended long-term plan for the country NDRA system.

The vision of Sendai Framework priority 1, Understanding disaster risk, and the approach presented in these *Guidelines*, is to have a well-established central system for understanding disaster risk in every country that produces the risk information needed for prevention, mitigation, preparedness, response and recovery, in order to build a resilient future. This central system, with a multi-stakeholder governance system, updates the NDRA every few years, conducts specific risk assessment on demand and maintains the national clearinghouse of risk data and information.

It is important to put in place a long-term sustainability plan for the NDRA system. The plan should include the following:

- Clarity on NDRA updating time cycle.
- Operational mechanisms for "on-demand" customized risk assessments such as sectoral risk assessment, or site-specific hazard assessment for significant investments.
- Defining a financial strategy both for NDRA updates and "on-demand" assessments from public and private entities.
- Open data policies and data sharing from "on-demand" private assessments.
- Mechanisms for international exchange and access to science and technology advances in risk assessment, including tools for communication and application in disaster risk reduction.

Iterative processes for NDRA will further help to modify the course towards sustainable development. This requires having a legally and institutionally supported regular process of NDRA that is inclusive, science-based and sufficiently responsive to specific needs of the people, areas, sectors and assets most at risk.

Concluding notes

The Sendai Framework calls for strong political leadership, commitment and involvement of all stakeholders, at all levels, to pursue the goal of preventing new and reducing existing disaster risk "through the implementation of integrated and inclusive economic, structural, legal, social, health, cultural, educational, environmental, technological, political and institutional measures that prevent and reduce hazard exposure and vulnerability to disaster, increase preparedness for response and recovery, and thus strengthen resilience".

Such a complex task requires novel approaches and methods, and perhaps most importantly, new mindsets. Building resilience against disasters is largely a cross-cutting theme and starts from understanding disaster risk. A national disaster risk assessment sets the stage for successful disaster risk management ranging from prevention and reduction to preparedness and response and recovery strategies.

Understanding disaster risk and its interaction with the Sustainable Development Goals, climate change adaptation and disaster risk drivers requires more effort to be directed at extensive risk and its interaction with intensive risk. It also requires a disaggregated exposure, vulnerability, risk and loss mapping, as well as a deeper discussion of potential governance deficits.

While understanding disaster risk reveals inherent dependencies and interdependencies across many sectors, the notion of "socially constructed disaster risks" remains central, suggesting that vulnerabilities and capacities define and shape the disaster risk profile in a society.

Addressing those vulnerabilities allows modification of the structural conditions of unsustainable development models, such as poverty and inequality that exacerbate disaster risk. This inherent linkage of disaster risks and long-term development brings another importance to NDRA as an instrument for managing a short- to long-term risk-informed development model that is sustainable and integrated, allowing for the consideration of multiple cascading effects across different sectors.

References

European Commission, 2015. Risk Management Capability Assessment Guidelines, Official Journal of the European Union, retrieved from site: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52015XC0808%2801%29.

Inter-Agency Standing Committee and the European Commission, n.d. Index for risk management (INFORM), Joint Research Centre of the European Commission, retrieved from site: www.inform-index.org.

IPCC, 2012. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA.

Identification and Assessment (Priority 2) Multi-Stakeholder Working Session, United Nations World Conference on Disaster Risk Reduction, Sendai, Japan.

IRDR, 2014. Peril Classification and Hazard Glossary. Integrated Research on Disaster Reduction, Beijing, China.

J. Birkmann, O. D. Cardona, M. L. Carreño, A. H. Barbat, M. Pelling, S. Schneiderbauer, S. Kienberger, M. Keiler, D. Alexander et al., 2013. Framing Vulnerability, risk and societal responses: the MOVE framework

National Diet of Japan, 2012. The Official Report of the Fukushima Nuclear Accident Independent Investigation Commission: Executive Summary, The National Diet of Japan, Tokyo, Japan.

Pescaroli, G. and Ilan Kelman, I., 2016. How Critical Infrastructure Orients International Relief In Cascading Disasters. Journal of Contingencies and Crisis Management, 25(2), pp. 56–67.

United Nations General Assembly, 2016. Report of the Open-Ended Intergovernmental Expert Working Group on Indicators and Terminology Relating to Disaster Risk Reduction, United Nations General Assembly, Geneva, Switzerland.

UNISDR, 2015. Sendai Framework for Disaster Risk Reduction 2015 - 2030, The United Nations Office for Disaster Risk Reduction, Geneva, Switzerland.

UNISDR, 2015. Global Assessment Report on Disaster Risk Reduction (GAR) 2015, The United Nations Office for Disaster Risk Reduction, Geneva, Switzerland.

UNISDR, 2011. Global Assessment Report on Disaster Risk Reduction (GAR) 2011, The United Nations Office for Disaster Risk Reduction, Geneva, Switzerland.

UNISDR, 2016. Open-ended Intergovernmental Expert Working Group on Indicators and Terminology relating to Disaster Risk Reduction: Report of the Second Session (Informal and Formal), The United Nations Office for Disaster Risk Reduction, Geneva, Switzerland.

UNISDR, 2009. Disasters and Poverty: The Risk Nexus, [Juneja, S.], United Nations International Strategy for Disaster Reduction Secretariat, Geneva, Switzerland.

United Nations World Conference on Disaster Risk Reduction, 2015.

In addition to the references above, the guideline's main body have used resources listed in Annex 1.

ANNEXES

Annex 1: Further resources and relevant guidelines

Title	Author	Date	Link
International or regional guidelines			
Risk management: Principles and guidelines on implementation ISO/DIS 31000	International Organization for Standardization	2009	https://www.iso.org/standard/43170.html
Risk management - Risk assessment techniques ISO/IEC 31010	International Electrotechnical Commission (IEC)/ International Organization for Standardization (ISO)	2009	https://www.iso.org/obp/ui/#iso:std:iec:31010:ed-1:v1:en
Using national risk assessment to develop risk management capabilities at the country level	International Risk Governance Council	2012	www.irgc.org/wp-content/uploads/2013/02/IRGC_12December2012_workshop_15Feb.pdf
Risk Assessment and Mapping Guidelines for Disaster Management	European Commission	2010	https://ec.europa.eu/echo/files/about/COMM_PDF_SEC_2010_1626_F_staff_working_document_en.pdf
National-level Risk Assessments: An Analysis Report	European Union Agency for Network and Information Security	2013	www.enisa.europa.eu/publications/nlra-analysis-report/at_download/fullReport
INFORM index for risk management	European Commission and IASC (Inter-Agency Standing Committee Reference Group on Risk, Early Warning and Preparedness)	2014	http://www.inform-index.org
National guidelines or reports on national risk assessment			
National Emergency Risk Assessment Guidelines	Australian Institute for Disaster Resilience	2015	www.aidr.org.au/media/1490/practice-guide-101-national-emergency-risk-assessment-guidelines.pdf

The National Risk Analysis of Disasters and Emergencies in Switzerland	Federal Office for Civil Protection FOCP	2015	http://www.babs.admin.ch/en/aufgabenbabs/gefaehrdrisiken/natgefaehrdanalyse.html
All Hazards Risk Assessment Methodology Guidelines 2012–2013	Public Safety Canada	2012	www.publicsafety.gc.ca/cnt/rsrcs/pblctns/ll-hzrds-ssssmnt/index-en.aspx
National Risk Assessment In the Netherlands	Organisation for Economic Co-operation and Development	2012	https://english.nctv.nl/binaries/national-risk-assessment-2012_tcm32-84266.pdf
Working with Scenarios, Risk Assessment and Capabilities in the National Safety and Security Strategy of the Netherlands	Ministry of Security and Justice, Netherlands	2009	www.preventionweb.net/files/26422_guidancemethodologynationalsafetyan.pdf
Handbook on Mitigating Spatial Relevant Risks in European Regions and Towns	MiSRaR project, Netherlands	2012	www.misrar.nl/UserFiles/File/MiSRaR practical handbook ENGLISH definitive version(1).pdf
A summary of relevant elements of the National Risk Assessment compilation based on selected parts of the Report on Threats to National Security	Rządowe Centrum Bezpieczeństwa	2015	http://rcb.gov.pl/wp-content/uploads/EN-Poland-A-summary-of-relevant-elements-of-the-national-risk-assessmentOK.pdf

Documents, reports, papers on various aspects of disaster risk assessment			
Global Assessment Report (GAR)	UNISDR	2009, 2011, 2013, 2015	http://www.preventionweb.net/english/hyogo/gar/2015/en/home/index.html
Science for Disaster Risk Management 2017: knowing better and losing less	Joint Research Center, European Commission	2017	http://drmkc.jrc.ec.europa.eu/knowledge/Challenges-Sharing
Overview of Natural and Man-made Disaster Risks the European Union may face	European Commission-Commission Staff Working Document	2017	http://www.preventionweb.net/files/53884_swd2017176overviewofrisks2.pdf
Understanding Risk in an Evolving World	GFDRR	2014	https://www.gfdrr.org/sites/gfdrr/files/publication/Understanding_Risk-Web_Version-rev_1.8.0.pdf
Making a Riskier Future	GFDRR	2016	https://www.gfdrr.org/sites/default/files/publication/Riskier%20Future.pdf
Open Data – Policy and Principles for DRM	GFDRR	2016	https://www.gfdrr.org/sites/default/files/publication/OpenDRI%20Policy%20Note.pdf
Risk Modelling tools	GFDRR	2014	https://www.gfdrr.org/understanding-risk-review-open-source-and-open-access-software-packages-available-quantify-risk

Recommendation of the Council on the Governance of Critical Risks	OECD	2014	http://www.oecd.org/gov/risk/Critical-Risks-Recommendation.pdf
OECD Recommendation on Disaster Risk Financing Strategies	OECD	2017	https://www.oecd.org/daf/fin/insurance/OECD-Recommendation-Disaster-Risk-Financing-Strategies.pdf
Unbreakable: Building the Resilience of the Poor in the Face of Natural Disasters	GFDRR	2017	https://www.gfdrr.org/sites/default/files/publication/Unbreakable_FullBook_Web-3.pdf

Annex 2: Country Cases

Country cases for the interim version of guidelines are limited. More cases will be included in the final version.

Country: United Kingdom

United Kingdom's approach to national risk assessment.

Introduction

The National Risk Assessment (NRA) is a comprehensive all-hazard assessment of the most significant emergencies (malicious and non-malicious) the United Kingdom could face over the next five years. It is updated every two years (the last iteration was completed in 2016) and it includes the publication of an unclassified National Risk Register. The first NRA was first produced over ten years ago and has been regularly updated and improved ever since.

The NRA draws on expertise from a wide range of departments and agencies of Government. Each department is responsible for leading the assessment of specific risks that relate to their policy remit and/or their responsibility for a specific sector of critical national infrastructure. The resulting product is an integrated whole-of-government approach to National Risk Assessment.

The NRA identifies generic risks rather than every possible scenario and uses a 'reasonable worst case scenario' methodology to capture the most challenging, but still reasonably plausible manifestation of a risk.

There are three stages to the assessment: the identification of risks; assessment of their likelihood and potential impacts; and comparison/prioritisation of the risks. All three stages involve consultation with subject matter experts including independent challenge groups of academics and government scientists.

Each of the risks in the NRA is described as a 'reasonable worst case scenario'.

For a risk to be included in the NRA, it must:

- have the potential to cause serious detrimental effects to the security of the UK, human welfare or the environment;
- have an expected impact that reaches a minimum threshold (typically significant damage to the UK); and
- have at least a 1 in 20,000 chance of occurring at least once in the UK in the next five years.

Each risk is assessed on the basis of its likelihood and its potential impacts on:

- human health (including, mental health impacts people displaced/ evacuated, injured, or killed by the events);
- the nation's critical infrastructure and essential services (such as electricity, telecommunications, transport, etc.);
- the environment; and
- the economy.

The assessment also includes a more qualitative analysis of the psychological impacts on the country (which includes public outrage and public perception of the risk).

As part of HM Government's duties under equality and diversity legislation, both the process and the outputs of the NRA have been reviewed to highlight how risks or the required response may affect/take into account the needs of people of a specific gender, age, sexual orientation, religion, ethnic/national origin or disability.

Long-term trends (such as climate change) are examined through their potential effects on the risks covered by the assessment.

The governance mechanism for a risk assessment

Each risk is assigned to a lead assessor (government department or agency) with support from internal and external experts. The overall production of the NRA, including setting the methodology, is led by the Civil Contingencies Secretariat, which is part of the National Security Secretariat in the Cabinet Office. The NRA is collectively agreed by Ministers.

The NRA builds on risk assessment work conducted throughout the whole of Government and across the scientific and academic community. As such it benefits from the governance arrangements already in place for work carried out by government departments (including parliamentary accountability).

Independent expert groups also help government departments and agencies improve their understanding of the consequences of their risks, such as the effect on the mental wellbeing of the population

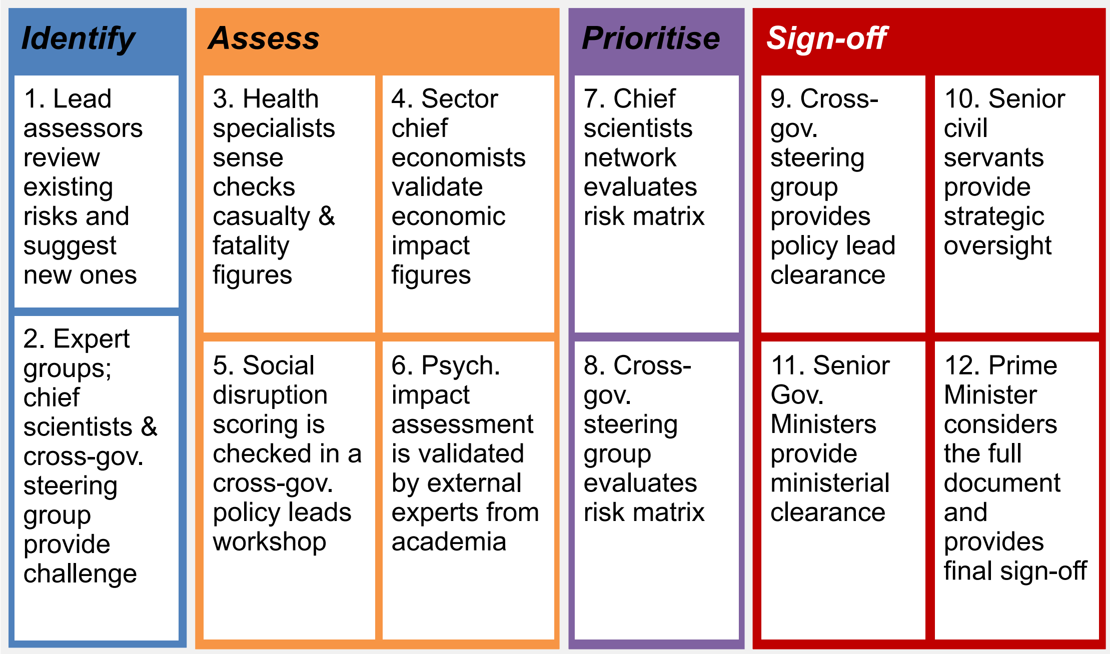


Figure 1 - Governance diagram

What were the existing technical, financial, and institutional capacities to conduct risk assessment?

Evidence based policymaking means that government departments and specialist agencies conduct risk assessment work on the areas of policy they lead on as part of their ongoing work. Existing technical capacities are also complemented by close partnerships between Government and industry, for example private operators of critical infrastructure have worked with regulators and government agencies to fund research aimed at understanding emerging risks such as space weather and cyber attacks.

Furthermore, Government works with the academic community to establish the areas of research where additional work is required.

The Natural Hazards Partnership is an example of the level of cross Government technical and institutional capacities in this field. This partnership is a consortium of 17 public bodies (mainly government departments and agencies, trading funds and public sector research establishments) which aims to build on partners' existing natural hazard science, expertise and services to deliver fully coordinated impact-based natural hazard advice.

What international support was used for the national disaster risk assessment? (if relevant)

On certain topics, such as flooding or radiation emergencies, European research projects have yielded additional evidence which has supplemented our national analysis.

The UK also regularly shares best practice with international partners bilaterally and through groups such as the Disaster Risk Management Knowledge Centre and the Disaster Prevention Expert Group (both EU initiatives) and the OECD High Level Risk Forum. Informal regional networks such as the North European Forum for Risk Assessment have also been a source of good practices which have enriched our country's approach.

What was the data management process?

A simple file sharing system supported by a secure online portal with strict access controls has been used to store and disseminate the information covered by the assessment.

As the NRA represents the synthesis of multiple assessments conducted by a variety of organisations, data informing the assessment for each risk is not centrally stored.

HM Government releases a significant amount of information, including data sets, to support transparent policy making and foster innovation. An online portal (data.gov.uk) brings it together into one searchable website. Making this data easily available means it will be easier for people to make decisions and suggestions about government policies based on detailed information. There are datasets available from all central government departments and a number of other public sector bodies and local authorities.

Technical methodologies

A variety of analysis methods have been used in producing the NRA, ranging from stochastic modelling to expert elicitation workshops using the Delphi method. Historical data and lessons learned from past occurrences have been combined with probabilistic modelling of scenarios.

How was the scope of the risk assessment defined?

The scope of the risk assessment is based on the UK’s national resilience legislation (the Civil Contingencies Act of 2004).

Every iteration of the NRA undergoes a validation process to ensure relevant risks are captured in the assessment. This validation process includes:

- Workshops with industry, academia and local responders;
- Cross-Government group discussions (at operational, senior management and ministerial levels);
- Consultation with the Government Chief Scientific Adviser and the network of chief scientists across Government; and
- Parliamentary oversight, via specialist committees such as the Lords Science and Technology Committee.

How was the risk assessment linked with DRR strategy and plans?

The NRA is used for considering national resilience challenges at a Government level, and to provide guidance to local emergency planners and responders on the kinds of risks which they may need to address in their local area.

The NRA is at the centre of the UK's national disaster risk reduction strategies. It informs national strategies on counter-terrorism, bio-security, flood resilience and cyber-security – amongst others. The NRA is also the backbone of a wider assessment of the national security risk landscape known as the National Security Risk Assessment (NSRA) which informs the National Security Strategy and Strategic Defence and Security Review.

What was the duration and budget of the risk assessment?

The NRA is produced every two years and is funded as part of the standard operating costs of the department and agencies involved in the assessment.

Were any guidelines used?

The Cabinet Office, as the coordinating agency for the NRA, produces its own guidelines and methodology for departments and agencies taking part in the assessment.

Country: New Zealand

New Zealand’s approach to initiating, designing, conducting and delivering national disaster risk assessment.

Introduction

Risk assessment of natural hazards has been completed in New Zealand for several decades, as legislated under the National Civil Defence Emergency Management Plan Order, which was last updated in 2015. However, up until recently, risk assessment was conducted in ‘silos’ (i.e. national security agencies were individually responsible for security assessments and natural hazard assessments were predominantly undertaken at a local level or independently by scientific research agencies). Further, there was not a consistent methodology available across Government agencies that enabled comparison of nationally-significant risks.

Understanding of the risks associated with specific hazards and event scenarios is based on assessments undertaken by Civil Defence Emergency Management (CDEM) Groups, national agencies, and the science and research sector. The recommended risk management standard to be used as the basis for risk assessment and management in New Zealand is AS/NZS ISO 31000.2009. Under current CDEM legislation, the following hazards require risk assessment:

a) earthquakes
b) volcanic hazards
c) landslides
d) tsunamis
e) coastal hazards (including coastal erosion, storm surges, and large swells
f) floods
g) severe winds
h) snow
i) droughts
j) wild fires and urban fires
k) animal pests and diseases
l) plant pests and diseases
m) infectious human disease pandemics (including water-borne illnesses)
n) infrastructure failure
o) hazardous substance incidents
p) major transport accidents
q) food safety incidents (for example, accidental or deliberate contamination of food)
r) terrorism.

Under the leadership of the Department of Prime Minister and Cabinet, New Zealand is developing a new methodology for assessment of nationally-significant risks. Hazards are assessed based on vulnerabilities and exposure, and taking a scenario-based approach, assesses overall level of risk against a standardised table of consequences across social governance and sovereignty, economic, environmental and built domains. The methodology also considers current and future risk management options.

The governance mechanism for a risk assessment

New Zealand takes an "all hazards, all risks" approach to national security, considering a variety of hazards, as well as traditional security threats. The governance mechanism for New Zealand's national risk assessment follows this approach by bringing together a wide range of stakeholders from different sectors, as the focus is on understanding and managing generic consequences and vulnerabilities instead of a specific hazard. The risk assessment governance mechanism brings together stakeholders at three levels of Government – Ministers; Chief Executives; Senior Officials and other officials. Relationships with local government, quasi-government agencies and the private sector are also leveraged.

Technical expertise used in the risk assessment itself was drawn predominantly from lead Government agencies, supported by the science and research sector as appropriate. A Project Team comprising officials from the Ministry of Civil Defence & Emergency Management, a business unit of the Department of Prime Minister & Cabinet, led a collaborative development and review process of the risk profiles and associated risk scoring.

The review process involves a step-by-step analysis to ensure lead agencies have followed the risk assessment methodology, that content was appropriately placed within the profile, and that the scenario assessments were supported by evidence and expertise. This was undertaken in phases:

1. An initial workshop with a large number of technical experts from agencies legislated to manage a variety of natural hazards. This provided an opportunity to test the assumptions behind consequence scoring and brainstorm alternative scenarios. The workshops were led by a member of the project team with appropriate technical acumen.
2. A cross-check from another project team member. This allowed for both technical and formatting quality control review to be undertaken to ensure consistency and completeness with the risk assessment methodology.
3. The project team also conducted an in-depth review of the risk assessment including:
    - Validating the risk assessment approach taken by each agency.
    - Reviewing all risk assessment material, including all 'workings'.

- Providing feedback to agencies on the review of the risk profile.
- Ensuring, to the best of the project teams' ability, that no gaps in existing knowledge were found.
- Ensuring all referencing was identified on the risk profile or on accompanying documentation.

What were the existing technical, financial, and institutional capacities to conduct risk assessment?

The standard used as the basis for risk assessment and management in New Zealand is AS/NZS ISO 31000.2009. This standard forms the basis for the national level risk assessment methodology, noting some customisation to make assessments suitable to New Zealand. Individual Government agencies hold their own capacities to conduct risk assessment, drawing from this standard. Conducting a national-level risk assessment requires additional commitment from many of these agencies. Through the first iteration of the national risk assessments, it was identified that methodologies and approaches within agencies was not uniform and where it was present, tended to be focused on operational rather than strategic risk. The Hazard Risk Management and Analysis team in the Ministry of Civil Defence & Emergency Management was used extensively in development and application of this methodology, coordinating cross-agency assessments.

What international support was used for the national disaster risk assessment? (if relevant)

International best practice for risk assessment was considered during development of the national level risk assessment methodology, drawing on a range of publically-available reports. Science and research reports were also incorporated into the risk assessment. International experiences of wild fires were considered when generating relevant scenarios.

What was the data management process?

While the majority of the information is based on national experience and publically available, data for assessments carries a security classification and is not 'open'. All risk assessment data is currently held within the Ministry of Civil Defence & Emergency Management and is managed in a variety of data formats, including excel spreadsheets. As part of continuous improvement of the risk assessment methodology it is anticipated that a shared database platform will be developed, enabling lead agencies to access and update assessment data as required. This will ensure that the methodology captures changes in risk over time.

Information on natural hazards is publically available and supported by a range of central and local government agencies, as well as science agencies and research institutes.

Technical methodologies

The fundamental component of the technical methodology is that all national level risks can be compared using a standard set of principles, using the same likelihood and consequences measures to determine a greater sense of the current and future, and acceptable and unacceptable risks New Zealand face, and provide the opportunity to identify changing and emerging risks.

The methodology for calculating scenario risk is based on a maximum credible event scenario approach, with consequence scoring for scenarios completed using a logarithmic scale. This approach allows different events, with quite different probabilities, to be effectively represented using simple scoring scales; a five point scale has been used thus far. The likelihood scale is also logarithmic, to be appropriate for a wide range of malicious and non-malicious risks.

Assessments are based on current, available information and current risk management practices. All risk assessments include a level of expert judgement in order to make effective decisions under uncertainty. The likelihood for each scenario is assessed quantitatively wherever possible, but based on qualitative expert judgement where there is no data or body of evidence. The process of completing the assessments allows central government agencies to identify gaps in evidence or understanding as well as include their level of confidence in the information used. A confidence ranking has been used to show best judgement has been used in the risk narrative and assessment.

How was the scope of the risk assessment defined?

The scope of the risk assessment has identified by central government agencies using a collaborative across-agency approach.

How was the risk assessment linked with DRR strategy and plans?

The national risk assessment is used to identify gaps in risk management, highlighting risks not currently accounted for or managed under Ministerial mandates, or central government agencies. Individual risk profiles identify current risk management practices across the '4R' framework (reduction, readiness, response and recovery). This includes identifying any governing legislation and plans. This can highlight any gaps in risk management of these individual risks.

The national risk assessment and the methodology underpinning it have been aligned with other relevant and related work, such as: The Treasury Living Standards Framework; Local Government New Zealand's establishment board for a risk management agency; the Financial Market Authority Assessment; the Sendai Framework for Disaster Risk Reduction; and the Climate Change Conference (COP 21) in Paris.

New Zealand is currently developing a National Disaster Resilience Strategy, which will be an implementation plan for the Sendai Framework in New Zealand. The national risk assessment will provide a key input into this work by describing the national risk profile, highlighting key exposures and vulnerabilities, and analysing wider 'system trends' that the strategy needs to take account of. Together these two pieces of work are key to promoting a broad conversation about risk and resilience in New Zealand, and how we best position ourselves for the future.

What was the duration and budget of the risk assessment?

The risk assessment does not have a defined budget and has been an ongoing process as the methodology and evidence utilised have evolved over time. Work commenced in August 2015.

Were any guidelines used?

This question is covered off above.

Examples of risk assessment results in use for DRR

Individual risk assessments are being used by senior government officials to test and further coordinate arrangements for risk reduction, readiness, response and recovery for high priority risks.

Annex 3: Definitions[34]

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.

Annotation: Capacity may include infrastructure, institutions, human knowledge and skills, and collective attributes such as social relationships, leadership and management.

Coping capacity is the ability of people, organizations and systems, using available skills and resources, to manage adverse conditions, risk or disasters. The capacity to cope requires continuing awareness, resources and good management, both in normal times as well as during disasters or adverse conditions. Coping capacities contribute to the reduction of disaster risks.

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.

Annotation: The definition of disaster risk reflects the concept of hazardous events and disasters as the outcome of continuously present conditions of risk. Disaster risk comprises different types of potential losses which are often difficult to quantify. Nevertheless, with knowledge of the prevailing hazards and the patterns of population and socioeconomic development, disaster risks can be assessed and mapped, in broad terms at least.

It is important to consider the social and economic contexts in which disaster risks occur and that people do not necessarily share the same perceptions of risk and their underlying risk factors.

Acceptable risk, or tolerable risk, is therefore an important subterm; the extent to which a disaster risk is deemed acceptable or tolerable depends on existing social, economic, political, cultural, technical and environmental conditions. In engineering terms, acceptable risk is also used to assess and define the structural and non-structural measures that are needed in order to reduce possible harm to people, property, services and systems to a chosen tolerated level, according to codes or "accepted practice" which are based on known probabilities of hazards and other factors.

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

34 UNISDR, 2016. Open-ended Intergovernmental Expert Working Group on Indicators and Terminology relating to Disaster Risk Reduction: Report of the Second Session (Informal and Formal), The United Nations Office for Disaster Risk Reduction, Geneva, Switzerland.

National Disaster Risk: intensive and extensive Disaster Risks that either have a potential (cumulative) impact that is significant and relevant for the nation as a whole and/or require national DRM coordination.

Annotation: The boundaries of National Disaster Risk depend on the purpose and scoping of a NDRA process. This has to be defined in each country, taking into account existing governance and DRM policies. National Disaster Risks at least include all risks that cannot be sufficiently managed at sub-national level.

Disaster Risk Assessment

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

Annotation: Disaster risk assessments include: the identification of hazards; a review of the technical characteristics of hazards such as their location, intensity, frequency and probability; the analysis of exposure and vulnerability, including the physical, social, health, environmental and economic dimensions; and the evaluation of the effectiveness of prevailing and alternative coping capacities with respect to likely risk scenarios.

National Disaster Risk Assessment*: the assessment of national disaster risks.*

Disaster Risk Governance

The system of institutions, mechanisms, policy and legal frameworks and other arrangements to guide, coordinate and oversee disaster risk reduction and related areas of policy.

Annotation: Good governance needs to be transparent, inclusive, collective and efficient to reduce existing disaster risks and avoid creating new ones.

Disaster Risk Management (DRM)

Disaster risk management is the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses.

Annotation: Disaster risk management actions can be distinguished between prospective disaster risk management, corrective disaster risk management and compensatory disaster risk management, also called residual risk management

Exposure

The situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas.

Annotation: 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.

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.

Annotations: Hazards may be natural, anthropogenic or socionatural in origin. Natural hazards are predominantly associated with natural processes and phenomena. Anthropogenic hazards, or human-induced hazards, are induced entirely or predominantly by human activities and choices. This term does not include the occurrence or risk of armed conflicts and other situations of social instability or tension which are subject to international humanitarian law and national legislation. Several hazards are socionatural, in that they are associated with a combination of natural and anthropogenic factors, including environmental degradation and climate change.

Impact The total effect, including negative effects (e.g., economic losses) and positive effects (e.g., economic gains), of a hazardous event or a disaster. The term includes economic, human and environmental impacts, and may include death, injuries, disease and other negative effects on human physical, mental and social well-being.

Resilience 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.

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.

Annotation: For positive factors which increase the ability of people to cope with hazards, see also the definitions of "Capacity" and "Coping capacity".

Special Topics

Words into Action Guidelines

National Disaster Risk Assessment

Special Topics

UNISDR
2017 - UNISDR

Contents

A. Public Communication for Disaster Risk Reduction

Key words:

risk communication, information ecosystem, communication channel

Advances in technology have improved scientific risk information dramatically in recent years. Yet this valuable information can too easily go to waste if it's not effectively communicated to people who need it to make decisions.

Effective communication helps technical experts develop and share data, it enables professional users to understand the data, and it influences how ordinary people take actions to reduce risk in their everyday lives. Communication is a process and should be considered throughout every stage of risk assessments.

This section focuses on communication with the general public. It provides guidance on how government officials and other professionals can communicate with general audiences to reduce the risk of disasters.

Why communicate about risk with the general public?

Effective communication is critical for ordinary people to understand the different types of risk they face, discuss what can be done and take action to manage those risks. Community members can also be an important source of risk information for analysts and can provide innovative solutions for managing risk.

Governments have a responsibility to provide clear information to the public about hazards and what actions can be taken at the household, community and government levels to reduce the risk of disaster.

The media can play a crucial role by engaging people on key issues, disseminating information, creating a platform to share ideas, and hosting discussions around governance and accountability for risk reduction.

Who is "the public"?

The public comprises all people in society, spanning old, young, rich, poor, male, female, urban, rural, etc. Yet, if you target everyone, you target no one. People face different risks, access information differently and take action on different issues.

Separate communication initiatives for target groups are vital to ensure that you connect with people on issues that matter most to them, in a way that will resonate. When grouping these target audiences, think beyond demographics. Knowing someone's age, gender, location, income and education only gives you part of their story. Consider what people know and believe about risk, how they feel about it, who they trust and which channels of information they refer to most, who they talk to about it and when, and what they already do about risk.

Practical questions

How well do you understand the characteristics of different groups within the general public? How well do different groups understand risks and what factors influence their ability to take action?   What challenges do they face in everyday life and what are their priorities? What scope do they have for long-term planning? Who do they feel is responsible for risk reduction?

What to communicate?

What you communicate will depend on the precise change you want to make among the target audience and how you think that change will happen. Prompting change will require more than information about what the risks are and what to do about them. People may require a shift in mindset, encouragement, discussion or support reaching a decision before they can take meaningful action. Thorough research and analysis is required to understand what action is required and why people are not currently taking that action.

Practical questions

What are the impacts of risks at household and local levels? (Don’t assume you have a full picture of these without consultation.) What are the biggest barriers to change for your target audience at the household and community levels? What small changes can be made to facilitate bigger changes? How can communication support these changes?

How to communicate about risk?

Communication should be woven throughout disaster management strategies to increase the reach and impact of the overall effort. Communication strategies should consider the following approaches:

- **Rely on research**
  Throughout the initiative, audience research should inform every step of your communication plan to ensure that you understand different groups and their needs and that you connect in a way that appeals to them. Monitoring and evaluation research will confirm if your initiative is having the effect that you intended and can convey the results you’ve achieved.

  Practical questions
  Have you invested sufficient resources to understand your audiences, to inform them about all aspects of your communication plan and to measure the results? Is your monitoring and evaluation approach effectively assessing impacts for the most marginalized?

- **Select the right media and communication platforms**
  Your choice of media and communication should be led by what your target audience uses and trusts and what you are trying to achieve. For example, social media may be an effective way to engage a younger, urban audience, whereas radio may be a good way to reach rural listeners with limited resources. Ideally, you will choose multiple methods to create a "360-degree" experience for your target audience, with an emphasis on enabling two-way flows of information.
  Media and communication channels may include print, radio, television, online, phone and face-to-face communication. The formats of each of those channels may vary widely – from drama to discussion or text messages (SMS) to public-service announcements. Other visual and audio devices may be used in early warning systems, such as flags, flashing lights, bells, drums and loudspeakers.
  Many of these channels and formats have the potential of offering two-way communication – from phone-in radio programmes to TV talk shows to social media. Discussion groups organized around media outputs offer additional possibilities for dialogue within communities.

  Practical questions
  What media and communication methods do specific target audiences use? For what purposes? When? With whom? Which people or channels do they trust the most? On what issues? How does that vary among different groups? What change are you trying to make? How can a combination of different media and communication activities support ongoing dialogue with the target audience and contribute to positive change? The communication infrastructure itself must be resilient. Can it withstand physical shocks and stresses and continue functioning during severe events?

- **Make it clear, relevant, engaging and practical**
  Too often, communication falls flat, contributing to the perception that risk reduction is either too scary to think about or too boring to deal with. Effective communication takes complex technical issues and conveys them in a clear and simple manner that is immediately relevant to the target audience. Effective initiatives will also be engaging and motivating; with practical, doable actions people can take to reduce their own risk.

  Practical questions
  What capacity exists to communicate about risk in a truly engaging way that appeals to target audiences? Are risk experts able to express themselves clearly and convincingly to the general public? Are local media outlets able to create engaging, accurate programming around risk that supports people to make informed decisions and take action?

- **Get people talking**

  People directly affected by risks have extremely valuable understanding about the potential impacts and how the risks could be addressed. From the outset, it is vital to communicate with the groups at risk to ensure a joint understanding of the risks and how they can best be addressed at all levels.

  Media can encourage"on-air"discussion among populations to amplify conversations, including discussion with officials to help ensure the actions being taken by the public and the government complement and reinforce each other to reduce disaster risk. It goes without saying that that scientists, decision makers and other risk professionals should engage in these conversations and respond to input from the general public.

  Media and communication initiatives can also encourage "off-air"conversations among people about risk and what they can do at home and within their communities to reduce it.

  Risk information from those at risk and from experts and decision makers is generated and shared in a complex and dynamic environment. Consider how information is produced, distributed, understood and influenced. When information flows through dynamic systems, it is often transformed by those who can either validate and amplify it or, if it comes from certain actors and sources, disqualify it.

  Practical questions

  To what extent do people talk about risk in an informed way? Who is engaged in those conversations? How could that dialogue be expanded to include more information and to reach more people? What resources are needed to support people to make decisions based on these conversations?

  Are information flows two-way? Are there channels for the development of risk information (scientific and technical) to be regularly informed by the concerns, impacts and understanding of those directly impacted? What skills do risk experts, officials and media professionals have to communicate effectively with the general public? How does the information ecosystem work during"normal"times? To what extent can reliable information flow through trusted channels effectively?

- **Work with others**

  Collaborating with multiple stakeholders more systematically can strengthen risk communication. Building relationships among professionals from media, science, government, the private sector and civil society can result in more effective communication and more sustainable platforms. Collaboration between national and local governments is always important to ensure that the information flows from officials to the public are consistent.

- ***Practical questions***
  Which other actors could improve the effectiveness of your risk communication? Who understands the interests and priorities of the audience and communicates in a way they will understand and trust? Who needs to listen to the public's perception and information about risks – including scientists, leaders, decision makers and members of other communities? How can you work with them systematically?

Box 1
Examples of government portals communicating risk with the general public

Armenia - Emergency Channel www.emergency.am/en/index

Australia (Queensland) - Get Ready https://getready.qld.gov.au/
Practical advice on how to reduce risk with the option of receiving localised information, with a focus on connecting local communities.

Canada - Get prepared www.getprepared.gc.ca/index-eng.aspx
Information on how to reduce risk.

Fiji - National Disaster Management Office www.ndmo.gov.fj/
Information on how to reduce risk and updates on current emergencies.

New Zealand - Get Thru www.getthru.govt.nz/
Information on how to reduce risk and what do to during an emergency, including a list of radio stations to listen to.

United Kingdom - Preparing for Emergencies
www.gov.uk/government/publications/preparing-for-emergencies/preparing-for-emergencies
Information on how to prepare for emergencies, including guidelines for community groups.

United States - Ready www.ready.gov/
Information on how to reduce risk, tailored to local hazards for residents in different parts of the country.

Resources for further information

- Twigg, John. Disaster Risk Reduction (revised 2015 edition). Chapter 10.1: Communications, information, education. Humanitarian Practice Network. Overseas Development Institute.
  http://goodpracticereview.org/9/communications-information-education/introduction/

- Organisation for Economic Co-operation and Development. Trends in Risk Communication Policies and Practices.
  www.oecdbookshop.org/en/browse/title-detail/?k=5JLWJ070RC32&cur=EUR&cid=

- Through a Different Lens: Behind Every Effect, There is a Cause. A guide for journalists covering disaster risk reduction. www.unisdr.org/files/20108_mediabook.pdf

- BBC Media Action (2014). Resilience and humanitarian response.
  www.bbc.co.uk/mediaaction/publications-and-resources/brochures/asia/bangladesh/resilience-and-humanitarian-response-2014

- Risk Communication and Behavior: Best practices and Research Findings (2016). NOAA Social Science Committee.
  www.performance.noaa.gov/wp-content/uploads/Risk-Communication-and-Behavior-Best-Practices-and-Research-Findings-July-2016.pdf

- Public Awareness and Public Education for Disaster Risk Reduction: Guide. International Federation of the Red Cross and Red Crescent.
  www.ifrc.org/Global/Photos/Secretariat/201610/302200-Public awareness DDR guide-EN_LR.pdf
  Key messages: www.ifrc.org/Global/Photos/Secretariat/201610/English.pdf

Author

Lisa Robinson (BBC Media Action)

Contributors and reviewers:

Mark Harvey (Resurgence), Sahar Safaie (UNISDR), Marjorie Sotofranco at IFRC, Ellis Hazendonk (Communication unit of the national crisis centre of the Netherlands)

B. Why Invest in Probabilistic Risk Assessment?

Key words:

probabilistic, stochastic deterministic, scenario, uncertainty

Background to probabilistic models

Policy and investment decisions for managing disaster risk rely on a sound knowledge of the risks. During the past decade, substantial progress has been made across the world in improving tools for hazard and risk assessment and producing risk information at different levels and on different scales. Much of this information exists in the form of probabilistic models and risk data that originated in the insurance sector in response to disasters in the late 1980s and early 1990s, which were costly in terms of insurance and economic losses.

Since then, probabilistic models have become a staple tool for facilitating better risk management in (re)insurance and are increasingly forming the basis for comprehensive risk-management strategies in civil society, government and the private sector – ultimately enabling risk reduction, risk adaptation and risk transfer mechanisms to be assessed individually and together as part of a holistic approach

Probabilistic risk modelling provides estimates of risk in terms of numbers of people affected and value of losses, as well as a measure of uncertainty around those estimates. A probabilistic risk model inherently includes all possible "impact scenarios" for a specific hazard and assets located in a specific geographical area (figure 1), incorporating both low-frequency and high-impact events, and high-frequency and lower-impact events. It is more sophisticated than deterministic ("scenario") modelling, which employs disaster scenarios (namely, a severe historical event or a "worst-case" scenario) to communicate risk in terms of the damage or loss that could result if the disaster occurred.

Probabilistic approaches are used to communicate risk in terms of the likelihood of an event and an associated severe impact occurring. To do this, probabilistic models use a large number of events that, as far as possible, represent the full range of events that might occur over a time frame of thousands of years. Typically, this will be tens of thousands of possible events, each with different permutations of event characteristics (e.g. wind speed, pressure and track direction for cyclones). These events are used to build "exceedance curves", which highlight the level of risk for different return periods – where flood might have the highest risk over shorter time frames (high-frequency events), but earthquakes and volcanic eruptions might have the highest impact if longer time frames (low-frequency events) are considered.

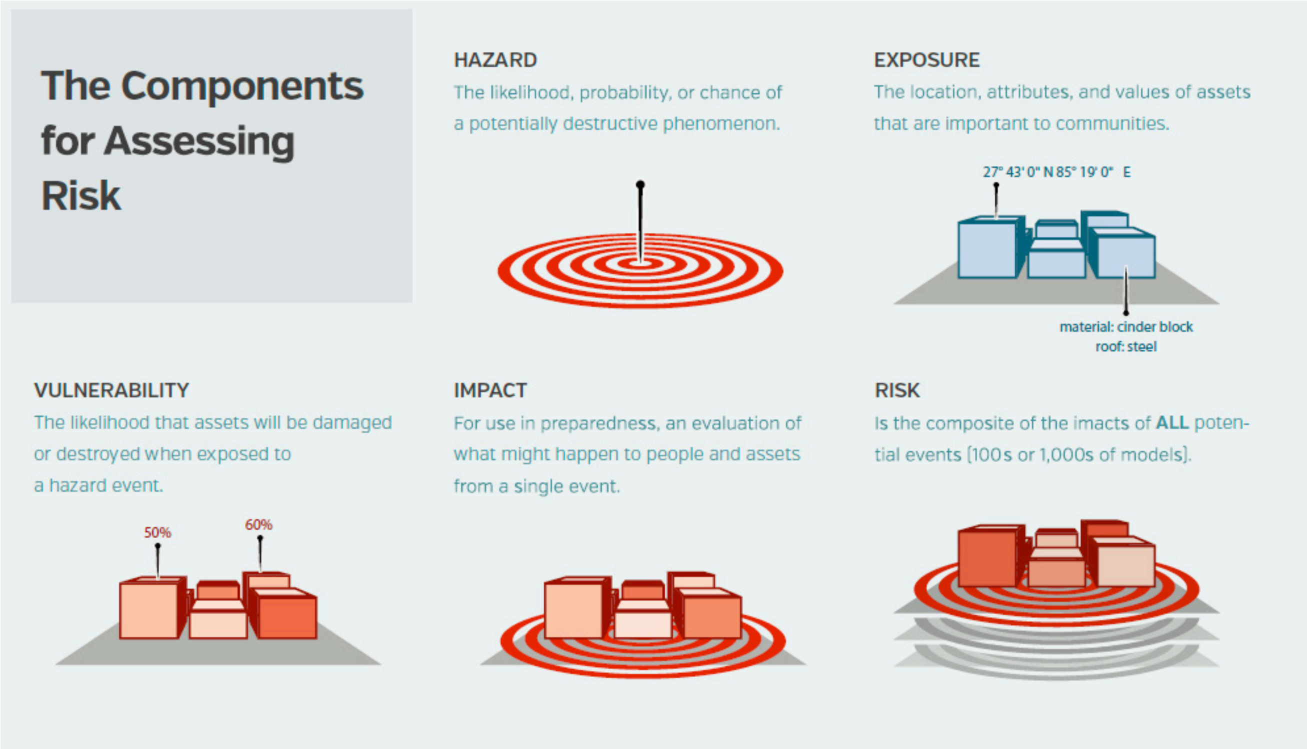


Figure 1 – Components of a risk assessment

Benefits of probabilistic modelling

Owing to the short and incomplete nature of our historical disaster catalogues (most records go back much less than 100 years and omit extreme events), we have an incomplete picture of possible events, although records from pre-history can be obtained from geological and paleoclimate archives. Figure 2 gives perspective on how limited a 100 years sample can be in giving the complete information about historical events. For most hazards, less is known about the characteristics of historical events prior to the advent of modern technological monitoring systems in the 1950s. A combination of understanding the physical drivers of the hazard in question and statistical analysis of historical observations is used to develop simulations of new events that could realistically occur but might not have done so in the recorded historical period. Each event is assigned a frequency of occurrence based on observed and science-theory-based relationships between event severity and frequency (with minor events generally occurring more frequently than severe events).

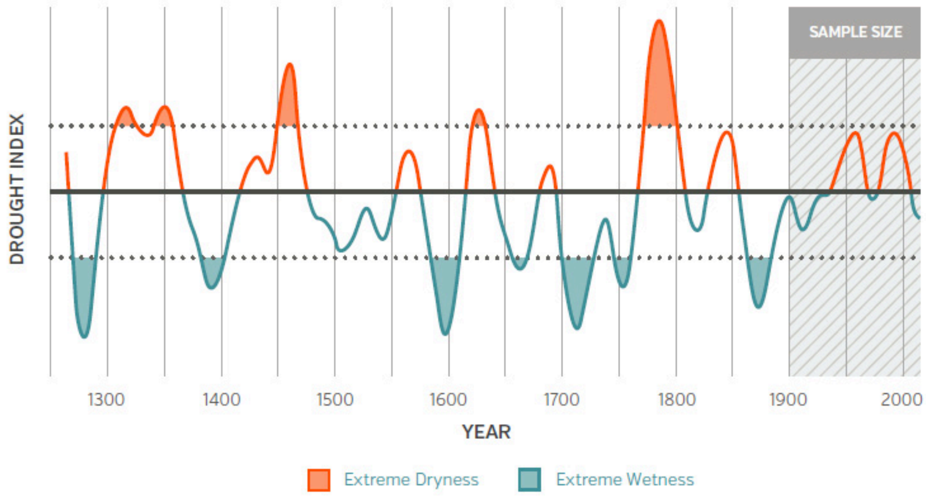


Figure 02–1
Hypothetical drought index showing periods of extreme dryness (above the dotted red line) and periods of extreme wetness (below the dotted blue line); the historical record does not capture extreme dry and wet periods experienced prior to its start in 1900.

Figure 2 – Drought index

Probabilistic models also account for uncertainty in the impact at a given location if an event occurs. This is a result of uncertainty in local intensity (e.g. how ground shaking varies from one site to another due to small-scale variations in rock or soil type) and in translating hazard intensity to damage proportion and loss, which is derived using information in the exposure and vulnerability data.

These uncertainties can arise from a combination of imperfect knowledge of the physical environment, the choice of model methodology, and other scientific and engineering factors.

The quantification of risk across a range of time horizons, enabling loss potential to be assessed in terms of its frequency, is a vital basis for decision-making in DRM/DRR, where both the frequency and severity of loss influence the choice of a mitigation strategy. Probabilistic models are important in providing evidence and informing risk reduction strategies and tools by assessing the extent of structural and infrastructure damage, population affected, and loss of income, etc. due to all possible hazards, at various time horizons.

This assessment forms the evidence base for the following DRM strategies:

- Assessing the vulnerability of a certain sector or geography to different natural hazards over different time periods. For example, it is possible to assess the overall risk profile of a country driven by frequent flood events, droughts, or rarer but potentially more costly and damaging earthquakes. Is the north of a country more at risk than the south? Is the education sector more vulnerable to flood than the transport sector? Probabilistic risk analysis can also enable a government to compare disaster risks alongside other risks (e.g. currency, cyber security risk).
- Identifying assets that are exposed to different hazards. For example,

which schools in a country are more vulnerable to earthquakes or flood?

- Identifying building types that are most vulnerable and drivers of risk. For example, which building type (steel, reinforced concrete, or unreinforced masonry, low rise or high rise) in residential housing stock is causing the highest loss of life and number of injuries in earthquakes? Where should a government invest its limited resources to get the greatest reduction in risk?
- Assessing the impact of climate change on risk levels in the future by modelling the impact of different climate change scenarios on hydrometeorological hazards or sea-level rise. For example, how will the frequency and severity of floods in a certain flood plain increase due to climate change and what are the consequences for flood protection design?
- Assessing socioeconomic factors of risk to estimate how risk is changing into the future – such as the extent to which urbanization is contributing to a growth in risk and how urban planning and building design can reduce this growth rate.
- Sovereign disaster risk financing:
    - Estimate the potential loss (and therefore impact on budget) due to multiple risks, and how this can be used in developing risk transfer strategies
      (e.g. insurance pools, bonds, reinsurance).
- Cost benefit analysis, e.g.:
    - Assessing the cost of building river flood defences (over the river defence design lifetime) versus the value of avoided losses, in terms of people and socioeconomic impacts.
    - Estimating the benefit of a structural "retrofit" programme (in both social and economic terms) on collapse rate of buildings in a city as the result of earthquakes of different frequency and severity.
    - Assigning hazard prone land to mixed light recreational use such as sporting, or for natural habitat creation rather than allowing urban development.

Availability of probabilistic models

Probabilistic models are widely available for earthquake, tropical cyclones and windstorms, tornado, hail, and flood – especially in developed countries. There are a growing number of such models in other regions too, as more models on national to global scales are being generated by governments and intergovernmental organizations.

Probabilistic drought, tsunami, landslide and volcano models are not as widely available, but progress is being made rapidly. In recent years there has been growth in open-source probabilistic risk modelling, as there is now recognition that openly available and interoperable source data, hazard and exposure data sets, vulnerability relationships, model components and risk models can provide efficiency gains in utilizing modelling for DRR.

Probabilistic modelling for national disaster risk assessment

Probabilistic modelling should be incorporated into national risk assessment where a quantitative assessment of risk is required to inform the DRR dialogue and risk reduction measures, such as land-use planning, risk mitigation initiatives and risk financing. It is vital to define the scope and scale of the risk assessment at the beginning of the process in conjunction with end-users, to ensure that risk outputs align with user requirements.

Scoping should determine the exposure types and hazards to be analysed, and the detail of analysis required to meet users' needs. It should also determine the requirement for assessing future risk, which can guide long-term investment and planning in areas subject to climate- and socioeconomic-induced changes in risk. These factors heavily influence the staff, technical resources and costs of the assessment process.

Developing a probabilistic model is a multi-stakeholder process. Data development can benefit from access to local data and knowledge of exposure characteristics and vulnerability relationships specific to the study area. Development of the input data for each model component is a key part of building risk models and requires topic-specific expertise, including population distribution modelling, geophysics and hydrometeorology, and structural engineering.

Data acquisition being an intensive exercise, crowdsourcing can be a useful strategy, and in some cases remote development of exposure data sets can be done using remote sensing techniques combined with openly available data for validation. An important part of the risk assessment process is the adequate communication of outputs, ensuring that the risk information can be used sustainably and for the purposes for which it was designed.

In summary, probabilistic risk modelling enables a wide range of evidence-based decision-making, allows the decision maker to evaluate risks in both the short and the long term, including uncertainty. It also enables the estimation of the likelihood of extreme events that have not happened in recent history, or that are becoming more likely because of climate change. However, as this approach can be resource intensive, it typically requires strong collaboration and cooperation between private, academic and public institutions to ensure trustworthy and robust results, reflecting local data and knowledge, and that can be regularly updated as new data become available or as conditions change.

It is therefore important for countries to invest in the following over the long term:

- Improving the collection of, access to and quality of fundamental hazard and risk data and observations.
- Deepening and expanding the capacity of experts to design, implement, understand and use probabilistic risk models (often through postgraduate training).
- Clarifying institutional arrangements for the design, development, communication and long-term maintenance of risk data and information.

CASE STUDY

Box 1 - Probabilistic risk assessment: case studies Afghanistan, Peru, Turkey, Pacific Islands, Netherlands

Afghanistan

National risk profile

After years of conflict and under-investment in development, the Government is taking an evidence-based approach to disaster and climate-proof development and reconstruction. With support from GFDRR and the Government of Japan, and in partnership with the World Bank, in May 2017 the Afghanistan National Disaster Management Authority launched a fully open and probabilistic risk assessment that considers the risk from earthquake, flood, avalanche, drought and landslide under current climate and socioeconomic conditions.

This assessment highlighted the greatest risk – with flood expected to cause annual average damage of US$ 54 million, and with rarer events causing over US$ 500 million in damage. Similarly, it highlighted the 3 million people exposed to landslide, the 2 million people exposed to avalanche, and the 6.5 million people affected by drought in the last 20 years.

Beyond highlighting the risk – by undertaking probabilistic risk analysis – the study made concrete recommendations based on cost-benefit analysis. For example, improvements in flood protection in Kabul could reduce flood damage by US$ 600,000 per year, and retrofitting schools for earthquake could reduce fatalities by 90 per cent and economic losses by 60 per cent. Similarly, retention structures, concrete galleries and early warning systems could substantially reduce the impacts on the 10,000 km of roads in Afghanistan exposed to avalanche, including the critical Salang Pass.

Peru

Understanding seismic risk to schools in Lima

The Ministry of Education, in partnership with the World Bank and GFDRR, is working mitigate against damage, protect students against the impact of earthquakes, and safeguard educational development. A probabilistic seismic risk assessment was conducted by the World Bank, focusing on 1,969 schools in the Lima Metropolitan Area.

According to the assessment, only 8 per cent of schools complied with seismic resistance design codes, and 64 per cent of schools were highly vulnerable to earthquakes, leaving 600,000 children at risk. Based on these results, the Government has introduced a national school infrastructure plan focused on improving the amenity of school infrastructure and on reducing potential seismic vulnerability for the 252 most vulnerable school facilities, with an estimated US$ 17 million investment.

Turkey

Reducing seismic risk to public buildings

Turkey has substantial seismic risk and vulnerable building stock. A seismic risk analysis in 2002 suggested that in earthquakes of magnitude 6.9 to 7.7, some 7-8 per cent of buildings would be heavily damaged, 87,000 people could be killed, and 135,000 severely injured. Istanbul’s schools, hospitals and other public buildings had high potential for collapse.

The assessment recommended urgent review and retrofits of 635 hospitals and 2,000 schools, and the creation of a disaster management centre and educational programmes to raise awareness.

In 2012 the Istanbul Metropolitan Municipality and the Government of Turkey used these recommendations as a basis for the Istanbul Seismic Risk Mitigation and Emergency Preparedness Project (ISMEP). The project has improved seismic resilience in Istanbul through better emergency preparedness, reduced risk at over 700 public facilities and made improvements in building code enforcement.

CASE STUDY

Pacific Islands

Pacific Catastrophe Risk Assessment and Financing Initiative

The Pacific Islands are extremely exposed to multiple natural hazards. With rising populations, increasing urbanization and changes in climate, the impact of these hazards is growing. In 2007, the World Bank created the Pacific Catastrophe Risk Assessment and Financing Initiative to develop disaster risk assessment tools and practical technical and financial applications to reduce and mitigate the vulnerability of Pacific Island countries to natural disasters.

The largest regional collection of geospatial information on disaster risks was created for 15 Pacific Island countries and is hosted by the Pacific Islands Applied Geoscience Commission. It comprises the following four databases:

- Historical tropical cyclones and earthquakes (hazard database)
- Accumulated losses (consequence database)
- Assets (exposure database)
- Modelled probabilistic losses.

Catastrophe risk profiles were developed, quantifying economic losses caused by earthquakes and tropical cyclones. This analysis determined that the average annual loss caused by natural hazards across the 15 countries is about US$ 284 million, or 1.7 per cent of regional gross domestic product (GDP). Vanuatu, Niue and Tonga experience the largest average annual losses, equivalent respectively to 6.6 per cent, 5.5 per cent and 4.4 per cent of their national GDP.

The analysis also found that in a given year, there is a 2 per cent chance that the Pacific region will experience disaster losses in excess of US$ 1.3 billion from tropical cyclones and earthquakes. Not only did this effort quantify risk on a regional basis in the Pacific for the first time, benefitting DRM and development planning, it also led to the establishment of a regional catastrophe risk pool (Pacific Catastrophe Risk Insurance Pool). This pool facilitates risk transfer between member countries and pays claims rapidly on a parametric trigger basis, such as cyclone intensity.

Netherlands

Flood risk protection

The Netherlands is vulnerable to flooding from the sea and from large rivers, such as the river Rhine. Dikes have been built throughout the ages to control the risk of flooding, often in response to a flood disaster. After the 1953 floods, standards for flood protection were introduced. These standards were partly based on an economic optimization of investment costs and the benefits of damage reduction.

As the standards were in need of updating, taking into account newest insights into flood probability, vulnerability of infrastructure and loss of life, new standards were developed based on a cost-benefit analysis that used a variety of models to determine an optimal investment strategy for dike reinforcements.

This strategy minimizes the discounted investment cost and residual flood damages over a long time horizon. The impacts of economic growth and climate change on flood risk are taken into account. The cost-benefit analysis uses information on flood probabilities, flood consequences and the costs of investments in dike reinforcement. The consequences consist not only of direct flood damages but also of an estimate of immaterial damages such as loss of life and indirect damages.

This was the first and most complete analysis to determine economically efficient flood protection standards in the world and included all areas in the Netherlands exposed to flooding. It provided policy makers not only with the expected economically efficient flood protection standard, but also with confidence intervals around those economically optimal standards.

The main conclusion from the cost-benefit analysis was that from an economic point of view, the current safety standards for the coastal areas (1/4.000 to 1/10.000 per year) are sufficiently high and that the safety standards for dikes along the major rivers (1/1250 to 1/2000 per year) should be increased. These standards were accepted and confirmed by parliament and became operational as of 1 January 2017. To reach the new standards, an initial amount for investment is needed of more than 5 billion of euros in the period up to 2028.

Terminology

Probability: likelihood of an event occurring compared to all the possible events that might occur. The exceedance probability is the likelihood of one event of a given intensity occurring or being exceeded within a defined time span.

Frequency: expected number of times that a particular event occurs in a defined time span. In theory, the frequency should equal the inverse of the probability of occurrence for any certain time frame.

Return period: average frequency with which a particular event is expected to occur. It is usually expressed in years, such as 1 in X number of years. This does not mean that an event will occur once every X numbers of years, but is another way of expressing the exceedance probability: A 1 in 200 years event has 0.5% chance to occur or be exceeded every year.

Probabilistic Risk Assessment: Uses a combination of probabilistic hazard scenarios, exposure and vulnerability, which is produced through modelling. Unlike historical estimates, probabilistic risk assessment takes into account all the disasters that could occur in the future, including extreme losses over long time horizons (and with long return periods), and thus overcomes the limitations associated with estimates derived from limited historical disaster data.

Loss Exceedance Probability (EP) Curve: Is a graphical representation of probability that a certain level of loss will be exceeded over a future time period.

Annual Average Loss (AAL): The long-term expected loss per year, averaged over many years. While there may be little or no losses, over a short period of time, the AAL accounts for 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's occurrence.

Probable Maximum Loss (PML), or loss expected at a certain annual probability or return period: is 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 PML is always accompanied by the return period associated with the loss.

The PML for different return periods can therefore be expressed as the probability of a given loss amount being exceeded over different periods of time. Thus, even in the case of a 1,000 year return period, there is still a 5% probability of a PML being exceeded over a 50-year time frame.

Resources for further information

International communities of practice focused on probabilistic modelling of various hazards:

- Global Earthquake Model: globalquakemodel.org
- Global Volcano Model: globalvolcanomodel.org
- Global Tsunami Model: http://globaltsunamimodel.rm.ingv.it/
- Global Flood Partnership: http://portal.gdacs.org/Global-Flood-Partnership
- Global Landslide Model: https://pmm.nasa.gov/applications/global-landslide-model
- Understanding Risk: www.understandrisk.org

Other substantial peer-reviewed guidelines

- GFDRR (2016). The Making of a Riskier Future: How our Decisions are Shaping Future Disaster Risk. www.gfdrr.org/sites/default/files/publication/Riskier Future.pdf
- GFDRR (2014). Understanding Risk in an Evolving World. Emerging Best Practices in Natural Disaster Risk Assessment. www.gfdrr.org/understanding-risk-evolving-world-emerging-best-practices-natural-disaster-risk-assessment
- GFDRR (2014). Understanding Risk – Review of Open Source and Open Access Software Packages Available to Quantify Risk from Natural Hazards. www.gfdrr.org/understanding-risk-review-open-source-and-open-access-software-packages-available-quantify-risk.
- United States Environmental Protection Agency (2014). Probabilistic risk assessment to inform decision making: Frequently asked questions. www.epa.gov/sites/production/files/2014-11/documents/raf-pra-faq-final.pdf
- United States Department of Energy (2013). Development of Probabilistic Risk Assessment for Nuclear Safety Applications. www.standards.doe.gov/standards-documents/1200/1628-2013/@@images/file
- United States Environmental Protection Agency (2009). Probabilistic Risk Assessment White Paper and Supporting Documents. www.epa.gov/osa/probabilistic-risk-assessment-white-paper-and-supporting-documents
- CAPRA Probabilistic Risk Assessment Platform. Documents. www.ecapra.org/documents

Authors:

Alanna Simpson (GFDRR), Stuart Fraser (GFDRR)

Contributors and Peer Reviewers:

ahar Safaie (UNISDR), Kelvin Berryman (Institute of Geological and Nuclear Science), Claire Souch (AWHA Consulting), Cees van de Guchte (Deltares), Mark de Bel (Deltares), Ferdinand Diermanse (Deltares)

BOX 2.

Global Facility for Disaster Risk Reduction has been supporting many countries in conducting national hazard and risk assessments that have incorporated probabilistic modelling. Below are few examples:

- Dozens of case studies included in publication: GFDRR. 2014. Understanding Risk in an Evolving World. Emerging Best Practices in Natural Disaster Risk Assessment. www.gfdrr.org/understanding-risk-evolving-world-emerging-best-practices-natural-disaster-risk-assessment
- A detailed disaster risk assessment for Afghanistan has been published highlighting the risk from drought, river flood, landslide, avalanche and earthquake annually (average annual loss) and for different return periods under current and future socioeconomic and climate conditions www.gfdrr.org/sites/default/files/publication/drp_afghanistan.pdf
- South West Indian Ocean Country Risk Profiles www.gfdrr.org/disaster-risk-profiles
- Rwanda Risk Atlas http://midimar.gov.rw/uploads/tx_download/National_Risk_Atlas_of_Rwanda_electronic_version.pdf

C. Cross-Sectoral and Multi-Risk Approach to Cascading Disasters

Key words:
cascading risk, cascading disasters, cascading effect

An introduction to cascading risk and cascading disasters

From utilities to the internet, over the last two decades technological networks have increased in interdependency and level of integration with society. They have also become more unstable and their behaviour has become harder to predict. Critical infrastructure (CI) is defined as those assets or systems that are vital to maintaining the socioeconomic functions of society. It is also an essential pillar that supports the provisions of the Sendai Framework for Disaster Risk Reduction.

CI can be conceptualized as nodes in the built environment that group together physical, functional and organizational attributes. With the increased complexity of the built environment, the definitions and sectors have evolved in concert with one another. They incorporate lifelines for the delivery of resources and services, essential sites for communities, and assets such as chemical plants, which are potentially vulnerable to hazards.

A causal chain generates secondary disasters from the interaction between anthropogenic and ecological systems. Despite major efforts by the international community, many challenges are still present in efforts to mitigate such phenomena. For example, current risk management strategies are insufficient for estimating the probability of rare events and coincidences, and for understanding cascades and event trees[1]. To improve the operational management of complexity, a system-wide approach to resilience is needed that embraces new forms of analysis, new methods and new tools[2]. Cascading disasters and risks present substantial challenges both to citizens and to the emergency management community.

The emerging nature of the field implies that for a long time it has remained ill-defined, and only recently has there been substantial investment by the European Commission, in the form of the Seventh Framework Programme and Horizon 2020 projects, which have enabled concept and practices to be defined better.

Starting from the idea that cascades could be modelled as a dendritic structure of evolving secondary events[3], it has been suggested that cascading disasters reveal complex risks, where the effects of primary triggers are

1 Helbing, D. (2013). Globally networked risks and how to respond. *Nature* 497 (7447), pp. 51-59.

2 Linkov, I. and others (2014). Changing the resilience paradigm. *Nature Climate Change* 4, pp. 407-409.

3 May, F. (2007). Cascading disaster models in postburn flash flood in: Butler, B.W. and Cook W. The fire environment – innovations, management and policy. Conference Proceedings. Washington, D.C. Department of Agriculture Forest Service, pp. 446–463.

amplified by the non-linear progression of the crisis over time[4]. In other words, the consequences of the initial or trigger impact become the primary sources of further crises, which, instead of decreasing as time progresses, become larger and require more resources to bring them under control.

The primary effects of the physical trigger are amplified by the disruption of entire sectors of critical infrastructure, such as air transportation and energy supply, and often by the hazardous components of CI, such as nuclear plants. The path of cause and effect exploits vulnerabilities that accumulate on different scales. They are manifest in unexpected events that escalate into full-blown cross-sectoral disasters. The vulnerabilities can be accumulated in macroscopic dynamics, such as the technological drivers of globalization, or micro dynamics such as local CI management or decision-making for land-use control.

As cascades are different from other topics analysed in the literature, new instruments are needed to mitigate them. This is because sectors of CI influence each other. For example, losses in the energy sector can disrupt the water sector, which depends on electricity for pumping and other functions. The connections are complex and dynamic. Similarly, cascades differ from compound disasters, because the latter are more focused on the concurrent and combined nature of climate extremes, such as flooding that occurs during a cold wave or heat waves that contribute to wildfires[5].

What is particularly needed to address cascading risk is to create scenarios, tools and information that could join the triggers with their patterns of consequences and thus help visualize the potential structure of secondary emergencies. The following examples will clarify the most salient issues for national risk assessments

Examples of cascading risks and disasters

The literature on critical infrastructure has analysed many examples of cascades in areas defined by high concentrations of technology, such as the energy shortage that followed Hurricane Sandy in 2012 in the United States, and the distributed effects of the 2015 floods in York, in the United Kingdom. Much less evidence has been provided for developing countries.

In 2007, Cyclone Sidr struck the south-west coast of Bangladesh – with 240 km/hr winds and a six-metre storm surge. Water and sanitation infrastructure

[4] Pescaroli, G. and D. Alexander (2015). A definition of cascading disasters and cascading effects: going beyond the"toppling dominos"metaphor. Planet@Risk, Global Forum Davos. 3(1), pp. 58-67.

[5] Intergovernmental Panel on Climate Change (2012). Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

was heavily damaged, including 11,612 tube wells, 7,155 ponds, and over 55,000 latrines. As human waste was generally not treated, waterborne diseases became a major public health concern. In many communities, drinking-water sources (tube wells and ponds) were contaminated with salt water and debris[6]. Further research is needed to understand how the specific needs and strategies at the local level can affect broader strategies for mitigating cascades.

Box 1
Eruption of Eyjafjallajökull volcano

The eruption of the Icelandic volcano Eyjafjallajökull in April 2010 is one of the events that have raised the tone of the debate about cascading risks. Although its direct physical damages were limited, it released an ash cloud that temporarily stranded 8.5 million airline passengers.

This disruption of the aviation sector became the main vector of the crisis. It highlighted the dependency of modern society upon functioning global networks. The temporary cessation of civil aviation increased the pressure on other forms of transportation, revealing its fundamental role in ordinary activities, from the delivery of perishable goods to air freight transportation of medical supplies, including organs for transplant.

Despite many precursors, volcanic ash clouds were not considered in the risk registers of countries that were involved in the 2010 crisis, such as the United Kingdom. One wonders what other, unconsidered triggers could cause high levels of disruption to critical infrastructure.

Box 2
Tōhoku earthquake

The triple disaster in Japan that started with the Tōhoku earthquake of 11 March 2011 had serious consequences in term of loss of life and long-term impacts on the environment. The consequences also included a boost to the worldwide debate on nuclear safety. Although only about 100 people died as a direct result of the primary trigger, the earthquake, about 18,000 were killed by the ensuing tsunami, and there was uncertainty about the consequences of the radioactive contamination resulting from the Fukushima Dai'ichi nuclear meltdowns.

The interaction between natural and technological hazards was amplified by local vulnerabilities, and the Fukushima nuclear accident was considered "a profoundly man-made disaster – that could and should have been foreseen and prevented" . Other critical infrastructure in the affected area was broadly compromised, which constrained efforts to contain the cascading effects of the primary disruption. This prompted the creation of new data sets to improve deployment in secondary disasters.

6 Jha, Abhas K., T.W Miner and Z. Stanton-Geddes, eds. (2013). *Building Urban Resilience: Principles, Tools, and Practice.* Washington: World Bank.

Implications of cascading risk and disasters for national risk assessments

Cascading risk and cascading disasters have serious implications for national risk assessment processes. It is vital not only to understand and assess cascades in critical infrastructure but also to know how to stop cascades from escalating. To address the possible impact of disruption, the United Kingdom and the United States ranked elements of CI according to their importance.[7] [8] The Netherlands uses an area-based approach, which enables the interdependencies of critical infrastructure elements to be mapped and assessed[9]. International work has striven to address the relationship between CI and society. When Peru estimated the resources that are essential to emergency response and recovery if an earthquake or tsunami were to strike the metropolitan areas of Lima and Callao, a high likelihood of poor functioning or paralysis of vital services was identified. This required new maps to be produced and alternative supply routes to be planned[10].

However, there is still no coherent and fully coordinated approach that responds properly to the provisions of the Sendai Framework for DRR. Risk maps that include the loss of CI and the impact of this loss are generally unavailable or lack uniformity. In Europe, natural and technological hazards tend to be separated or overlain without an accompanying context[11]. Even when risk registers and national strategies are implemented, the tendency is to focus heavily on the impacts that are deemed most likely to happen, not on those with the most complex consequences.

New strategies have been employed to address cascading failures, increase resilience and share information on possible common paths for the disruption of infrastructure. First, in recent years constant technological and scientific progress has led to cross-domain modelling of interdependent systems and economic impact assessment of critical events[12].

Together with research on empirical approaches, agent-based models and

---

[7] White House (2013). Presidential Policy Directive – Critical Infrastructure Security and Resilience. Directive/PPD-21. Washington D.C.

[8] United Kingdom, Cabinet Office. Keeping the Country Running: Natural Hazards and Infrastructure. London, 2011.

[9] Ministerie van Binnenlandse Zaken en Koninkrijksrelaties (MBZK). Bescherming vitale infrastructuur (Protection of Vital Infrastructure). The Hague, 2005.

[10] National Institute of Civil Defence, Peru, and United Nations Development Programme (2011). Cooperazione Internazionale. Sistema de información geográfico y análisis de recursos esenciales para la respuesta y recuperación temprana ante la ocurrencia de un sismo y/o tsunami en el área metropolitana de Lima y Callao.

[11] De Groeve, T. ed. (2013). *Overview of Disaster Risks that the EU faces*. European Commission Joint Research Centre.

[12] Galbusera, L. and others (2016). *Inoperability Input-Output Modeling: Inventory Optimization and Resilience Estimation during Critical Events. ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems Part A. Civil Engineering 2 (3)*.

interoperability input-output models, there has been an evolution in network-based approaches that aim to describe the connections and interlinkages between nodes of critical infrastructure (Ouyang 2014). The new resources available from geospatial technologies and computational tools have been integrated into digital support tools that consider local, regional, national and international interdependencies – for example, the Geospatial Risk and Resilience Assessment Platform, which is referred to in the resource section below. It is also possible to find new methods for improving training for disaster management in complex environments, such as fault trees, root causes and wider impact-tree analysis[13].

To improve the anticipation of crises, the PANDORA project, initiated by the Government of Denmark, has developed its "forward-looking cells strategy"[14]. A key driver is to approach complexity before possible events occur, involving different stakeholders in promoting awareness, in sharing information and in planning. For example, in the United Kingdom, London Resilience has produced a general model called Anytown, which could easily be replicated in other urban environments. In the United States, the National Institute of Standards and Technology has defined a step-by-step process to integrate buildings and infrastructure systems into community resilience (see resources section below).

A complementary approach suggests that the paths of cascades can be understood in advance of the triggering events by identifying sensitive nodes that generate secondary events and rapidly scale up a crisis. Risk scenarios based on hazard can be integrated with corresponding vulnerability scenarios based on escalation points that could be used to represent unknown triggers[15].

This approach was tested with two different studies. First, empirical comparisons showed that the disruption of critical infrastructure can orient international relief in terms of the goods and expertise needed in the emergency phase. Priorities can change as the cascade evolves, secondary emergencies escalate and new data sets are required for the optimization of deployment[16]. Secondly, the technological motivations of CI disruption can raise the emergency to larger geographical and temporal scales, which have not yet been included in legislation on cross-border and cross-sectoral

---

[13] MacFarlane, R. (2015). Decision support tools for risk, emergency, and crisis management: an overview and aide Memoire. Emergency Planning College Position Paper 1.

[14] Danish Emergency Management Agency (DEMA) (2016). PANDORA Forward Looking Cell. Birkerød: DEMA.

[15] Pescaroli G. and D. Alexander (2016). Critical infrastructure, panarchies and the vulnerability paths of cascading disasters. *Natural Hazards 82(1).* pp.175-192.

[16] Pescaroli, G. and I. Kelman (2016). How critical infrastructure orients international relief in cascading disasters. Journal of Contingencies and Crisis Management, vol. 25, issue 2, pp. 56-67.

crises[17]. Knowledge of such cases could be improved with multi-level scenarios based upon vulnerability frameworks that are already available[18]. Distributed systems characterized by modular design and digital technologies could be used to increase the resilience of communities and emergency services.

The involvement of emergency managers, associations and representatives of the business community could help determine which consequences of a disaster could become the principal drivers of cascades. A practical example illustrates this point. Europe's biggest training event to date ("Exercise Unified Response", www.london-fire.gov.uk) took place in London in February 2016. The exercise lasted four days and simulated a building that collapsed onto an underground railway station, with over 1,000 casualties. It involved all the major authorities in London and special rescue teams from Hungary, Italy and Cyprus.

Although the consequences of a loss of transportation for London were considered, promoting a wider focus on secondary emergencies and escalation points could help to improve the strategic framework for the future, whatever the nature of the primary trigger. In an increasingly interconnected world, emergency planning needs to consider the existence of intersectoral factors and identify the less evident connections that could modify the need for assistance and coordination[19].

In this sense, the International Risk Governance Council developed an approach to risk governance that could be a step forward because it integrates cascading risk into resilience-driven strategies. Of particular relevance is the application of a tiered approach that supports the assessment of resilience and its translation into applied management actions[20]. This kind of information may be critical to the work of emergency managers and the development of situational awareness tools at the operational, strategic and policy levels. This is particularly relevant for developing countries, where increasing the awareness of new strategies and support for the training of local people could make a significant difference by increasing the flexibility of response and matching it more closely to local needs.

---

17 Nones, M. and G. Pescaroli (2016). Implications of cascading effects for the EU Floods Directive. *International Journal of River Basin Management* 14(2), pp. 195-204.

18 Birkmann, J., S. Kienberger and D. Alexander (2014). *Assessment of Vulnerability to Natural Hazards: a European Perspective.* Amsterdam: Elsevier.

19 Alexander, D. (2016). *How to Write an Emergency Plan*. Edinburgh: Dunedin Academic Press.

20 Linkov, I. and C. Fox-Lent (2016). A tired approach to resilience assessment. IRGC Resource Guide on Resilience. Available from www.irgc.org/risk-governance/resilience/

Resources for further information

Various resources are available online:

The Research Group on Cascading Disasters at University College London is developing a series of guidelines written for non-academic users to improve the understanding of cascading risk. The documents and other papers are available at: www.ucl.ac.uk/rdr/cascading.

Similarly, the International Centre for Infrastructure Futures is releasing policy briefs and presentations on critical infrastructure interdependencies and societal resilience. The documents are available at: www.icif.ac.uk .

Other international sources provide information and guidance outside academia. The International Risk Governance Council produced policy recommendations on Managing and Reducing Social Vulnerabilities from Coupled Critical Infrastructures, while their Resource Guide to Resilience focuses on the governance of risks distinguished by high uncertainties. These and other reports can be downloaded free of charge at: .

Other resources and compilations of lessons learned have been produced by initiatives such as the Rockefeller Foundation's One Hundred Resilient Cities: www.100resilientcities.org.

A wide range of methods and digital tools could be used to address cascading failures. The Joint Research Centre of the European Commission created the GRRASP platform, based on open source technologies, to support the analysis of cross-sectoral interdependencies and critical infrastructure disruptions: www.ec.europa.eu/jrc/en/grrasp.

The European Commission has also funded projects on cascading effects that produced methodologies and software for modelling cascading effects, such as FORTRESS (www.fortress-project.eu), CIPRnet (www.ciprnet.eu), CascEFF (www.casceff.eu), PREDICT (www.predict-project.eu) and SnowBALL (www.snowball-project.eu). The websites of these projects have made different resources available for download, including decision-support systems and deliverables.

The interaction between cascading risk and compounding drivers can be widely explored by accessing the resources provided by the United States Climate Resilience Toolkit, which includes a catalogue of more than 200 digital tools for building resilience: www.toolkit.climate.gov.

Different resources are available in open access for supporting the training and preparedness of stakeholders. London Resilience, which acts on behalf of the Mayor of London, London's local authorities and London Fire Brigade, has developed Anytown, a conceptual model designed “to improve the understanding of infrastructure interdependencies by non-experts”. The model is generic and has been developed to be used easily in different urban contexts. This and other information can be found at www.londonprepared.gov.uk.

In the United States, the National Institute of Standards and Technology developed the Community Resilience Planning Guide for Buildings and Infrastructure Systems. The guide aims to support the prioritization and management of resources to improve preparedness and recovery by using a practical six-step process to identify the linkages and dependencies between the social dimensions and the vital services provided by infrastructure (www.nist.gov). Also on its website, the Institute provides standards and guidelines on cyber security for critical infrastructure.

Authors:

Gianluca Pescaroli and David Alexander (University College London)

Contributors and Peer Reviewers:

Igor Linkov (US Army Engineer Research and Development Center)

D. Direct and Indirect Economic Impact

Key words:
socio-economic well-being, economic vulnerability, financial risk, lifeline infrastructures

How national economic systems are organized plays a central role in determining disaster risk by shaping their exposures and vulnerabilities; economic systems are then, in turn, significantly affected when disasters strike. The well-being of people and communities is intimately linked with the economic health and functioning of the community and region where they live. Most importantly, well-being is a function of the capabilities to pursue meaningful lives, capabilities that are directly influenced by the access to gainful employment and meaningful livelihood, to the requisite incomes, health and education services, and to all other resources necessary to pursue satisfying lives. It is these capabilities that are potentially diminished by disasters.

Long-term losses

Not only direct losses matter in assessing risk to well-being. When disasters hit, damages are experienced in terms of mortality and morbidity, as well as of assets, infrastructure and the environment. Long-term access to employment and education opportunities and resources that determine well-being may also be diminished by disasters. This is particularly significant for poorer households, which do not have many, if any, assets to lose, but which as a result of disasters typically experience more health and education setbacks, employment challenges and consequently reduced income, and other hindrances.

Measuring disaster risk must therefore involve understanding the exposure and vulnerability of economic systems to shocks and their ability to rebound and recover from them (their resilience), as well as the longer-term losses associated with their occurrence.

The assessment of risks to socioeconomic well-being at the national level involves both a sectoral and geographical assessment of vulnerabilities, and an additional assessment of linkages, the availability of financial and non-financial resources for recovery, and the likely recovery trajectories and pitfalls.

Unique vulnerabilities

Unique sectoral vulnerabilities, and the interactions between the exposure of these sectors and their vulnerabilities to specific hazards, must be assessed. One needs to understand the extent to which the sectors operating in one region, for example, are exposed to a specific hazard, and how these exposed/vulnerable sectors in the affected region interact with other regions and their economic activities, thereby creating more systemic (interregional) risks.

Regional and local economies are often dominated by a few sectors, and some sectors are much more vulnerable to specific types of hazards than others. Agriculture can be directly very vulnerable to some hazards (e.g. extreme temperatures) but less, and only indirectly, to others, such as earthquakes (because of their impact on transportation and processing facilities).

Manufacturing is directly vulnerable to hazards that destroy production and storage facilities, and the required infrastructure such as electricity networks. And tourism is uniquely vulnerable to hazards that affect perceptions of safety (or lack thereof) as these are presented in the mass media. As such, any national risk assessment needs to identify the specific vulnerabilities of the main sectors and those risks facing large firms or employers in each region that is being assessed.

Of specific concern is the increased vulnerabilities faced by some populations. This is especially serious for groups that face obstacles even during the best of times, such as people with low income and assets, minority ethnic and religious groups, the disabled and other marginalized groups. Each of these demographics, further distinguished by gender, is vulnerable in unique ways, and accounting for these is important if one is to understand the likely impact of a disaster on their well-being.

Spillovers and ripple effects

An assessment of unique regional economic vulnerabilities should also examine the links between regions and how impacts in one region may spill over to other regions. Spillovers are especially likely if the sectors that are dominant involve longer supply chains, and these supply chains have blockages or lack sufficient redundancies to make them more robust to temporary cuts in some links in the chain.

For the economy to function well, lifeline infrastructure (water, electricity, transportation, communication), beyond the direct effect on well-being, is especially important. Without lifelines, even if there is no direct damage to the population, the economy – and therefore employment – will grind to a halt.

Vulnerabilities in lifelines are amplifiers for other vulnerabilities and their role should be emphasized in risk assessment. One should assess how long it would take to re-establish lifeline connections in the aftermath of a disaster, and how one can eliminate or reduce the period of disconnection.

Financial constraint to reconstruction

Beyond lifelines, the main constraint for recovery is generally financial. Risk assessment therefore also needs to consider a realistic assessment of the amount of resources that might be available during the prolonged recovery phase, and how one can plan for any necessary additional resources. Given the constraints around resources, pre-disaster planning for recovery should also assess the opportunities to use the available resources as effectively as possible.

Although financial resources are only some of the inputs needed for recovery, they have a significant impact on recovery trajectories as the inflow of timely financial resources to affected sectors, households and governments contributes to reducing the medium- and long-term consequences of disasters. Many financial resources – formal and informal – can be employed (e.g. savings, credit, assistance). Pre-event arrangements (risk financing) are, however, generally preferable, as they guarantee a timely inflow.

Many countries have set up national and regional catastrophe funds, and generally some sort of market-based insurance, at varying levels of coverage and public-sector involvement. Any comprehensive assessment of financial risk options should include an assessment of who bears and transfers which financial risks, and where these financial risks ultimately reside (domestically/offshore). Options for risk financing to consider should also include agreements with multilateral organizations to provide financial support should an event occur (e.g. contingent credit programmes) or an assessment of the amount of official development assistance that will likely be received.

Other constraints to the reconstruction

The ability to access international assets, resources and knowledge – other than financial – is equally important; especially for the emergency phase, which will involve an assessment of the kinds of assets that could be required (e.g. transportation modes for evacuations), where they are located, and how they can be made accessible. This should also include an assessment of early warning systems, as these can also be used to move economic assets out of harm’s way. For very catastrophic events, resource constraints – other than financial – may also hinder a successful recovery (e.g. skilled labour for the construction sector).

It is crucial to assess the capacity of a government to mobilize and organize resources, from whatever source, in the aftermath of a disaster. Governance and institutional capacity play a significant part in the ability of the economy to recover. Where applicable, a government should also assess its own preparedness and ability to mobilize, even in cases when some of its own assets get damaged and its employees get injured in a disaster event.

Resources for further information

Clarke, D. and S. Darcon (2016). *Dull Disasters*. Oxford: Oxford University Press.

United Nations, Economic Commission for Latin American and the Caribbean (2014). *Handbook of Disaster Assessment*.

Stephane, H. and others (2017). *Unbreakable: Building the Resilience of the Poor in the Face of Natural Disasters.* Climate Change and Development Series. Washington: World Bank.

Intergovernmental Panel on Climate Change (2012). Managing the risks of extreme events and disasters to advance climate change adaptation. Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. New York: Cambridge University Press.

Mechler R., J. Mochizuki and S. Hochrainer-Stigler (2016). Disaster risk management and fiscal policy: Narratives, tools, and evidence associated with assessing fiscal risk and building resilience. World Bank Group.

Mochizuki, J. and others (2014). Revisiting the 'disaster and development' debate – Toward a broader understanding of macroeconomic risk and resilience. *Climate Risk Management* 3, pp. 39-54.

Smith, N., C. Brown and W. Saunders (2016). Disaster risk management decision-making: review of full cost accounting of disaster risk management decisions. Resilient Organisations Research Report 2016/04.

Authors:

Ilan Noy (Victoria University of Wellington)

Contributors and Peer Reviewers:

Stephane Hallegate (World Bank), Reinhard Mechler and Junko Mochizuki (International Institute for Applied Systems Analysis)

E. Health Aspect in Disaster Risk Assessment

Key words:
public health risk assessment, health emergency risk assessment, Strategic Tool for Assessing Risks (STAR)

Public health risk assessments are carried out across the different stages of disaster risk management of prevention, preparedness, response and recovery, where diverse types of health information are needed to determine evidence-based actions for dealing with natural and man-made hazards, including biological hazards.

To ensure comprehensive multi-hazard and multisectoral National Risk Assessment (NRA) for disasters, public health risk assessments should be integrated, including exposure, vulnerability and capacity analyses, as an integrated policy approach. This is aligned with the broad scope of the Sendai Framework, which covers all types of hazards, including biological hazards.

The integration can be done through the following means:

- Identifying linkages between public health and DRR risk assessment and also the trade-offs, particularly when the two are considered in isolation.
- Defining levels of intervention in integration by strengthening the base for health risk management.
- Ensuring that health is considered by the government agencies or coordination mechanisms charged with making decisions about how a risk may be mitigated, avoided, or reduced (such as DRR national platforms and other policy or technical coordination mechanisms) so that integrated policy measures are developed, including addressing emerging needs for health for the different population groups or geographical areas.
- Ensuring that specific DRR policy measures address the potential impact of disasters of all types of hazards on health.

This section outlines the objectives, principles and types of public health risk assessments as conducted throughout the emergency risk management stages.

The public health risk assessment process

Public health risk assessment is the process of estimating the nature and probability of adverse health effects in humans who may be exposed to different hazards, including biological hazards, now or in the future.

Information used in public health risk assessments

Despite the different needs during the preparedness and response phases of disaster risk management, all forms of risk assessment use health information to determine actions to reduce the public health risk of and potential for an ongoing event.

The main question answered in such assessments refers to the potential public health impact (i.e. what is the risk related to exposure to a particular hazard in a particular location, or to a particular population at a particular time) in terms of health consequences of mortality, morbidity and disability and also refers to the health measures required to minimize this impact. Risk questions typically focus on who is likely to be affected, the likely exposure to a hazard, and when, why and how a population might be adversely affected by exposure to a hazard.

A public health risk assessment includes four basic steps leading to risk characterization:

1. **Identifying the characteristics of a hazard and its associated health consequences**
   Hazards to health can be biological, geological, hydrometeorological, technological or societal. They can include infectious, toxic or radiological agents under the International Health Regulations (IHR). Hazards can be specifically identified during the risk assessment process, but at the early stages of an actual event the specific aetiology (specific cause of disease) is often unknown.

2. **Evaluating the exposure of individuals and populations to likely hazards**
   This provides information on the number of people exposed to the hazard and the number of exposed people or groups who are likely to be susceptible (i.e. capable of getting a disease because they not immune). The information required to evaluate exposure includes the following: mode of transmission (e.g. human-to-human, droplet spread, sexual transmission, animal-to-human; occupational risk); information related to the vector (e.g. distribution, density, infectivity) and/or animal hosts (density, prevalence, existing control programmes); incubation period (known or suspected); estimation of the potential for transmission (e.g. R0 basic reproduction number); immune status of the exposed population;

Figure 1 – Public health risk assessment components

and dose and duration of exposure.

3. **Analysing the context, vulnerabilities and capacities associated with the hazard**
   The context and/or vulnerability analysis takes into account the evaluation of the environment in which the event is taking place, the underlying health characteristics of the exposed populations and the capacity of a health system to respond to a given event.
   This can include analysing the physical environment such as climate, vegetation, land use (e.g. farming, industry) and water systems and sources, as well as the health of the population (e.g. nutritional status, disease burden and previous outbreaks), infrastructure (e.g. transport links, health-care and public health infrastructure), cultural practices and beliefs.
   The information about the capacity of the health system to deal with the event can be used to determine the likelihood that events will be identified, the likelihood that events will require medical care and the likelihood of severe disease or outbreaks or a large-scale impact of natural disasters on health.
4. **Characterizing the public health impact**
   Public health impact is the estimation of the overall extent of the direct or indirect consequences of hazards on the health of a population. It relies on the understanding of all components of the risk – hazard, exposure and the context, capacities and vulnerabilities.
   All types of consequences, in addition to the expected morbidity, mortality and direct long-term health consequences of the event (e.g. disability) should be taken into consideration, including the STEEEP consequences (social, technical and scientific, economic, environmental, ethical, and policy and political).

Risk characterization

The characterization of the overall level of risk is then based on estimates of the likelihood, in combination an estimate of the public health impact. A useful tool to assist the team in this characterization is a risk matrix, which also helps to assess and document changes in risk before and after control measures are implemented.

Types of Public Health Risk Assessment

A strategic risk assessment is used to catalyse action to prevent, prepare for and reduce the level of risk associated with a particular hazard and its consequences on health.

Actions that stem from this type of risk assessment can include prioritizing limited resources towards hazards whose impact and likelihood are the greatest, identifying particularly vulnerable populations or locations, developing emergency response and contingency plans, and implementing preparedness and risk mitigation activities.

Numerous approaches exist for conducting strategic risk assessments and for prioritizing risks. One example is the Strategic Tool for Assessing Risks (STAR). The range of hazards to assess under STAR includes the health consequences of natural or human-induced emergencies, the health events covered under IHR (zoonoses, chemical, radio-nuclear, food safety) and events occurring in neighbouring countries or regions.

When an event occurs, and in order to inform early warning and response measures, the level of risk posed by the event itself is assessed on a continuous basis through a process of Rapid Risk Assessment, a systematic, consistent and interdisciplinary approach. It includes defined search strategies and the use of any pre-prepared relevant information, ensures a transparent, reproducible risk assessment, which also records available information and reasons for judgments, and documents uncertainties.

During the initial phase of acute public health events, since the hazard may be unknown, such as in emerging infectious diseases, the initial rapid risk assessment can be used to develop a differential diagnosis on the basis of the known or suspected characteristics[21]. The stages of a rapid risk assessment include preparing and collecting event information, performing structured literature search/systematically collecting information about the (potential) etiologic agent, extracting relevant evidence, appraising the evidence and estimating the risk[22].

Under IHR[23], event risk assessments[24] (the rapid collection of ad hoc information about acute public health events) also include the risk to human health, the risk of international spread of disease and the risk of interference with international travel or trade. The four decision criteria to be used by States Parties in assessing a public health event are (a) the seriousness of the event's public health impact, (b) the unusual or unexpected nature of the event, (c) the risk of international disease spread and (d) the risk that travel or trade restrictions will be imposed by other countries.

---

21 http://ecdc.europa.eu/en/publications/Publications/emerging-infectious-disease-threats-best-practices-ranking.pdf

22 http://ecdc.europa.eu/en/publications/Publications/1108_TED_Risk_Assessment_Methodology_Guidance.pdf

23 The International Health Regulations (2005) (IHR) are an international agreement that is legally binding on 194 countries (States Parties).

24 The scope of IHR is purposely broad and inclusive in respect of the public health event. It covers communicable, chemical, biological and radio-nuclear hazards.

Also under IHR, countries build their core capacities[25] to detect, report and respond to public health events, including biological, chemical and radio-nuclear hazards, and monitor their progress in doing so.

IHR capacity requirements are defined in article 5 as "the capacity to detect, assess, notify and report events". Each State Party must assess the ability of existing national structures and resources to meet the minimum requirements described in IHR, annex1. Annex 1A covers "Core capacity requirements for surveillance and response" and annex 1B covers "Core capacity requirements for designated airports, ports and ground crossings".

The core capacity monitoring framework has a checklist and indicators that are used for monitoring progress in the development of countries' IHR core capacities. As a result of such assessments, States Parties must develop and implement plans of action to ensure that these core capacities are present and functioning.

Following risk assessment, Member States use the IHR annex 2 decision instrument for the assessment and notification of events to decide whether an acute public heath event requires formal notification to the World Health Organization (WHO) and then a declaration of a public health emergency of international concern.

Recently, Joint External Evaluations (JEE)[26] have been implemented as a voluntary, collaborative and multisectoral process to assess a country's IHR capacity for ensuring health security and inform joint planning processes to increase capacity. The tool draws on the original IHR core capacities and incorporates lessons learned from other tested external assessment tools and processes that have supported the building of capacity to health threats.

The assessment tool consists of three core elements: preventing and reducing the likelihood of outbreaks and other public health hazards and events defined by IHR (2005), detecting threats early, and multisectoral, national and international coordination and communication for rapid, effective response.

---

[25] The scope of IHR is purposely broad and inclusive in respect of the public health event. It covers communicable, chemical, biological and radio-nuclear hazards.

[26] www.jeealliance.org/global-health-security-and-ihr-implementation/joint-external-evaluation-jee/ and http://apps.who.int/iris/bitstream/10665/204368/1/9789241510172_eng.pdf

CASE STUDY

Box 1
Case study of health emergency risk assessment

Event: A cluster of 22 cases of severe respiratory diseases with seven deaths in country X were admitted to hospital over the past 17 days. The event is occurring 8km from the border and cases have been reported from three villages by a local health-case worker (HCW). The area is charge a consultation fee and consequently the local population self-medicates during mild illness. There are also beliefs that 'strange diseases' are caused by sorcery.

Risk Question: What is the likelihood of further spread of sever cases of respiratory disease and what would be the consequences (type and magnitude) to public health if this were to occur?

Information used to assess the likelihood of further spread:

- Cases are still being reported 17 days after the first known cases were detected
- The specifications and modes of transmission have not been identified
- It is also likely that some cases are not being detected (e.g. mild cases are less likely to seek care from health services and are therefore not included in the official reports).

Therefore, it is highly likely that further cases will occur if nothing is done.

Information used to assess the consequences of further spread:

- The disease has a high case fatality ratio (even when under reporting is taken into account)
- The health-care system is poor and the ability to treat the cases is already limited; new admissions will further stress acute care services and lead to worse clinical outcomes for hospitalized patients.
- Negative economic and social impact of the cases and deaths in the affected communities
- There is potential for unrest in communities because of cultural beliefs that sorcery is causing the deaths
- The event is occurring in a border area and could affect the neighbouring country
- Therefore the consequences if the further cases occur will be severe.
- Using the risk matrix to combine the estimate of the likelihood and the estimate of consequences leads to estimate of the overall risk; in this case, the overall level of risk is high.
- The confidence in the risk assessment is low-medium.
- Although the report is from a local HCW, the information is limited and it is not clear if the HCW has examined the suspect cases or is reporting a rumor.

CASE STUDY

Box 2

A case of a country good practice

Iceland - Iceland is an island country located in the North Atlantic Ocean. It has a population of approximately 330,000 inhabitants and an area of 103, 000 km2, making it one of the most sparsely populated countries in Europe. Over two thirds of the population live in the southwest part of the country, which makes up the Reykjavik capital area, while the rest is scattered along the coastal area.

The Chief Epidemiologist in Iceland and Civil Protection of the National Commissioner of Police are responsible for the national health crisis preparedness planning for communicable, chemical, biological and radio-nuclear hazards, as well unknown events. They are also responsible for national risk assessment, risk reduction and response management during times of a public health crisis.

The preparedness plans in Iceland are all-hazard plans and involve the following sectors: the primary health care and hospitals, ambulance services, distributors of medicines, Icelandic Medicine Agency, Icelandic Food and Veterinary Authority, food suppliers and distributors, Icelandic Farmers Association, Icelandic Transport Association, Icelandic Tourist Board, the financial sector, Icelandic Environmental Agency, Icelandic Federation of Energy and Utility Companies, Icelandic road and coastal administration, prisons, Icelandic Red Cross and rescue services, Icelandic National Broadcasting Service and the Evangelical Lutheran Church of Iceland.

Currently, two national preparedness plans have been published and implemented, including an influenza preparedness plan and a plan for airports and aviation. Plans for health care institutions, ships and harbours and a chemical, biological, radiological or nuclear (CBRN) hazard plan are also being processed and will be finalized and implemented in the near future.

The main health hazards in Iceland result from natural disasters such as volcanoes, earthquakes, avalanches and severe weather. CBRN hazards are also considered important and are included in the preparedness planning.

The preparedness plans in Iceland have been used in real life scenarios during the pandemic influenza in 2009 and during several volcanic outbreaks in recent years. The plans have proven to be very useful and the main challenge in the coming years is to keep them updated regularly.

Authors:

Jonathan Abrahams (World Health Organization), Catherine Smallwood (World Health Organization), Anne Anacia (WHO), Chadia Wannous (UNISDR), Laura Espinosa (ECDC), Massimo Ciotti (ECDC), Vetla Tsolova (CEPS), Graham Fraser (ECDC), Tarik Derrough (ECDC), Ettore Severi (ECDC), Thorolfur Gudnason (The Directorate of Health), Jonathan Suk (ECDC)

Contributors and Peer Reviewers:

Ali Ardalan (Tehran University of Medical Sciences; Harvard Humanitarian Initiative)

F. Data Management throughout the National Risk Assessment Process

Key words:
data management, data license, open data, metadata

This section provides a general introduction for non-specialists to some of the main concepts involved in data management for national risk assessments.

Data management is an important part of a national risk assessment and can help ensure that the process is both effective and impactful. Risk assessment is an extremely data-intensive process and conducting a national risk assessment may involve accessing information from a wide range of stakeholders, including mapping agencies, scientific and technical ministries from across government, universities, research institutions and the private sector.

In addition, valuable new data and analysis are created during risk assessments. A strategy must therefore be developed to efficiently organize and manage the data as they come in, as well as to distribute the results to participants and stakeholders.

Data management plans govern the process by which data are gathered from participating entities, the technical and quality standards to which new data will be produced, how data will be maintained during the risk assessment, and the means by which the output data will be shared or secured.

Why Invest in Data Management for National Risk Assessments?

The data sets required for conducting risk assessment are valuable resources. They can be expensive to create but, when managed properly, can be used by a diverse set of users for multiple purposes beyond those for which they were initially produced. Conversely, if data are managed poorly, the investment made in creating them will not yield a full return.

Improper management or limiting access to data can lead to duplication of effort (other organizations may be recreating data that already exist). A well-crafted data-management plan can help encourage stakeholders to share their data and ensure that the processes for sharing data are effective and transparent. This will increase the value of the investment in the data and build trust in the results of the risk assessment, as more stakeholders have access to the raw data that underlie it.

Stakeholder Involvement and Accountability

To successfully develop and implement a data-management strategy for national risk assessment, stakeholders such as data producers and users should be involved early on in the planning. This will help ensure that the data management activities meet the needs of participants and increase their sense of ownership of the process – which is vital for successful implementation.

Many government entities engaged in national risk assessment are subject to legal regulation that controls the conditions under which they produce, maintain and share data. It is important to identify these constraints at the start of the process. The various obligations that stakeholders have in relation to creating or sharing data for risk assessment purposes can be documented in memorandums of understanding, signed by each participating organization, in order to formalize the agreement.

Standard Data Formats

Data management plans should also specify the preferred formats in which data sets should be created, maintained and shared. Generally speaking, these should always be standard data formats agreed upon by groups such as the Open Geospatial Consortium[27]. This will help alleviate compatibility challenges that have in the past made it difficult for data created in one software to be used in another.

Some examples include .csv for tabular data or .shp, .geojson and .kml for spatial data. Other data standards, the resolution at which spatial data are recorded or the attributes associated with records in an asset database, for example, should be considered during risk assessments where significant amounts of new data will be created.

Data Licences

A central element of any data-management strategy is clear articulation of the conditions under which data are to be shared. These conditions are specified by a data licence or terms of use that should accompany each data set. A well-written data licence should cover, at a minimum, attribution, modification and redistribution.

Attribution refers to citation of the owner of the data on products in which they are used. Modification governs the conditions that users of the data must comply with when altering the data set or combining it with other data. Redistribution refers to the permissions that users have to redistribute the data or any derived works once they have accessed them, and whether they may be used for commercial purposes.

In recent years, there has been increasing advocacy for adopting open data policies across government and academic research. Open data advocates argue that liberal, "open", data licensing supports transparency, efficiency and participation in government, peer review of science, and more widespread and effective data use for decision-making in general. If a country has concerns over sensitive asset data, it is important not to lose sight of the potential

[27] Open Geospatial Consortium (2017). Available from www.opengeospatial.org/ .

value of releasing this information in aggregate form and making other components of the risk assessment, such as hazard data, openly available for further use by the public and private sector and academia. The Global Facility for Disaster Reduction and Recovery Open Data for Resilience Initiative (OpenDRI) has been working on these issues related to disaster and climate risk assessment since 2011 (box 1).

Metadata

The creation and maintenance of metadata is an essential component of data management. Metadata provide information about how and when data sets were created, what their attributes signify, who the initial authors and owners were, and the terms of the data licence. There are several well-recognized standards for metadata, including those published by the International Organization for Standardization[28] and the United States Federal Geospatial Data Committee[29]. Much geographic information system software also includes tools for authoring and sharing metadata. Data-management strategies should also include plans for storing, sharing and updating metadata when necessary for every data set they cover.

---

28 International Organization for Standardization (2014). ISO 19115-1 *Geographic Information Metadata Part 1: Fundamentals*.

29 Federal Geographic Data Committee (2017). Content Standard for Digital Geospatial Metadata. Available from www.fgdc.gov/metadata/csdgm-standard.

CASE STUDY

Box 1
Open data: Malawi Spatial Data Working Group

Event: A cluster of 22 cases of severe respiratory diseases with seven deaths in country X were Since 2012, the Malawi Spatial Data Working Group has been sharing spatial data using MASDAP, the Malawi Spatial Data Platform (www.masdap.mw). The group began as a partnership between government ministries and other organizations working on flood risk assessment in the Shire River basin. Participants formed the Malawi Spatial Data Working Group to manage the activity and share important data during the project.

The working group, which meets monthly, has continued its efforts to gather and share data following the conclusion of the risk assessment, and MASDAP is now a valuable source of risk information for the whole country. MASDAP received support from the Global Facility for Disaster Reduction and Recovery Open Data for Resilience Initiative (OpenDRI).

OpenDRI has partnered with national governments, universities and community-based organizations to launch data-sharing platforms such as the Sri Lanka Disaster Risk Information Platform (http://riskinfo.lk), to support community mapping projects for disaster risk assessment (www.opencitiesproject.org) and to build tools to communicate complex risk information to diverse stakeholders (http://inasafe.org). More information about the data available through OpenDRI projects can be found at https://opendri.org

Recommendations

- Incorporate stakeholders from both potential contributors to and users of risk assessment data early in the planning process. Provide stakeholders with an understanding of the importance and value of their data for the quality of the risk assessment results. Give them an opportunity to make substantive contributions to the data-management plan.
- Agree upon the data licensing, metadata standards, acceptable formats and other protocols as early as possible.
- Whenever possible, release data under open licences that encourage wide use for many purposes.
- Develop a common repository for data during the risk assessment, which can also be used to share the results and outputs when the assessment is completed.
- Document the data-sharing plan in a memorandum of understanding or other formal agreement that can clarify the expectations and responsibilities of participating stakeholders

Free and open source tools for data management

- Various free and open source tools have been used to support the management and sharing of spatial and tabular data.
- GeoNode (www.geonode.org) is a tool that allows users to share and visualize geospatial and tabular data on the internet. The software is free but it requires installation and customization. Metadata authoring tools are also included.
- CKAN (http://ckan.org/) is another tool that acts as a full featured web-based data and metadata-sharing platform.
- QGIS (www.qgis.org/) is a desktop-based GIS software that provides features for data editing, manipulation and conversion. Free extensions can be used to automate some parts of metadata creation.

Resources for further information

- Field Guide to the Open Data for Resilience Initiative. Available from www.gfdrr.org/sites/gfdrr/files/publication/opendri_fg_web_20140629b_0.pdf
- Future Trends in Geospatial Information Management: The Five to Ten Year Vision. Available from http://ggim.un.org/docs/UN-GGIM-Future-trends_Secondedition.pdf
- A Guide to the Role of Standards in Geospatial Information Management. Available from http://ggim.un.org/docs/StandardsGuideforUNGGIM-Final.pdf
- Why Information Matters: A Foundation for Resilience. Available from www.internews.org/sites/default/files/resources/150513-Internews_WhyInformationMatters.pdf

Authors:

Robert Soden (GFDRR)

Contributors and Peer Reviewers:

Peer Reviewer: Paul Henshaw (Global Earthquake Model Foundation), Keiko Saito (World Bank)

G. Use of Geospatial Data in Implementing NDRA

Key words:
geospatial data, spatial data, geographic information systems, GIS

Geospatial information, also known as spatial or location information, is crucial for understanding disaster risk. We cannot consider the physical processes causing disasters, or how they impact on people and their assets, infrastructure and the environment, if we ignore their location on earth. For example, variations in topography and surface cover play a key role in determining the local flood hazard. Proximity to a tectonic fault influences the earthquake hazard. Spatial distribution of exposure (elements at risk), in proximity to a hazard, is a significant factor of disaster risk; a large magnitude earthquake in an unpopulated area may not cause any damage, whereas a smaller event under a population centre may have disastrous impacts.

Risk mitigation options also vary spatially, as evacuation zones or construction standards reflect the spatially variable nature of hazard. A national risk assessment needs to take into account the geospatial characteristics of the hazard, exposure, vulnerability and coping-capacity components for any particular event. Such information therefore underpins the national risk assessment process.

Geospatial information describes a location or is information/data that can be referenced to a location. There are two types of geospatial data: vector and raster data. Vector data include data stored as point, line and polygon features. For example, point location of a township, or an earthquake felt report; geographic contours and topographic road or rail features characterized as lines; or polygon shaped features of land parcels or a flooding extent. Raster data include aerial photographs, imagery from satellites or digital pictures or scanned maps. Both vector and raster data can be used to support national risk assessments.

Geospatial information underpins most, if not all, national risk assessments, as illustrated in Figure 1. Consequently, geospatial analysis is used in many risk assessment approaches. Using and analysing geospatial data requires specific enabling technologies such as information management systems and analysis and processing tools such as geographic information system (GIS).

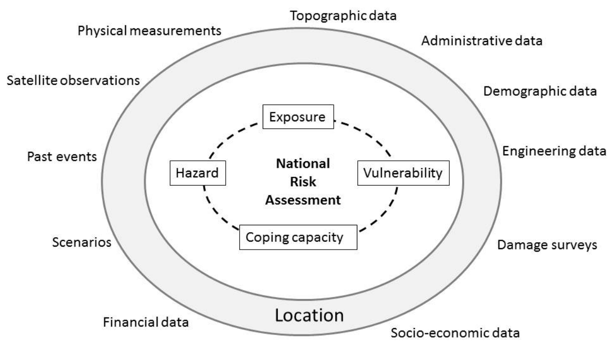


Figure 1 – Examples of the key role of spatial information in a risk assessment

Enabling technology

Technology stack solutions for working with geospatial data can be deployed on desktop, enterprise, cloud and mobile platforms. Software solutions include both commercial off-the-shelf and Free Open Source (FOSS) applications. A valuable comprehensive list of open source geospatial technology stack solutions is maintained by the Open Source Geospatial Foundation (OSGeo)[30].

GIS is a computer system that enables the capture, management, analysis and visualization of geographic information[31]. The value of a GIS is that it “understands”the spatial nature of information, enabling the ability to explore relationships, patterns and trends in relation to other spatial and non-spatial information. Over the past decades, GISs have improved in sophistication and are now a very powerful decision-making tool used for a wide range of applications.

At the same time, there is no one type of system or tool that is uniquely suitable for a national risk assessment. Computational solutions other than strict GIS packages are available or can be developed to better suit particular geospatial data sets or applications. Choices of tool and system should be determined by the context and purpose of the data analysis required.

In addition to contacting individual data custodians, the internet facilitates the sharing of geospatial data through Spatial Data Infrastructures (SDI)[32]. These build on web-based technologies such as content management systems (e.g. GeoNode[33]), web services (e.g. GeoServer[34]) and Linked Data. This infrastructure enables applications to directly consume geospatial data and maps products, without the need to download the data.

Quality management systems

Comprehensive standards systems such as defined by the Open Geospatial Consortium (OGC)[35] and the International Organization for Standardization (ISO) ensure interoperability and consistent quality of geospatial data and their metadata (information about the data)[36][37]. Consistency and interoperability of spatial data is important, especially because natural disasters cross both jurisdictional and sectoral boundaries.

---

30 www.osgeo.org

31 www.nationalgeographic.org/encyclopedia/geographic-information-system-gis/

32 https://en.wikipedia.org/wiki/Spatial_data_infrastructure

33 http://geonode.org/

34 https://live.osgeo.org/en/overview/geoserver_overview.html

35 www.opengeospatial.org/

36 www.iso.org/iso/home/store/catalogue_ics/catalogue_detail_ics.htm?csnumber=53798

37 https://www.fgdc.gov/metadata/csdgm-standard

Geospatial reference systems

A fundamental characteristic of geospatial data is that they contain a spatial reference system or have the ability to be tied to a reference system (e.g. coordinate system, projections and datum; able to be identified by an address, place or region name). A GIS maintains the variety of coordinate systems, projection and geodetic datums within the data set itself. As a result, a GIS allows data sets that have different coordinate systems to be overlaid and viewed seamlessly if required data sets are re-projected in order to combine them for analyses. The geospatial reference system is a key metadata element to be captured for all geospatial data sets.

Scale and resolution

Geospatial data or map scale is simply the ratio of map to ground measurement. Zooming in or increasing the scale does not increase the level of accuracy or detail but it will make it clearer to visualize. Data resolution, however, refers to the smallest feature that can be distinguished in the data. For example, a satellite image may capture surface reflectance in 30m pixels. Surface features smaller than 30m will not be individually distinguishable. If data are used beyond their resolution, any results will have a greater level of uncertainty. Therefore, understanding the purpose and resolution at which the data were captured helps understand the level of detail and the accuracy of the information available.

At the same time, processes underpinning disasters, impacts and risk have characteristic scales. Thunderstorms typically impact on smaller spatial scales than hurricanes. Demographic characteristics tend to vary across a country, but may be homogeneous within a suburb. The resolution of the geospatial data used for a risk assessment should be adequate to reflect the detail and level of accuracy required to assess both the processes considered and the scale of analysis. Otherwise, there is a significant risk that a risk assessment is meaningless; or worse, misleading. For example, tsunami inundation is influenced by local variability in elevation. As a result, a national tsunami risk assessment based on low-resolution elevation data may identify local areas as safe, whereas they are actually at risk of inundation[38].

Geospatial data and national risk assessment

A robust national risk assessment requires good quality and consistent geospatial data and tools to support the hazard, exposure, vulnerability and coping capacity components of the risk. If hazard assessments are not already

---

38 Griffin J. and others (2015). An evaluation of onshore digital elevation models for modeling tsunami inundation zones. Frontiers in Earth Science 3:32. doi: 10.3389/feart.2015.00032

available, a national risk assessment may require fundamental geospatial data such as topography, rainfall observations or soil data that underpin hazard assessments. Not only for hazard, but also for exposure, vulnerability and coping capacity dimension, the data resolution should reflect the relevant spatial variability at the scale of the assessment.

Typically, collating the data for a national risk assessment will involve multiple agencies and stakeholders that collect different data sets. Data may not be stored as spatial information, but data records can still contain some kind of spatial reference, including street address, suburb or administrative boundary. Integrating different spatial data sets and administrative non-spatial information in a GIS can inform the exposure, vulnerability and coping capacity dimensions of a national risk assessment. Metadata complying with a standard (e.g. ISO 19115[39]) support interoperability of data, and will support the application of different data sets for a national risk assessment.

CASE STUDY

Box 1
A case of a country good practice

Indonesia
Ambon Tsunami Table Top exercise

In 2016, the National Disaster Management Authority (BNPB) used credible hazard science, open spatial data and spatial decision support tools to prepare contingency plans in support of a disaster management exercise. The exercise was based on a worst-case scenario for tsunami hazard in Ambon. Working together with the Humanitarian OpenStreetMap Team (HOT) and the community, it mapped OpenStreetMap exposure data for buildings and roads. The hazard scenario was analysed in the FOSS GIS-based disaster scenario package InaSAFE, (e.g. figure 1) to estimate the impact on communities and infrastructure and to support the participatory development of three subnational contingency plans: for Ambon City, Maluku City and Central Maluku.

Figure 1 - Tsunami impact map of Ambon province

The national Tsunami Table Top exercise tested the tsunami emergency management governance, coordination and communication at the national, provincial and district level. With this activity, BNPB has demonstrated how spatial data and spatial analysis can provide a credible evidence base for disaster risk management activities.

39 www.iso.org/standard/53798.html

CASE STUDY

Box 2
A case of a country good practice

Australia
Sharing spatial data through the Foundation Spatial Data Framework

The Australian and New Zealand Foundation Spatial Data Framework (FSDF) provides a wide variety of users with a common reference for the assembly, maintenance and a way to discover key government spatial data sets. It contains 10 themes that broadly categorize information, with each theme containing one or more FSDF data sets. Key input data sets for risk assessments are included in many different themes, including geocoded addressing, administrative boundaries, elevation and depth, land cover and land use, imagery, land parcel and property, positioning, water, transport and place names.

FSDF delivers a national coverage of the best available, most current, authoritative source of foundation spatial data that are standardized and quality controlled for over 1,000 input data sets derived from multiple tiers of government.

To organize information within the program, a system called the Location Information Knowledge Platform (LINK) has been developed. LINK is the first attempt in Australia to document and publish in a user-friendly way location information governance, business information and provenance for all of Australia's foundation spatial data. LINK is a cloud-based online content management system that provides users with a range of different ways to interrogate information and discover data they are interested in. LINK provides a common platform to help understand roles and responsibilities of suppliers, aggregators and consumers of the data. It also provides a framework to manage working groups tasked with improving FSDF data into the future.

Resources for further information

There are many relevant communities of practice that focus on the use of spatial data, with a wealth of useful guidelines, tools and case studies that can support geospatial data use for national risk assessments.

The United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM) develops guiding principles, policies, frameworks, standards and institutional arrangements around geospatial information. UN-GGIM also holds governance of a global ”gazetteer” and global boundaries data, a global geodetic reference frame.

As part of the global community of practice of spatial data, UN-GGIM provides access to extensive knowledge resources through its website[40]. Under UN-GGIM is the Working Group on Geospatial Information and Services for Disasters (WG-DISASTERS)[41].

The Committee on Earth Observation Satellites (CEOS) also has a working group that focuses on disasters, which aims at increasing the contribution of earth observation data to risk management applications[42].

Data Management Association International (DAMA) is a global community of practice for data management. It provides learning and networking opportunities and education materials for data management professionals, and includes a focus on geospatial information[43].

The Open Geospatial Consortium (OGC) is committed to making quality open standards for the geospatial community, enabling better data sharing and interoperability for spatial data[44].

The Open Source Geospatial Foundation (OSGeo) was created to support the collaborative development of open geospatial software. Its webpages include links to a wide range of open source tools and technologies for geospatial data, as well as serving as a hub for technical communities of practice. These pages provide links to open source tools for geospatial data that can be used for national risk assessments.2 These include "generic" GIS tools such as QGIS and GRASS GIS, content management systems such as GeoNode, geospatial libraries such as GDAL and PostGIS, metadata catalogues, and web-mapping tools such as GeoServer and OpenLayers. Additionally, there are more specific disaster mapping tools such as InaSAFE11, a QGIS plugin. Again, the choice of application or tool should be determined by the questions needing to be answered, the type of analysis required and the resolution of the data that are available.

Authors:

Martine Woolf (Geoscience Australia)

Contributors and Peer Reviewers:

Robert Soden (GFDRR)

---

40 http://ggim.un.org/

41 www.nationalgeographic.org/encyclopedia/geographic-information-system-gis/

42 http://ceos.org/ourwork/workinggroups/disasters/

43 www.dama.org

44 www.opengeospatial.org/

H. Citizens’ Participation and Crowdsourcing

Key words:
crowdsourcing, data collection, exposure, risk communication

Crowdsourcing can make important contributions to risk assessments. The term was coined in 2006 by journalist Jeff Howe to describe the ways in which the internet and mobile phones are facilitating the outsourcing to the public of tasks traditionally reserved for experts[45].

Crowdsourcing and related approaches of citizen science and participatory mapping are gaining recognition and acceptance within disaster risk communities; but in reality, public participation in gathering scientific observation about the world is not a new phenomenon. Following the devastating Lisbon earthquake of 1755, volunteers from all over Europe reported their experiences to help researchers create an early version of a "shake map" that estimated the extent and intensity of the event[46]. Today, the public participates in all kinds of scientific activity – from monitoring wildlife activity in their neighbourhoods to using internet platforms to classify distant galaxies. These approaches can play a valuable, if underexplored, role in national risk assessment.

Benefits of Crowdsourcing

The most obvious benefit of crowdsourcing is that it can be used to help collect large amounts of data in real time at potentially lower costs than traditional approaches. Indeed, the "power of the crowd", when combined with modern information and communication technologies, is the ability to conduct simple tasks such as measurement or observation at scale by enlisting large numbers of participants. Though this potential is certainly significant, it is definitely not the only benefit of crowdsourcing information about risk assessment.

Another important reason to consider including crowdsourcing in risk assessment is that in addition to providing information, participants are themselves learning about risk in their area. Crowdsourcing thus becomes an avenue for risk communication through outreach and sensitization. Through involving new participants in the process, crowdsourced approaches also create opportunities to make risk assessment more inclusive. This can both improve the quality of the risk assessment through including local knowledge and raise public confidence in the results through increased understanding and ownership of the results.

---

[45] Howe, J. (2006). The Rise of Crowdsourcing. *Wired magazine* 14 (6). Available from www.wired.com/2006/06/crowds/

[46] Coen, D.R. (2012). *The Earthquake Observers: Disaster Science from Lisbon to Richter*. Chicago: University of Chicago Press.

CASE STUDY

Box 1
Open Cities Kathmandu project

Nepal. In 2012, the Government, in partnership with the World Bank and the Global Facility for Disaster Reduction and Recovery, decided to conduct a risk assessment of health and education infrastructure in the Kathmandu Valley. The assessment was intended to help plan a major seismic retrofitting programme. Since, at the time, there was no comprehensive map of facilities or information about their condition or structural characteristics, it was necessary to develop an asset database that contained the location and basic exposure information for every school and medical post in Kathmandu.

Instead of contracting an engineering firm to develop this database, the project developed a unique partnership between the Government, the OpenStreetMap (OSM) community and several local universities and technical agencies to crowdsource this information.

The Open Cities Kathmandu project worked with local earthquake safety experts to develop a data model and training materials that would allow undergraduate students (with no background in engineering) to collect basic structural information such as the number of floors that could be used for risk assessment purposes.

Student volunteers from local universities, some of whom received course or internship credits for their participation, were trained in surveying methods and mapping using the OSM platform. Each team of volunteers was given responsibility for collecting information about schools and health facilities in a different section of the Kathmandu Valley. A small organizing team coordinated their work and ensured that the data were entered into OSM.

Over the course of eight weeks, participants produced a full asset database for over 2,500 schools and 350 health facilities in Kathmandu. The data were then made publicly available through the OSM platform. Using the skills and network of connections developed through the project, the organizing team went on to form a non-profit technology organization to pursue similar work in partnership with other development organizations working in Nepal. The group Kathmandu Living Labs provided technology and mapping support to the Government and aid agencies working in the response and recovery periods following the 2015 Nepal earthquakes.

Issues to consider when planning a crowdsourcing project

Designing an effective crowdsourcing project requires careful consideration of many factors, (a complete discussion of which is beyond the scope of this section). The first step is to decide what information participants will be asked to contribute to the risk assessment. Whether this is building characteristics to develop an asset database or mapped extents of past flood events, the request should be tailored to the level of expertise of the participants while meeting the scientific demands of the risk assessment it will inform. Once the desired information is known, options for collecting the data, whether via mobile app, website, or more analog approaches, can be assessed.

It's important to define early in the planning who "the crowd" will be. What, if any, technical background should participants have? How many participants are needed? How will they be recruited? Will they be compensated? Will the risk assessment team have time to provide active oversight and feedback? How can the project be sure to reach vulnerable or marginalized groups that typically might not be included?

Partnerships with universities, professional organizations and civil society groups can often be an effective means of identifying and enrolling contributors. These groups can also potentially support quality-control efforts for crowdsourced data. Examples such as the Open Cities Kathmandu project (box 1) demonstrate that, with proper forethought, crowdsourcing techniques can be used to provide high-quality data for national risk assessment.

Resources for further information

- Open Data for Resilience Initiative: Guide to Planning an Open Cities Mapping Project. Available from www.opencitiesproject.org/guide/
- Crowdsourced Geographic Information in Government. Available from www.gfdrr.org/sites/gfdrr/files/publication/Crowdsourced Geographic Information Use in Government.pdf
- Open Mapping for the Sustainable Development Goals: A Practical Guide to Launching and Growing Open Mapping Initiatives at the National and Local Levels. Available from https://static1.squarespace.com/static/55f7418ce4b0c5233375af19/t/57f2c796e6f2e11b28718f00/1475528602076/OpenMappingfortheSDGsGuide.pdf

Authors:

Robert Soden (GFDRR)

Contributors and Peer Reviewers:

Melanie Eckle (Heidleberg University), Robert Banick (GFDRR), Tyler Radford (Humanitarian OpenStreetMap Team)

I. Supporting DRR Investment Decision-making

Key words:

scenario assessment, cost-benefit analysis, multi-criteria analysis, robust decision making approaches

Investments in prospective and corrective risk reduction, preparedness, response and recovery have multiple benefits that often exceed the potential reduction in direct and indirect losses arising from a disaster. Although the exact benefit-cost ratio (BCR) varies widely, the United States Federal Emergency Management Agency (FEMA), for example, estimated an average BCR of approximately four in a review of over 4,000 DRR investment projects in the United States.[47][48]

Investing in resilience-building activities such as ecosystem-based DRR interventions and community-based interventions can also yield significant economic, social and environmental co-benefits, even in the absence of a disaster. However, the significant upfront costs required for investment in DRR and resilience-building activities, combined with the long timespan required to witness their benefits, offer limited incentives for decision makers to invest proactively.[49]

DRR policy scenario assessment – evaluating welfare and disaster risk implications with and without DRR interventions – may be incorporated into national risk assessment to assist selection among alternative DRR policy and investment options. The common methodologies for evaluating DRR policy scenarios include cost-benefit analysis, cost-effectiveness analysis, multi-criteria analysis and robust decision-making approaches, with each having distinct applicability in a variety of decision contexts.[50]

- **Cost-benefit analysis (CBA)** supports decision-making based on the efficiency criteria, maximizing net benefits of investment over time, as measured in monetary terms. CBA has been the primary approach for prioritizing among risk reduction investment options in developed countries. Ideally, a CBA includes all relevant impacts, be they physical, social, economic or ecological, analysing both direct or "stock" impacts, such as loss of life and property damage, as well as indirect or "flow" losses including unemployment and reduced income due to direct and

---

47 Multihazard Mitigation Council (2005). Natural hazard mitigation saves: an independent study to assess the future savings from mitigation activities. Vol. 1 – Findings, Conclusions, and Recommendations. Vol. 2 – Study Documentation. Appendices. Multihazard Mitigation Council, National Institute of Building Sciences, Washington, D.C.

48 Rose, A. and others (2007). Benefit-cost analysis of FEMA hazard mitigation grants. *Natural Hazards Review* 8, pp. 97-111.

49 Kunreuther, H. C. and E.O. Michel-Kerjan (2009). *At War with the Weather: Managing Large-scale Risks in a New Era of Catastrophes*. Massachusetts: MIT Press.

50 Mechler, R. (2016). Reviewing estimates of the economic efficiency of disaster risk management: opportunities and limitations of using risk-based cost–benefit analysis. *Natural Hazards* 81(3), pp. 2121-2147.

indirect (multiplier effect) business interruption losses.[51][52] Given that CBA necessitates the monetization of every impact, a particular challenge lies in estimating the value of intangibles, including the values of environment, community cohesion and places of significant cultural or historical heritage values. It can also include co-benefits of DRR.[53][54] Monetization of mortality and morbidity risks into a CBA is another key consideration. The common approach is to use"value of statistical life"(VSL) estimates, often quantified based on projections of lost future earnings – an approach not without moral or ethical controversy.

- **Cost-effectiveness analysis (CEA)** identifies least-cost options to meet a certain, predefined target or policy objective (which, in effect, represents the project benefit measured in monetary terms). CEA does not require the quantification of benefits, as the project costs are the key variable of consideration to be minimized. Project goals such as reducing disaster fatalities and losses to a certain level must be determined beforehand.

- **Multi-criteria analysis (MCA)** assesses how well DRR investments achieve multiple objectives such as economic, social, environmental and fiscal goals, as well as co-benefits. Using selected criteria and indicators as verifiable measures for monitoring across time and space, MCA observes and evaluates DRR investment performance in quantitative or qualitative terms. Because MCA does not require the monetization of all values, it is seen as potentially more palatable and flexible than CBA and CEA.[55] A major challenge, however, is assigning weights to the criteria.

- **Robust decision-making approaches (RDMA)** has received increasing emphasis recently, particularly in the context of climate change adaptation. Comprising both quantitative and qualitative methodologies, RDMA draws the focus away from optimal decisions (such as those supported with CBA and CEA) and aim to identify options with minimum regret, that is, minimal losses in benefits of a chosen strategy under alternative scenarios where some parameters are highly uncertain and impacts are potentially

---

51 Rose, A. (2004). Economic principles, issues, and research priorities in natural hazard loss estimation. In Y. Okuyama and S. Chang, eds. *Modeling the Spatial Economic Impacts of Natural Hazards.* Heidelberg: Springer, pp.13-36.

52 National Academies of Sciences (2012). *Disaster Resilience: A National Imperative.* Washington D.C.: National Academies Press.

53 Rose, A. (2016). Private sector co-benefits of disaster risk management. In E. Surminski and T. Tanner, eds. *Realising the Triple Resilience Dividend: A New Business Case for Disaster Risk Management*. Heidelberg: Springer.

54 Surminski, S. and T. Tanner, eds. (2016). *Realising the Triple Resilience Dividend: A New Business Case for Disaster Risk Management.* Heidelberg: Springer.

55 Steele, K. and others (2009). Uses and misuses of multicriteria decision analysis (MCDA) in environmental decision making. Risk Analysis 29 (1), pp. 26-33.

devastating or irreversible.[56][57]

These various scenario assessment methodologies are routinely used to inform DRR investment decisions in both developed and developing countries. The following are two recent examples of a DRR policy scenario assessment, in which alternative scenarios – risk- versus non-risk based and pre- and post-DRR investment – are compared to support public decision-making on wildfire and cyclone risk.

Wildfire DRR options analysis in Australia: an MCA approach

The state of Victoria in south-east Australia is highly prone to wildfires, with recent devastating disasters claiming hundreds of lives. Wildfire fuel management – the controlled burning of vegetation (fuel) – is a critical element of wildfire risk management. Following the 2009 bushfire, the government of Victoria adopted a new policy target of prescribed burning applied to, at minimum, 5 per cent of public land (known as the Victorian Bushfires Royal Commission recommendation 56).

In 2013, however, the Bushfires Royal Commission Implementation Monitor – an official body responsible for monitoring and reviewing the Royal Commission – found that this hectare-based target was "not achievable, affordable or sustainable" and subsequently proposed a wildfire DRR policy scenario assessment comparing two fuel management options.

While the status quo approach prescribed the burning of a proportion of public land annually, the alternative prescribed burning to achieve a certain reduction in wildfire risk. The risk-reduction target is defined in comparison to the scenario of maximum fuel loads (i.e. before fuel management activities are undertaken), as estimated by computer simulation of wildfire behaviour in the landscape using the PHOENIX RapidFire model.[58] The latter approach identified the specific areas for prescribed burning that are most effective at reducing risk, while the former simply identified the total areas to be burned.

As part of the review, external risk experts undertook a policy assessment using a multi-criteria analysis. The two policy options were assessed against

---

56 Kalra, N. and others (2014). Agreeing on robust decisions: new processes for decision making under deep uncertainty. Policy Research Working Paper No. 6906. Washington D.C.: World Bank.
Available from www-wds.worldbank.org/external/default/WDSContentServer/IW3P/IB/2014/06/04/000158349_20140604102709/Rendered/PDF/WPS6906.pdf

57 11 Lempert, R. and others (2013). Ensuring robust flood risk management in Ho Chi Minh City. Policy Research Working Paper No. 6465. Washington D.C.: World Bank.

58 State of Victoria (2015). Review of performance targets for bushfire fuel management on public land.
Available from www.igem.vic.gov.au/home/reports+and+publications/reports/review+of+performance+targets+for+bushfire+fuel+management+on+public+land+report

their potential to meet twelve criteria assessing effectiveness (e.g. in terms of reducing risk to human life, infrastructure, economic activities and ecosystems), stakeholder and community engagement, policy sustainability, economic efficiency, and distribution and equity considerations. The alternative policy with the risk reduction objective was found to be superior, and the government subsequently revised its fuel management target based on this recommendation.

The policy scenario assessment was designed to fit the needs of decision makers in terms of policies being assessed (status quo and viable alternative), criteria (derived from existing mandates) and transparency of process (clear and easy to follow). This case study highlights the way in which decision-support methods can be incorporated effectively into a wider policy dialogue.

Cyclone retrofit options analysis in Indian Ocean Commission countries: a cost-benefit analysis application

As part of UNISDR/ISLANDS Joint Programme On Financial Protection Against Climatic and Natural Disaster Risks, "forward-looking" probabilistic cost-benefit analyses of cyclone retrofitting options were conducted for Madagascar and Mauritius using newly compiled hazard, exposure and vulnerability data. Spatially explicit data on the probability and intensity of cyclone winds were combined with those of location and construction materials of private and public infrastructure and buildings using the open source CAPRA software to yield baseline estimates of economic damage due to cyclones.

These estimates were then revised assuming the likely benefit of housing retrofitting options (i.e. improvement of wooden and unrefined masonry houses from low to medium design quality in Madagascar and iron concrete and wooden houses from medium to high design quality in Mauritius[59][60] to yield the economic damage after DRR intervention. The benefit of DRR intervention – the differences between economic damages before and after DRR – is then compared with the cost of DRR intervention, using an appropriate discounting rate, which yielded decision metrics such as net present value, benefit-cost ratio and internal rate of return.

For example, assuming retrofitting options cost 10 per cent of the total housing value, cyclone wind-proofing at a discounting rate of 5 per cent yielded the benefit-cost ratio of 2.02, while that of unrefined masonry was

---

59 United Nations Office for Disaster Risk Reduction (2015a). UNISDR Working Papers on Public Investment Planning and Financing Strategy for Disaster Risk Reduction: Review of Madagascar.
Available from www.unisdr.org/we/inform/publications/43522

60 UNISDR (2015b). Review of Mauritius. UNISDR working papers on public investment planning and financing strategy for disaster risk reduction. http://www.preventionweb.net/publications/view/43523

estimated at 1.04 in Madagascar.[61] This case study demonstrated that the probabilistic cost-benefit analysis can be conducted easily with the newly collected risk information, and similar assessments were conducted using "backward-looking"probabilistic cost-benefit analysis based on recently collected DesInventar disaster damage and loss database for Comoros, Seychelles and Zanzibar.

It is generally not advisable to use scenario assessment tools strictly in a prescriptive manner. Instead, analyses using the tools described above should be used as part of a larger process of national disaster risk planning involving all stakeholders. Stakeholders can and should be involved at all stages of disaster risk assessment, such as problem definition and objective setting, identification of alternative investment options, quantification of impacts and analysis and prioritization (Floods Working Group (2012)).

To ensure transparency and accountability of scenario assessment processes, a number of countries have adopted common analytical tools or a system of third-party review such as the FEMA BCA software and a series of "second opinions" provided by the CPB Netherlands Bureau for Economic Policy Analysis.

Authors:

Junko Mochizuki (IIASA)

Contributors and Peer Reviewers:

Adam Rose (University of Southern California Sol Price School of Public Policy)

---

61 UNISDR (2015a). Review of Madagascar. UNISDR working papers on public investment planning and financing strategy for disaster risk reduction. www.unisdr.org/we/inform/publications/43522

Resources for further information

- Society for Benefit-Cost Analysis https://benefitcostanalysis.org/
- MCA4climate www.mca4climate.info/about/
- Society for Decision Making Under Deep Uncertainty www.deepuncertainty.org/welcome/

Other substantial peer-reviewed guidelines

- CPB Netherlands Bureau for Economic Policy Analysis (2013). *General Guidance for Cost-Benefit Analysis.* Available from www.cpb.nl/en/publication/general-guidance-for-cost-benefit-analysis
- Organisation for Economic Co-operation and Development (2009). *Integrating Climate Change Adaptation into Development Co-operation: Policy Guidance*. Available from www.oecd.org/dac/environment-development/integrating-climate-change-adaptation-into-development-co-operation-policy-guidance-9789264054950-en.htm
- Federal Emergency Management Agency. Benefit-Cost Analysis programme (tools etc.). Available from www.fema.gov/benefit-cost-analysis
- Floods Working Group (2012). *Flood Risk Management, Economics and Decision Making Support*. http://ec.europa.eu/environment/water/flood_risk/pdf/WGF_Resource_doc.pdf
- United Kingdom Environment Agency (2010). *Flood and Coastal Erosion Risk Management appraisal guidance.* Available from www.gov.uk/government/uploads/system/uploads/attachment_data/file/481768/LIT_4909.pdf
- C. Benson and J. Twigg, with T. Rossetto (2007). *Tools for Mainstreaming Disaster Risk Reduction: Guidance Notes for Development Organisations.* Available from www.preventionweb.net/files/1066_toolsformainstreamingDRR.pdf
- R. Mechler (2005). *Cost-benefit Analysis of Natural Disaster Risk Management in Developing Countries (manual).* Available from http://maail1.mekonginfo.org/assets/midocs/0003131-environment-cost-benefit-analysis-of-natural-disaster-risk-management-in-developing-countries-manual.pdf

Toolboxes and other useful resources

- Econadapt toolbox
  http://econadapt-toolbox.eu/methods/cost-benefit-analysis
- Provia/mediation adaptation platform
  www.mediation-project.eu/platform/
- EcosHaz: economics knowledge base
  www.ecoshaz.eu/site/knowledge-toolkit-2/economics-knowledge-base/
- Open source tools
  http://documents.worldbank.org/curated/en/765581468234284004/pdf/714870WP0P124400JAKARTA0CAN0THO0WEB.pdf

Successful and well-documented national hazard and risk assessments that have incorporated this topic and with results used in DRR

- Australian Business Roundtable for Disaster Resilience and Safer Communities (2013). Building our nation's resilience to natural disasters
  http://australianbusinessroundtable.com.au/assets/documents/White%20Paper%20Sections/DAE%20Roundtable%20Paper%20June%202013.pdf

J. Developing Risk Assessment to Support Sovereign Risk Financing and Risk Transfer

Key words:
risk transfer schemes, sovereign risk financing, probabilistic catastrophe risk modelling, insurance pool, risk assessment

Sovereign risk financing and risk transfer schemes - a critical component of a comprehensive disaster risk management strategy

Financial losses associated with extreme events are experienced across many stakeholders, hampering socioeconomic development, particularly in the most vulnerable countries

When a disaster strikes, it can lead to significant financial burdens that can be felt either directly or indirectly by governments, businesses and individuals.[62]

A region's economic vulnerability to extreme events will depend on a range of factors, linked to (a) increasing exposure and vulnerabilities such as higher concentrations of people and property in cities in exposed coastal regions, poor development planning, complex interdependent supply chains and trade patterns, cascading failure effects of critical infrastructure, and interlinkages of natural and man-made catastrophes, and (b) increasing incidence and severity of hazards such as extreme weather events due to climate change. These factors are contributing to the rising financial impacts of disasters.

In absolute terms, the financial costs of disasters are highest for high-income countries. However, in relative terms, the financial effects of extreme events are much more devastating for middle- and low-income countries, when analysed in relation to their average gross domestic product (GDP). In those countries, recurring disasters present a significant challenge to socioeconomic development and poverty reduction efforts in those countries. As is too often the case, the poorest communities are the most vulnerable.

A comprehensive risk management strategy is required to prevent or limit the economic impacts of disasters

A comprehensive risk management strategy should consider several options to reduce and prevent economic losses. Preventive measures such as land-use planning, enforcement of appropriate building codes, retrofitting of structures, better construction practices, and investment in the natural infrastructure (e.g. wetlands) are critical for reducing and preventing economic losses associated with disasters. These can be combined with emergency preparedness and response procedures linked to early warnings to further reduce the risks.

The decision to invest in such measures should be underpinned by

62 World Bank (2014). Financial protection against natural disasters: an operational framework for disaster risk financing and insurance.

understanding the risk, and by cost-benefit analysis of risk reduction and risk prevention measures. However, despite such efforts, some residual economic risk will always remain. Risk financing and risk transfer measures (such as insurance) provide protection cover and can distribute or pool the residual economic risk. A number of recent studies indicate that, following a major disaster, countries with lower levels of insurance penetration experience larger declines in economic output and more considerable fiscal losses than those with higher levels of insurance penetration.[63] Finally, these can be complemented by effective reconstruction plans (that may also consider re-zoning) that aim to reduce future disaster risks and build resilience after any major event.

Disasters lead to a number of direct and indirect financial impacts on governments, businesses and individuals

The direct impact on a government's budget could include:

- Emergency relief and response expenditures
- Relocation of affected or at-risk citizens
- Reconstruction or improvements of non-insured or partially insured public infrastructure and family dwellings
- Costs of social and economic programmes for rehabilitation and recovery
- Contingent liabilities for State-owned and other enterprises that are critical to economic recovery.

Indirect impacts could include:

- Decreased tax revenues associated with business interruption and decline in GDP growth
- Opportunity cost of diverting funds from intended development plans to reconstruction and recovery programmes
- Additional expenditures related to effectiveness of social recovery programmes
- Increased borrowing costs and potential negative impacts on the sovereign credit rating
- Migration of population as a result of loss of livelihoods.

Direct impacts on businesses/individuals could include:

- Cost of reconstruction of uninsured or partially insured assets

---

63 Von Peter, G., S. von Dahlen and S. Saxena (2012). Unmitigated disasters? New evidence on the macroeconomic cost of natural catastrophes. BIS Working Papers No. 394. Basel: Bank for International Settlements.

- Cost of replacement or repairs of uninsured or partially insured assets
- Health care
- Loss of sources of income
- Decline in property value owing to destruction of surrounding infrastructure.

Indirect impacts on businesses/individuals could include:

- Loss of income owing to business interruption, unemployment, death or economic decline
- Increased borrowing costs
- Additional costs such as relocation and alternative housing, and long-term disability.

At a sectoral level, the economic consequences of some disaster risks can be felt across an entire supply chain and can affect economic output by interrupting supply chain and market accessibility. For example, they can affect a country's exports or have global impacts from supply chain disruptions.

On the other hand, in countries with limited economic diversity, a single catastrophe can lead to profound economic impacts. For low-income countries, these types of economic shocks can deepen poverty levels and lead to complex emergencies, requiring significant humanitarian and relief interventions.

Post-disaster financial needs are often defined by three phases: (a) immediate relief and rescue response, (b) early recovery and (c) the reconstruction phase.

Funding needs will differ in each phase. Relief and rescue requires immediate access to funds for urgent rescue, food, medicine, clean water and shelter for those injured, affected and displaced. Early recovery requires funding, within weeks, to restore livelihoods, help communities return to some level of normality and restart their economic activities. Reconstruction requires more substantial funds to be mobilized for repairing and rebuilding damaged assets such as homes and critical infrastructure.

Funds are therefore required on different timescales. Delays in receiving funding can hamper each phase, negatively impacting the population and the economy.

Sovereign risk financing and risk transfer measures offer a variety of solutions to provide cover against financial impacts of disasters on governments, businesses and individuals as well as financing some of the post-disaster expenses

Sovereign risk transfer can take several forms, each with different trigger mechanisms, payout conditions and timescales. The suitability of this approach will differ depending on each government's budget and risk contexts. [64][65]

The first important distinction is whether public or private assets are being considered and whether these are on aggregate level (e.g. via a sovereign insurance scheme) or individual level (See boxes 1 and 2). Another important distinction is between indemnity-based and parametric insurance. With the former, claim payments are linked to the actual losses incurred by the insured. Under indemnity cover, all claims need to be individually checked, which may lead to significant transaction costs.

On the other hand, parametric trigger-based insurance contracts make a payout if a physical loss parameter (e.g. wind speed or amount of precipitation) is reached, and not on the basis of actual losses incurred by the insured.

Compared with indemnity-based insurance, loss parameters used in risk transfer schemes with parametric triggers are available immediately after the event causing losses. The most significant disadvantage of parametric triggers

---

[64] Organisation for Economic Co-operation and Development (2015a). *Disaster Risk Financing: A Global Survey of Practices and Challenges*.

[65] Golnaraghi, M. and P. Khalil (2017). The stakeholder landscape in extreme events and climate risk management. The Geneva Association, Zurich.

Organisation for Economic Co-operation and Development (2015b). Financial instruments for managing disaster risks related to climate change. OECD Journal: Financial Market Trends, vol. 2015, No.1.

The Geneva Association: www.genevaassociation.org

The World Bank Global Facility for Disaster Risk Reduction (GFDRR). The GFDRR website provides a large library of research, tools and publications that relate to every aspect of resiliency and protection against natural disasters, including disaster risk financing and insurance.
Available from www.gfdrr.org/

Golnaraghi, M., ed. (2012). Institutional Partnerships in Multi-Hazard Early Warning Systems. Heidelberg/New York: Springer Verlag.

Organisation for Economic Co-operation and Development (2017). OECD Recommendation on disaster risk financing strategies.
Available from www.oecd.org/daf/fin/insurance/OECD-Recommendation-Disaster-Risk-Financing-Strategies.pdf

World Bank (2012). Disaster Risk Financing and Insurance Concept Note: Sovereign Disaster Risk Financing. Available from
http://siteresources.worldbank.org/EXTDISASTER/Resources/SDRF_Concept_Final.pdf

is basis risk, i.e. the difference between the actual loss incurred by the insured and the payout.

Since the 1990s, a number of "alternative risk transfer" (ART) capital market instruments have been developed to complement the more traditional (re)insurance solutions. These insurance-linked securities (ILS) (e.g. catastrophe bonds) provide substantially more reinsurance capital to cover catastrophe losses by transferring risks to the capital markets.

Key considerations for development of sovereign risk financing and risk transfer programmes in middle- and low-income countries

When developing sovereign risk transfer programmes in middle- and low-income countries, several factors should be taken into consideration:[66]

1. There must be a clear understanding of the objectives of the sovereign risk transfer programme. For example, the programme may be: (a) primarily required to provide stimulus for domestic insurance markets, or (b) to provide cover that the government is not able or willing to provide such as for public emergency relief, or (c) used to protect public assets, or (d) required to supplement budgetary measures that can provide a portion of post-disaster financing to help expedite recovery.

2. Any risk transfer product should cover the appropriate risks, to the appropriate level of cover that aligns with the government's risk appetite and budget for covering post-disaster costs. It is necessary to understand what risks require cover, the likely frequency and size of losses that the government may have to cover, what percentage of these costs the government will pay from its own budget and what proportion it wishes to insure or finance. The estimated costs should help to determine the risk the government may wish to retain (i.e. the proportion of the post-disaster costs that it can cover from its own budget).

3. There must be adequate data and technical expertise to support the pricing, structuring and provision of the risk transfer or financing cover.

    - The data should be able to describe the magnitude, frequency and geographic distribution of potential losses in order to correctly price and structure cover.

    - These data can be generated by risk assessment methods, referred to as probabilistic catastrophe (Cat) modelling. The development, calibration and utilization of such models require multidisciplinary technical expertise and experience with interpretation of model output. Input data are often unavailable or incomplete. Incomplete knowledge of hazard events and their impact means more uncertainty for insurance pricing and penetration.

4. When developing new risk transfer mechanisms, a number of market considerations may also be considered, depending on the objectives:

    - A strong and reliable primary insurance market and access to

---

[66] Golnaraghi, M., S. Surminski and K. Schanz (2016). An integrated approach to managing extreme events and climate risks: towards a concerted public-private approach: with recommendations to harness potential contributions of the insurance industry. The Geneva Association, Zurich.

reinsurance are important. In the absence of mature institutions to partner with, there may be a need to provide (re)insurance capacity and expertise, and there may be higher associated costs of distribution, claims verification and settlement.

- There should be awareness of and appreciation for any regulatory issues within the market.
- Potential for adverse risk selection by the insurers, owing to scarcity of data, particularly in markets that are not yet well developed.
- Risk of limited take-up resulting in a small pool of policyholders.
- Creation of a moral hazard, unless new insurance protection incentivizes risk-reducing behaviour.

5. Understanding the linkages of insurance premiums, frequency of payments and insured limit/cover is important. Calculation of the Annual Expected Loss (AEL) is the single most important individual contributor to the final cost (premium) of an insurance product. The expected loss is a result of a calculation looking at how often (frequency) and how much (insured limit or cover) will be paid to the insured. This relationship is key, as changing one of the three elements (premiums, frequency and insured limit) will immediately impact one of the other two.

Risk Assessment: a Critical Step for Design of Sovereign Risk Financing and Risk Transfer Programmes

To determine the required scope and type of risk financing or risk transfer in a country, a government should first understand the risk context; for example, the potential impacts of disasters on the population, infrastructure and economy

Disaster risk assessment modelling provides this understanding and quantification. Results are presented not only in terms of the annual average loss that is expected to occur in any year (AAL), but also, more usefully, of the probability that losses exceed a given size in any given year (also presented as "Return Period" or "recurrence interval" or "1 in 100 year loss", for example). Losses can be broken down by geographic region, event type etc.

Disaster risk is a function of three interlinked components: hazard, exposure and vulnerability.

Probabilistic catastrophe (Cat) models provide a systematic and rigorous approach to pricing, underwriting and managing complex risk portfolios

Since the 1980s, Cat risk modelling has been developed by the insurance industry to create a systematic approach to pricing, underwriting and managing complex insured risk portfolios.

Increasingly, Cat models, or variations thereof, are being used by national authorities to design sovereign risk financing and risk transfer applications. These models include the following three modules:

> *Hazard module:* developed by assigning spatial and temporal distributions to hazard events and their characteristics. This is typically based on the historical catalogue of events in a region. These catalogues are incomplete owing to unrecorded events, especially as we look further back in time. Therefore a probabilistic model is required, in which simulations are used to augment the historical catalogue with distribution of possible realistic events that could be expected to occur, but may not yet have been observed.
>
> *Exposure module:* a representation of assets (e.g. buildings, agricultural crops) that could sustain a loss and that should describe the location, value and construction attributes of each asset.
>
> *Vulnerability module:* comprises a relationship for each asset (e.g. a building) and its properties (e.g. construction type), describing how hazard intensity relates to damage sustained (generally as a proportion of asset value).

Before conducting an assessment for risk financing and risk transfer, the scope and type of financing mechanism should also be defined, as this influences the required content, fidelity and extent of modelling. In turn, this affects the level of investment and partnerships required in developing the hazard, exposure and vulnerability data.

In the risk assessment stage, it is important to define the goals of the risk assessment and identify who can and should do the assessment

A government may want to use an existing assessment, or design and implement its own risk assessment using internal scientists and experts. In considering these options, the methods and outputs should be assessed to confirm whether they may be seen as acceptable for use by the insurance market. If an assessment is deemed unacceptable for insurance market use, engagement with experienced external catastrophe (Cat) modelling organizations may be required to develop risk models and implement assessments specifically for use by this market.

For some countries and perils, several models exist and each is likely to provide different estimates of risk. A common question is 'which model is right?'

Different models employ different assumptions and processes in each step of the model chain, owing to available data or resources, alignment with a particular statistical or computational method, or how the model treats uncertainties. Combined, these differences contribute to (sometimes large) differences in the estimated losses. A government should look to evaluate the methods and validate input and outputs when making a judgement on which model(s) to use as a basis for designing its risk financing or risk transfer programmes. It should assess the source and scientific justification of methods, ensure that uncertainty is correctly accounted for in each component and retained throughout the model.

The input data used to develop a model should be from a reliable source, and should be as complete as possible, with any assumptions around data contents being adequately justified. Data and methodological transparency is important in being able to validate models. This is improving with the growth in availability of open source models. However, for commercial models, validation should be conducted through detailed discussions with model developers.

Parametric options may be considered when exposure and vulnerability information is lacking or unreliable, particularly for financing emergency response and early recovery, rather than financing reconstruction

In instances where hazard information for a particular region is reliable but data for exposure and vulnerability are either not available or are of low quality, mechanisms for financial payouts could be constructed based on hazard data alone. This would require analysis and design of the settlement index, triggers and associated payout. If the index is not carefully designed, it may pay out when there is little or no impact or even worse, not pay out when there has been an impact.

Key stakeholders

The development of a successful risk financing and risk transfer programme requires the collaboration of multiple stakeholders and information providers

Risk assessments and development of sovereign risk financing and risk transfer programmes should engage a variety of stakeholders from the government (relevant ministries), national technical agencies and data providers, academia and centres of excellence, (re)insurance industry, international and regional development banks, non-governmental organizations and the risk modelling community.

Multistakeholder processes should ensure (a) consideration of end users' needs and requirements, (b) development of in-country technical and operational capacities, (c) utilization of the risk assessment by all stakeholders and (d) incentives for take-up of the programme and for promoting its sustainable use.

Specifically:

5. Data and models should be developed in collaboration with national operational services and data providers to build capacity and promote the sustainable maintenance of the risk data. These may include academics, national meteorological, hydrological and geological services, as well as other government and non-governmental agencies that collect and maintain sectoral data such as the national bureau of statistics.

6. From the buy-in perspective, cooperation within and across government agencies (including national, provincial and local governments) is important to generate buy-in to the transfer programme and incentivize insurance take-up at individual level where required.

7. From sustainability and effectiveness perspective, partnership with a variety of risk transfer experts is important. Development of risk transfer solutions appropriate to the government's requirements could benefit from risk modelling, actuarial and risk transfer expertise of the domestic and international private (re)insurance industry; as well as regional or international development banks and groups such as the Insurance Development Forum. Where a risk transfer mechanism targets a specific sector, for example agriculture, it is paramount to include sector specialists in data provision and generation, and in solution design to ensure the risk transfer product can be effective for its target market and beneficiaries.

8. NGOs may have an important role to play in a number of areas, as per their expertise. For example, in the promotion and assisting with the take

up of these solutions at the local level.

9. The above may be further supplemented by bringing in other domestic and international experts.

Examples

Over the past years, a number of initiatives have been established to offer coverage for the protection of government budgets, communities and individuals in a disaster situation. Prominent examples of regional pools include the Caribbean Catastrophe Risk Insurance Facility (CCRI), the Pacific Disaster Risk Financing and Insurance Programme, which was built upon the Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI), and the African Risk Capacity (ARC) (box 1). Other national risk transfer programmes have also emerged (box 2). A comprehensive list is provided in Golnaraghi and Khalil (2017).

CASE STUDY

Box 1
Examples of regional pools

Caribbean Catastrophe Risk Insurance Facility (CCRIF)
www.ccrif.org
Established in 2007 as the first multi-country risk facility, CCRIF provides catastrophe insurance to 16 Caribbean governments. Initial funding came from grants – the largest being from the Governments of Canada and the United Kingdom – and sponsorship by the World Bank.
CCRIF is a mutual insurance company owned by its client country members. It is designed to provide emergency relief to governments on a parametric basis, allowing swift payment after a loss. The largest payment it has made for a single event was US$ 23.4 million to Haiti, under the country's tropical cyclone and excess rainfall policies, as a result of Hurricane Matthew in October 2016.
Initially, most members were dependent upon premium funding in order to be able to join, but now all but one, Haiti, pay their premiums.
CCRIF also provides educational and technical support across the Caribbean and has spawned several micro-insurance schemes. It buys traditional reinsurance and issued a Catastrophe bond in 2014. It is advised by a United Kingdom-based reinsurance broker on risk modelling, reinsurance design, pricing and placement.

Pacific Disaster Risk Financing and Insurance Program
www.pacificdisaster.net/pdnadmin/data/original/WB_2011August_PDRFIS.pdf
Launched in 2013, the Pacific Disaster Risk Financing and Insurance Program provides parametric disaster insurance for tropical cyclones and earthquakes. Currently there are five participating countries: Marshall Islands, Samoa, Tonga, Vanuatu and Cook Islands
The overall aim is to provide short-term liquidity to participating governments in the event of disaster. The first payout was made to Tonga in January 2014 (US$ 1.27 million).
The pool is part of the Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI), a joint initiative of the World Bank, the Secretariat of the Pacific Community (SPC/SOPAC) and the Asian Development Bank, with financial support from the Government of Japan, the Global Facility for Disaster Reduction and Recovery (GFDRR) and the Africa, Caribbean, Pacific-European Union Natural Disaster Risk Reduction Program.
PCRAFI was launched in 2007 to provide the Pacific island countries with disaster risk assessment and financing tools for enhanced disaster risk management and climate change adaptation.

African Risk Capacity (ARC) http://www.africanriskcapacity.org/

ARC was formed in 2014, initially to provide cover against drought to African countries. Its creation was sponsored by the World Food Programme, operating under the African Union. Like the Caribbean Catastrophe Risk Insurance Facility Segregated Portfolio Company (CCRIF), ARC is a mutual insurance company, although countries that provided loans to capitalize the company (Germany and United Kingdom) are also members. Cover is on a parametric index basis offering drought and windstorm policies.
ARC Insurance Company Limited has a sister organisation, ARC Agency, which provides African governments with advice on why insurance is required, how its insurance contract should be structured and how to create contingency plans.
ARC has 32 member countries, with 8 currently buying insurance. In January 2015, Senegal, Niger and Mauritania received an insurance payout of more than US$ 26 million, triggered by the drought in the Sahel, before an international humanitarian aid appeal was made. Twenty-four reinsurers participate in reinsurance cover, including Lloyd's syndicates.
Note: When engaging in regional facilities, the availability of premium financing among governments can strongly influence take-up of sovereign risk transfer. As of May 2017, only eight of 32 member countries in the ARC purchase cover, with the most significant barrier to growth being a lack of a premium financing facility.
CCRIF overcame such issues by providing such a facility, which allowed members to join and phase in premium payment over several years. With such a facility, it is estimated that by 2020, ARC could cover 20 countries, meeting a significant proportion of the G7's InsuResilience target – 400 million people in developing countries to be brought under the coverage of catastrophe insurance by 2020.

CASE STUDY

Box 2
Examples of national risk transfer programmes

Turkey: Turkish Catastrophe Insurance Pool (TCIP) www.tcip.gov.tr
The ever-present threat from widespread earthquake damage led to the creation of TCIP in 1999. TCIP provides earthquake and fire insurance coverage at affordable yet actuarially sound rates for registered urban dwellings, limits the Government's financial exposure to loss, builds long-term catastrophe reserves and encourages risk reduction and mitigation practices in residential construction.
During the first five years, the World Bank provided a contingent credit layer that would have provided capital relief should there be a shortfall as a result of claims activity.
Reinsurance cover per event is purchased through various layers. Current market penetration is around 34 per cent (approximately 5.6 million policies), with an average premium per policy of €59.

India: Telenor Suraksha Micro-insurance https://microensure.com/telenors-free-life-insurance-scheme-suraksha-recognised-efma-accenture-innovation-insurance-awards-2016/
In September 2015, Telenor India launched Telenor Suraksha, India's first mass-market life insurance product, in partnership with MicroEnsure, a leading United Kingdom-based micro-insurance specialist, and Shriram Life Insurance.
Cover is offered via Telenor's network of 48 million customers, who can sign up when topping up their phones. The electronic registration process is simple and no paper policy document is required. Cover is offered without exclusions and is offered for free for a certain amount of airtime usage as a reward to loyal subscribers.
Education on the benefits of insurance is made through marketing materials, text messages (SMS) and a phone menu that provides all the information required. Claims are paid using mobile money. Within 148 days, more than 22 million customers had opted for the programme, with most of thesepeople living in rural areas. Over 95 per cent of customers had never had any form of insurance previously.

France: Caisse Centrale de Réassurance (CCR) www.ccr.fr
CCR was created in 1946 as a pool to cover all perils not traditionally insured through the private market, including flood, mudslide, earthquake, landslide, subsidence and tidal waves. Losses are only covered when an event is declared a natural disaster by government decree and results in property damage. Cover is compulsorily included (to avoid adverse selection) in fire and property damage policies covering homes, commercial and industrial properties, farms and motor vehicles, including any business interruption cover where provided in original policy.
A flat premium rate is applied, which is set by the State, to each eligible policy which varies by class. Gross written premium is above €1 billion. CCR has an unlimited State guarantee and purchases its own reinsurance programme in the open market to manage volatility.

Checklist for conducting risk assessment for design of sovereign risk financing and risk transfer programs

For protection of government budget	For protection of individuals
Define geographical coverage of programme, e.g. national, subnational, city [1,2]	Define geographical or unit of coverage of programme, e.g. national, subnational, city, community, household [1,2]
Define hazard(s) or peril(s) to be covered by the programme, e.g. windstorm, drought, cyclone, excess rainfall, earthquake, epidemic [1,2]	Define hazard(s) or peril(s) to be covered by the programme, e.g. windstorm, drought, cyclone, excess rainfall, earthquake, epidemic [1,2]
Define what risk(s) are to be covered, e.g. budgetary risks post disaster, property, critical infrastructure agriculture, infrastructure [1,3]	Define what risk(s) are to be covered, e.g. residential property, agriculture, infrastructure, livelihoods. [1,3]
Identify existing government protection arrangements (includes risk transfer programmes, credit lines, or budget allocation) to be used to disburse funds in the event of disaster. Define objectives and assess how a new programme will efficiently enhance or add to existing schemes [1,3]	Identify existing insurance arrangements to protect individuals (includes risk pools, government-backed insurers) to be used to pay individuals' claims in the event of disaster. Assess how a new programme will efficiently enhance or add to existing schemes [1,3]
Define the type of trigger that will be used to signify payout, e.g. indemnity (loss) or parametric (hazard) NB: possible to migrate over time or have both components in a scheme [1,3] Collect, assess and quality assure data for the hazard, exposure and vulnerability modules of the models [2,3]	Define the type of trigger that will be used to signify payout, e.g. indemnity (loss of an asset) or parametric (based on characteristics of hazard) NB: possible to migrate over time or have both components in a scheme [1,3] Collect, assess and quality assure data for the hazard, exposure and vulnerability modules of the models [2,3]
Determine level of international sponsorship of the programme from e.g., international development banks, global insurance and reinsurance companies [1]	Define cover types compulsory (possibly politically unpopular) or optional (possible adverse selection and low take-up) [1]
Determine who will guarantee the programme, e.g. reinsurance purchase, or capital markets [1,4]	Determine who will guarantee the programme, e.g. government as insurer of last resort, reinsurance purchase, or capital markets [1,4]
Determine premium rate conditions: flat-rate (increases social solidarity) or risk-adjusted (influencing behaviour and often required by international schemes). Determine whether premium financing scheme is required to encourage take-up [1,4]	Determine premium rate conditions: flat-rate (increases social solidarity) or risk-adjusted (influencing behaviour and often required by international schemes) [1,4] Identify potential hurdles to take-up
Identify internal and external experts to support the development, interpretation and guide the utilization of the risk model(s) [1,2, 3, 4]	Identify internal and external experts to support the development, interpretation and guide the utilization of the risk model(s) [1,2, 3, 4]
Conduct risk modelling of appropriate fidelity and scope to support the design of risk transfer programme, based on outcomes of above steps. [1,3]	Conduct risk modelling of appropriate fidelity and scope to support the design of risk transfer programme, based on outcomes of above steps. [1,3]

Note: [ ] indicates the stakeholders who should be involved in each step:

[1] Government authorities at all the relevant levels, ministries of finance and other relevant ministries; insurance experts and insurance industry representatives (domestic and international) to define needs of programme.

[2] Academics, domestic technical experts, technical operational centres that collect and maintain hazard (national meteorological, hydrological, geological services) and sectoral data (and when required regional and international experts).

[3] Risk analysis experts / risk modellers.

[4] International sponsors (e.g. development banks, NGOs).

Authors:

Maryam Golnaraghi (The Geneva Association), Ian Branagan (RenaissanceRe, Insurance Development Forum (IDF)), Stuart Fraser (Fraser Disaster Risk Consulting Ltd, IDF), Jonathon Gascoigne (Willis Towers Watson, IDF), Anne Marie Gordon (RenaissanceRe, IDF)

Contributors and Peer Reviewers:

Paul Nunn (SCOR SE), Gerry Lemcke (Swiss Re), Peter Hoppe and Earnst Rauch (Munich Re), Simone Ruiz-Vergote (Allianz) and Alanna Simpson (World Bank)

K. Consideration of Marginalized and Minority Groups in a National Disaster Risk Assessment

Key words:

marginalized groups, cross-sectionality, ethnic minorities, indigenous people, children, women, migrants, people with disabilities, older people

This chapter will cover the essential stages of designing, implementing and monitoring a national risk assessment (NRA) that is inclusive of all within society. It will focus on different marginalized groups, whose differences need to be considered by the policymakers, officials and risk specialists when developing an NRA.

Marginalized groups

A natural or technological hazard can have different short or long-term impacts on various groups within society[67]. A person's gender, age, physical abilities, ethnicity and sexuality, for instance, can lead to a higher risk of death or injury, longer recovery times or greater risk of mental or physical trauma.

Equally, different groups may bring unique skills, resources and knowledge to reduce risk and overcome the aftermath of a disaster. The strengths and challenges of each group should be recognized at an early stage of preparing the assessment.

The Sendai Framework identifies the following groupings:

- **Women (or gender more broadly):** Women and girls may often face greater risks than men and boys in the aftermath of a disaster. This is often due to societal constructs, which can mean that they are less socially mobile, less economically independent and less educated.[68] The risks can also come from indirect outcomes of a disaster such as gender-based violence, which always increases after a disaster.[69]
  Women contribute on a number of levels in the aftermath of a disaster. Their high level of risk awareness, extensive knowledge of their own communities and experience in managing natural environmental resources all mean that they constitute a powerful resource in dealing with disasters.[70]

  Those same societal constructs can also result in increased risks for men and boys. As assumed leaders of their community, men and boys will often be tasked with roles that increase the risk of injury or death. These types

67 Bankoff, G., G. Frerks and D. Hilhorst (2004). *Mapping vulnerability: disasters, development, and people.* London and Sterling VA: Routledge.

68 Niaz, U. (2009). Women and disasters. *Contemporary Topics in Women's Mental Health: Global Perspectives in a Changing Society.* Chichester: Wiley.

69 Enarson, E. (1999). Violence against women in disasters: a study of domestic violence programs in the United States and Canada. *Violence Against Women,* vol. 5, pp. 742-768.

70 Aguilar, L. and others (2008). Training Manual on Gender and Climate Change. San José: International Union for Conservation of Nature, United Nations Development Programme, Global Gender and Climate Alliance.

of gendered roles have been shown to lead to post-traumatic stress disorder and other mental health issues.[71]

- **Children and youth:** Children and young adults may experience the impact of a hazard differently, depending on their age. Children have developmental (physical and psychological) differences, which need to be recognized.[72] Children and youth are often recognized as agents of change and can bring innovative thinking to an emergency situation. This should be done within the proper legal and institutional framework and in no way that might exploit the young people.

- **Older people:** When a disaster occurs, more older people die or are injured than the younger members of a community. And more complex medical requirements, lack of mobility and exclusion from mainstream society are all factors that can contribute to increased risk.[73]
  Older people also have a huge amount of life experience and knowledge of previous disasters and can provide that experience to disaster risk reduction.

- **People with disabilities:** People with disabilities (e.g. physical disability, intellectual impairment or mental health problems) can be at a high risk from disasters.[74] Less mobility, speed and reduced sensory input can mean more risk of injury or death.
  Nonetheless, they are not deprived of certain capacities – as in the case of blind people, whose sensorial skills may provide them with a unique ability to evacuate an earthquake-stricken building in the dark.
  Specialist planning and attention is required to respond to the needs and requirements of this group during a disaster. A 2014 UNISDR report highlighted that only 15 per cent of people with disabilities had actually been consulted in their own community resilience plans.[75] Programmes around the world have shown how providing such persons with education and training creates greater levels of independence and reduces the number of injuries and death.

- **Migrants:** Because of poverty, language barriers or discrimination, migrants often struggle to access resources and means of protection that

---

71 Neumayer, E. and T. Plümper (2007). The gendered nature of natural disasters: the impact of catastrophic events on the gender gap in life expectancy, 1981-2002. *Annals of the Association of American Geographers*, vol. 97, issue 3, pp. 551-566.

72 American Academy of Pediatrics. The youngest victims: disaster preparedness to meet children's needs. Available from www.aap.org/en-us/advocacy-and-policy/aap-health-initiatives/Children-and-Disasters/Documents/Youngest-Victims-Final.pdf

73 Pekovic, V., L. Seff and M. Rothman (2007). Planning for and responding to special needs of elders in natural disasters. *Generations*, vol. 31, No. 4, pp. 37-41.

74 Smith, F., E. Jolley and E. Schmidt (2012). Disability and disasters: the importance of an inclusive approach to vulnerability and social capital. Sightsavers.

75 United Nations Office for Disaster Risk Reduction (2014). *Living with Disability and Disasters: UNISDR 2013 Survey on Living with Disabilities and Disasters - Key Findings.* Available from www.unisdr.org/2014/iddr/documents/2013DisabilitySurveryReport_030714.pdf

are available to locals before, during and after disasters. Illegal migrants cannot even claim such access to protection.[76]
On the other hand, migrants may bring valuable knowledge of different hazards and send to their home communities remittances that often prove essential for reducing risk and overcoming disasters.

- **Ethnic minorities and indigenous peoples:** Minority ethnic groups and indigenous peoples often face difficulties in accessing their share of resources and assistance in dealing with disasters. Marginalization of these groups may also become exacerbated in the aftermath of disaster.[77] Traditional knowledge held by indigenous groups can provide alternative ideas for disaster risk reduction.[78] Integrating traditional knowledge within the administrative frameworks of a city or region must be done with a full understanding of how each will enhance or detract from the other.[79]

The categories detailed above are often those focused on, particularly by large international non-governmental organizations, in the aftermath of a disaster. However, care should be taken to recognize any other groups, within the local, national or regional context, that require separate consideration or have experienced marginalization. For example:

- **Sexual minorities:** People identified as sexual minorities within a community (largely associated with the Global North definition of gay, lesbian, bisexual, transgendered or intersex persons) will often find increased hostility from others in the community.[80] This can be compounded by the specific medical needs of some (HIV medication, hormone replacement therapy for transgendered people).

It is also imperative that the issue of cross-sectionality (also known as intersectionality) be recognized an inclusive risk assessment process is being designed and implemented. Cross-sectionality is the recognition that social identities will often overlap, and increase or decrease a person's vulnerability

---

76 Sudmeier-Rieux, K. and others (2016). *Identifying Emerging Issues in Disaster Risk Reduction, Migration, Climate Change and Sustainable Development*. Springer.

77 Bolin, B. (2007). Race, class, ethnicity, and disaster vulnerability. In *Handbook of Disaster Research*. New York: Springer.

78 Le De, L., J.C. Gaillard and W. Friesen (2015). Remittances and disaster: policy implications for disaster risk management. *Migration, Environment and Climate Change: Policy Brief Series,* vol. 1, issue 2. Available from https://environmentalmigration.iom.int/policy-brief-series-issue-2-remittances-and-disaster-policy-implications-disaster-risk-management

79 Miller, M.A. (2014). Decentralized disaster governance: a case for hope from Mount Merapi in Indonesia? Asia Research Institute Asian Urbanisms blog. Available from https://nus.edu/2pzpqtv

80 Balgos, B., J.C. Gaillard and K. Sanz (2012). The warias of Indonesia in disaster risk reduction: the case of the 2010 Mt. Merapi eruption in Indonesia. *Gender & Development*, vol. 20, No. 2, pp. 337-348.

accordingly.[81] An older woman who belongs to an ethnic minority group within her society and has a form of physical disability would find recovering from a disaster much harder than a younger woman who is part of the majority ethnic group and has no physical disabilities.

Development of an inclusive process – the basics

A national risk assessment that is inclusive and helps all within a community relies on the appropriate recognition, appreciation and understanding of marginalized communities.[82] This recognition will enable discussion and thought to be applied to steps that may have otherwise excluded or ignored at-risk people and groups. Development of an inclusive national risk assessment will also require work to build dialogue and trust between authorities and those sections of the community that have been marginalized or overlooked.

Marginalized groups should be included in risk assessment and DRR policy and practice. This inclusion must be made without tokenism and for the benefit of all within the community.[83]

Agreement should then be reached on which elements of society are most at risk, or most excluded, before, during and after a disaster within the country.[84] This could be in the form of achieving greater inclusion for specific marginalized groups or a better understanding of the risks associated with specific situations within a disaster outcome (reducing violence against women and girls, or increasing resilience and capacity of indigenous people).

Once these clear components have been established and the aim of the action has been decided, key stakeholders will need to be identified. These individuals or organizations will reflect the views and needs of all sectors of society, including the most marginalized and vulnerable, and provide the necessary knowledge and background for successfully incorporating the agreed aims into the NRA.

Civil society organizations, academic institutions, local and national government agencies and non-government organizations are a few examples

---

81 Donner, W. and H. Rodríguez (2008). Population composition, migration and inequality: the influence of demographic changes on disaster risk and vulnerability. *Social forces,* vol. 87, No. 2, pp.1089-1114.

82 McEntire, D.A. (2005). Why vulnerability matters: exploring the merit of an inclusive disaster reduction concept. *Disaster Prevention and Management: An International Journal*, vol.14, No. 2, pp. 206-222.

83 O'Meara, C. (2012). Disability Inclusive Community Based Disaster Risk Management: A toolkit for practice in South Asia. Handicap International. Available from http://g3ict.org/download/p/fileId_1001/productId_312

84 Benson, C. and J. Twigg (2007). Tools for mainstreaming disaster risk reduction. Geneva: International Federation of Red Cross and Red Crescent Societies/ProVention Consortium.

of key stakeholders. It is essential to foster a dialogue between all these stakeholders throughout the whole process so that everyone recognizes the specific vulnerabilities and capacities of the marginalized groups.

Using the aims, components and stakeholders identified, the NRA team will then need to decide on the best data collection methodologies and analysis process so as to produce a comprehensive and inclusive risk assessment.

The importance of include representatives of marginalized groups within this process cannot be overemphasized. These will assist in ensuring that aspects not normally considered by others outside these groups are heard and included. This stage also requires careful thought on intersectionality and conflict avoidance or reduction to ensure that the identification and reduction of risks does not inadvertently lead to a transfer of risk to another marginalized group.[85]

The incorporation of such marginalized groups should begin at the very initial stages of NRA development. Ensuring an effective and appropriate communication strategy to reach all sections of society from the outset is vital to understanding and considering how each of these groups may be affected by a disaster and allows for planning, design and risk reduction policy to be developed within the strategy.

---

85 Mitchell, T. and others (2010). C*limate Smart Disaster Risk Management, Strengthening Climate Resilience.* Brighton: Institute of Development Studies.

Resources for further information

High level multi-stakeholder partnership dialogue - Inclusive Disaster Risk Management – Governments, Communities and Groups Acting Together
www.wcdrr.org

For information on building a gender-responsive DRR system
www.gdn-online.org

Good example of an Inclusive Framework and Toolkit for Community-Based Disaster Risk Reduction
www.preventionweb.net/files/48286_48286inclusiveframeworktoolkitforcb.pdf

E-learning action, research, capacity building and policy advocacy project - Inclusive Community Resilience for Sustainable Disaster Risk Management (INCRISD)
www.incrisd.org/index.php

Authors:

Kevin Blanchard (DRR Dynamics), Maureen Fordham (University College London), JC Gaillard (University of Auckland), Virginia Murray (Public Health England (PHE)

Contributors and Peer Reviewers

Owen Landeg (Public Health England), Zehra Zaidi (Euro-Mediterranean Centre for Climate Change)

L. Cross-border risk assessment

Key words:

Cross-border risk, systemic and cascading risk

Disaster risk knows no national boundaries, as movements of goods, people and finances are intricately linked across borders. While most disasters observed globally are geographically confined incidents occurring on a subnational scale, disasters routinely displace millions of people within and across borders (IDMC 2016).

Around the world, over 270 rivers cross the borders of two or more countries. Ten per cent floods reported globally in periods between 1985 and 2005 were transboundary incidents, which affected approximately 60 per cent of the population (Bakker 2009). Transboundary resources such as rivers may act as a mechanism for the spread of contamination, as in the Sandoz chemical spill of 1986, when the river Rhine conveyed toxic chemicals through Europe after a fire at a Sandoz factory in Switzerland (Boos-Hersberger 1997).

When countries share critical infrastructure, commerce and supply chains (including food, water, fuel and medical supply chains), temporary shutdown of cross-border flows can significantly disrupt economic and social functions. Recent disasters such as the 2011 Thailand flood and the 2011 Japan earthquake and tsunami also illustrated the potential economic spillover impacts well beyond their borders (UNISDR 2013).

Following the destruction of the manufacturing industry in Tohoku, for example, the automobile production in Thailand and China's Guangdong Province declined by 11.5 per cent and 14.3 per cent in the second quarter of 2011, respectively (GFDRR/WorldBank). As more people travel across borders and are affected by disasters overseas, their countries of origin often become active in rescue – as seen in the Indian Ocean tsunami of 2004 and the New Zealand earthquake of 2016. These systemic and cascading consequences of natural disasters call for careful attention to cross-border concerns in national disaster risk assessment and management

In principle, cross-border risk assessment and transboundary coordination take place based on mutual respect for national sovereignty and require broad political support of national leaders and domestic stakeholders (Edwards 2009). Transboundary consideration for DRR – bilaterally or multilaterally – may be incorporated in a variety of forms such as joint risk assessment, contingency planning and exercises, financing and risk pooling arrangements, and technical cooperation. These may be promoted under non-legally binding arrangements such as intergovernmental meetings and strategic frameworks, or through explicit treaties such as the ASEAN Agreement on Disaster Management and Emergency Response, the CARICOM Caribbean Disaster Emergency Response Agency and the SAARC Agreement on Rapid Response to Regional Disasters (Brookings Institution 2013). Existing intergovernmental bodies also provide common platforms for mutual collaboration: the Mekong, Zambezi and Danube River commissions,[86] for example, are regional bodies

86 www.mrcmekong.org/; http://www.zambezicommission.org/;https://www.icpdr.org/main/

with varied extent of transboundary risk management involving major riparian States.

The establishment of common guidelines, harmonization of terminologies, and sharing of information using multiple languages are some of the first steps in harmonizing cross-border risk assessment (European Commission 2010; EXCIMAP 2007).

The United Nations Economic Commission for Europe recommends that countries jointly identify technological risk if an industrial facility is located within 15 km of the shared border or if an accidental substance released could reach a neighbouring country within two days. The Convention on the Transboundary Effects of Industrial Accidents also encourages member countries to share their risk assessment methodologies (UNECE 2001).

The current EU guidelines on national risk assessments also encourages the development of transboundary risk mapping, giving practical tips on how to facilitate such cross-border collaboration. The guidelines recommend broadening the scope of risk assessment as a way to garner stakeholder support, involving such sectors as air quality, spatial development, noise reduction, crisis management and others to engage in joint risk assessment (EXCIMAP 2007).

In addition to these intergovernmental platforms, recent years have also seen public- and private-sector collaboration such as RiSE promoted globally[87] and the Otagai project[88] between Thailand and Japan. These public-private initiatives encourage greater visibility of risk and DRR benefits using common risk metrics and certification schemes applicable to business investment decisions.

Cross-border DRR coordination and harmonization are advisable both to facilitate operation and to leverage limited resources and technical capacity. Collective policy response, such as the establishment of regional catastrophe risk pools. saves considerable public funds through "the law of large numbers". By pooling drought risk across the African continent, it is estimated that the African Risk Capacity (ARC) reduces its contingency funding needs by as much as 50 per cent (Clarke and Hill 2012). In the ARC, countries participate in an index-based insurance for infrequent, severe droughts, upon completion of initial processes such as the customization of the common risk assessment tool (Africa RiskView software), signing memorandums of understanding for capacity-building activities, agreeing on a contingency plan for ARC payouts, etc.

The fund's initial capital comes from member countries' premium contributions supplemented by partner contributions. In addition to ARC, similar gains from

---

87 www.preventionweb.net/rise/home

88 http://kenplatz.nikkeibp.co.jp/otagaien/project/

regional risk pooling initiatives are estimated for existing regional pools such as the Caribbean Catastrophe Risk Insurance Facility and the Pacific Catastrophe Risk Assessment and Financing Initiative.

With increased movements of capital, goods and populations, along with systematic drivers such as climate change, greater awareness of transboundary risk and bilateral and multilateral DRR cooperation will likely be needed.

References

Bakker, M. H. (2009). Transboundary river floods and institutional capacity. Journal of the American Water Resources Association, vol. 45, issue 3, pp. 553-566.

Boos-Hersberger, A. (1997). Transboundary water pollution and State responsibility: the Sandoz spill. Annual Survey of International & Comparative Law, vol. 4, No.1, pp. 103-131.

Brookings Institution (2013). In the Neighborhood: the Growing Role of Regional Organizations in Disaster Risk Management. www.brookings.edu/research/in-the-neighborhood-the-growing-role-of-regional-organizations-in-disaster-risk-management/

Caribbean Catastrophe Risk Insurance Facility. Brief for journalists, 22 February 2007. http://siteresources.worldbank.org/INTOECS/Resources/CCRIFBriefforJournalistspart1final.doc

Clarke, D. J. and R. Vargas Hill (2012). Cost-benefit analysis of the African risk capacity facility. www.foodsecurityportal.org/sites/default/files/arc_cost_benefit_analysis_clarke_hill.pdf

Edwards, F. L. (2009). Effective disaster response in cross border events. Journal of Contingencies and Crisis Management, vol.17, No. 4, pp. 255-265.

European Commission (2010). Risk assessment and mapping guidelines for disaster management. https://ec.europa.eu/echo/files/about/COMM_PDF_SEC_2010_1626_F_staff_working_document_en.pdf

European Exchange Circle on Flood Mapping [EXCIMAP] (2007). Handbook on Good Practices for Flood Mapping in Europe. http://ec.europa.eu/environment/water/flood_risk/flood_atlas/pdf/handbook_goodpractice.pdf

Global Facility for Disaster Reduction and Recovery (2012). Advancing Disaster Risk Financing and Insurance in ASEAN Member States: Framework and Options for Implementation. www.gfdrr.org/sites/gfdrr/files/publication/DRFI_ASEAN_REPORT_June12.pdf

Global Facility for Disaster Reduction and Recovery/WorldBank. The Economics of Disaster Risk, Risk Management, and Risk Financing. Economic Impacts.

Internal Displacement Monitoring Centre (2016). Global Report on Internal Displacement www.internal-displacement.org/assets/publications/2016/2016-global-report-internal-displacement-IDMC.pdf

United Nations Economic Commission for Europe (2001). Conference of the Parties to the Convention on the Transboundary Effects of Industrial Accidents www.unece.org/fileadmin/DAM/env/documents/2001/ece/cp/teia/ece.cp.teia.2.e.pdf

United Nations Office for Disaster Risk Reduction (2013). Global Assessment Report on Disaster Risk Reduction 2013. From Shared Risk to Shared Value: the Business Case for Disaster Risk Reduction. www.preventionweb.net/english/hyogo/gar/2013/en/home/index.html

World Bank (2013). Pacific Catastrophe Risk Insurance Pilot http://siteresources.worldbank.org/EXTDISASTER/Resources/8308420-1361321776050/Pacific-Catastrophe-Risk-Insurance-Pilot_4pager_12Feb13.pdf

Authors

Junko Mochizuki, Stefan Hochrainer, Keating Adriana and John Handmer (IIASA)

Contributors and Peer Reviewers

Peeranan Towashiraporn (Asian Disaster Preparedness Center)

Hazard Specific Risk Assessment

In support of the Sendai Framework
for Disaster Risk Reduction 2015 - 2030

UNISDR
United Nations Office for Disaster Risk Reduction

Words into Action Guidelines

National Disaster Risk Assessment

Hazard Specific Risk Assessment

UNISDR

2017 - UNISDR

Contents

1. Earthquake Hazard and Risk Assessment

Key words:
vulnerability function, probabilistic seismic hazard analysis (PSHA), ground motion prediction equation (GMPE), exposure model, earthquake hazard map

The uncontrolled growth of the global population led to an increase in annual earthquake-related losses from US$ 14 billion in 1985 to more than US$ 140 billion in 2014. Similarly, the average affected population rose from 60 million to over 179 million within the same period.[1] Earthquakes constitute approximately one fifth of the annual losses due to natural disasters, with an average death toll of over 25,000 people per year.[2]

Earthquakes may cause liquefaction, landslides, fire, and tsunami which would lead to far higher level of damage and losses. This module is focused on assessing only earthquake shaking hazard and risk. The assessment of earthquake risk constitutes the first step to support decisions and actions to reduce potential losses. The process involves developing (a) earthquake hazard models characterizing the level of ground shaking and its associated frequency across a region, (b) exposure data sets defining the geographic location and value of the elements exposed to the hazards and (c) vulnerability functions establishing the likelihood of loss conditional on the shaking intensity.

Risk metrics can support decision makers in developing risk reduction measures that can include emergency response plans, the enforcement of design codes, the creation of retrofitting campaigns and development of insurance pools.

Global earthquake activity

Most earthquakes are generated at boundaries where plates converge, diverge or move laterally past one another[3]. The greatest amount of seismicity occurs in regions where lithospheric plates converge. These convergent boundaries may manifest as regions of subduction, where oceanic crust is forced down beneath either the continental plate (e.g. west coast of South America) or of younger oceanic crust. Convergent boundaries may also produce regions of continental collision resulting in tectonic compression (e.g. the Himalayas).

Both types of environments are characterized by regions of high earthquake activity and host faults capable of generating very large earthquakes. Divergent plate boundaries represent areas where shallow crust is being pulled apart. These may manifest as rift zones (e.g. East African Rift), where the shallow continental crust is undergoing extension, resulting in moderate to high seismicity. Transform and transcurrent plate boundaries manifest where the relative movement of plates is lateral (e.g. San Andreas Fault in California). Because of their proximity to many large urban centres, these systems can pose a significant threat to society (e.g. Istanbul). Figure 1

---

1 Global Facility for Disaster Reduction and Recovery. The Making of a Riskier Future: How Our Decisions are Shaping Future Disaster Risk. Washington D.C.: World Bank.

2 EM-DAT (Emergency Events Database) (2017). www.emdat.be (last accessed on 24 Jan. 2017).

3 Bird, P. (2003). An updated digital model of plate boundaries. Geochemistry, Geophysics, Geosystems, G3, vol. 4, issue 3, doi:10.1029/2001GC000252.

illustrates the global distribution of earthquakes between 1900 and 2014, as well as the main plate boundaries.

Records of earthquake events throughout history are fundamental to our understanding of the earthquake process. Systematic recording of earthquake waves using more precise seismometry began at the end of the nineteenth century. The modern era of instrumental seismology was transformed, however, in the early 1960s with the establishment of the World-Wide Network of Seismograph Stations, which deployed over 120 continuously recording stations. The International Seismological Centre maintains the most comprehensive bulletin of parameterized earthquake events since 1964. The bulletin defines the location and size of earthquakes from an integrated network of approximately 14,500 earthquake stations.[4]

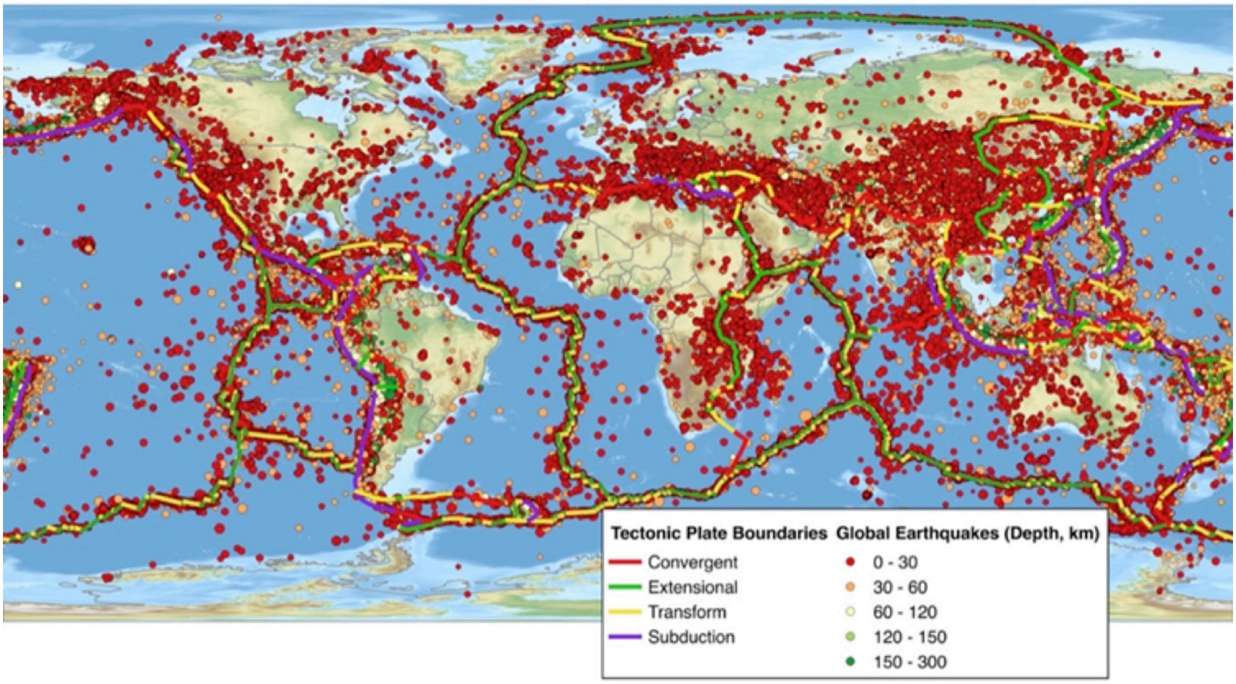


Figure 1 - The global distribution of earthquakes in the period from 1900 to 2014, and global plate boundaries

[4] Storchak, D. and others (2015). The ISC-GEM Global Instrumental Earthquake Catalogue (1900-2009): Introduction. Physics of the Earth and Planetary Interiors, vol. 239, pp. 48-63.

Earthquake hazard assessment

Earthquake hazard assessment enables the likelihood of ground shaking across a region to be calculated, which is a fundamental component in earthquake risk assessment or hazard mapping for design codes. The process may require several components, such as earthquake catalogues (historical and instrumental), active geological faults, geodetic estimates of crustal deformation, seismotectonic features and paleoseismicity.

Earthquake hazard may be analysed in two main ways: deterministically, in which a single (usually) most adverse earthquake scenario is identified, or probabilistically, in which all-potential earthquake scenarios are explicitly considered along with their likelihood of occurrence. Deterministic approaches may be perceived as conceptually simpler and more conservative.

The development of a probabilistic earthquake hazard analysis (PSHA) model requires complex mathematical formulations to account for uncertainties in earthquake size, location and time of occurrence, and the outputs relate various levels of ground shaking that may be observed at a site with a corresponding exceedance probability in a given time period.

This relation between ground shaking and probability constitutes a hazard curve. The expected ground shaking for a probability of exceedance within a time span (e.g. 10 per cent in 50 years) or a return period (e.g. 475 years) can be calculated for a given region, leading to a hazard map. Figure 2 shows a fault data set, an earthquake catalogue and a earthquake hazard map for a return period of 475 years for Colombia.

Since the inception of PSHA by Cornell (1968)[5] and McGuire (1976)[6], several critical developments can be identified such as the complex representation of the earthquake source, the derivation of new models to describe the recurrence of earthquakes, sophisticated ground motion prediction equations (GMPE) and the use of logic trees for the propagation of epistemic uncertainties.[7]

Probabilistic earthquake hazard analysis typically follows two main approaches: time-independent – incorporating geological and geodetic evidence with both instrumental and historical earthquake catalogues to derive a seismogenic model covering earthquake cycles up to thousands of years; and time-dependent – accounting for periodic trends in earthquake recurrence to predict the likelihood of earthquakes occurring in a source given the time elapsed since the previous event.

---

5 Cornell, C. (1968). Engineering seismic risk analysis. *Bulletin of the Seismological Society of America*, vol. 58, pp.1583-1606.

6 McGuire, R. (1976). FORTRAN computer program for seismic risk analysis. *United States Geological Survey open-file report*, pp. 76-67.

7 Bommer, J. and F. Scherbaum (2008). The use and misuse of logic trees in probabilistic seismic hazard analysis. E*arthquake Spectra,* vol. 24, pp. 997-1009.

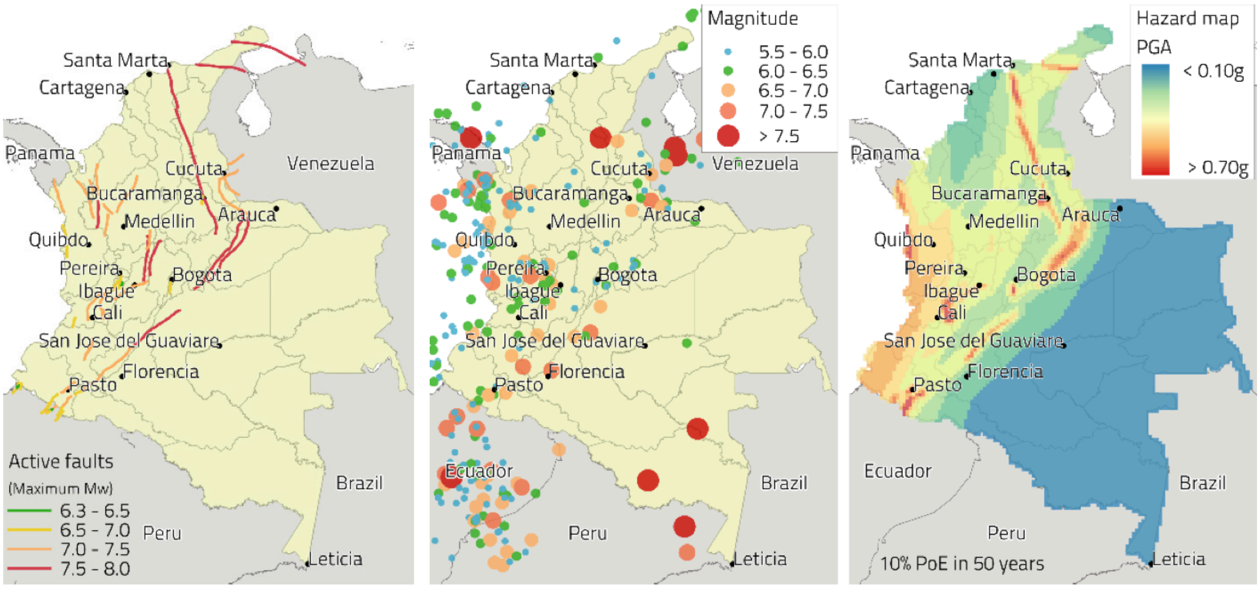


Figure 2 – Fault data set (left), earthquake catalogue (centre) and earthquake hazard map (right) in terms of peak ground acceleration for a return period of 475 years for Colombia[9]

As time-dependent approach requires detailed information concerning the past earthquakeity in the region andfault rupture history application of time-dependent earthquake hazard analysis is still limited to only a few places in the world with well-studied active faults (e.g. California, Japan). Various software packages are available for calculating earthquake hazard using deterministic or probabilistic approaches. OpenQuake[8] is one such package and has been adopted in recent regional projects for earthquake hazard assessment in Europe, the Middle East, Latin America, the Caribbean and Africa.

Assessment of earthquake expected losses

Carrying out an assessment of the impact of single earthquake events (deterministic approach) is a useful tool for developing risk reduction measures. For example, Anhorn and Khazai (2014)[9] investigated the need for shelter spaces in Kathmandu (Nepal) considering several destructive

earthquakes. Mendes-Victor et al. (1994)[10] and the Portuguese National Civil Protection Authority (2010)11 estimated the expected losses in Lisbon and the Algarve (Portugal), respectively, for strong earthquake events. The National

8 Pagani, M. and others (2014). OpenQuake engine: an open hazard (and risk) software for the Global Earthquake Model. *Seismological Research Letters*, vol. 85, issue 3, pp. 692-702.

9 Anhorn, J. (2014). Open space suitability analysis for emergency shelter after an earthquake. *Natural Hazards and Earth System Sciences Discussions,* vol. 1, issue 2, pp. 4263-4297.

10 Mendes-Victor, L. and others (1994). Earthquake damage scenarios in Lisbon for disaster preparedness. In: Tucker B.E., M. Erdik and C.N Hwang, eds. Issues in urban earthquake risk. NATO ASI series E, *Applied Science*, vol. 271, pp. 265-289. Dordrecht: Kluwer Academic Press.

11 National Civil Protection Authority (2010). Estudo do risco sísmico e de tsunamis do Algarve. ISBN: 978-989-8343-06-2. Autoridade Nacional de Protecção Civil, Carnaxide, Portugal (in Portuguese).

Civil Protection Authority used these results to develop emergency response plans.

This analysis requires the definition of an earthquake rupture, which can be a hypothetical event (defined based on historical earthquakes or a PSHA model[12, 13]) or a recent earthquake (whose parameters can be computed using inversion analyses[14]). In the former approach, the ground shaking is calculated using one or multiple GMPEs. In the latter, the ground shaking can be calculated using GMPEs and recordings from earthquake stations.15 In general, this distribution of ground shaking can be used to calculate damage or losses, using an exposure model and a set of fragility or vulnerability functions.

An exposure model describes the spatial distribution of the elements exposed to the hazards, as well as their value and vulnerability class.16 A fragility function establishes the probability of exceeding a number of damage states conditional on a set of ground shaking levels, whereas a vulnerability function relates the probability of loss ratio for a set of ground shaking levels.17, 18 The ground shaking, exposure model and fragility/vulnerability functions can be combined to calculate the distribution of damage or losses,19 as illustrated in figure 3 for a region around Bogotá, Colombia.

---

12 Bendimerad, F. (2001). Loss estimation: a powerful tool for risk assessment and mitigation. *Soil Dynamics and Earthquake Engineering*, vol. 21, issue 5, pp. 467-472.

13 Ansal, A. and others (2009). Loss estimation in Istanbul based on deterministic earthquake scenarios of the Marmara Sea region (Turkey). *Soil Dynamics and Earthquake Engineering*, vol. 29, pp. 699-709.

14 Ji, C., D. Wald and D. Helmberger (2002). Source description of the 1999 Hector Mine, California earthquake; Part I: Wavelet domain inversion theory and resolution analysis. *Bulletin of the Seismological Society of America,* vol. 92, issue 4, pp. 1192-1207.

15Worden, B. and D. Wald (2016). *ShakeMap Manual.* United States Geological Survey technical report, dx.doi.org/10.5066/F7D21VPQ.

16 Yepes-Estrada, C. and others (2017). A uniform residential building inventory for South America. *Earthquake Spectra*. doi: 10.1193/101915EQS155DP.

17 Rossetto, T., I. Ioannou and D. Grant (2015). Existing Empirical Fragility and Vulnerability Functions: Compendium and Guide for Selection. *Global Earthquake Model (GEM) technical report. Pavia, Italy*: GEM Foundation. doi:10.13117/GEM.VULNSMOD.TR2015.01.

18 D'Ayala, D. and others (2015). Guidelines for analytical vulnerability assessment of low/mid-rise buildings. *GEM technical report* 2015-08 v1.0.0, GEM Foundation, Pavia, Italy. doi: 10.13117/GEM.VULN-MOD.TR2014.12.

19 Silva, V. (2016). Critical issues in earthquake scenario loss modeling. *Journal of Earthquake Engineering*, vol. 20, issue 8, pp.1322-1341.

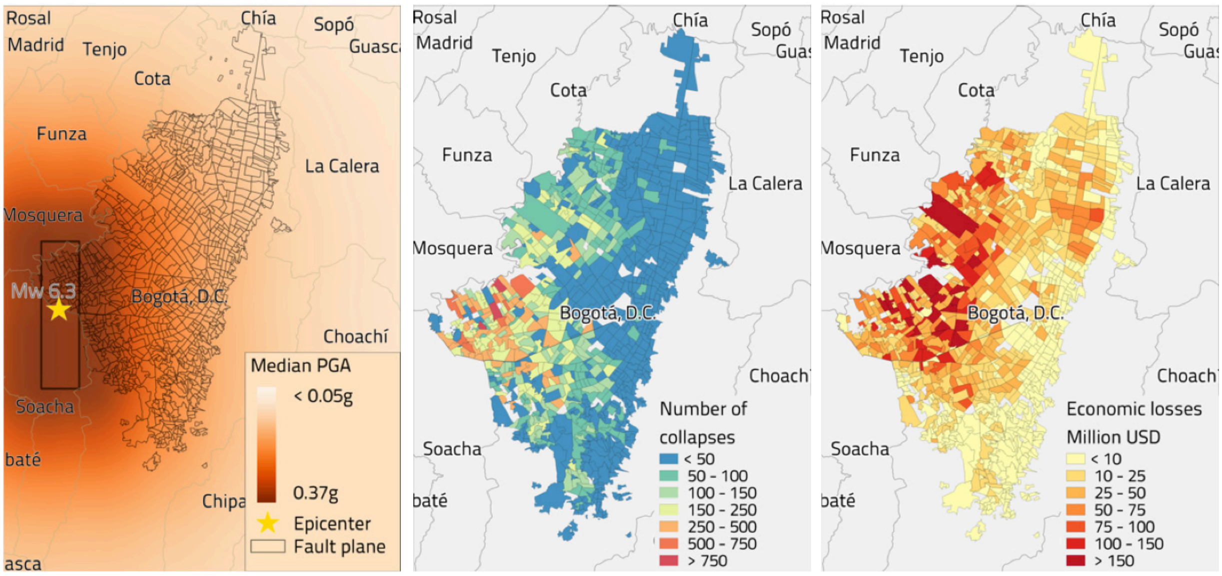


Figure 3 – Mean ground shaking in terms of peak ground acceleration for a M6.5 event west of Bogotá (left), and resulting mean number of collapses (centre) and mean economic losses (right)

Certain risk reduction measures may require the consideration of all of the possible earthquake scenarios along with their frequency of occurrence, which can be developed using probabilistic modelling. For example, these analyses can enable the prioritization of regions or building classes in need of risk reduction interventions. Valcárcel et al. (2013)[20] explored this type of analysis to assess the effectiveness of the earthquake retrofitting of schools in South and Central America. They used a probabilistic earthquake risk model to calculate the expected annual losses considering the portfolio of schools and the savings as a result of the retrofitting or rebuilding interventions.

Another risk reduction measure that requires a probabilistic approach is the creation of insurance pools. These financial mechanisms reduce the economic burden of the reconstruction on local governments and householders by transferring the financial risk to the international insurance market. A good example of such a measure is the Turkish Catastrophe Insurance Pool (TCIP).[21] It was created after the Kocaeli and Düzce earthquakes in 1999, following which the reconstruction costs had to be covered mostly by the Government. These additional funds can also reduce the time to recover from the earthquake.

PSHA model can be used to generate large sets of stochastic events, each representing a possible realization of the seismicity within a given time span (e.g. 10,000 years). For each event, several GMPEs can be used to calculate the spatial distribution of the ground shaking at the location of the assets within the exposure models. Then, using the set of vulnerability functions, the losses for the entire portfolio can be calculated. This distribution of losses can

20 Valcárcel, J.A. and others (2013). Methodology and applications for the benefit cost analysis of the seismic risk reduction in building portfolios at broadscale. *Natural Hazards,* vol. 69, issue 1, pp. 845-868. doi:10.1007/s11069-013-0739-2.

21 Bommer, J. and others (2002). Development of an earthquake loss model for Turkish Catastrophe Insurance. *Journal of Seismology,* vol. 6, pp. 431-446.

be used to calculate the average annual losses or the aggregated losses for specific return periods.[22]

These metrics can be compounded with the local socioeconomic conditions in order to provide a holistic representation of the earthquake risk.[23, 24, 25] To this end, the risk metrics can be aggravated or attenuated according to a social vulnerability index. The index is derived from a large number of socioeconomic indicators such as education, poverty, crime, age or unemployment.

Figure 4 presents an exposure model for the residential building stock for Colombia, along with the associated average annual economic losses and socio-vulnerability index at the second administrative level. Such calculations can be performed using the OpenQuake engine26 from the Global Earthquake Model.

---

22 Silva, V. (2017). Critical issues in probabilistic seismic risk analysis. *Journal of Earthquake Engineering.*

23 Carreño, L., O. Cardona and A. Barbat (2007). Urban seismic risk evaluation: a holistic approach. *Natural Hazards,* vol. 40, pp.137-172.

24 Khazai B. and F. Bendimerad (2011). Risk and resilience indicators. *Earthquakes and Megacities Initiative (EMI) topical report*, vol. 565, TR-1 03.

25 Burton, C. and V. Silva (2016). Assessing integrated earthquake risk in OpenQuake with an application to mainland Portugal. *Earthquake Spectra,* vol. 32, issue 3, pp.1383-1403.

26 Silva, V. and others (2014). Development of the OpenQuake engine, the Global Earthquake Model's open-source software for seismic risk assessment. *Natural Hazards*, vol. 72, issue 3, pp. 1409-1427.

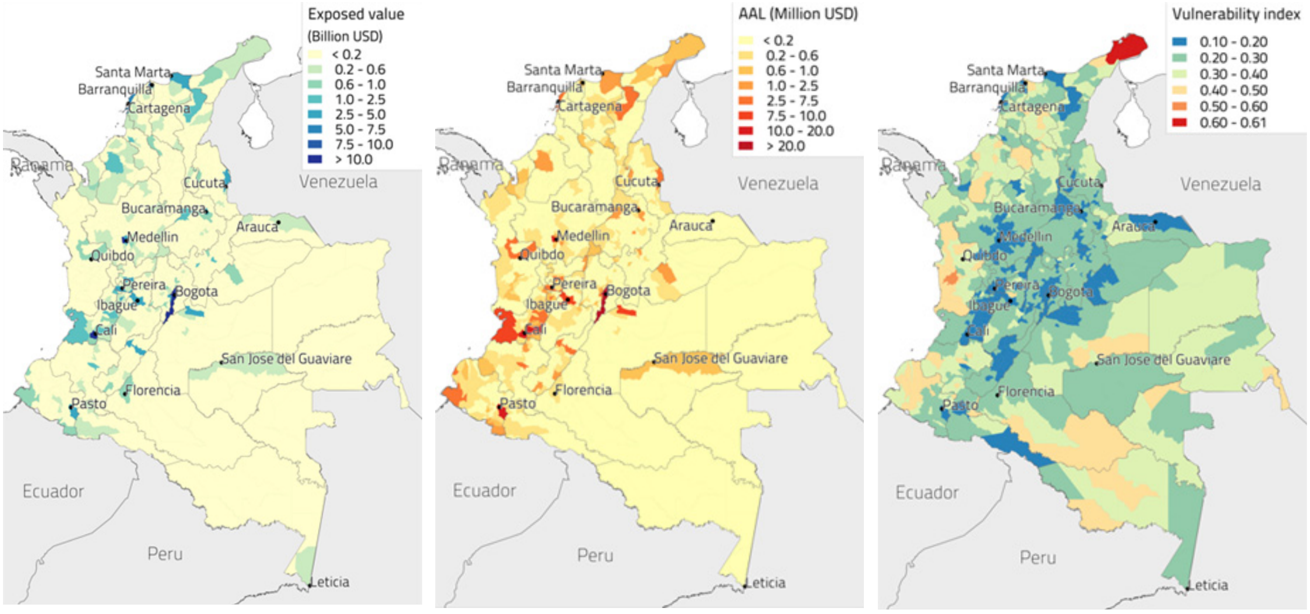


Figure 4 – Exposure model (left), average annual economic losses (centre) and socioeconomic vulnerability index (right) for the residential building stock in Colombia[28, 29]

Conclusion

Earthquakes can cause large economic and human losses, and represent a serious impediment to socioeconomic development, creation of jobs and availability of funds for poverty reduction initiatives. Earthquake hazard and risk assessment are fundamental tools for developing risk reduction measures. This process involves collecting earthquake catalogues and fault data, developing seismogenic models, selecting ground motion prediction equations, creating exposure models and deriving sets of fragility or vulnerability functions.

Combining these components for assessing earthquake hazard and risk requires complex software packages, some of which are currently publicly available. Several examples around the world have demonstrated how earthquake hazard and risk information can be used to develop risk reduction measures and ultimately mitigate the adverse effects of earthquakes.

Authors

Vitor Silva, Catalina Yepes-Estrada, Graeme Weatherill (Global Earthquake Model Foundation)

Contributors and Peer Reviewers:

Carmine Galasso (University College London)

2. Tsunami Hazard and Risk Assessment

Key words:

tsunami hazard, physical vulnerability, probabilistic tsunami hazard analysis (PTHA), tsunami early warning systems

Globally, tsunami risks are dominated by rare but often very destructive events. Assessment of tsunami hazard and risk is required to support preparedness measures and effective disaster reduction. In most coastal locations, highly destructive tsunami events are not well represented in historical records, which tend to be short compared to the return period of large tsunamis (hundreds to thousands of years). In this way, tsunamis are different from more frequent hazards (such as floods or cyclones) for which historical records often provide a more useful reference for understanding the hazard and its impacts.

The "low frequency/high consequences"character of tsunamis induces considerable uncertainty into tsunami hazard and risk assessments. Recent history highlights that these uncertainties are commonly underestimated. The 2004 Indian Ocean tsunami and the 2011 Tohoku tsunami caused more than 225,000 and 19,800 fatalities, and US$ 9.9 billion and US$ 210 billion in direct monetary losses, respectively.[27] But the impact of those events was not widely anticipated or planned for,[28] in spite of the fact that these two events constituted a major proportion of the global fatalities and economic losses due to natural hazards in the last 100 years.

Sources and setting

Submarine earthquakes have generated about 80 per cent of all tsunami events recorded globally. The majority of tsunamigenic earthquakes occur at subduction zones along the Ring of Fire in the Pacific Ocean, while other important source regions include the Sunda Arc and the Makran subduction zone in the Indian Ocean, the northeastern Atlantic, Mediterranean and connected seas,[29] eastern Indonesia and the Philippines, and the Caribbean Sea.

Subduction zone earthquakes with magnitudes above M9 cause the largest tsunamis and these can propagate across oceans. Smaller earthquakes can also generate locally damaging tsunamis. Finally, a class of earthquakes termed "tsunami earthquakes" generate more intense tsunamis than expected from their seismic moment magnitude. Considering that recent events in all of these categories were not fully anticipated and integrated in pre-existing tsunami hazard assessments, we must be cautious in future hazard assessments, accounting for: (a) the possibility that M9 earthquakes might occur on virtually every major subduction zone[30] and (b) the complexity of

---

27 Centre for Research on the Epidemiology of Disasters (CRED). 2009. Emergency Events Database (EM-DAT). Available from www.emdat.be

28 Synolakis, C. and U. Kanoglu (2015). The Fukushima accident was preventable. *Philosophical Transactions of the Royal Society.*

29 Papadopoulos G. A. and others (2014). Historical and pre-historical tsunamis in the Mediterranean and its connected seas: geological signatures, generation mechanisms and coastal impacts. *Marine Geology*, vol. 354, pp. 81-109.

30 Kagan, Y.Y and D.D. Jackson (2013). Tohoku Earthquake: A Surprise? Bulletin of the Seismological Society of America, vol. 103, pp.1181-1194.

recent earthquakes and tsunamis in terms of tsunami generation and resulting impacts.

The second most important sources of tsunamis are volcanoes and landslides. Tsunamigenic landslides often trigger earthquakes but other mechanisms can also trigger them. Tsunami hazard and risk assessment methods for these sources are less well established than those for earthquakes because they are less frequent and because their tsunami generation mechanisms are complex and diverse. Some of the most powerful tsunamis in history, however, have been caused by these sources, such as the seventeenth century B.C. Santorini (Greece) and the 1883 Krakatau (Indonesia) volcanic tsunamis, or the 1958 Lituya Bay (Alaska) earthquake-triggered landslide. Compared with earthquakes, landslides and volcanoes tend to produce tsunamis that are more spatially localized, although they can result in much higher run-up. Tsunamis from these tsunami sources are also more difficult to warn against effectively. Thus they should be considered at least for local tsunami hazard assessments.

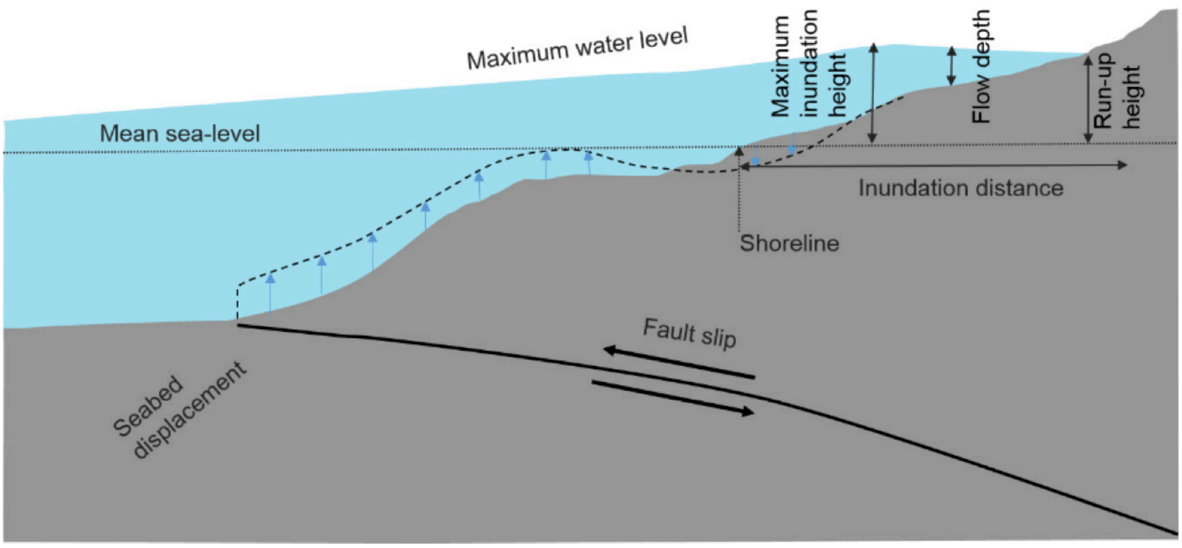


Figure 1 - Sketch showing main features of tsunamis induced by earthquake slip. The fault slip causes a seabed displacement that generates the tsunami. Shoaling gives rise to increased maximum water levels towards the coast.

Tsunami hazard assessment

While tsunami hazard assessments were previously routinely developed using worst-case scenarios, probabilistic approaches for estimating tsunami hazard and risk are progressively becoming the new standard.

In a probabilistic tsunami hazard analysis (PTHA), parameters that describe all possible tsunami sources and their occurrence rates are established first. Subsequently, tsunami propagation and inundation metrics are modelled, most often by means of numerical models combined with high-resolution bathymetry and topography. The results are then aggregated according to the source probability and modeled tsunami impact, providing hazard curves describing the exceedance probability for different tsunami intensity thresholds.

PTHA explicitly addresses different types and sources of uncertainty, caused by lack of knowledge of the source mechanism and the frequency of the largest events, limitations of input data, and modelling approximations. As a consequence, different alternative models are usually developed to quantify the uncertainty.

Another source of uncertainty derives from the lack of sufficiently accurate high-resolution digital elevation models and the computationally intensive nature of tsunami propagation modelling, which together limit the model resolution and the number of scenarios that can be simulated. When available, empirical tsunami data can be integrated into the analysis or be used for checking PTHA results.

Description of input data	National entities that most commonly have these data	Examples of open databases available from international sources
Bathymetry and topography	national mapping agencies; geological survey; marine science institutions; meteorological, marine, environmental protection agencies	GEBCO, ETOPO, SRTM (not suitable for high-resolution inundation modelling).
Tsunamigenic sources	geological survey; earth science, geophysical institutions	ISC-GEM Catalogue; global CMT Catalog;GEM faulted earth; literature
Past tsunami observations	meteorological, marine, environmental protection agencies; geophysical institutions	NOAA NGDC; Euro-Mediterranean Tsunami Catalogue, HTDB/WLD Database; literature
Exposure	local government; national agency responsible for census; various ministries, private sector, United Nations	WorldPop, Landscan, or GPW Global Population Data Global Exposure Database
Vulnerability models	engineering community; academia	Literature (e.g. reporting post-tsunami surveys or laboratory testing); Geoscience Australia; Comprehensive Approach for Probabilistic Risk Assessment (CAPRA)

Table 1 - Sources of data at each stage of the probabilistic tsunami hazard analysis

Exposure and vulnerability assessment

Tsunami inundation will vary according to the topography and surface roughness, but is limited to within a few kilometres of the coastline. In the inundation zone, the exposure encompasses both the population and the built-up environment (buildings, infrastructure and critical facilities).

The possible effect of a tsunami is quantified by measures of vulnerability – the relationship between tsunami flow depth or velocity, and the resulting damage or loss. Vulnerability is often divided into the study of (a) the probability of human casualties, influenced by a population's risk awareness and behaviour during a tsunami, (b) structural damage and the resulting economic loss, influenced by building type and construction material and (c) social vulnerability, which deals with damage to livelihoods and communities and their post-event recovery.

Socioeconomic vulnerability is influenced by socioeconomic factors, gender, availability of infrastructure, and coping capacity. Assessing impacts entails very large uncertainty; even the most common damage metric, probability of structural damage is not yet very well understood. The landmark 2004 and 2011 tsunamis are relatively recent events, and the tsunami community is still in the early stages of understanding how to quantify both the physical and the societal vulnerability.

Tsunami risk assessment use in national DRR measures

Local- and regional-scale risk assessments should combine the modelled hazard (e.g. overland flow depths, velocities) with exposure databases and vulnerability models, ideally using a probabilistic approach to risk quantification. Regional and global assessments are generally broad-scale and hence are not suitable to directly perform local-scale decision making; but rather they can serve as a guide to understanding national level tsunami risks to prioritize regions requiring more detailed site-specific studies.[31]

Long-term tsunami risk reduction measures can be devised based on local or regional scale risk assessments through approaches such as land-use planning, tsunami building codes, early warning systems and evacuation planning, installation of engineered defenses, and specific measures for nuclear and non-nuclear critical infrastructure.

Several tsunami DRR measures are now implemented worldwide. Regional Tsunami Early Warning Systems (TEWS) are today operational almost everywhere and provide regional scale warnings for any Member State of the

31 Løvholt, F., J. Griffin and M.A. Salgado-Gálvez (2015). Tsunami hazard and risk assessment on the global scale. *Encyclopedia of Complexity and Systems Science*. Meyers R.A., ed. Berlin and Heidelberg: Springer.

CASE STUDY

Box 1 - Master Plan for Reducing Tsunami Risk

Indonesia

Following the 2004 Indian Ocean Tsunami, Indonesia invested heavily in disaster management. In 2007 it passed a Disaster Management Law, establishing the National Disaster Management Agency (BNPB).

This was followed in 2008 by the establishment of the multi-agency Indonesian Tsunami Early Warning System (InaTEWS), with the support of international partners. Investment in the full warning chain, from monitoring, decision support and warning systems through to "last mile" dissemination and evacuation planning has been critical, especially due to the short time frames for evacuation in many parts of the country.

A first national scale PTHA was undertaken in 2012 and incorporated into the national Master Plan to spatially prioritize where to invest in tsunami mitigation. Technical guidelines defining minimum standards for hazard and risk assessment have been written to support implementation of the Master Plan, assisting local governments in implementing informed tsunami risk reduction activities such as evacuation planning and tsunami shelter construction.

In line with a strong political agenda to develop Indonesia's maritime-based economy, tsunami risk assessment is identified as an important tool for safeguarding development investments and coastal industries, including fishing and tourism, and for building resilient coastal villages. Although challenges remain, Indonesia demonstrates how a robust understanding of tsunami risk can underpin tsunami risk reduction measures at national and local level.

Indian Ocean Commission. However, they might be ineffective without one of the most important DRR measures at the national level: the local scale assessment of the regional warning and the implementation of "last mile" actions in response – rapid alert dissemination and evacuation on pre--established evacuation routes.

However, in many countries with tsunami risk, these elements are not in place. Engineered mitigation measures such as breakwaters and seawalls are even less common globally because of the cost of constructing and maintaining them, but they have been built along the coastlines of Japan. Tsunami evacuation buildings have also been implemented, although in limited areas. These enable vertical evacuation of people in flat or isolated locations with few options to evacuate inland during near-field tsunamis. Although the physical measures may be effective in places, in general they cannot eliminate the risk. Even with warning systems and engineered solutions, risk awareness among the population is necessary for reducing casualties.

In countries such as Chile and Japan, the relatively high rate of self-evacuation in recent events is likely to have reduced the overall death tolls. Tsunami educational programmes have been implemented across the world to expand this awareness.

Resources for further information

Freely available software exists for simulating tsunami propagation and inundation. Some widely used open source or community models include ComMIT (National Oceanic and Atmospheric Administration, United States), GeoClaw (University of Washington, United States), ANUGA (Australian National University and Geoscience Australia) and TUNAMI (Tohoku University, Japan). However, these models require appropriate skills and training to be used effectively.

It is also crucial that such codes be validated and verified. Relevant information about models, past events, etc. can be found through national stakeholders, such as the Pacific Marine Environmental Laboratory (PMEL) (United States).[32] Others include the International Tsunami Information Center (ITIC),[33] the North-Eastern Atlantic and Mediterranean Tsunami Information Center (NEAMTIC)34 and the Indian Ocean Tsunami Information Center (IOTIC).

In contrast, there are no comparable widely used models for quantifying tsunami frequencies or vulnerability because of the diversity of approaches used to model these factors. Notwithstanding, new guidelines from the American Society of Civil Engineers (ASCE) for assessing forces due to tsunami loads have recently become available.

General open risk assessment modules and initiatives, such as CAPRA,[35] can combine the hazard, exposure and vulnerability, to quantify commonly known risk metrics such as average annual losses, probable maximum losses and loss exceedance curves, as done at the global level for UNISDR's GAR15.[36] We also refer to the tsunami risk guidelines of UNESCO-IOC.[37]

At present, the approaches for tsunami risk analysis are not well standardized. Therefore, current methods, some of which are described in the online references, need guidelines accepted by the tsunami community.

32 NOAA Center for Tsunami Research (2017). Pacific Marine Environmental Laboratory. United States Department of Commerce. Available from http://nctr.pmel.noaa.gov

33 International Tsunami Information Center. 2017. Intergovernmental Oceanographic Commission of UNESCO. Available from http://itic.ioc-unesco.org/index.php

34 North-Eastern Atlantic, Mediterranean and connected seas Tsunami Information Centre. 2017. Intergovernmental Oceanographic Commission of UNESCO. Available from http://neamtic.ioc-unesco.org

35 Indian Ocean Tsunami Information Center (2017). *Intergovernmental Oceanographic Commission of UNESCO.* Available from http://iotic.ioc-unesco.org

36 United Nations Office for Disaster Risk Reduction (2015). *Global Assessment Report on Disaster Risk Reduction* 2015.

37 Chock, G. and others (2016). Target structural reliability analysis for tsunami hydrodynamic loads of the ASCE 7 standard. *Journal of Structural Engineering,* vol. 10, 1061/(ASCE) ST. 1943-541.

To organize and focus efforts on such issues, a Global Tsunami Model has been proposed to provide coordinated action for tsunami hazard and risk assessment. While the Model is not yet fully operational, many publications illustrate methods that can be adapted for future hazard and risk analysis in the Model.[38,39 40]

Authors

Finn Løvholt (Norwegian Geotechnical Institute)

Contributors and Peer Reviewers:

Gareth Davies (Geoscience Australia), Jonathan Griffin (Geoscience Australia), Stefano Lorito,, Manuela Volpe, Fabrizio Romano (GTM/INGV), Mario Salgado Galvez (GTM/CIMNE), Eric Geist, Stephanie Ross (GTM/USGS), Ignacio Aguirre Ayrebe (GTM/ Univ. Cantabria), Stuart Fraser (GTM/Fraser Disaster Risk Consulting), Hong Kie Thio (GTM/AECOM), Miquel Canals (GTM/Univ. Barcelona), Frank Gonzalez (GTM/Univ. Washington), Jascha Polet (GTM/ Caltech), Mohammed Mokhtari (GTM/IIEES), Utku Kanoglu (GTM/METU), Raphael Paris (GTM/LVM), Christa Andrade (GTM/NOAA), Mario Ana Baptista (GTM/IPMA), Hamzah Latief (GTM/ITB), Gerassimos Papadopoulos (National Observatory of Athens)

---

38 United Nations Educational, Scientific and Cultural Organization and Intergovernmental Oceanographic Commission (2009). *Tsunami Risk Assessment and Mitigation for the Indian Ocean: Knowing Your Tsunami Risk and What to Do About It.* Paris: UNESCO.

39 Geist, E. and T. Parsons (2006). Probabilistic analysis of tsunami hazards. *Natural Hazards*, vol. 37, pp. 227-314.

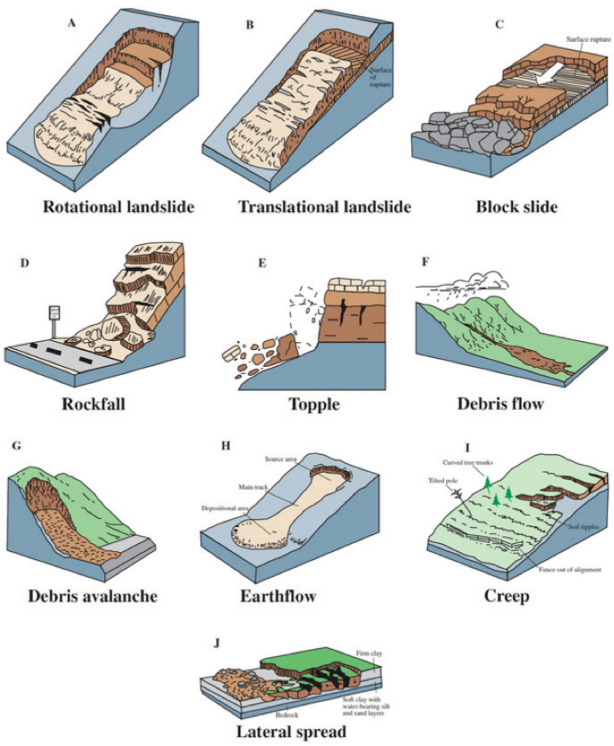
40 Davies G. and others (2017). *A Global Probabilistic Tsunami Hazard Assessment* from Earthquake Sources. Geological Society of London Special Publications, 456.

3. Landslide Hazard and Risk Assessment

Key words:

landslide, landslide hazard, landslide vulnerability, landslide hazard map, risk management

The term “landslide” refers to a variety of processes that result in the downward and outward movement of slope-forming materials, including rock, soil, artificial fill, or a combination of these. The materials may move by falling, toppling, sliding, spreading, or flowing. The schematics in figure 1 illustrate the major types of landslide movement.



In many parts of the world, landslides are a frequent natural hazard and a major threat to humans and the environment. According to the International Disaster Database of the Centre for Research on the Epidemiology of Disasters (CRED) (EM-DAT)[42], since 1900 some 130,000 persons have lost their lives because of landslides and flash floods; and the economic losses amounted to over US$ 50 billion. In the period from 2000 to 2014, the corresponding figures were around 26,000 deaths and US$ 40 billion in losses. The actual figures are, however, much higher.

In the CRED-EM database, the losses due to earthquake-triggered landslides are attributed to earthquakes, and many landslide events with no casualties, but significant material losses are not reported. For example, 20-25 per cent of the 87,000 casualties (69,000 confirmed killed and 18,000 missing) caused

---

41 United States Geological Survey (2004). Landslide types and processes. Fact sheet 2004-3072. Available from https://pubs.usgs.gov/fs/2004/3072/fs-2004-3072.html

42 Guha-Sapir, D., R. Below and P. Hoyois. The CRED/OFDA *International Disaster Database*. Université catholique de Louvain. Belgium.

by the Sichuan (or Wenchuan) Earthquake of 12 May 2008 were the result of the landslides triggered by that event.[43] Recent catastrophic landslides in Afghanistan, United States, the Philippines and India illustrate that landslides are still a major threat in developed as well as developing countries.

The volume of soil and rock mobilized in a landslide can vary from a small individual boulder to millions, and in rare cases billions, of cubic metres. Generally, the potential destructiveness of a landslide is a function of the volume of the masses that are mobilized, and their velocity. But even a single boulder can cause several fatalities.

Sources and setting

The primary driving factor of landslides is gravity acting on a portion of a slope that is out of equilibrium. The following are some of the major landslide triggering mechanisms:

- River erosions, glaciers, or ocean waves
- Weakening of rock and soil slope proprieties through water saturation by snowmelt or heavy rains
- Stresses, strains and excess of pore pressures induced by the inertial forces during an earthquake (earthquakes of magnitude greater than or equal to 4.0 can trigger landslides)
- Volcanic eruptions with the production of loose ash deposits that may become debris flows (known as lahars) during heavy rains
- Stockpiling of rock or ore, from waste piles, or from man-made structures
- Changes of the natural topography caused by human activity.

43 Zhang, L.M., S. Zhang and R.Q. Huang (2014). Multi-hazard scenarios and consequences in Beichuan, China: the first five years after the 2008 Wenchuan earthquake. *Engineering Geology*, vol.180, pp. 4-20.

Landslide hazard assessment

Landslide hazard is a function of susceptibility (spatial propensity to landslide activity) and temporal frequency of landslide triggers, and its assessment may be done on local (individual slope), regional, national, continental, or even global scales. The most appropriate method in each scale depends on the extent of the study area and on the available data. Examples of various methodologies for landslide hazard assessment on different scales can be found in the literature.[44,45,46,47]

In any type of landslide hazard assessment, there is a need to consider topography and other factors that influence the propensity to landslide activity (susceptibility factors), as well as landslide triggering factors (precipitation, earthquakes, human activity). Table 1 lists the input data typically required for landslide hazard assessment at regional to national scales.

---

44 Nadim, F. and others (2006). Global landslide and avalanche hotspots. *Landslides*, vol. 3, issue 2, pp. 159-173.

45 Nadim, F., H. Einstein and W.J. Roberts (2005). Probabilistic stability analysis for individual slopes in soil and rock. *Proceedings of the International Conference on Landslide Risk Management.*

46 Norwegian Geotechnical Institute (2010). SafeLand project. *Overview of landslide hazard and risk assessment practices.*

47 Corominas, J. and others (2014). Recommendations for the quantitative analysis of landslide risk. *Bulletin of Engineering Geology and the Environment,* vol. 73, issue 2, pp. 209-263.

Description of input data	National entities that most commonly have this data	Examples of open databases available from international sources
Digital elevation model	National mapping and cartography authority	SRTM30 (NASA)
Lithology	National geological survey	UNESCO (CGMW, 2000), One Geology initiative
Vegetation cover	National agriculture/ environment and/or national forest agency	GLC2000 database
Soil moisture factor	National agriculture/ environment and/or national meteorological agency	Climate Prediction Center
Hourly, daily and monthly precipitation	National meteorological agency	Global Precipitation Climatology Centre of the German National Meteorological Service, DWD
Seismicity	National building code(s)	Global Seismic Hazard Program, Global Earthquake Model
Infrastructure and road/railway network in mountainous regions	National road and/or railway authority	Google maps

Table 1 - Sources of data for landslide risk assessments at regional and national scale

There are many sources and types of uncertainty in landslide hazard assessment. By far the main source of uncertainty is the epistemic uncertainty related to our limited knowledge about the materials that make up the slope(s), their response under various external perturbations, and the characteristics of the triggering factors.

Soils, rocks and other geomaterials exhibit significant spatial variability (aleatory uncertainty) and their properties often change markedly over small distances. Many non-local scale landslide hazard assessment models are empirical and should be calibrated/validated with regional and/or national database(s) of previous landslide events. Landslide inventory maps are often an important input for the landslide susceptibility/hazard assessment and/or validation.

However, even in developed countries, the databases of landslide events are usually far from complete. Often they only cover the events from the recent past, and/or have an over-representation of landslides triggered by a single extreme event, and/or are heavily biased towards the events reported by a single source, such as the national road or rail authority.

Climate change increases the susceptibility of surface soil to instability because of abandoned agricultural areas, deforestation and other land-cover modifications. Anthropogenic activities and uncontrolled land-use are other important factors that amplify the uncertainty in landslide hazard assessment.

Exposure and vulnerability assessment

Exposure of the population and/or the built environment to landslide risk can be assessed by superimposing landslide hazard map(s) on maps of population density, the built environment and infrastructure. However, this type of assessment provides only a qualitative picture of the exposure. Landslides vulnerability assessment is a complex process that should consider multiple dimensions and aspects, including both physical and socioeconomic factors. Physical vulnerability of buildings and infrastructure is a function of the intensity of the landslide event and the resistance levels of the exposed elements.[48,49,50,51,52,53]

Societal vulnerability and resilience of a community, on the other hand, are related to factors such as demographics, preparedness levels, memory of past events, and institutional and non-institutional capacity for handling natural hazards. Although a significant amount of literature exists[54] on the assessment of societal vulnerability to natural hazards, few studies specifically address the social and economic vulnerability to landslides.

In the SafeLand project, an indicator-based methodology was developed to assess the (relative) societal vulnerability levels. The indicators represent the underlying factors that influence a community’s ability to deal with and

---

48 Uzielli, M. and others (2008). A conceptual framework for quantitative estimation of physical vulnerability to landslides. *Engineering Geology,* vol.102, issues 3-4, pp. 251-256.

49 Norwegian Geotechnical Institute (2011). SafeLand project. *Physical vulnerability of elements at risk to landslides: methodology for evaluation, fragility curves and damage states for buildings and lifelines.*

50 ___________ Case studies of environmental and societal impact of landslides – Part A: Rev. 1. Case studies for environmental (physical) vulnerability.

51 Papathoma-Köhle, M. (2016). Vulnerability curves vs. vulnerability indicators: application of an indicator-based methodology for debris-flow hazards. *Natural Hazards and Earth System Sciences*, vol. 16, pp. 1771-1790.

52 Eidsvig, U.M.K. and others (2014). Quantification of model uncertainty in debris flow vulnerability assessment. *Engineering Geology*, vol. 181, pp.15-26.

53 Winter, M.G. and others (2014). An expert judgement approach to determining the physical vulnerability of roads to debris flow. *Bulletin of Engineering Geology and the Environment,* vol. 73, issue 2, pp. 291-305.

54 Cutter, S., J. Boruff and L. Shirley (2003). Social vulnerability to environmental hazards. *Social Science Quarterly,* vol. 84, issue 2, pp. 242-261.

recover from the damage associated with landslides.[55,56] The proposed methodology includes indicators that represent demographic, economic and social characteristics such as the human development index and gross domestic product, and indicators representing the degree of preparedness and recovery capacity. The purpose of the societal vulnerability assessment is to set priorities, serve as background for action, raise awareness, analyse trends and empower risk management.

Risk assessment use in national DRR measures

Studies on global distribution of landslide hazard,[57] as well as detailed assessment of the reported occurrence of landslide disasters in the CRED-EM database, suggest that the most exposed countries to landslide risk are located in south Asia, along the Himalayan belt, in east Asia, south-eastern Asia, and in Central and South America.

In most developed countries with high landslide hazard, landslide events rarely end up as disasters. This is mainly due to the low exposure in the most landslide-prone areas, as well as the increasing ability to identify the landslide-prone areas and to implement appropriate landslide risk management actions.

Many countries that have areas with high landslide hazard lack the necessary legislation and regulations to prioritize and implement a landslide risk mitigation plan. Often it is asserted that it "takes a disaster to get a policy response", and case studies of landslide risk management in different countries show a relationship between the incidence of disasters, and progress and shifts in landslide risk management.[58]

Disasters can catalyse moments of change in risk management aims, policy and practice. Increasingly, the decision-making processes of the authorities in charge of reducing the risk of landslides and other hazards are moving from "expert" decisions to include the public and other stakeholders.[59]

In practice, effective landslide risk mitigation should be implemented at local (individual slope) or regional level. On the local scale, the design of a risk

---

55 Norwegian Geotechnical Institute (2012). SafeLand project. M*ethodology for evaluation of the socio-economic impact of landslides (socio-economic vulnerability)*.

56 Eidsvig, U.M.K. and others (2014). Assessment of socioeconomic vulnerability to landslides using an indicator-based approach: methodology and case studies. *Bulletin of Engineering Geology and the Environment,* vol. 73, issue 2, pp. 307-324.

57 Nadim, F. and others (2012). *Assessment of Global Landslide Hazard Hotspots*. Berlin and Heidelberg: Springer.

58 Norwegian Geotechnical Institute (2011). SafeLand project. *Five scoping studies of the policy issues, political culture and stakeholder views in the selected case study sites – description of methodology and comparative synthesis report.*

59 Scolobig, A., M. Thompson and J. Linnerooth-Bayer (2016). Compromise not consensus: designing a participatory process for landslide risk mitigation. *Natural Hazards,* vol. 81, supplement 1, pp. 45-68.

mitigation measure, for example an early warning system, can be based on a number of reasonable scenarios and may involve the following steps:

- Define scenarios for triggering the landslide(s) and evaluate their probability of occurrence
- Estimate the volume and extent of the landslide and compute the run-out distance for each scenario
- Estimate the losses for all elements at risk for each scenario
- Compare the estimated risk with risk acceptance/risk tolerance criteria
- Implement appropriate risk mitigation measures if required.

It is not clear that this level of rigour is always practised in landslide risk management, especially in poor countries where resources are limited.

Good practice of landslide risk management

One of the best examples of good landslide risk management practice is found in Hong Kong, China. Hong Kong is situated on the south-eastern coast of China, has a subtropical climate with an average annual rainfall of 2,300 mm, peaking in the summer, with regular rainfall events of intensities exceeding 100 mm/hour.

Hong Kong has a small land area of about 1,100 km2, over 60 per cent of which is located on hilly terrain. Its population has increased steadily from 2 million in 1950 to over 7 million today. This has led to a huge demand for land for residential use and infrastructure, and resulted in a substantial portion of urban development located on or close to man-made slopes and natural hillsides. Man-made slopes that are not properly designed and steep hillsides are susceptible to landslides during heavy rainfall, and debris flows are common in natural terrain. As a result, landslides are a large natural hazard in Hong Kong, where they can cause significant casualties and socioeconomic impacts.

On 18 June 1972, after days of heavy rainfall, two destructive landslides in Sau Mau Ping and at Po Shan Road in Hong Kong killed one hundred and thirty-eight people, covered a resettlement area with landslide debris and caused a high-rise building to collapse. In 1977, in the aftermath of these and other fatal landslide disasters, the Geotechnical Control Office (now the Geotechnical Engineering Office (GEO)) was set up to strategically implement a comprehensive system to maintain slope safety.

The Slope Safety System it developed comprises several initiatives to reduce landslide risk in a holistic manner. The key components of the system are comprehensive enforcement of geotechnical standards, community participation for slope safety, systems for early warning and emergency response, and comprehensive databases of landslide events and implemented risk mitigation measures. Several studies show that the implementation of the Slope Safety System has reduced the annual fatalities due to landslides by over 50 per cent since the late 1970s.[60] There have now been no fatalities in almost a decade.

Programmes that have achieved this level of success are rare and are obtained at considerable cost. In developing countries, few, if any, examples exist of successful countrywide reduction in landslide losses as a result of such initiatives. Landslides are among the most potentially manageable of all natural hazards, given the range of approaches and techniques that are available to reduce the level of hazard. There is much scope to reduce their impacts.

60 Malone, A.W. (1997). *Risk Management and Slope Safety in Hong Kong*. The Hong Kong Institution of Engineers.

Resources for further information

The following sources provide useful information and tools for landslide hazard and risk assessment, and landslide risk management:

- European Commission FP7 Project SafeLand[61]
- Geological Survey of Canada landslide guidelines[62]
- International Consortium on Landslides[63]
- United States Geological Survey landslide hazards programme[64]
- Geotechnical Engineering Office, Hong Kong slope safety[65]
- UNISDR global assessment reports on disaster risk reduction[66]
- MoSSaiC: Management of slope stability in communities[67]

Authors

Farrokh Nadim (Norwegian Geotechnical Institute)

Contributors and Peer Reviewers:

Bjørn Kalsnes (NGI), Dave Petley (Sheffield University), Michel Jaboyedoff (University of Lausanne), Nicola Casagli (University of Florence), Paola Reichenbach, Fausto Guzzetti (Italian National Research Council)

61Norwegian Geotechnical Institute (2012). SafeLand project. R&D program Safeland. Abstract available from www.ngi.no/eng/Projects/SafeLand

62 Government of Canada (2017). Hazards: Landslides. Available from www.nrcan.gc.ca/hazards/landslides

63International Consortium on Landslides. Available from http://icl.iplhq.org/category/home-icl/

64 Landslide Hazards Program. Available from http://landslides.usgs.gov/

65 Geotechnical Engineering Office (2012). Hong Kong Slope Safety. Available from http://hkss.cedd.gov.hk/hkss/eng/index.aspx

66 United Nations Office for Disaster Reduction (2015). Global Assessment Report. Available from www.preventionweb.net/english/hyogo/gar/

67 Anderson, M. and L. Holcombe. Management of Slope Stability in Communities. Available from www.bristol.ac.uk/geography/research/hydrology/research/slope/mossiac/

4. Flood Hazard and Risk Assessment

Key words:

floods, flood hazard map, historic flood risk assessment, preliminary flood risk assessment (PFRA), flood risk assessment (FRA)

Description of the hazard, sources and setting

Water is a resource before being a threat. That is why it would be of little use to consider flood risk assessment (FRA) by itself without casting it in the framework of flood risk management and water management at large. Any measures undertaken to reduce flood risk have an effect on other segments of water use (e.g. potable water, industrial use and irrigation, recreation, energy production) and many of them modify flood risk in different geographical areas.

Flood risk can be analysed through the lenses of the main terms of the risk equation: hazard, vulnerability, exposure and capacity. In comparison to other types of risk, flood suffers from a very strong imbalance in the level of maturity in assessing the different elements: whereas hazard modelling is well advanced, exposure characterization and vulnerability analysis are underdeveloped.

This section presents some highlights on the most developed practices for flood risk assessment without entering into the details of specific methodologies. It will try to clarify the states of research and practice in FRA in relation to different uses of flood hazard and risk information. It will also discuss the issue of scale, the challenge in capturing flood correlation on large-scale events, the need to consider climate change, and the strong links with other perils determining complex multi-hazard scenarios.

Flooding occurs most commonly from heavy rainfall when natural watercourses lack the capacity to convey excess water. It can also result from other phenomena, particularly in coastal areas, by a storm surge associated with a tropical cyclone, a tsunami or a high tide. Dam failure, triggered by an earthquake, for instance, will lead to flooding of the downstream area, even in dry weather conditions. Various climatic and non-climatic processes can result in different types of floods: riverine floods, flash floods, urban floods, glacial lake outburst floods and coastal floods.

Floods are the natural hazard with the highest frequency and the widest geographical distribution worldwide. Although most floods are small events, monster floods are not infrequent.

In 2010, approximately one fifth of the territory of Pakistan was flooded, affecting 20 million people and claiming close to 2,000 lives. The economic losses were estimated to be around US$ 43 billion. One year later, another monster flood struck South-East Asia. The flood event extended across several countries and a few separate limited flood events affected parts of the same countries: Thailand, Cambodia, Myanmar and Viet Nam. Meanwhile, the Lao People's Democratic Republic also sustained flood damage, with the death toll reaching close to 3,000.

If we consider only Thailand in terms of economic losses, this flood ranks as the world's fourth costliest disaster as of 2011,[68] surpassed only by the 2011 earthquake and tsunami in Japan, the 1995 Kobe earthquake and Hurricane Katrina in 2005.

The 2014 floods in South-East Europe killed 80 people and caused over US$ 3.8 billion in economic losses; and the levee failures in Greater New Orleans in 2005 during Hurricane Katrina, the costliest disaster from a natural hazard in the United States in recent history, caused losses of around US$ 150 billion.

Flood magnitude depends on precipitation intensity, volume, timing and phase, from the antecedent conditions of rivers and the drainage basins (frozen or not or saturated soil moisture or unsaturated) and status. Climatological parameters that are likely to be affected by climate change are precipitation, windstorms, storm surges and sea-level rise.

Climate change has a prominent role when assessing flood risk, as it is captured in many legal documents and directives. However, the uncertainty connected to climate-change impacts on flood hazard and vulnerability sometimes limits the possibility of evaluation adaptation measures according to classical methodologies such as cost-benefit analysis. It is therefore suggested to tackle the problem by adopting the following guidelines.

First, base the risk assessment studies on a sufficiently large climate-change scenario ensemble in order to capture as much as possible the uncertainty associated with such evaluations. Second, choose robust strategies of adaptation rather that aiming at optimal ones, focusing on the ones that meet the chosen improvement criteria across a broad range of plausible futures. Third, increase the robustness of the adaptation process by choosing "adaptive" strategies that can be modified as the future scenarios unfold.

Including climate change in a scientifically sound way in flood risk assessment and management remains a challenge. The basic concepts that represent the basis of decision-making are sometimes being invalidated. As an example, the widely used concept of "return period", at the basis of flood protection design targets, needs to be rethought in a non-stationary context as the one put forward by climate change. Therefore, new approaches have to be developed so that the risks can be quantified.

In the stationary case, there is a one-to-one relationship between the m-year return level and m-year return period, which is defined implicitly as the reciprocal of the probability of an exceedance in any one year. Return periods were assumedly created for the purpose of interpretation: a 100-year event may be more interpretable by the general public than a 0.01 probability of occurrence in any particular year.

68 From World Bank estimates.

Hazard assessment

The sudden changes of the inundation maps and flood hazard maps is a distinctive feature that influences flood hazard assessment. This implies that different methodologies are needed to define flood hazard when different scales are considered.

Implementing very detailed inundation models is often very expensive: data hungry and calibration intensive. That is why flood hazard and risk assessment exercises are often broken down into two stages: a preliminary flood risk assessment (PFRA)[69] and a final, more detailed, flood risk assessment (FRA).

PRFA is extensive geographically and in terms of the flooding mechanisms considered (i.e. different types of floods), while it uses approximated approaches to hazard and many times neglects vulnerability. PFRA has the objective of defining priority areas for further characterization with advanced models using detailed information about topography (digital elevation models (DEMs)), break lines and flood defences.

In this way resources are invested where risk is higher, maximizing the return on investment in detailed assessment in areas where high social and economic value are threatened. Attention should also be paid to areas of potential new development that might not appear as priorities in the preliminary assessment from the point of view of exposure and existing risk.

PFRA is related to areas where potential significant flood risks exist or are probable in the future. Such areas are identified as "areas of potentially significant flood risk"(APSFR). If in a particular river basin, sub-basin or stretch of coastline no potential significant flood risk exists or is foreseeable, no further action would have to be taken. If APFSR are identified, a full detailed flood hazard and risk assessment should be undertaken.

As in the case of all natural and technological hazards, and both in the case of PFRA and the full FRA, the hazard assessment needs to physically and statistically model the initiation event (i.e. the trigger, which is usually rainfall)70 and after that to model the run-out/evolution of that event. In the case of fluvial flooding hazard, the run-out is modelled using a hydrological model to properly assess the routing of precipitation from rainfall to runoff and a hydraulic model to evaluate in detail the spatial extensions of floodable areas.

After the hazard assessment is completed, a risk assessment should be conducted. FRA should quantitatively assess the potential adverse

69 A Communication on flood risk management: flood prevention, protection and mitigation. Available from http://ec.europa.eu/environment/water/flood_risk/com.htm

70 Many other triggers for flooding exist, e.g. sudden outbursts from glaciers (ephemeral lakes), collapses of hydraulic structures such as dams or levees, surges caused by wind, tides.

consequences associated with flood scenarios and should consider impacts on the potentially affected inhabitants, on the relevant economic activity of the potentially affected area and on all relevant risk receptors.

The definition of risk receptors is also a political decision and a discussion phase with relevant governmental bodies and stakeholders should be made. In both PFRA and FRA, a combination of the following approaches should be used when possible:

- Historic flood risk assessment: information on floods that have occurred in the past, both from natural sources of flood risk and floods from infrastructure failure.
- Predictive analysis assessing the areas that could be prone to flooding, as determined by predictive techniques such as modelling, analysis or other calculations, and the potential damage that could be caused by such flooding.
- Expert opinions especially of departments and agencies to identify areas prone to flooding and the potential consequences that could arise both as a validation step and as complementary information for the predictive analysis.

In the case of flood risk, this type of approach connects to the planning phase that informs land-use planning in order to not create new flood risk by locating new assets in flood-prone zones and, if possible, to reduce the current level of risk by strategies for modifying the land use or developing appropriate flood protection.

Therefore, the main tools to use are the hazard maps; and risk maps are intended as a simple overlay of hazard maps and exposure in order to identify the exposed elements on which to intervene; while a full probabilistic approach, based on the development of a full scenarios set, is often neglected.

The outputs of probabilistic quantitative risk approaches are the probability of occurrence of certain loss levels usually presented as risk curves (a) plotting expected losses against the probability of occurrence for each hazard type individually and (b) expressing the uncertainty by representing a probability distribution at each point of the curve, in many cases drawn as a confidence interval at a certain significance level or generating at least two loss curves expressing the minimum and maximum losses for each return period of triggering events and associated annual probability.

The risk curves can be made for different reference asset units, e.g. administrative units such as individual slopes, road sections, census tracts, settlements, municipalities, regions, provinces or a country.

Whereas for some hazards (e.g. seismic hazard) quantitative approaches to risk assessment are frequently fully probabilistic in nature, this is not always so for floods. Many times, the approach to flooding assesses the geographical distribution of the severity of loss due to the occurrence of a postulated event (i.e. scenario) or based on a hazard map with assigned frequency, which does not take into consideration spatial correlation within a catchment or among different catchments.

Source events are non-homogeneous in space and non-stationary in time, and the probability of a source event is a complex function of both location and time. For rainstorms, in any given year, the probability of a source event depends on spatial differences in topography and atmospheric circulation patterns that change relatively slowly with time (here, atmospheric circulation patterns refer to average annual climatic conditions, not day-to-day variability).

Among all source events, rainfall probabilities are among the most difficult to model because of the unlimited scope of potential source events that must be considered when evaluating flood hazards. Every rainstorm has a different temporal and spatial signature that defies classification, although some classification attempts can be found in the literature.[71]

Even an objective definition of an event, especially when large spatial domains are considered, magnitude is still a debated research topic that hampers the definition of proper magnitude-frequency relationships, constraining scientists to less efficient scenarios simulation methodologies. Eventually, the very expensive modelling of the flooding process sometimes causes the impossibility of using methodologies (e.g. logic trees) for uncertainty estimation and propagation that are widely used in other "hazard" communities. All of these reasons make probabilistic risk assessment a challenge in the case of floods.

Nevertheless, the management of flood risks is based on a judicious combination of measures that address risk reduction, retention and transfer through a strategic mix of structural and non-structural measures for preparedness, response and recovery.

Decisions have to be made on how to share the cost of taking risk among governments (central, regional and local governments), interested parties (such as private companies), communities and individuals. This is even more true if we consider that vicinity to water is an advantage for all main human activities (e.g. urban development, transport, energy production, entertainment) and coastal and flood-plain areas are valuable assets in this sense. Therefore, a full quantitative assessment based on a fully probabilistic approach is essential to properly meet the flood risk management objectives.

---

71 Pinto, J. G. and others (2013). Identification and ranking of extraordinary rainfall events over Northwest Italy: the role of Atlantic moisture. *Journal of Geophysical Research – Atmospheres*, 118, doi:10.1002/jgrd.50179

Description of input data	National entities that most commonly have these data	Examples of open databases available from international sources
DTM	National cartographic institute	SRTM Global DEM, ASTER G-DEM
Land cover/ Land use	National cartographic institute	Global Land Cover from different organizations (NASA, FAO), GlobCover from Envisat/Meris, MODIS GlobCover
River hydrography	National cartographic institute	Hydrosheds
Rainfall data	National hydro-meteorological services	gauge data sets (e.g. CRU TS, GPCC, APHRODITE, PREC/L), satellite-only data sets (e.g., CHOMPS) and merged satellite-gauge products (e.g. GPCP, CMAP, TRMM 3B42)
Streamflow data	National hydro-meteorological services	Global Runoff Data Centre (GRDC)
Geologic/ pedologic/soil parameters	National cartographic institute	Harmonized World Soil Database
Dams	National dam-regulation body	Global Reservoir and Dam Database

Exposure and vulnerability

Vulnerability represents a crucial step in properly evaluating flood impact and all quantitative indicators that are the final product of probabilistic risk assessment. So far, in flood risk assessment, this is probably the weakest link. Convincing methodologies exist to evaluate social vulnerability to floods[72] and can be considered up to the reliability level that is expressed for other hazards.

When a more quantitative vulnerability assessment for floods is needed, which involves as a first step the evaluation of the physical damage through a vulnerability or fragility curve or table, the level of accuracy and data availability is still a challenge.

For seismic risk, the loss quantification is driven by the necessity of evaluating residual risk in the aftermath of an event to quantify the numbers of displaced people that need to be managed. This results in a more organized and refined loss data collection.

72 Samuel Rufat and others (2015). Social vulnerability to floods: review of case studies and implications for measurement. *International Journal of Disaster Risk Reduction,* vol. 14, part 4, pp. 470-486. Available from http://dx.doi.org/10.1016/j.ijdrr.2015.09.013

For floods, structural safety is less of a concern and the loss data gathering is less structured, resulting in heterogeneous data sets that could hardly be used to derive empirical vulnerability curves. Additionally, a large part of the loss is due to the damaged content, which increases the data variability, hampering the application of regression methods to derive vulnerability curves directly from the data. Physical modelling of vulnerability to floods is based on isolated attempts due to the high cost of this approach, which is not compensated by other applications as in the case of other perils (e.g. for seismic for the evaluation of retrofitting strategies).

Expert judgement remains the most diffuse approach. However, as flood vulnerability is affected by factors such as settlements conditions, infrastructure, policy and capacities of the authorities, social inequities and economic patterns, expert judgement is sometimes unable to capture all these aspects. Therefore, a competent mix of expert judgement verified by field data seems the most robust methodology to derive quantitative vulnerability curves.

Vulnerability assessment is closely related to the ability to properly characterize the exposed elements to floods. The exposure characterization is another field where cooperation in a multi-hazard framework would be beneficial for different reasons. Although some exposure characteristics are functional to the flood vulnerability assessment only (e.g. the height of the entrances with respect to the street level) most are common and could be collected in a joint effort when performing a full disaster risk assessment study. To make this process efficient, proper standardization would be needed, starting from the taxonomy up to the IT formats to describe the assets.

Risk assessment and use in national DRR measures

Floods are the most frequent and damaging in terms of cumulative and annual expected loss (AEL) worldwide. People tend to gather close to rivers and lakes or concentrate in the coastal areas because water is a resource before being a threat: this determines a high that concentration of assets, and therefore a high level of risk, in flood-prone areas – a tendency will likely increase in future.

Flood risk assessment, therefore, needs to be closely linked to flood management or even integrated flood management, where the goal is to maximize the net benefit from the use of flood plains rather than try to fully control floods.

In this sense it is necessary to put forward the concept of integrated flood management. This concept is promoted by the Associated Programme on Flood Management (APFM) of both the World Meteorological Organization (WMO) and the Global Water Partnership; it manages flood risk through the application of risk management principles such as:

- Adopting a best mix of strategies
- Reducing vulnerability, exposure and risks
- Managing the water cycle as a whole by considering all floods, including both extremes
- Ensuring a participatory approach
- Integrating land and water management, as both have impacts on flood magnitudes and flood risks
- Adopting integrated hazard management approaches (including risks due to all related hazards such as landslides, mudflows, avalanches, storm surges) and creating synergies.

A guidance document has been developed by APFM to support the design of well-balanced strategies for Integrated Flood Management.[73]

The last point ties into one of the other peculiarities of flood risk, which is the strong correlation with other perils that are either triggered by the same event or that materialise as a cascading effect either downstream or upstream of the flood event. A complete flood risk assessment should take into consideration those aspects at least in a worst-case scenario approach.

Floods are in essence a multi-hazard phenomenon, as their trigger (e.g. storm) frequently brings along compound effects (e.g. combined riverine flood and storm surge in coastal areas), coupled effects (e.g. diffuse landslides

73 Most, H. van der and M. Marchand (2017). Selecting Measures and Designing Strategies for Integrated Flood Management, a Guidance Document. World Meteorological Organization. Available from www.floodmanagement.info/guidance-document

during high-intensity precipitation events), amplification effects, disposition alteration and cascading effects. It would be an incomplete risk assessment if those conditions were not taken into account at least in a qualitative way.

However, despite the growing demand for multi-hazard risk assessment capabilities worldwide, and the many global initiatives and networks that develop and deliver natural hazard and risk information, the focus of global initiatives has been mainly on hazards and in individual hazard domains. Moreover, while existing global initiatives recognize the importance of partnerships with local experts, connecting hazard and risk information from local to global scales remains a major challenge.

Even if science may not be ready to perform a scientifically sound and exhaustive multi-hazard risk assessment in fully probabilistic terms, it would be incautious to take decisions without considering at least a set of "reasonable" worst-case scenarios able to capture the multi-hazard essence of the environment analysed.

It is therefore suggested to start from a multi-hazard risk identification process to identify how the complexity of the territorial system interacts with multiple causes. This analysis starts with, but is not limited to, a deep historical analysis by means of conventional and unconventional sources of information. From there, the expert performing the analysis should select the most appropriate scenarios and characterize them in terms of impacts of their likelihood and uncertainty. This would represent a fundamental part of the risk assessment determining coping capacity and resilience of the system analysed.

A case of a country good practice

FEMA flood hazard maps and the National Flood Insurance Program

In the United States, the Federal Emergency Management Agency (FEMA) is the government agency responsible for developing and disseminating flood hazard maps (flood insurance rate maps (FIRM)). Flood maps for a particular area are developed or updated through collaboration between local, state and federal government officials. A watershed is identified given the need, the available data and the regional knowledge.

The map is then developed by using the best available data and the scientific modelling approach that these data can support. The accuracy of the map depends on what kind of data and methods were used to develop it.

FEMA maps depict flood zones, ranging from high to low hazard. The source of flooding can be pluvial (induced by precipitation), fluvial (riverine) or storm surge. The maps are traditionally distributed in (~3.5 mi2) panels; but they can also be viewed seamlessly through an interactive geographic information system (GIS) portal.

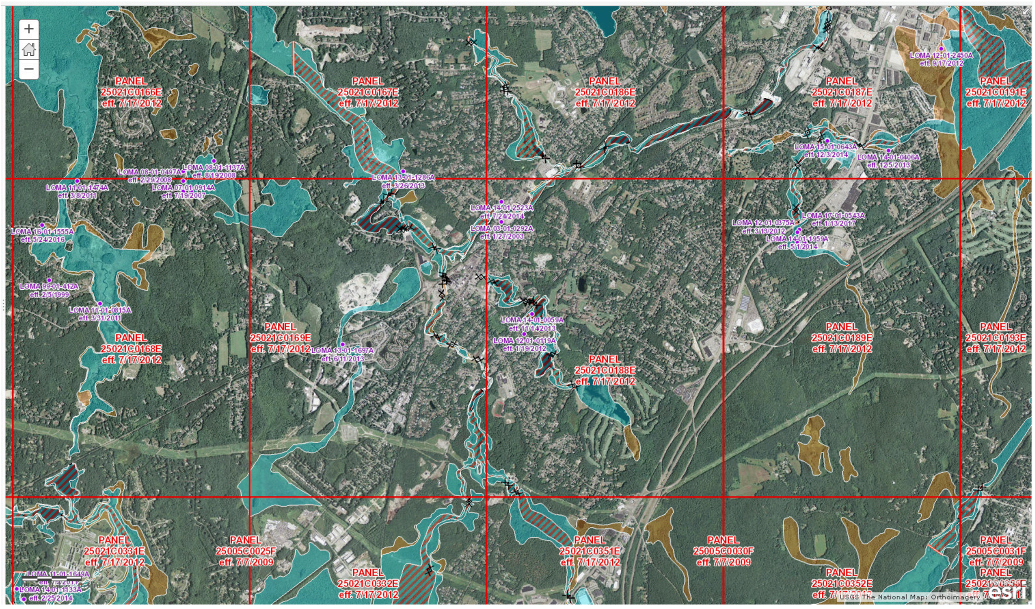


Figure 1 - GIS viewer showing the FEMA's national flood hazard layer (Official)

The map panels, associated flood insurance study (FIS) reports, data sheets and letters of modification can be downloaded from https://msc.fema.gov/portal/availabilitySearch. The maps are under an ongoing cycle of revision and updating due to the increasing availability of related information, whether scientific data or new events that change the assumed probability structures.

The maps can be used for residential and commercial or industrial insurance programmes. For residential insurance, the National Flood Insurance Program (NFIP) was created to enable property owners in participating communities to purchase insurance protection, administered by the Government, against flood losses. The programme requires flood insurance for all loans or lines of credit that are secured by existing buildings, manufactured homes or buildings under construction that are located in a community that participates in the programme.

FEMA, which administers the programme, publishes information and statistics to the public through the official NFIP website: www.floodsmart.gov/floodsmart/.

Malawi flood hazard risk profile

Africa shows a continuously increasing level of risk materializing through natural hazard extremes. These natural risks are a hurdle to the development of many African countries that see their gross domestic product and investments impaired by the impact of such natural hazards. This is particularly true for Malawi, which is periodically hit by severe floods like the one that occurred in 2015 when the Shire River south of Lake Malawi and tributaries flooded large parts of the country in several flood waves. More than 170 people lost their lives, thousands were displaced and crops were lost.

In order to increase science-supported awareness of risk at the national and subnational level, the Global Facility for Disaster Risk Reduction, with European Union African, Caribbean and Pacific Group of States (ACP) funds, has financed the production of hazard flood maps to form the basis for a preliminary risk assessment work producing risk figures. The final purpose of that being engaging with the governments in a risk-financing programme for Malawi. Risk financing could play a key role in protecting the financial investments and could lead the way to a future where such risk is understood, reduced and controlled.

The study was conducted at country level using the TANDEM-X 12.5m resolution global DEM, producing maps with very fine resolution. Such maps are then used to compute in a full probabilistic manner economic parameters such as annual average loss caused by floods broken down into different categories of assets, residential, commercial, industrial buildings, agriculture, critical assets and infrastructures; as well as impact on the population and gross domestic product.

All this analysis is carried out in both present and climate-change conditions. Although the country-level scope frames this study as a preliminary flood risk assessment, the nature of the parameters computed enables an informed dialogue with the national authorities to plan necessary mitigation measures, including further studies in the hotspots highlighted by the study.

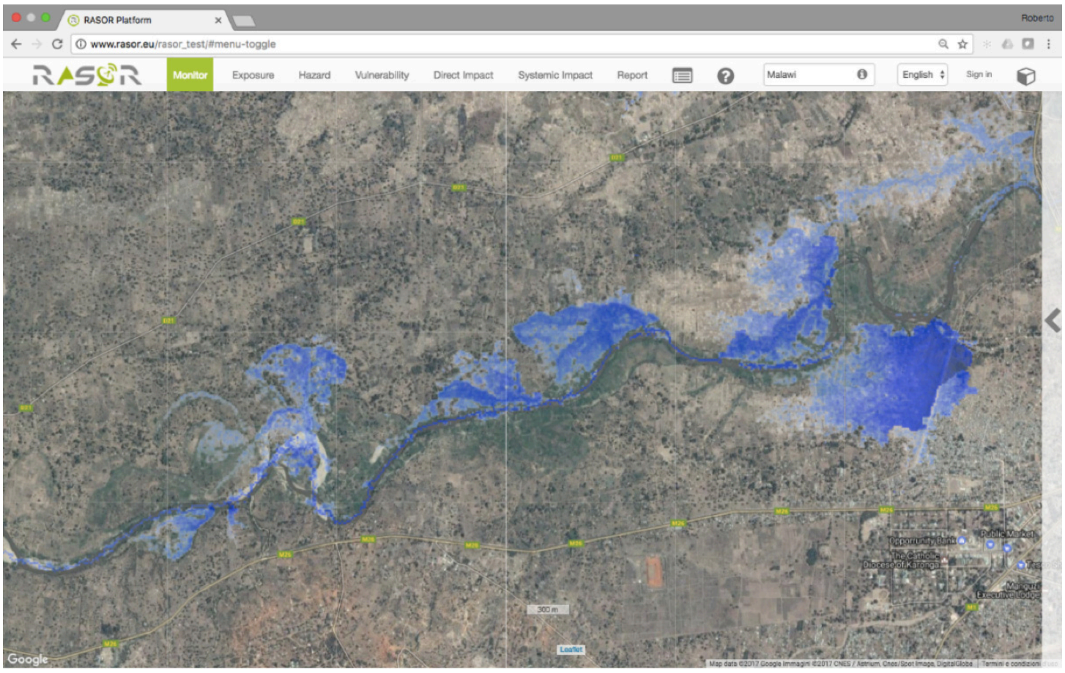


Figure 2 - 100-year flood map depicting maximum water depth for the river flowing into Karonga city in Malawi

Resources for further information

- International community of practice focused on this hazard
  - preventionweb.org
  - gfdrr.org
  - UR
- Other substantial peer-reviewed guidelines from reputable institutions
  - APFM tools
- Open source hazard and risk modelling tools
  - Think hazard
  - GAR
  - RASOR
  - World Bank Caribbean Risk Information Programme
  - Aqueduct Global Flood Analyzer
  - GloFAS
  - GFMS
  - Dartmouth Flood Observatory
  - OpenStreetMap
  - InaSAFE
  - Global Assessment Report Risk Data Platform
- Successful and well documented national hazard and risk assessment with results used in DRR
  - United Kingdom
  - Netherlands

Authors

Roberto Rudari (CIMA Foundation)

Contributors and Peer Reviewers:

Contributors and Peer Reviewers: Yasir Kaheil (FMGlobal), Paolo Scussolini (Vrije Universiteit Amsterdam), Cees Van de Guchte (Deltares)

5. Biological Hazards Risk Assessment

Biological hazards are a major source of risk that may result in emergencies and disasters. They cause significant loss of life, affect many thousands of people, have the potential for major economic losses through loss of livestock and crops, and may also cause damage and loss to the natural heritage, including to endangered fauna and flora.

The management of risks due to biological hazards is a national and community priority. It has been recognized as part of the Sendai Framework, and is globally addressed under the International Health Regulations (IHR).

Biological hazards – what are they?

Biological hazards are of organic origin or conveyed by biological vectors, including pathogenic microorganisms, toxins and bioactive substances. Examples are bacteria, viruses or parasites, as well as venomous wildlife and insects, poisonous plants, and mosquitoes carrying disease-causing agents [1].[74] These hazards are usually the result of a natural occurrence, but can also result from deliberate or accidental release.

Biological hazards also pose a risk to animals, including livestock, and to plants. However, we are focusing here on human health. The consequences of a biological hazardous event may include severe economic and environmental losses. Some examples of recent large outbreaks,[75] epidemics[76] or pandemics[77] due to biological hazards either on their own or following a disaster are:

- The Ebola Virus Disease outbreak in West Africa in 2013-2016, the largest epidemic of its kind to date in the populations of Guinea, Liberia, and Sierra Leone.
- The ongoing outbreak of Zika virus infection in the Americas and the Pacific region, associated with congenital and other neurological disorders.
- Significant increase in diarrheal disease incidences following recurrent floods in most African countries or significant increase following the 2004 tsunami in Indonesia and Thailand [2].
- Outbreaks of yellow fever in Angola, the Democratic Republic of Congo and

74 http://preventionweb.net/go/488

75 A disease outbreak is the occurrence of cases of disease in excess of what would normally be expected in a defined community, geographical area or season. An outbreak may occur in a restricted geographical area, or may extend over several countries. It may last for a few days or weeks, or for several years. A single case of a communicable disease long absent from a population, or caused by an agent (e.g. bacterium or virus) not previously recognized in that community or area, or the emergence of a previously unknown disease, may also constitute an outbreak and should be reported and investigated. www.who.int/topics/disease_outbreaks/en/

76 Epidemic: The occurrence in a community or region of cases of an illness, specific health-related behaviour, or other health-related events clearly in excess of normal expectancy. http://www.who.int/hac/about/definitions/en/

77 A pandemic is the worldwide spread of a new disease. www.who.int/csr/disease/swineflu/frequently_asked_questions/pandemic/en/

Uganda in 2016.

- Outbreaks of Middle East Respiratory Syndrome – Coronavirus (MERS CoV), an emerging disease identified in 2012.

Assessing the risk of biological hazards can be challenging owing to their unique characteristics:

- **Agent diversity.** Biological hazards range from microorganisms such as bacteria or viruses, to toxins to insect infestations. They can be transmitted to humans from the environment, from animals, from plants, and from other humans.
- **Routes of transmission.** These include airborne transmission, ingestion, absorption (through the skin, eyes, mucous membranes, wounds), animal vectors (e.g. mosquitos or ticks), and bodily fluids (e.g. blood, mother-to-child transmission, sexual transmission).
- **Pathogenicity and virulence.** Some biological hazards can cause severe disease in extremely low concentrations and can multiply quickly once within its host. For example, 1-10 aerosolized organisms of Lassa virus or Ebola are sufficient to cause severe disease in humans.
- **Hazard identification.** As microbes are not visible to the naked eye, they are often not easy to identify on the basis of epidemiological information derived from clinical signs and symptoms. They therefore require specific diagnosis techniques, including polymerase chain reaction (PCR), to amplify a single copy or a few copies of a piece of DNA, microbial cultures, whole genome sequencing.
- **Endemic diseases with potential for epidemic transmission.** Unlike some other hazards (e.g. earthquakes or floods), biological hazards can be present in the community (i.e. they are endemic) and usually pose low risk when the population is largely immune. The risk may change when crises or emergencies arise, exacerbating the conditions favourable for disease transmission, or when people migrate from disease-free areas to endemic regions typically lacking immunity, making them susceptible to infection and transmission of the disease resulting in cases in excess of normal expectancy. Biological hazards, which are not endemic also pose a risk when they are introduced to a new host community with no immunity.
- **Sensitivity to climate, environmental or land use changes.** Biological hazards – particularly zoonoses[78] and vector-transmitted diseases such as malaria, dengue, Zika and Ebola – may increase in incidence, lethality or change geographic distribution or seasonal patterns directly due to climate and weather sensitivity, environmental or land-use changes, or mediated

78 Zoonoses are diseases and infections that are naturally transmitted between animals and humans. A zoonotic agent may be a bacterium, a virus, a fungus or other communicable disease agent. www.who.int/neglected_diseases/diseases/zoonoses/en/

through changes in ecosystems resulting from human activities, thus changing human exposures and susceptibility to these hazards.
An estimated 75 per cent of emerging infectious diseases of humans that have evolved from exposure to zoonotic pathogens [3] warrant risk assessments for health threats at the interface between animal, human and ecosystems.

Assessing the risk of biological hazards

Approaches in assessing the risks of biological hazards differ according to the purpose of the assessment:

- **Strategic Risk Assessmen**t is used for risk management planning with a focus on prevention and preparedness measures, capacity development and medium- to longer-term risk monitoring and evaluation.
- **Rapid Risk Assessment** is used to determine the level of risk associated with detected events and to define response interventions accordingly.
- **Post-event assessment** is used for recovery planning, updating and strengthening the overall risk management system.

Pre-event: Strategic Risk Assessments

Strategic Risk Assessments are used for risk management planning with a focus on prevention and preparedness and capacity development before events occur. They can be used for medium- to longer-term risk monitoring and evaluation, which tracks changes in risk over time. They catalyse targeted action to reduce the level of risk and consequences for health based on assessment of the hazard, exposure, vulnerabilities and capacities.

In relation to addressing the risk of biological hazards, the term vulnerability refers to the risk factors that exist in exposed populations, such as the burden of endemic diseases, living conditions (e.g. overcrowding) and environment (e.g. favourable environment for the growing of the pathogen). This is in addition to factors that are addressed in risk assessments for other hazards, such as demographics (e.g. age or gender), the availability of health services to those populations and the degree of resilience of the health systems.

Some examples of strategic risk assessment methods for biological hazards are outlined below.

A quantitative microbiological risk assessment (QMRA) is an example of a strategic risk assessment for prevention and mitigation of risks. The hazard identification includes identifying the characteristics of the pathogen/microbial agent (i.e. case fatality ratios, transmission routes, incubation times…) and the human diseases associated with the specific microorganism. This information can be found in the literature and it could be also helpful to search for similar outbreaks as references.

The exposure assessment of the QMRA measures the dose of the pathogen that an individual ingests, inhales or comes in contact with. It also requires data on the concentration of the pathogen in the source, route of transmission and timing of the exposure.

For this purpose, the QMRA Wiki [4] is a community portal with evolving knowledge repository for the QMRA. In addition, some other available and free access QMRA tools are E3 Geoportal (European Environment and Epidemiology Network) QMRA for Food and Waterborne Diseases [5] and the QMRA spot for drinking water [6].

To prepare for an event involving biological hazards, different approaches to ranking risks could be used, including multi-criteria decision analysis (MCDA) and burden of diseases. These approaches allow for better risk prioritization and planning of public health preparedness.

The World Health Organization (WHO) STAR approach to strategic risk assessment enables countries to incorporate an evidence-based approach to strategic risk assessments. The approach is designed to: engage multisectoral stakeholders around a risk assessment developed for risks affecting public health; provide a systematic, transparent and evidence-based approach to identify, rank and classify priority hazards by level of risk; and for each hazard, to define the level of national preparedness and readiness required to mitigate its risk. The tool is available from WHO on request.

Multi-Criteria Decision Analysis (MCDA) is a stochastic/randomized approach in which several criteria with their levels are identified according to the outcome of interest. Criteria may include information on epidemiological, economic and perception data of the diseases. The criteria can have equal or different weights depending on their relative importance for the outcome. These data can be collected from literature, databases from the official sources, prevalence studies or studies in the field, and from expert consultations. An example is a tool developed by the European Centre for Disease Prevention and Control (ECDC) for ranking infectious diseases to support preparedness planning in the European Union/European Economic Area countries with two versions: a qualitative and less detailed version and a semi-quantitative and more detailed version. Both versions are developed in a flexible way, allowing the users to modify the weighting factors to their own countries. MCDA has also been applied in the WHO Research and Development Blueprint for action to prevent epidemics, which utilizes a combination of the Delphi technique, questionnaires and multi-criteria decision analysis to review and update the Blueprint's priority list of diseases [7].

The Global Burden of Disease (GBD) estimates provide comprehensive and comparable assessment of mortality and loss of health due to diseases, injuries and risk factors, examining trends from 1990 to the present and making comparisons across populations. The estimates provides an understanding of the changing health challenges facing people across the world [8]. GBD research incorporates both the prevalence of a given disease or risk factor and the relative harm it causes. The tools allow decision makers to compare the effects of different diseases and use that information for policymaking. The flexible design of the GBD machinery allows for regular updates as new data and epidemiological studies are made available. In that way, the tools can be used at the global, national and local levels to understand health trends over time [9-10].

The Burden of Communicable Disease in Europe toolkit [11] estimates the burden for 32 communicable diseases and six healthcare-associated infections, applying composite health measures – disability-adjusted life years (DALYs) – to summarize the overall burden in one single metric and compare the relative burden of each communicable disease.

Detection and response: Rapid Risk Assessment

When an event occurs, and in order to inform early warning and response measures, the level of risk posed by the event itself is assessed on a continuous basis through rapid risk assessments [12,13]. The key parameters to take into account in the risk assessment of communicable diseases are the probability (likelihood of transmission in the population) and the impact (severity of the disease), as well as the context in which the disease occurs.

The initial rapid risk assessment must be generated within a short time period when information is often limited and circumstances can evolve rapidly. The assessment should be undertaken in the initial stages of an event or of an incident being reported and verified, and should ideally be produced within 24 to 48 hours. The level of risk should be re-assessed based on evolving information on the event and disease pattern. Risk assessments will help determine whether a response is indicated, the urgency and magnitude of the response, the design and selection of critical control measures; and they will inform the wider implications and further management of the incident.

In the light of time constraints, the assessment generally relies on published research evidence, on specialist expert knowledge, and on experience gathered through previous similar events. Some sources for identifying outbreaks and obtaining disease information are listed in the WHO Rapid Risk Assessment manual [12], and in appendix 3 of the ECDC operational guidance on rapid risk assessment methodology [13]. The principles of transparency, explicitness and reproducibility strictly apply to a rapid risk assessment. In addition, uncertainties must be identified, clearly documented and communicated.

It is important for the public health team in charge of risk assessment to have the following available:

- A repository of events that occurred in the past
- Evidence-based protocols and guidance ready to use for responding to incidents
- Protocols for identifying sources of key information for rapid risk assessment
- Strategies for rapid literature searches
- Lists of experts who can be consulted.

Post-event or post-disaster assessments and after-action reviews

As health needs might not be immediately apparent, it is important to assess the risk of biological hazards after natural or human-induced disasters. Damage to health-care facilities and diagnostic and treatment equipment and interruption of services such as power cuts can have long-reaching consequences affecting the proper functioning of health facilities, including the preservation of the vaccine cold chain.

The availability of safe water, sanitation facilities and hygiene conditions before, during and after a disaster can greatly determine the impact on a community's health and can result in water-related communicable diseases or vector-borne diseases. Other diseases such as tetanus are also associated with natural hazardous events, where contaminated wounds – particularly in populations where vaccination coverage levels are low – are associated with illness and death from tetanus.

Population displacement is also associated with outbreaks of diseases associated with overcrowding. Disasters can also exacerbate non-communicable diseases and mental health needs and increase demands for sexual and reproductive health services.

Post-disaster assessments also inform the implementation of recovery, reconstruction, rehabilitation and restoration of services and other health-related activities, including plans for ongoing and latent risks to population health, and the application of "build back better" principle to ensure that future risks of emergencies and disasters are reduced.

Health impact assessments include identifying existing and latent risks to population health. A rapid risk assessment of these potential risks to human health, and reports on the acute event and syndromic surveillance indicators are needed. As an example of how to implement a syndromic surveillance in a specific population, ECDC launched a handbook and supporting tool for implementing syndromic surveillance in migrant centres and other refugee settings [14].

Post-event reviews (e.g. after-action reviews (AAR) or critical incident reviews) are qualitative reviews of actions at any level, usually focused on the response to an event, as a means of identifying best practices and lessons learned [15]. An AAR seeks to identify what worked well and how these practices can be institutionalized and shared with stakeholders; and what did not work and requires corrective action. AARs can be used as an evaluation of the real response capacities and processes in place.

AARs following epidemics and pandemics usually include evaluations of the capacity of the organization and health and multisectoral systems to deal with the risk, the availability and the enforcement of legal instruments, and issues of leadership and coordination. For example, several reviews have been conducted following the Ebola outbreak in West Africa 2013-2016 [16-18]. A typical review looks at the scale of the epidemic, origins of human infection, spread patterns of the infection, the effects of the interventions taken in both timing and magnitude, the declaration of the end of the epidemic, and finally lessons learned for future preparedness and response.

Risk assessment and use in national DRR measures

Risk assessment will inform policymaking of the management of the risks, including biological hazards, by answering the following important questions:

- Who is at risk? Who is more exposed or in vulnerable situations? What is the level of exposure and the rate of assumed risky behaviours?
- What are the routes of transmissions within and between communities?
- What is the level, severity and scale of the risks? What are the established thresholds that apply to this particular pathogen based on past and present disease incidence?
- What is the risk of international spread that warrants reporting the event under the International Health Regulations (2005) and which may lead to a declaration by WHO of a Public Health Emergency of International Concern?
- What are the effective treatment and control measures available to use to contain and stop the risk?
- What are the environmental and ecological factors or drivers affecting the risk? What is the likelihood and impact of emerging or evolving health threats? How can they be mitigated?
- What are the contextual factors to take into account when managing the risks? These include public perception and behaviour, media interest and political and economic issues.

Policy makers and DRR practitioners use this information to trigger actions that reduce risk of biological hazards i.e. effective and timely prevention, preparedness and response actions, including measures to reduce exposure of groups at increased risk of infection due to biological hazards, contain the spread of the risk, and eventually stopping it.

Measures include protective equipment, behaviour-change practices by raising awareness and education of the public through appropriate communication channels, and effective treatment and/or vaccine if and when available.

Risk information is also used to inform preparedness and contingency planning at various levels and capacity-development measures for health workers to match the full risk profile of the community, including for biological hazards.

Risk assessment information provides the foundation for investment in measures to reduce the risk. For example, identification and mapping of hazardous areas inform the decisions for building critical infrastructure such as water, sanitation and health systems and services to manage the risks of biological hazards as well as other types of emergencies. They also provide the foundation for developing financial applications to manage or transfer the risk.

Impact modelling and rapid risk assessment inform early and rapid estimates of impacts on the populations, on services in health and other sectors, and provide critical information for recovery and rehabilitation reconstruction when needed.

Case studies of a country good practice

Case study: Rapid Risk Assessment of a severe respiratory disease

Event: A cluster of 22 cases of severe respiratory disease with seven deaths in country X were admitted to hospital over the past 17 days. The event is occurring 8 km from the border and cases have been reported from three villages by a local health-care worker. The area is the poorest in the country and health infrastructure is limited.

Many of the health-care facilities charge a consultation fee and consequently the local population self-medicates during mild illness. There are also strong beliefs that "strange diseases" are caused by sorcery.

Risk question: What is the likelihood of further spread of severe cases of respiratory disease and what would be the consequences (type and magnitude) to public health if this were to occur?

Information used to assess the likelihood of further spread:

- Cases are still being reported 17 days after the first known cases were detected
- The specific hazard and mode(s) of transmission have not been identified
- It is also likely that some cases are not being detected (e.g. mild cases are less likely to seek care from health services and are therefore not included in the official reports).

Therefore, if nothing is done, it is highly likely that further cases will occur.

Information used to assess the consequences of further spread:

- The disease has a high case fatality ratio (even when underreporting is taken into account)
- The health-care system is poor and the ability to treat the cases is already limited; new

admissions will further stress acute care services and lead to worse clinical outcomes for hospitalized patients

- Negative economic and social impact of the cases and deaths in the affected communities
- Potential for unrest in communities because of cultural belief that sorcery is causing the deaths
- The event is occurring in a border area and could affect the neighbouring country.

Therefore, if further cases occur, the consequences will be severe.

Using the risk matrix to combine the estimates of likelihood and consequences leads to an estimate of the overall risk. In this case, the overall level of risk is high. The confidence in the risk assessment is low to medium.

Although the report is from a local health-care worker, the information is limited and it is not clear if that person has examined the suspect cases or is merely reporting a rumour.

Source: http://apps.who.int/iris/bitstream/10665/70810/1/WHO_HSE_GAR_ARO_2012.1_eng.pdf

Case study – Collaboration between the Chief Epidemiologist and Civil Protection in Iceland on risk assessment

An island country located in the North Atlantic Ocean, Iceland has a population of some 330,000 inhabitants and an area of 103,000 km2, making it one of the most sparsely populated countries in Europe. Over two thirds of the population live in the southwest part of the country, which makes up the Reykjavik area, while the rest are scattered along the coastal area.

Iceland's Chief Epidemiologist and the Civil Protection service of the National Commissioner of Police are responsible for the national preparedness planning for communicable diseases, as well as chemical, biological and radio-nuclear hazards and events where the source is unknown. Additionally, the Chief Epidemiologist, in cooperation with the Civil Protection service, is responsible for the national risk assessment, risk reduction and response management for these types of events.

In times of crisis, the risk assessment is performed in cooperation with responders and scientists at formal meetings at the National Coordination Centre. Meetings are scheduled as often as needed and a press release issued after each meeting. The objective of the meetings is to share information, assess the risk and decide whether preparedness plans should be activated.

The preparedness plans in Iceland are all-hazard plans and involve the following sectors [19]: primary health care and hospitals, ambulance services, distributors of medicines, Icelandic Medicine Agency, Icelandic Food and Veterinary Authority, food suppliers and distributors, the Farmers Association of Iceland, Icelandic Transport Association, Icelandic Tourist Board, the financial sector, Icelandic Environmental Agency, Icelandic federation of energy and utility companies, Icelandic road and coastal administration, prisons, Red Cross and rescue services, Icelandic National Broadcasting Service and the Evangelical Lutheran Church of Iceland.

The main health hazards in Iceland result from natural hazards such as volcanoes, earthquakes, avalanches and severe weather. Hazards from volcanoes have been a great concern in Iceland for years. These hazards can result from heavy ash fall and various gases being emitted from eruptions, the main one being sulphur dioxide (SO_2).

The evaluation of possible health effects involves various agencies but the final risk assessment, risk mitigation and communication to the public is the responsibility of the Chief Epidemiologist and Civil Protection. Several Icelandic studies have been published that describe the health effects of volcanic eruptions in Iceland. These studies are invaluable in the making of preparedness plans for hazards due to volcanic activities in Iceland as well as for carrying out risk assessment and risk reduction.

Resources for further information

Open-source modelling tools available

- E3 Geoportal (E3 tools): Vibrio, West Nile, E3 map viewer (Dengue, Chikungunya, mosquitoes), Quantitative Microbial Risk Assessment for food and waterborne diseases (QMRA).
- ECDC Legionnaires' disease GIS tool. "It allows field epidemiologists to quickly plot cases and potential outbreak sources, and to make a basic spatial analysis to support the source identification".
- European Up–Front Risk Assessment Tool (EUFRAT). "Quantification of the risk of infection transmission by blood transfusion in an outbreak-affected region, or the risk from a stream of donors who have visited such a region".
- Global Burden of Disease Data Tool. "[…]tool to quantify health loss from hundreds of diseases, injuries, and risk factors, so that health systems can be improved and disparities can be eliminated".
- Burden of Communicable Disease in Europe toolkit. "[…] stand-alone software application which allows calculation of disability-adjusted life years (DALYs) for a selection of 32 communicable diseases and six healthcare-associated infections".
- Joint External Evaluation Tool. "[…] is intended to assess country capacity to prevent, detect, and rapidly respond to public health threats independently of whether they are naturally occurring, deliberate, or accidental".

List of entities to consult for more guidance on health risk assessment

- Departments of health at national, provincial and municipality levels
- Health emergency management sections
- Civil protection agencies
- Food safety agencies
- Vector control agencies
- Water and sanitations agencies
- Civil society organizations working on health: including NGOs, associations of doctors, nurses, public health professionals and foundations on health
- International and regional organizations working on health, such as WHO and ECDC.

References

1. United Nations (2016). Final report of the open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction. Available from www.preventionweb.net/files/50683_oiewgreportadvanceuneditedversion.pdf

2. Kouadio Koffi Isidore and others (2012). Preventing and controlling infectious diseases after natural disasters. United Nations University. Available from https://unu.edu/publications/articles/preventing-and-controlling-infectious-diseases-after-natural-disasters.html - info

3. World Health Organization (2003). *Climate change and human health: risks and responses.* A. J. McMichael and others, eds. Available from www.who.int/globalchange/publications/climchange.pdf

4. Center for Advancing Microbial Risk Assessment. Quantitative Microbial Risk Assessment (QMRA) Wiki 2015. Available from http://qmrawiki.canr.msu.edu/index.php/Quantitative_Microbial_Risk_Assessment_(QMRA)_Wiki

5. European Centre for Disease Prevention and Control (2017). E3 Geoportal QMRA for Food and Waterborne Diseases. Stockholm: ECDC. Available from https://e3geoportal.ecdc.europa.eu/SitePages/E3 Tools.aspx

6. Environment DNIfPHat (2011). Tool for Quantitative Microbial Risk Assessment (QMRAspot) from Surface Water to Potable Water. Available from http://rivm.nl/media/WHO-QMRA/

7. World Health Organization (2017). A research and development Blueprint for action to prevent epidemics. Available from www.who.int/csr/research-and-development/en/

8. (2017). Global Health Estimates (GHE). Available from www.who.int/healthinfo/global_burden_disease/en/

9. Institute for Health Metrics and Evaluation (2015). Global Burden of Disease (GBD) Data tool. Available from www.healthdata.org/gbd/about

10. GBD 2016 SDG collaborators and others (2017). Measuring progress and projecting attainment on the basis of past trends of the health-related Sustainable Development Goals in 188 countries: an analysis from the Global Burden of Disease Study 2016. The Lancet, vol. 390, No. 10100 Available from http://thelancet.com/gbd

11. European Centre for Disease Prevention and Control (2015). Burden of Communicable Disease in Europe (BCoDE) toolkit. Version 1.4. Stockholm: ECDC.

12. World Health Organization (2012). *Rapid Risk Assessment of Acute Public*

Health Events. Available from http://apps.who.int/iris/bitstream/10665/70810/1/WHO_HSE_GAR_ARO_2012.1_eng.pdf

13. European Centre for Disease Prevention and Control (2011). Operational guidance on rapid risk assessment methodology. Stockholm: ECDC. Available from http://ecdc.europa.eu/en/publications/publications/1108_ted_risk_assessment_methodology_guidance.pdf

14. (2016). *Handbook on implementing syndromic surveillance in migrant reception/detention centres and other refugee settings.* Stockholm: ECDC. Available from http://ecdc.europa.eu/en/publications/_layouts/forms/Publication_DispForm.aspx?List=4f55ad51-4aed-4d32-b960-af70113dbb90&ID=1589

15. World Health Organization (2017). After Action Review. Available from https://extranet.who.int/spp/after-action-review

16. WHO Ebola Response Team (2016). After Ebola in West Africa – unpredictable risks, preventable epidemics. *New England Journal of Medicine,* 375(6): pp. 587-596.

17. World Health Organization (2015). *Report of the Ebola Interim Assessment Panel.* Available from www.who.int/csr/resources/publications/ebola/report-by-panel.pdf

18. United Nations (2016). Protecting Humanity from Future Health Crises. Report of the High-level Panel on the Global Response to Health Crises. Available from www.un.org/News/dh/infocus/HLP/2016-02-05_Final_Report_Global_Response_to_Health_Crises.pdf

19. Influenza Pandemic National Plan (2016), (in Icelandic). Available from www.landlaeknir.is/servlet/file/store93/item29596/2016_áætlun vegna heimsfaraldurs inflúensu- útgáfa 2.pdf

Authors

Chadia Wannous (UNISDR), Catherine Smallwood (WHO), Jonathan Abrahams (WHO), and Anne Ancia (WHO), Massimo Ciotti (ECDC), jonathan Suk (ECDC), Laura Espinosa (ECDC), Josep Jansa (ECDC), Svetla Tsolova (ECDC), Ettore Severi (ECDC), Tarik Derrough (ECDC), and Graham Fraser (ECDC)

Contributors and Peer Reviewers

Ali Ardalan (Tehran University of Medical Sciences; Harvard Humanitarian Initiative)

6. Wildfire Hazard and Risk Assessment

Key words:
wildfires, wildfire hazard, risk assessment, wildfire exposure, wildfire vulnerability, risk mitigation, wildland-urban interface

Globally, the occurrence of vegetation fires is common in all continents. Natural vegetation fires have been documented since prehistoric times and have significantly shaped the composition and dynamics of some ecosystems, including forests and open landscapes.

Since the beginning of land cultivation by early humans, the use of fire has contributed to the evolution of humanity and the formation and productivity of cultural landscapes. Today, the vegetated area annually affected by fire globally may range between 300 million and 600 million hectares (3 million-6 million square kilometres).[79]

While some natural ecosystems and land-use systems are dependent, adapted or tolerant to fire, other ecosystems are highly susceptible. With increasing human population and expanding land-use change, the interfaces between vegetation fires and vulnerable human assets are becoming more abundant, critical and conflicting.

And scientific evidence reveals that the indirect effects of vegetation fires have significant impacts on the environment and society. Most importantly, the fire emissions (gas and particle emissions) influence the composition of the atmosphere and thus affect the global climate, as well as human health and security.[80]

Wildfires in wildland-urban interfaces (WUIs) pose a serious threat to communities in many countries worldwide as they can be extremely destructive, killing people and destroying homes and other structures, as happened in California in 2003 and 2007, Greece in 2007, Australia in 2009, Israel in 2016 and Chile in 2017.[81,82,83,84] According to the fire fatalities database of the Global Fire Monitoring Center, an annual average of 297 fatalities caused by wildfires (both civilians and firefighters) was reported globally between 2008 and 2015.[85]

---

79 Mouillot, F. and C. Field (2005). Fire history and the global carbon budget: A 1×1 fire history reconstruction for the 20th century. *Global Change Biology*, vol. 11, pp. 398-420.

80 Goldammer, J.G., ed. (2013). *Vegetation Fires and Global Change: Challenges for Concerted International Action*. A white paper directed to the United Nations and international organizations. Global Fire Monitoring Center publication. Remagen-Oberwinter: Kessel Publishing House. www.fire.uni-freiburg.de/latestnews/Vegetation-Fires-Global-Change-UN-White-Paper-GFMC-2013.pdf

81 Haynes, K. and others (2010). Australian bushfire fatalities 1900–2008: exploring trends in relation to the 'Prepare, stay and defend or leave early' policy. *Environmental Science & Policy*, vol. 13, pp. 185-194.

82 Mell, W.R. and others (2010). The wildland-urban interface fire problem – current approaches and research needs. *International Journal of Wildland Fire*, vol. 19, pp. 238-251.

83 For the wildfire situation in Israel in November 2016, see an exemplary report on WUI fires and damages:
www.chabad.org/news/article_cdo/aid/3503826/jewish/Damage-and-Destruction-as-75000-Return-Home-from-Raging-Fires-in-Israel.htm

84 For the wildfire situation in Chile in February 2017, see www.fire.uni-freiburg.de/GFMCnew/2017/01/20170125_cl.htm

85 Global Fire Monitoring Center, Global Wildland Fire Fatalities and Damages Annual Reports 2008-2015, GFMC / IWPM / UNISDR Global Wildland Fire Network Bulletins Nos. 13 to 21: www.fire.uni-freiburg.de/media/bulletin_news.htm

Wildfires also affect the ecological functioning of many ecosystems, as they partially or completely burn the vegetation layers and affect post-fire soil and vegetation processes such as soil erosion, debris flow, flooding and vegetation recovery.[86]

Figure 1 - Wildfire burning at the Wildland-Urban Interface

In addition to global impacts, fires also have serious local impacts, which are commonly associated with fire frequency and intensity, and imply loss of life and infrastructure, soil degradation, and changes in vegetation and biodiversity. These changes can also affect ecosystem services such as food production and stocks of fresh water or wood products. This process particularly affects tropical rain forest, which has little adaptability to fire.

Wildfire hazard assessment

The term "hazard" is considered a process, a phenomenon or a human activity that may cause loss of life, injury, or other health impacts, property damage, social and economic disruption or environmental degradation. Wildfire hazard is usually computed or expressed as potential fire behaviour (e.g. fireline intensity) or fuel physical and chemical properties (e.g. loading or biomass).

Land managers and firefighting officials need to consider the wildfire hazard potential in order to (a) identify local wildfire threats and assess the risks to

86 Morgan, P. and others (2014). Challenges of assessing fire and burn severity using field measures, remote sensing and modeling. *International Journal of Wildland Fire*, vol. 23, pp. 1045-1060.

communities, (b) educate and motivate homeowners and landowners and increase community involvement with wildfire awareness and preparation, (c) assist land managers and planners in making appropriate decisions about land management and development in fire-prone areas and (d) assist local fire protection districts in pre-attack planning.[87]

The spatial estimation of wildfire hazard can be difficult owing to the complexity of fire occurrence across multiple spatiotemporal scales.[88] The dominant factors determining wildfire behaviour, or the fire spread and intensity in space and time, are fuel availability and fuel conditions, topography, atmospheric conditions and the presence of firefighting. Wildfire hazard has been estimated through a variety of approaches considering some or several of these drivers, including expected fire behaviour, spatial arrangement of fuels, topography variables, and expert knowledge.

Wildfire Risk Assessment

Wildfire risk is the likelihood of a fire occurring, the associated fire behaviour, and the impacts of the fire. Risk mitigation is achieved when any of the three parameters (likelihood, behaviour and/or impacts) are reduced. Wildfire risk has been defined in a variety of ways. However, most of them refer only to wildfire likelihood and behaviour and do not take into consideration the expected fire impacts.[89,90,91,92]

Recent advances in landscape wildfire behaviour modelling have led to a number of new tools and approaches for applying risk frameworks to wildfire management problems which allow land managers to estimate all of the above-mentioned primary wildfire risk components to a number of high-value resources located within forest stands and lands.

Computer models can now perform spatially explicit fire simulations over heterogeneous fuels and map wildfire behaviour characteristics across large landscapes. These approaches have been recently incorporated as a key

87 Calkin, D.E. and others (2011). A comparative risk assessment framework for wildland fire management: the 2010 cohesive strategy science report. *General Technical Report RMRS-GTR* 262. United States Department of Agriculture Forest Service Rocky Mountain Research Station.

88 Keane, R. and J. Menakis (2014). Evaluating wildfire hazard and risk for fire management applications. Making *Transparent Environmental Management Decisions* (K. Reynolds, P. Hessburg and P. Bourgeron, eds.), 111-135. New York: Springer.

89 Hardy, C. (2005). Wildland fire hazard and risk: roblems, definitions, and context. *Forest Ecology and Management*, vol. 211, 73-82.

90 Chuvieco, E. and others (2012). Integrating geospatial information into fire risk assessment. *International Journal of Wildland Fire*, vol. 2, pp. 69-86.

91 Blanchi R., M. Jappiot and Alexandrian D. (2002). Forest fire risk assessment and cartography. A methodological approach. In: Viegas, D., ed. *Proceedings of the IV International Conference on Forest Fire Research.* Luso, Portugal.

92 Carmel, Y. and others (2009). Assessing fire risk using Monte Carlo simulations of fire spread. *Forest Ecology and Management*, vol. 257, pp. 370-377.

element for assessing risk in wildfire management in the United States[93] on a national scale and in Euro-Mediterranean countries on a regional scale.[94] They are also used to support tactical and strategic decisions related to the mitigation of wildfire risk, the post-fire impacts, the forest carbon pools estimation, the forest restoration, and the post-fire soil erosion.

Wildfire Exposure and Vulnerability

Wildfire exposure defines the situation of people, infrastructure, housing, production capacities and other tangible human assets located in wildfire-prone areas.[95] Wildfire exposure is simply the spatial juxtaposition of wildfire likelihood and intensity metrics with the location of Highly Valued Resources and Assets (HVRAs) found in a specific area. Wildfire vulnerability expresses the potential damage from wildfires and it may be defined as: "The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging impacts of a hazard".[96] The assessment of vulnerability to wildfire should consider the expected damage caused by wildfire, which is a critical part of an integrated wildfire risk assessment.

The combination of wildfire exposure, vulnerability and risk assessment has been widely used as an integrated framework for holistic fire management in many fire-prone parts in the world. [97, 98, 99, 100]

---

93 Scott, J., M. Thompson and D. Calkin (2013). A wildfire risk assessment framework for land and resource management. United States Department of Agriculture Forest Service, Rocky Mountain Research Station, *General Technical Report RMRS-GTR 315.*

94 Mitsopoulos, I., G. Mallinis and M. Arianoutsou (2015). Wildfire risk assessment in a typical Mediterranean Wildland–Urban Interface of Greece. *Environmental Management,* vol. 55, pp. 900-915.

95 Fairbrother, A. and Turnley, J. (2005). Predicting risks of uncharacteristic wildfires: application of the risk assessment process. *Forest Ecology and Management*, vol. 211, pp. 28-35.

96 United Nations Office for Disaster Risk Reduction (UNISDR) (2009). UNISDR terminology on disaster risk reduction. Available from www.unisdr.org/we/inform/terminology

97 Calkin, D.C. and others (2011). Progress towards and barriers to implementation of a risk framework for US Federal wildland fire policy and decision making. Forest Policy and Economics, vol.13, pp. 378-389.

98 Acuna, M.A. and others (2010). Integrated spatial fire and forest management planning. Canadian Journal of Forest Research, vol. 40, pp. 2370-2383.

99 Alcasena, F.J., M. Salis and C. Vega-García (2016). A fire modeling approach to assess wildfire exposure of valued resources in central Navarra, Spain. European Journal of Forest Research, vol. 135, pp. 87-107.

100 Plucinski, M. and others (2017). Improving the reliability and utility of operational bushfire behaviour predictions in Australian vegetation, *Environmental Modelling & Software*, vol. 91, pp. 1-12.

Recently, the concepts of wildfire risk transmission and human and natural systems have been studied in the United States in order to create assessment methods that can advance concepts for cross-boundary wildfire risk governance and facilitate the development of more effective policies and practices for fire-prone landscapes.[101, 102]

101Ager, A. and others (2017). Network analysis of wildfire transmission and implications for risk governance. PLOS ONE 12 (3): e0172867.

102 Spies, T. A. and others (2014). Examining fire-prone forest landscapes as coupled human and natural systems. Ecology and Society, vol. 19, No. 3, art. 9.

Risk Assessment and Use in National DRR measures

A critical component of effective wildfire prevention policies and strategies is a long-term wildfire risk assessment, based on robust methods accounting for the spatial and temporal nature of wildfire risk.[103, 104] On a local scale, such wildfire risk assessment could be used for areas to be treated for wildfire risk reduction, fuel treatment practices implementation, fire towers and water tank construction. This information is extremely useful in implementing efficient preventive strategies and measures, since fire prevention is not only preferable but also a cost-effective way to manage forest fires when compared to fire fighting and suppression. Availability of information on wildfire risk assessment on a regional scale supports optimal allocation of fire-fighting personnel and the protection of critical infrastructure.[105]

Holistic wildfire management and implementation plans at landscape level should be based on wildfire risk scenarios that take into consideration wildfire danger warning systems, coupled with physical and socioeconomic parameters.[106]

For global scale wildfire risk assessment, the focus is shifted towards identifying supra-national patterns of similarities and differences, developing and coordinating effective prevention and response mechanisms, identifying areas where more detailed risk assessment models should be implemented, and facilitating research on the context of climate change. Global wildfire risk assessment also is necessary for comprehensive wildfire protection and policy development.

A Regional Case Study

Wildfires constitute a severe threat to cultural heritage and archaeological sites, particularly in countries where most of these sites are covered with vegetation or situated close to forests and other flammable vegetation. Reports of damage caused to historical sites by wildfires are becoming more frequent and alarming. Wildfire events in recent years have threatened UNESCO Natural World Heritage Properties in recent years, including Garajonay National Park (Canary Islands, Spain), Nea Moni Monastery (Chios Island, Greece), Olympia (Greece), and Laurisilva (Madeira Island, Portugal).

---

103 Chuvieco, E. and others (2010). Development of a framework for fire risk assessment using Remote Sensing and Geographic Information System technologies. *Ecological Modelling*, vol. 221, pp. 46-58.

104 Jones, T. and others (2012). Quantitative bushfire risk assessment framework for severe and extreme fires. *Australian Meteorological and Oceanographic Journal*, vol. 62, pp.171-178.

105 Kalabokidis, K. and others (2012). Decision support system for forest fire protection in the Euro-Mediterranean region. *European Journal of Forest Research*, vol. 131, pp. 597-608.

106 Morgan, P., Hardy, C.C., Swetnam, T.W., Rollins, M.G. and Long, D.G. (2001). Mapping fire regimes across time and space: understanding coarse and fine-scale fire patterns. International Journal of Wildland Fire, vol. 10, pp. 329-342.

In 2016, a regional wildfire risk and exposure assessment was carried out at Mount Athos in Greece, a UNESCO World Heritage Site. This case study is an example of the use of satellite remote sensing and geographic information system (GIS) for wildfire risk assessment on a regional and local scale (Figure 1).[107]

The special characteristics of the surroundings, the monasteries and their architecture, the relatively limited human activity, and the singular and isolated location of the peninsula have combined to make Mount Athos one of the most unique and important coastal landscapes in Greece and the Mediterranean area as a whole. Mount Athos includes 20 monasteries and other structures that are threatened by increasing frequency of wildfires. Assessing wildfire risk and exposure enabled fire management plans to be developed and implemented for this region, supporting the management of its important cultural heritage.

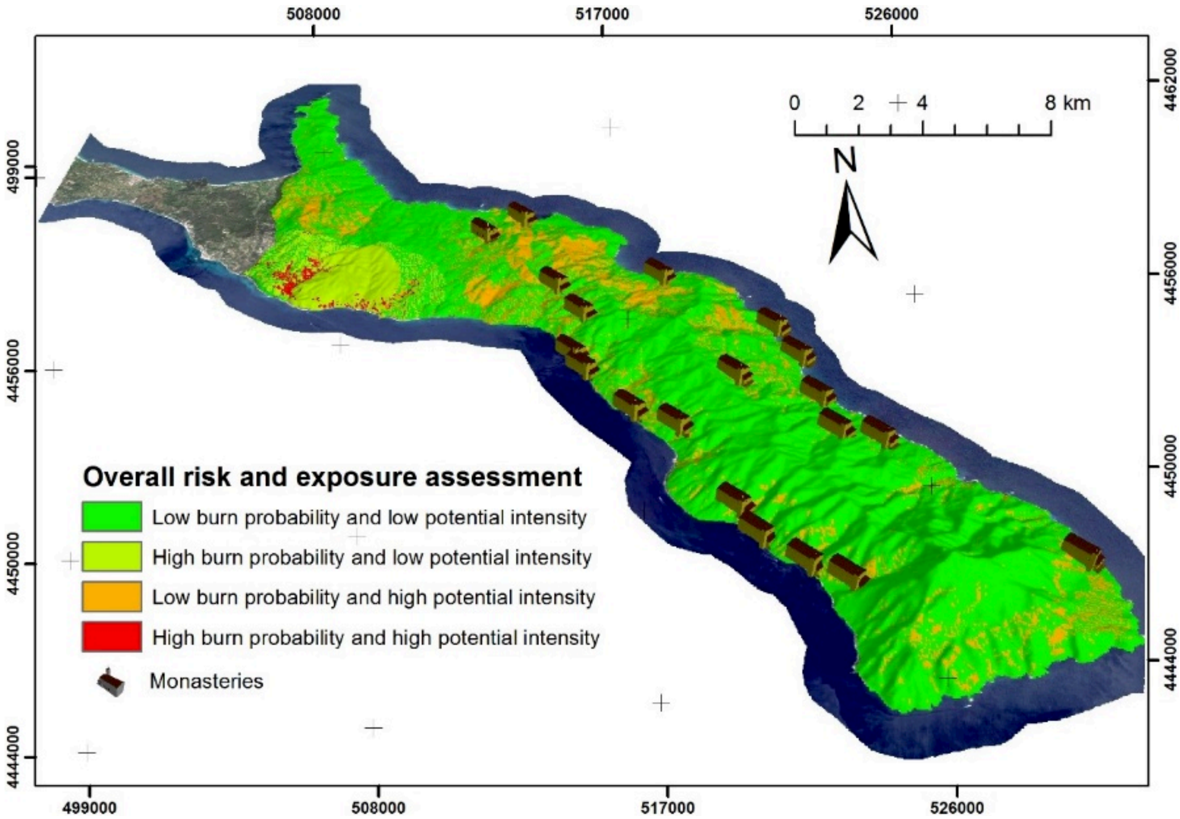


Figure 2 - Fire risk and exposure assessment at Mount Athos, Greece

107 Mallinis, G. and others (2016). Assessing wildfire risk in cultural heritage properties using high spatial and temporal resolution satellite imagery and spatially explicit fire simulations: the case of Holy Mount Athos, Greece. Forests, vol. 7, issue 2.

Resources for Further Information

Freely available software tools exist for simulating wildfire propagation and wildfire impacts on different temporal and spatial scales. Some widely used models include BehavePlus, FlamMap, FARSITE and FOFEM. These models require appropriate skills, training and adequate knowledge of GIS and wildland fuel modelling to be used effectively. Most of the software and tools have been validated against prescribed fires and medium-low intensity wildfires.

Relevant information about models and the software tools can be found through the Fire, Fuel, and Smoke Science Program web portal.[108] ArcFuels is a streamlined fuel management planning and wildfire risk assessment toolbar implemented in ArcMap GIS software that creates a trans-scale (stand to large landscape) interface to apply various forest growth (e.g. Forest Vegetation Simulator) and fire behaviour models (e.g. FlamMap).[109]

Methods for enhancing capacities of local communities in wildfire disaster risk reduction are provided by numerous initiatives.[110] The FireWise USA community programme is a collaborative approach that encourages local solutions for safety by involving homeowners in taking individual responsibility for protecting their homes against the threat of wildfire.[111] FireSmart is a Canadian initiative that provides to communities and individuals across Canada the information and tools they need to confront interface fire protection issues.[112]

The Global Fire Monitoring Center (GFMC) provides a global portal for wildland fire documentation, information and monitoring and is publicly accessible through the internet.[113] The regularly updated national to global wildland fire products of GFMC are generated by a worldwide network of cooperating institutions.

Web-based information and GFMC services include:

- Early warning of fire danger and near-real time monitoring of fire events, including the Global Wildland Fire Early Warning System.[114]
- Interpretation, synthesis and archive of global fire information.
- Support of countries and international organizations to develop long-term strategies or policies for wildland fire management, including community-

108 Rocky Mountain Research Station Fire Sciences Laboratory www.firelab.org

109 Software and functional tutorial www.fs.fed.us/wwetac/tools/arcfuels/

110 Portal of global initiatives in participatory/community-based fire management www.fire.uni-freiburg.de/Manag/CBFiM.htm

111 FireWise community programme http://firewise.org/

112 FireSmart Canada www.firesmartcanada.ca/

113 www.fire.uni-freiburg.de

114 www.fire.uni-freiburg.de/gwfews/index.html

based fire management approaches and advanced wildland fire management training for decision makers, especially in preventing and preparing for wildfire disasters.

- Serve as advisory body to the United Nations system through the coordination of the UNISDR Wildland Fire Advisory Group and the UNISDR Global Wildland Fire Network.[115]
- Emergency hotline and liaison capabilities for providing assistance for rapid assessment and decision support in response to wildland fire emergencies under cooperative agreements with the Emergency Services Branch of the United Nations Office for the Coordination of Humanitarian Affairs.[116]

Authors:

Johann Goldammer (Global Fire Monitoring Center), Ioannis Mitsopoulos (Global Fire Monitoring Center), Giorgos Mallinis (Emocritus University of Thrace Orestiada), Martine Woolf (Geoscience Australia),

Contributors and Peer Reviewers:

Bill de Groot (Canadian Forest Service), Matthew Thompson (U.S. Forest Service)69

115 www.fire.uni-freiburg.de/GlobalNetworks/globalNet.html

116 www.fire.uni-freiburg.de/emergency/un_gfmc.htm

7. Coastal Erosion Hazard and Risk Assessment

Key words:
Coastal erosion hazard and risk assessment, built environment, risk mitigation

Description of the Hazard, Sources and Setting

Coastal erosion (or shoreline retreat) is the loss of coastal lands due to the net removal of sediments or bedrock from the shoreline. Erosion is typically driven by the action of waves and currents, and by mass wasting processes on slopes, and subsidence (particularly on muddy coasts). Significant episodes of coastal erosion are often associated with extreme weather events (coastal storms, storm surge and flooding) but also with tsunami, both because the waves and currents tend to have greater intensity, and because the associated storm surge or tsunami inundation may allow waves and currents to attack landforms that are normally out of their reach.

On coastal headlands, such processes may lead to the undercutting of cliffs and steep slopes and contribute to mass wasting. In addition, heavy rainfall can enhance the saturation of soils, with high saturation leading to a reduction in the shear strength of the soil and a corresponding increase in the chance of slope failure. Coastal erosion is a natural process that occurs whenever the transport of material away from the shoreline is not balanced by the deposition of new material onto the shoreline. Many coastal landforms naturally undergo quasi-periodic cycles of erosion and accretion on timescales of days to years – this is especially evident on sandy landforms such as beaches, dunes, and intermittently closed and open lagoon entrances.

However, human activities can also strongly influence the propensity of landforms to erode. For example, the construction of coastal structures (e.g. breakwaters, groynes (coastal barriers) and seawalls) can lead to changes in coastal sediment transport pathways, resulting in erosion in some areas and accretion in others.[117] The removal of sediments from the coastal system (e.g. by dredging, sand mining), or a reduction in the supply of sediments (e.g. by the regulation of rivers) may also be associated with unintended erosion.

117 Cooper, A. and O.H. Pilkey (2012). *Pitfalls of Shoreline Stabilization. Selected Case Studies.* Coastal Research Library 3, DOI 10.1007/978-94-007-4123-2_1. Dordrecht : Springer Netherlands.

Shoreline retreat in the highly populated mega-deltas of Asia is partly attributed to regulation of rivers, reducing the sediment supply to the shoreline and associated deltaic plains, in addition to groundwater extraction, which has increased subsidence rates118. On larger scales, natural and human-induced climate change can modulate the likelihood and rate of coastal erosion. For example, mean sea level is predicted to increase in the coming decades/centuries due to anthropogenic climate change, and this is expected to increase the frequency of coastal inundation events and thus opportunities for shoreline erosion.[119]

Coastal erosion becomes a hazard when society does not adapt to its effects on people, the built environment and infrastructure. Many human settlements are constructed in areas vulnerable to coastal erosion, with early estimates suggesting that around 70 per cent of the global coastline is eroding.[120] But it is difficult to accurately quantify the global distribution of the hazard and risk, since coastal landforms and human settlements can vary significantly over spatial scales of metres to kilometres, and current global scale data sets are inadequate for assessments at this scale. National scale assessments[121] highlight that there is considerable spatial variability in the risk at these fine scales.

118 Queensland Government (2013). Coastal hazard technical guide: Determining coastal hazard areas (last accessed 26 Jan. 2017 www.ehp.qld.gov.au/coastalplan/pdf/hazards-guideline.pdf)

119 Intergovernmental Oceanographic Commission (2012). Guide on adaptation options in coastal areas for local decision makers: Guidance for decision making to cope with coastal changes in West Africa. IOC Manual and Guide No. 62, ICAM Dossier No. 7 (last accessed 26 Jan. 2017 www.accc-africa.org/sites/default/files/documents/2012/09/14/une-guide_acca_en_bd.pdf)

120 Bird, C. F. (1985). *Coastline Changes*. New York: John Wiley.

121 Department of Climate Change (2009). Climate Change Risks to Australia's Coast: A First Pass National Assessment. Department of Climate Change, Australia. Available from www.environment.gov.au/climate-change/adaptation/publications/climate-change-risks-australias-coasts, last accessed 16 Feb. 2017)

Examples of coastal erosion

Rapid:

- **Storm surge:** Australia has experienced a number of coastal erosion events, some dating from the 1800s. One of Australia's most damaging storms was the 1974 sequence, impacting Queensland and New South Wales.[122]
- **Tsunami:** The 2004 Indian Ocean Tsunami caused severe coastal erosion in a number of locations, including Thailand.[123] Impact was also observed on coral reefs, sea grass and mangroves.[124]

Slow (sea-level rise):

- Happisburgh (United Kingdom), on Norfolk's North Sea coast, was once some distance from the sea. Historic records indicate that over 250m land was lost between 1600 and 1850. It is likely that the Norfolk cliffs have been eroding at the present rate for about the last 5,000 years when the sea level rose to within a metre or two of its present elevation.
- From most countries in the Pacific region there are many anecdotal reports that sea-level rise is already causing significant erosion and loss of land. Evidence of erosion includes beach scarps, undercutting of vegetation, including coconut palms, and outcrops of beach rock that have become uncovered by shoreline changes.
- The coastline of Tongatapu (Tonga) is subject to a range of coastal protection studies and works. The Ministry of Meteorology, Energy, Information, Disaster management, Climate Change and Communications has recognized the vulnerability of that coastline to coastal erosion processes, launching the Coastal protection Project in 2015.

Hazard assessment

A wide range of methodologies have been applied for coastal erosion hazard assessment. The key factors influencing these methodologies include:

- The spatial and temporal scale of the analysis. This may range from an entire continent as part of a national assessment to a regional analysis at local government level or a single sediment compartment to inform a particular erosion issue.

---

122 Callaghan, J. and P. Helman (2008). Severe storms on the east coast of Australia 1770-2008. Griffith Centre for Coastal Management (last accessed 26 Jan. 2017 www.goldcoast.qld.gov.au/documents/bf/storms-east-coast-1770-2008.pdf)

123 Choowong, M. and others (2007). Erosion and Deposition by the 2004 Indian Ocean Tsunami in Phuket and Phang-nga Provinces, Thailand. *Journal of Coastal Research*, vol. 23, issue 5, pp. 1270-1276.

124 Thom, B. (2014) Coastal Compartments Project - Summary for policy makers. (last accessed 24 April 2017 www.environment.gov.au/climate-change/adaptation/publications/coastal-compartments-project-summary-policy-makers)

Likewise, the timescale of analysis can range from short-term (subannual) to better understand coastal behaviour across the seasonal weather cycle or long-term (decadal) to incorporate climate variability and inform planning decisions.

Geological timescales are also relevant on those coasts where sea-level rise is ongoing due to natural subsidence (e.g. deltaic coasts such as in the Gulf of Mexico) or continued adjustments of land masses following deglaciation after the last ice age (e.g. eastern Canada and northeastern United States).

These natural changes across various timescales provide important context for understanding coastal erosion processes on short time scales and when making planning decisions (see figure 1 in [18]).[125] The timeline then defines the range of events that should be considered. For example, residential buildings in Australia (life of asset expected to be at least 50 years) are designed for events with an annual probability of exceedance of 1/500 (for wind and earthquake).

- The nature of the coastal landforms and the offshore environment in the area of interest. At a general level, the form and composition of coastal landforms and the presence of barrier islands and reefs in the offshore environment determines the sets of physical processes that should be considered in an erosion assessment. Sandy shorelines, coastal cliffs, fringing reef coasts and deltaic coasts are each affected by somewhat different processes.
- The nature of the sea action being considered. The underlying driver for erosion (e.g. sea-level rise, storms or tsunami) will determine the types of analysis or modelling that will inform an assessment. In addition, future trends associated with climate change are critical and the event being considered (e.g. design event (specified event possibly based on consequence or likelihood criteria) or extreme event (largest event believed possible) or the full range of events (e.g. via a probabilistic analysis).

Our understanding of the coastal environment, and particularly how and where sediment is transported (i.e. the sediment budget) will critically affect the appropriate choice of spatial scale for the study. Data availability place limitations on the nature of the hazard assessment (see table below for examples of input data for hazard assessments).

Coastal compartments represent one way to define the scales that should be considered when taking actions that could affect sediment budgets. For example, construction of a groynes may protect a community as intended but cut off sediment supply to another part of the same coastal compartment, thereby leading to coastal erosion downdrift. A typical coastal compartment

[125] Ibid.

identifying the sediment transport pathways can be found in the Climate Change Adaptation Guidelines published by Engineers Australia (see figure 4).[126]

When data are sparse or non-existent, it is helpful to understand the physical context and history of an eroding beach through available imagery (e.g. Google Earth), conduct site surveys to assess the wave climate and beach state, map coastal infrastructure (such as groynes) and features that may be controlling the sediment supply to the coastal zone of interest, and engage with the local community. Establishing a baseline may also be necessary if suitable data do not exist. For example, shoreline mapping to record erosion lines and subsequent recovery over time will assist in understanding the impact of seasonal cycles in beach dynamics.

Estimating how a shoreline will change over time is an evolving science. State-of-the-science approaches include some form of shoreline response modelling that can be applied to coastal erosion hazard assessments. Modelling can be done to provide information to address questions such as:

- How far would the shoreline retreat for the design level scenario?
- Which parts of the shoreline are more vulnerable to coastal erosion?
- Are there offshore features (e.g. reefs, barrier islands) that are vulnerable to sea-level rise?
- What is the probability of 1m, 5m or 10m of shoreline retreat (shown spatially for the region of interest)?
- What is the confidence (and uncertainty) in these estimates?
- What is the effectiveness of coastal defence options?

However, complex shoreline evolution models may not necessarily outperform simpler approaches[127] and are not suitable for national-scale assessments.

---

126 Engineers Australia (2012). *Climate Change Adaptation Guidelines in Coastal Management and Planning* (last accessed 24 April 2017 www.engineersaustralia.org.au/sites/default/files/content-files/2016-12/climate_change_adaptation_guidelines.pdf)

127 Kinsela, M.A. and D.J. Hanslow (2013). Coastal erosion risk assessment in New South Wales: limitations and potential future directions. Proceedings of the NSW Coastal Conference, 2013 (last accessed 16 Feb. 2017 www.coastalconference.com/2013/papers2013/NSWCC_Kinsela_Hanslow_2013.pdf)

Description of input data	National entities that most commonly have these data	Examples of open databases available from international sources
Elevation data (onshore and offshore)	National spatial agencies, local government, lands department, universities / academia	LINZ Data Service, 3DEP (USGS), US Interagency Elevation Inventory, Digital Coast (NOAA), ELVIS (onshore elevation),
Information on landform types (geomorphology and substrate) and sediment transport pathways	National research and development agencies (e.g. United States Army Corps of Engineers), national geological survey, local government, universities / academia	Smartline (Australia), Geomorphic classification of the coastal zone (Australia), Coastal compartments (used in Australia, United States, United Kingdom, some parts of Europe), ground-penetrating radar (to determine location of bedrock)
Historic shoreline positions (e.g. from aerial photographs) and/ or elevation transects	National research and development agencies (e.g. United States Army Corps of Engineers), national geological survey, local government, lands department, academia, local knowledge in community	University of California Santa Barbara Map and Imagery Laboratory (MIL) aerial photography collection includes areas of China, central Asia, Africa, and Pacific Islands, Nationwide Environmental Title Research (NETR) Online Historic Aerials, United States Geological Survey (USGS) Coastal Change Hazards Portal, Narrabeen-Collaroy historic beach profiles (Australia), historic aerial imagery
Exposure data (locations and characteristics of buildings, infrastructure, human population)	Local government (e.g. asset registers), bureau of statistics, lands department	National Exposure Information System (NEXIS)
Historic sea levels and ocean waves, forecast sea level and ocean wave scenarios (including tsunami)	Intergovernmental Panel on Climate Change (IPCC), hydrographic office national weather service, academia	Tsunami waveforms from national probabilistic tsunami hazard assessments, CAWCR Wave Hindcast 1979-2010, and 2013-2014, Manly Hydraulic Laboratory, IPCC

Table 1- Sources of data for coastal erosion risk assessment

Tsunami risk assessment use in national DRR measures

A risk assessment will typically be determined by combining the knowledge of the hazard, the elements at risk (e.g. built environment) and an understanding of the vulnerability of those elements. This vulnerability is often described by classes of damage, ranging from "no damage" through to "complete damage" (e.g. total destruction of an asset). In the case of the coastal erosion hazard, buildings (residential, commercial, public, etc.) can be considered as requiring complete replacement or as being uninhabitable where their foundations are undermined. If the risk assessment process considers other elements at risk – such as parts of the surrounding landforms and ecosystem (e.g. dunes, mangroves, saltmarsh) – vulnerability models describing the level of damage to these elements will need to be determined. Coastal inundation hazards may also be included in the risk assessment, in which case suitable vulnerability models would need to be sourced (a starting point could be to employ flood damage models).

Case study: The New South Wales (Australia) coastal erosion risk assessment[128] is a broad-scale assessment for the entire coastline of that State, (over 2,000 km) combining the elements described above. Over several decades, New South Wales has seen a number of severe coastal erosion events, and with population increasing in the coastal zone, the risk profile is changing.

The assessment led to the identification of coastal erosion hotspots, and this information allows the government to prioritize its coastal management activities. The study also suggests that the assessment should be guided by the level of risk, and that there needs to be agreement among stakeholders on the acceptable thresholds of that risk.

Recommendations to reduce risk should be based on these assessments, and may take many forms, including:

- Land-use policy and/or regulation, such as planning laws to limit development in at-risk areas (e.g. by defining coastal setback lines)
- Physical shoreline protection, such as beach nourishment, sea walls and groynes to maintain sediment volumes and help stabilize shoreline position
- Physical offshore protection, such as breakwaters and artificial reefs, to modify and redistribute the energy of storm waves
- Environmental remediation approaches, such as maintaining or restoring natural ecosystems (e.g. mangrove forests, coral reefs and dune

128 Intergovernmental Panel on Climate Change (2014). *Climate Change 2014: Impacts, Adaptation and Vulnerability.* Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

vegetation) to provide natural buffers to storm events.

Recent examples of the implementation of risk reduction measures:

- United Kingdom. Clacton coastal defences[129]
- United States. Barrier Islands, New Jersey https://toolkit.climate.gov/case-studies/restoring-natural-dunes-enhance-coastal-protection
- United States. Ventura, California https://toolkit.climate.gov/case-studies/restoring-surfers-point-partnerships-persistence-pays
- United States. Hawaii. O'ahu North Shore https://toolkit.climate.gov/case-studies/confronting-shoreline-erosion-o%E2%80%98ahu
- New Zealand, Bay of Plenty dune rehabilitation www.mfe.govt.nz/publications/climate-change/coast-care-bay-plenty-dune-restoration/coast-care-bay-plenty-dune

National case study

The National Coastal Risk Assessment for Australia, which was conducted in 2010 and 2011,[130] identified the spatial extent of settlements and infrastructure, ecosystems and industries in the coastal zone which would be impacted from inundation and erosion for a range of sea-level rise scenarios. The infrastructure assessed included residential, commercial, light-industry buildings, and transport systems. The assessment was led by the Federal Department of Climate Change with input from a range of technical experts (government science agencies, research institutions and consultants), as well as from State government departments responsible for coastal management.

The assessment required the development of national data sets, including: the digital elevation model (necessary for inundation modelling); high water level and storm tide (necessary for inundation modelling) and coastal geomorphology (to identify segments of the coast which are susceptible to erosion).

Through the assessment, a number of key areas emerged where various kinds of data were lacking on the national scale: estuaries and knowledge of their shoreline geomorphology; national exposure of important infrastructure; regional and local influences on coastal instability (i.e. inputs for coastal erosion models) and higher resolution digital elevation models (as coarse resolution models were not suitable for modelling inundation in low gradient coastal plains).

---

129 Environment Agency (2016). Managing flood and coastal erosion risks in England 1 April 2015 to 31 March 2016 (last accessed 24 April 2017 www.gov.uk/government/uploads/system/uploads/attachment_data/file/575139/National_Flood_Risk_Report_LIT_10517.pdf)

130 Kinsela, M.A. and D.J. Hanslow (2013). Coastal erosion risk assessment in New South Wales: limitations and potential future directions. Proceedings of the NSW Coastal Conference, 2013 (last accessed 16 Feb www.coastalconference.com/2013/papers2013/NSWCC_Kinsela_Hanslow_2013.pdf)

Key findings from the assessment were:

- Between $41 and $63 billion AUD (2008 replacement value) of existing residential buildings are potentially at risk of inundation from a 1.1 m sea-level rise (between 157,000 and 247,600 individual buildings of the 711,000 existing buildings).
- Nearly 39,000 buildings located within 110 m of "soft" shorelines were at risk from accelerated erosion due to sea-level rise and changing climate conditions.
- The concentration of infrastructure in the coastal zone around population centres will bring risks to those assets which could have consequences for the delivery of community and essential services, regional economies and possibly the national economy. For example, there are 258 police, fire and ambulance stations, 5 power stations/substations, 75 hospitals and health services, 41 landfill sites, 3 water treatment plants and 11 emergency services facilities located within 200 m of the shoreline.
- While there is a lack of information on social vulnerability to climate change, remote Indigenous communities in the north of Australia and communities living on the low-lying Torres Strait Islands are particularly vulnerable to sea-level rise.

The assessment provided a case for early action to reduce risk. There is a large legacy risk in the coastal zone from buildings and other infrastructure constructed in the past, without regard to climate change and the instability of some coastal landforms. For "at-risk" areas, strategies to protect, accommodate or retreat will need to be developed, as sea level is projected to continue rising for several centuries. Triggers will be needed to identify when on-ground responses are needed to manage increasing risks. State and local government, industry and communities will have a primary role to play in on-ground coastal adaptation action.

Continued work is required on developing standards and benchmarks, providing information, auditing infrastructure at risk, on-ground demonstrations of adaptation options, and local capacity-building. Areas of uncertainty for the science components also need to be addressed.

Resources for further information

Climate change adaptation guidelines are another source of information for coastal managers:

- The Intergovernmental Oceanographic Commission (IOC) advises policy makers and managers on reducing risks from tsunamis, storm surges, harmful algal blooms (HABs) and other coastal hazards by focusing on implementing adaptation measures to strengthen the resilience of vulnerable coastal communities, their infrastructure and service-providing ecosystems. IOC is implementing the project "Adaptation to climate change in coastal zones of West Africa"[131]
- United Nations Environment Programme (UNEP)[132]
- United Nations Development Programme (UNDP) Climate change adaptation – coastal zone development programme http://adaptation-undp.org/thematic-areas/coastal-zone-development (example case studies in Africa, Samoa)

Other substantial peer-reviewed guidelines from reputable institutions:

- National Oceanic and Atmospheric Administration (NOAA) Office for Coastal Management https://coast.noaa.gov/digitalcoast/tools/hazards-portal.html
- Engineers Australia: Climate Change Adaptation Guidelines in Coastal Management and Planning, includes information on coastal processes and sediment budgets www.engineersaustralia.org.au/sites/default/files/content-files/2016-12/climate_change_adaptation_guidelines.pdf
- CATALYST project (funded by the European Commission) Capacity development for hazard risk reduction and adaptation www.catalyst-project.eu and Hare et al. 2013
- United States Army Corps of Engineers – Manuals: www.publications.usace.army.mil/USACE-Publications/Engineer-Manuals/
    - Environmental Engineering for Coastal Shore Protection
    - Design of Coastal Revertments, Seawalls, and Bulkheads
    - Coastal Engineering Manual - Part I to Part VI and Appendix A

131 Intergovernmental Oceanographic Commission (2012) Guide on adaptation options in coastal areas for local decision makers: Guidance for decision making to cope with coastal changes in West Africa. IOC Manual and Guide No. 62, ICAM Dossier No. 7 (last accessed 26 Jan. 2017 www.accc-africa.org/sites/default/files/documents/2012/09/14/une-guide_acca_en_bd.pdf)

132 United Nations Environment Programe (2010). *Technologies for Climate Change Adaptation: Coastal Erosion and Flooding*. TNA guidebook series (last accessed 26 Jan. www.unep.org/pdf/TNAhandbook_CoastalErosionFlooding.pdf)

Open source hazard and risk modelling tools:

- United States Army Corps of Engineers (USACE) Coastal Modeling System www.erdc.usace.army.mil/Media/Fact-Sheets/Fact-Sheet-Article-View/Article/484188/coastal-modeling-system/
- USACE Beach-fx. Analyzing Evolution and Cost-Benefits of Shore Protection Projects
www.erdc.usace.army.mil/Media/Fact-Sheets/Fact-Sheet-Article-View/Article/476718/beach-fx/
- Deltares – XBeach. https://oss.deltares.nl/web/xbeach/
- University of Southampton – SCAPE+ (Soft Cliff And Platform Erosion)
- United States Geological Survey Digital Shoreline Analysis System (shoreline change) – requires ArcGIS 9.x or above
- https://woodshole.er.usgs.gov/project-pages/DSAS/
- SWAN (wave model) http://www.swan.tudelft.nl/
- NIWA Beach Profile Analysis Toolbox (BPAT) – free licence for academic (with restriction on number of regions), NZ$850 for first commercial licence https://www.niwa.co.nz/our-science/coasts/tools-and-resources/tides/bpat

Successful and well-documented national hazard and risk assessment with results used in DRR:

- The U.S. Climate Resilience Toolkit shows a number of case studies relating to coastal erosion - https://toolkit.climate.gov/topics/coastal-flood-risk/coastal-erosion

- The synthesis report[133] shows a number of case studies where assessments were made that led to adaptation measures being implemented to reduce the risk of coastal erosion.

133 Hare, M, C., J. van Bers and J. Mysiak, eds. (2013). *A Best Practices Notebook for Disaster Risk Reduction and Climate Change Adaptation: Guidance and Insights for Policy and Practice from the CATALYST Project.* Trieste: The World Academy of Sciences (last accessed 26 Jan. www.catalyst-project.eu/doc/CATALYST_D65_Best_Practices_Policy_Notebook.pdf)

Authors:

Martine Woolfe (Geoscience Australia)

Contributors and Peer Reviewers:

Tom Baldock (University of Queensland)

8. Sea-level Rise

Key words:
Sea level change, glacial melting, land movement, flooding, storm surge, coastal adaptation

Global climate change is expected to impact the entire globe by the end of this century. The release of carbon dioxide and other greenhouse gases is responsible for rapidly rising global mean surface temperatures, which could increase by as much as 4.8°C by 2100.134 This warming is causing ice to melt, along with an expansion of warming waters that is expected to increase global sea levels between 0.26 and 0.82 metres according to the 2013 report of the Intergovernmental Panel on Climate Change.

These rising sea levels pose an extreme risk to many global cities135, including Shanghai (China), Mumbai (India), Rio de Janeiro (Brazil), New York (United States) and London (United Kingdom). Many global regions, such as the South Pacific island of Tuvalu and low-lying coastal areas of Bangladesh, are already experiencing significant coastal flooding and inundation due to sea-level rise.136,137 But this is merely the beginning, as it is expected that, without adaptation, 0.2 to 4.6 per cent of the global population will be flooded annually by the end of this century, costing approximately 0.3 to 9.3 per cent of global gross domestic product.138

In undertaking hazard assessment, we need to keep in mind that because sea-level rise occurs gradually, it behaves very differently from many other hazards. Its impacts may not be immediately seen or coalesce around a single sea-level rise event. Permanent flooding on land is a direct hazard caused by sea-level rise; however, a number of indirect (secondary) hazards need to be incorporated into the assessments. These include extended damage caused by storm surges or saltwater contamination of fresh water sources.

Hazard assessment

Understanding disaster risk related to sea-level rise is essential to understanding the scale of impact this hazard could have for a particular locality. In the United States, the Mississippi River delta – including the city of New Orleans – is already experiencing severe flooding. Other regions, such as south-east Alaska, are not expected to experience rising sea levels until later in the century.

The table below lists some resources that are currently available to assess the risk of sea-level rise. It also provides links to sources on strengthening disaster risk reduction governance to manage sea-level rise, on enhancing

---

134 Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. *Climate Change 2013: The Physical Science Basis.* Cambridge: Cambridge University Press.

135 Nicholls, R. J. and A. Cazenave (2010). Sea-level rise and its impact on coastal zones. Science, vol. 328, pp.1517-1520.

136 Church, J. A., N.J. White and J.R. Hunter (2006). Sea-level rise at tropical Pacific and Indian Ocean islands. *Global and Planetary Change,* vol. 53, issue 3, pp.155-168.

137 Hamlington, B. D. and others (2014). Uncovering an anthropogenic sea-level rise signal in the Pacific Ocean. *Nature Climate Change,* vol. 4, pp. 782-785.

138 Hinkel, J. and others (2014). Coastal flood damage and adaptation costs under 21st century sea-level rise. Proceedings of the National Academy of Sciences 111, pp. 3292-3297.

disaster preparedness for effective response and on guiding resilience investment.

The global costs of protecting the coast with dikes alone are estimated to range between US$ 12 billion and US$ 71 billion by 2100.5 While this investment in disaster risk resiliency may appear costly, it is still much less than the projected loss of gross domestic product – as forced migration of between 1.6 million and 5.3 million people caused by sea-level rise, without adaptation, is estimated to cost between US$ 300 billion and US$ 1,000 billion.[139]

Description of input data	National entities that most commonly have this data	Examples of open databases available from international sources
Rates of past sea-level change from tide gauges	National Oceanic and Atmospheric Administration, British Oceanographic Data Centre	www.gloss-sealevel.org/ www.psmsl.org/
Sea-level altimetry data	United States National Aeronautics and Space Administration	www.nodc.noaa.gov/SatelliteData/jason/
Future sea-level projections	United Nations Intergovernmental Panel on Climate Change	www.ipcc-data.org/
Sea-level adaptation strategies	United States National Park Service, United States Environmental Protection Agency, Australian Government Geoscience Australia OzCoasts programme	www.cakex.org/ https://coastadapt.com.au/
Examples of general adaptation projects	weADAPT, a collaborative platform supported by Sweden	www.weadapt.org/placemarks/maps https://toolkit.climate.gov/

Table 1- Sources of data for sea-level rise risk assessment

Table 1 includes input data required for understanding disaster risk. However, uncertainties exist that could influence the outcome of risk assessment. These uncertainties can be due to the following:

- Choice of sea-level rise scenario (also known as greenhouse gas concentration representative concentration pathways)[140]

139 A global analysis of erosion of sandy beaches and sea-level rise: An application of DIVA. *Global and Planetary Change* (2013). vol. 111, pp. 150-158.

140 Van Vuuren, D. P. and others (2011). The representative concentration pathways: an overview. *Climatic Change,* vol. 109, pp. 5-31.

- Accuracy of the models used (to be specified by the authors of the models)
- Secondary hazards (e.g. storm surge and groundwater intrusion) that could provide a "tipping point" for reconstruction, adaptation, or abandonment
- Willingness across all scales (intergovernmental, within the State, community, individual) to invest in planning to manage risk.

Exposure and vulnerability assessment

It is estimated that US$ 9.6 trillion to US$ 11 trillion in global assets and 290 million to 310 million people live within the present-day 100 year flood zone.5 This number does not include those working within the coastal zone who could be exposed to sea-level rise by 2100.

Neumann et al.141 offer four different scenarios under which demographic data are combined with sea-level rise data to identify the most vulnerable regions. People living in the coastal zone in China, India, Bangladesh, Indonesia and Viet Nam are estimated to be most vulnerable due to secondary storm surge hazards. Africa is also in a precarious position due to its rapid population growth and urbanization in the coastal zone, which will make Egypt and sub-Saharan countries in eastern and western Africa more vulnerable to sea-level rise and its associated hazards. Prevention measures and long term planning early on can help reduce vulnerabilities by retreating from any zones of potential exposure. Funds should be secured for any critical resources or infrastructure that cannot be moved but can be protected using engineered methods (e.g. elevate roads and buildings).

Risk assessment use in national DRR measures

A number of national-level DRR measures are important for management, after the risk of sea-level rise has been assessed.142 These measures include the following:

- Promoting the collection of appropriate data and encourage the use of standardized baselines for the periodic assessment of sea-level risk and secondary hazards such as storm surge and groundwater intrusion.
- Adopting and implementing national sea-level rise plans that take into account changes in sea level across multiple timescales and climate change scenarios.
- Putting in place mechanisms to periodically assess and publicly report on progress in implementing resiliency measures to address sea-level rise.

---

141 Neumann, B. and others (2015). Future coastal population growth and exposure to sea-level rise and coastal flooding - a global assessment. PLOS ONE 10.

142 United Nations Office for Disaster Risk Reduction (2015). Sendai Framework for Disaster Risk Reduction 2015-2030, p. 37.

The reports should promote public scrutiny and be subject to institutional debates, including by parliamentarians, as well as scientists from the climate change arena.

- Promoting the mainstreaming of sea-level plans and assessments that include mapping and management strategies for rural development planning and management of wetlands, coastal floodplains areas, and any other areas prone to flooding.
- Encouraging the revision of existing building codes to include the impact of sea-level rise in designated flood and storm surge zones; and assessing buildings based on their adaptive capacity and ability to be relocated if necessary.
- Promoting cooperation among diverse institutions across multiple spatial scales.
- Promoting the inclusion of planning to adapt to sea-level rise into post-storm and other post-disaster documents. This includes rebuilding based on future shoreline positions.
- Considering the relocation of public facilities and infrastructure.

CASE STUDY

Box 1
A case of country good practice: Australia

The Government is actively planning for sea-level rise. In 2015 the Department of the Environment and Energy released its National Climate Resilience and Adaptation Strategy, which outlined the following four priorities for national engagement: (a) understand and communicate, (b) plan and act, (c) check and reassess and (d) collaborate and learn.

Managed retreat has been implemented in many parts of the country. Five guiding principles exist for those attempting this strategy. Managed retreat may not be an option for many less economically developed countries if they do not seek to establish and maintain protective coastal ecosystems. Sea-level rise will continue to be a hazard in regions that promote population growth along the coastline while ignoring the cumulative impacts of development and asserting political pressure for coastal development.

Liability laws that favour developers also put those at risk, since many are unaware of their potential future exposure to sea-level rise. The establishment of conditional occupancy rights (managed retreat via compensation for present-day landowners to abandon future at risk property) is one proposed technique to raise homebuyers' awareness of this issue, although stakeholder attitudes towards this approach vary.

Australia is an economically developed country, which makes adapting to sea-level rise easier because it can afford to pursue a number of strategies such as seawalls, beach sand replenishment and subsidized managed retreat to reduce the risk from sea-level rise and its associated secondary hazards.

But a number of less economically developed countries are also leading the way in creating strategies for reducing their sea-level rise risk. The Least Developed Countries Fund was established to help enhance and adapt infrastructure and develop community-based projects that build adaptive capacity across 51 least developed countries.

Resources for further information

Further information about understanding and preparing for sea-level risk:

- The Potsdam Institute for Climate Impact Research has information on the latest sea-level science, as well as links to ongoing global projects.
- The United Nations Environment Programme offers information on various adaptation and mitigation strategies related to climate change. Links to information regarding finance tools to fund projects can be found here: http://web.unep.org/climatechange/
- The Pacific Climate Change Portal was established as a resource for planners and managers so they could get information on projects, country profiles and sources of finance for climate change-related projects in the Pacific region.
- The EcoAdapt Climate Adaptation Knowledge Exchange (CAKE) manages a global database of climate change-related adaptation case studies, and as well as providing links to various tools : www.cakeex.org

Authors:

Rebecca Beavers (USA National Park Service), Maria Caffrey (University of Colorado)

Contributors and Peer Reviewers:

Andrew Williams (University of Plymouth)

9. Natech Hazard and Risk Assessment

Key words:

Natech, technological risk, chemical accident, industrial safety, loss of containment, cascading effect, Natech risk assessment

The impacts of natural hazard events on chemical installations, pipelines, offshore platforms and other infrastructure that process, store or transport dangerous substances can cause fires, explosions and toxic or radioactive releases.[143] Although these "Natech" accidents are a recurring feature in many natural disasters, they are often overlooked, despite the fact that they can have major social, environmental and economic impacts.

They may cause multiple and simultaneous releases of hazardous substances over extended areas, damaging or destroying safety barriers or systems, and downing lifelines often needed for accident prevention and mitigation.

In addition, emergency responders are usually neither equipped nor trained to handle several substance releases at the same time, in particular as they also have to respond to the natural hazard event consequences in parallel.[144,145,146]

Because of the inherent multi-hazard nature, Natech risk assessment concerns industry operators and authorities in charge of chemical accident prevention and civil protection. Natech risk assessment and management therefore requires a comprehensive understanding of the interdependencies of human, natural and technological systems. Successfully controlling a Natech accident has often turned out to be a major challenge – if not impossible – where no prior risk assessment and proper preparedness planning had taken place.

Sources and setting

Examples of recent major events that highlight the importance of the serious consequences of Natech accidents include the 2002 river floods in Europe, which resulted in significant hazardous substance releases, including chlorine[147] and dioxins, the 2011 Tōhoku earthquake and tsunami, which caused a meltdown at a nuclear power plant and raging fires and explosions at oil refineries,[148] and Hurricane Sandy in 2012, which triggered multiple hydrocarbon spills.

The Tōhoku earthquake, in particular, is a textbook example of a cascading

143 Showalter, P.S. and M.F. Myers (1994). Natural disasters in the United States as release agents of oil, chemicals, or radiological materials between 1980-1989: analysis and recommendations. *Risk Analysis,* vol. 14, issue 2, pp. 169-182.

144 Krausmann, E., A.M. Cruz and E. Salzano (2017). Natech Risk Assessment and Management - *Reducing the Risk of Natural-Hazard Impact on Hazardous Installations.* Amsterdam: Elsevier.

145 Girgin, S. (2011). The natech events during the 17 August 1999 Kocaeli earthquake: aftermath and lessons learned. *Natural Hazards and Earth System Sciences*, vol. 11, issue 4, pp. 1129-1140.)

146 Krausmann, E., A.M. Cruz and B. Affeltranger (2010). The impact of the 12 May 2008 Wenchuan earthquake on industrial facilities. *Journal of Loss Prevention in the Process Industries*, vol. 23, pp. 242-248.

147 Hudec, P. and O. Lukš (2004). Flood at Spolana a.s. in August 2002. *Loss Prevention Bulletin,* issue 180. Institution of Chemical Engineers, United Kingdom.

148 Krausmann, E. and A.M. Cruz (2013). Impact of the 11 March 2011, Great East Japan earthquake and tsunami on the chemical industry. *Natural Hazards*, vol. 67, issue 2, pp. 811-828.

risk, because the earthquake itself caused only limited damage owing to the stringent protection measures in place. However, the tsunami and its impact on a nuclear power plant resulted in the most severe technological disaster ever recorded in the region and whose adverse effects still persist.

It does not necessarily require a major natural hazard event, e.g. a strong earthquake or flood, to cause a Natech accident; it can be triggered by any kind and size of natural hazard event. Consequently, Natech risks exist both in developed and developing countries where hazardous industrial sites are located in natural hazard regions. Industrial growth, climate change and the increasing vulnerability of a society that is becoming more and more interconnected will increase the likelihood and impact of such events in the future.

Hazard assessment

Natech events are joint disasters that combine natural and technological hazards and that feature very complex consequences owing to amplifying effects between the two types of hazard. Adequate prevention, preparedness and response are specifically needed, therefore, to prevent them and mitigate their consequences.

Unfortunately, disaster risk reduction frameworks do not always consider technological hazards and chemical accident prevention and preparedness programmes often overlook the specific aspects of Natech risk. This results in a lack of dedicated methodologies and guidance for risk assessment and management for industry and authorities.

Adequate national-level Natech risk assessment is therefore important to see the overall picture and pinpoint potential risk hotspots that require detailed risk assessment. Many such potential hotspots, such as refineries, petrochemical complexes, and oil and gas pipelines, are also considered critical infrastructures. Consideration of Natech risk is required for their effective protection. In this context, it is important to consider all natural hazards that a hazardous installation can be subject to in a certain area.

Although the consequences of hazardous materials release are well known and industrial practices exist to cope with most scenarios, including major events, the cost of additional safety measures to reduce the Natech risk can result in reluctance to accept that such risks exist and to act to reduce them. This also means a limited amount of data from industry, which are required for national risk assessment. Adequate legislative frameworks and their enforcement should ensure that operators share information that is critical for Natech risk assessment.

Exposure and vulnerability

National Natech risk assessments should consider that major natural hazards can impact large areas, affecting the population, the building stock, industry and infrastructure. Potential multiple and simultaneous releases from various installations and also from different parts of each installation, as well as the possibility of on- and off-site secondary cascading (domino) events, should be taken into account when assessing exposure.

Industrial facilities handling hazardous materials are inherent vulnerabilities for the social system in which they are nested. If not managed well, not only extreme events but also low-level hazards can generate broad chain effects if vulnerabilities are widespread in the system and the risks are not handled properly.[149]

By analysing past Natech accidents, conclusions were drawn concerning the most vulnerable types of industrial equipment per natural hazard, common damage and failure modes, and the hazardous substances mostly involved in the accidents.[150,151,152,153]

---

149 Pescaroli, G. and D. Alexander (2015). A definition of cascading disasters and cascading effects. Going beyond the "toppling dominos" metaphor. Global Risk Forum, Davos, Switzerland.

150 Cozzani, V. and others (2010). Industrial accidents triggered by flood events: analysis of past accidents. *Journal of Hazardous Materials*, vol. 175, pp. 501-509.

151 Renni, E., E. Krausmann and V. Cozzani (2010). Industrial accidents triggered by lightning. *Journal of Hazardous Materials*, vol. 184, pp. 42-48.

152 Krausmann, E. and others (2011). Industrial accidents triggered by earthquakes, floods and lightning: lessons learned from a database analysis. *Natural Hazards*, vol. 59 (285).

153 Girgin, S. and E. Krausmann (2016). Historical analysis of U.S. onshore hazardous liquid pipeline accidents triggered by natural hazards. *Journal of Loss Prevention in the Process Industries*, vol. 40, pp. 578-590.

Among the process and storage units commonly used by industry, atmospheric storage tanks, especially those with floating roofs, appear to be particularly vulnerable to natural hazards. This is critical from an industrial-safety point of view, as these units usually contain large amounts of flammable liquids that may ignite and escalate into major fires or explosions during Natech accidents. The likelihood of ignition is high in earthquake- or lightning-triggered Natech events.

Oil and gas pipelines transporting vast amounts of hazardous substances are also vulnerable to natural hazards, especially at river crossings. Because the pipelines are usually located in the countryside, detection of pipeline accidents can be late, leading to major spills and significant economic damage. 6

Natech accidents may result in exposed areas that are much greater than for ordinary industrial accidents. For example, if floods cause an overflow of containment dikes at a facility, any released substances that would normally be captured within the dikes can easily be dispersed by the flood waters and contaminate the environment up to hundreds of kilometres through the river network. In the case of earthquakes, cracks that occur on dike floors as a result of ground movement may leak hazardous liquid substances that can lead to significant ground water pollution.

The vulnerability of the population may also be significantly increased during Natech conditions. For instance, when there is toxic atmospheric dispersion caused by an earthquake, shelter might not be possible because of structural damage to buildings. Also, evacuation from the location of an industrial accident might not be feasible because of the blockage of escape routes by debris or flooding. And residents might be reluctant to evacuate an area if relatives are still trapped under the debris. Such factors should be considered in undertaking exposure and vulnerability analysis.

Natech risk assessment use in national DRR measures

Risk assessment is a powerful tool for identifying hazards and estimating the associated risk. Industrial risk assessment methodologies vary across countries, ranging from fully quantitative to qualitative approaches. For Natech risk assessment, existing methodologies need to be extended to include equipment damage models for natural-hazard impact and the possibility of multiple loss-of-containment events at several industrial units at the same time.

Unlike many natural hazards, technological hazards are usually localized – an aspect that needs to be considered in the national risk assessment. In order to assess the Natech risk to a hazardous installation, operators should determine if their site is located in a natural hazard zone and, if so, what the expected severity of the natural hazards on the site would be.[154]

This needs to be followed by an analysis of which parts of the installation would be affected and how, since not all equipment is equally vulnerable. Priority should be given to the most hazardous equipment. The natural hazard risks to these selected facilities should then be analysed. This analysis should also include an assessment of the impacts of the natural events on the prevention and mitigation measures in place. Once the potential consequences have been assessed and a need for further risk reduction identified, dedicated protection measures should be implemented. This process requires a significant amount of input data. However, as much of this information (natural risk maps, industry information) is already gathered in the framework of the national risk assessment, these data could also be used for the Natech risk assessment. Krausmann (2017)[155] provides a detailed discussion of the requirements and steps for Natech risk assessment. Risk assessment methodologies and tools have inherent uncertainties that need to be considered in the decision-making process.

A number of research and policy challenges and gaps exist that can prevent effective Natech risk reduction. These include a lack of data on equipment vulnerability against natural hazards, and the unavailability of a consolidated methodology and guidance for Natech risk assessment, which has, for instance, resulted in a lack of Natech risk maps.

The few existing Natech risk maps are usually only overlays of natural hazards with industrial site locations and are therefore only Natech hazard maps. Natech risk maps must also include an estimate of the potential

---

154 Krausmann, E. (2016). Natech accidents - an overlooked type of risk? *Loss Prevention Bulletin*, vol. 250. Institution of Chemical Engineers, United Kingdom.

155 (2017). Natech risk and its assessment. In: Krausmann, E., A.M. Cruz and E. Salzano. Natech Risk Assessment and Management - Reducing the Risk of Natural-Hazard Impact on Hazardous Installations. Amsterdam: Elsevier.

consequences, which may differ significantly from site to site. Attention should be paid to the inherent limitations of existing equipment vulnerability models from non-Natech applications if these are used to substitute for the missing Natech models.

There is the misconception that engineered and organizational protection measures in place to prevent and mitigate conventional industrial accidents would be sufficient to protect against Natech events. But the very natural event that damages or destroys industrial buildings and equipment can also render unavailable the instrumentation (e.g. sensors, alarms), the engineered safety barriers (e.g. containment dikes, deluge systems) and the lifelines (e.g. power, water for firefighting or cooling, communication) needed for preventing an accident, mitigating its consequences and keeping it from escalating. Therefore, for effective Natech risk reduction, additional Natech-specific safety measures need to be put in place to accommodate the characteristics of Natech accidents.

The assessment of Natech risk can therefore be challenging, even for the impact of a single natural hazard on a hazardous installation. Consideration of multiple natural hazards and cascading events (e.g. domino effects) that may involve multiple process units or installations at the same time is much more difficult.

Currently no assessment tools exist to capture all aspects of Natech risks. Recently, however, risk assessment tools and methodologies that can rapidly estimate regional and national Natech risk have become available. These include RAPID-N for semi-quantitative risk assessment[156] based on natural hazard information and the data on hazardous industrial installations entered by the user, ARIPAR for a quantitative treatment of the problem[157] and PANR for a qualitative assessment methodology.[158] Although still limited to selected natural hazards and certain types of installations, the tools are in active development to cover additional hazards and industries, and can significantly facilitate national risk assessment studies.

Being an emerging risk – even in developed countries – national authorities are still not assessing Natech risk comprehensively. Although there are no risk assessments at country level, several national and international programmes and regulations exist that require the operators of hazardous installations to include Natech risks in their safety plans.

---

156 Girgin, S. and E. Krausmann (2013). RAPID-N: Rapid natech risk assessment and mapping framework. *Journal of Loss Prevention in the Process Industries,* vol. 26, issue 6, pp. 949-960.

157 Antonioni, G. and others (2009). Development of a framework for the risk assessment of Natech accidental events. *Reliability Engineering and System Safety*, vol. 94, issue 9, 1442-1450.

158 Cruz, A.M. and N. Okada (2008). Methodology for preliminary assessment of Natech risk in urban areas. *Natural Hazards,* vol. 46, issue 2, 199-220.

CASE STUDY

Box 1
Good practices for addressing Natech risk

European Union - Directive 2012/18/EC on the control of major-accident hazards involving dangerous substances (Seveso III Directive), which regulates chemical accident risks at fixed industrial installations, explicitly addresses Natech risks and requires the installations to routinely identify environmental hazards, such as floods and earthquakes, and to evaluate them in safety reports.
The inclusion of Natech risks in the Seveso Directive acknowledges that awareness of this risk has been growing steadily in Europe since the Natech accidents during the 2002 summer floods.

Japan - The Law on the Prevention of Disasters in Petroleum Industrial Complexes and Other Petroleum Facilities was updated after the Tokaichi-oki earthquake triggered several fires at a refinery in 2003. Moreover, the amended Japanese High Pressure Gas Safety Law requires companies to take any additional measure necessary to reduce the risk of accidents, and to protect their workers and the public from any accidental releases caused by earthquakes and tsunamis.

United States - The State of California released the California Accidental Release Prevention (CalARP) Program, which calls for a risk assessment of potential hazardous materials releases as the result of an earthquake.

The Natech database eNatech is specifically designed for the systematic collection and analysis of worldwide Natech accident data (available at http://enatech.jrc.ec.europa.eu).

Rapid Natech risk assessment and mapping tool RAPID-N allows quick regional and local Natech risk assessment, including natural hazard damage assessment and accident consequence analysis with minimum data requirements (available at http://rapidn.jrc.ec.europa.eu). (Requires prior authorization).

The Natech addendum to the OECD Guiding Principles for Chemical Accident Prevention, Preparedness and Response contains amendments to the original guiding principles (available at www.oecd.org/chemicalsafety/guiding-principles-chemical-accident-prevention-preparedness-and-response.htm).

Authors:

Serkan Girgin, Amos Necci, Elisabeth Krausmann (Joint Research Centre)

Contributors and Peer Reviewers:

Ernesto Salzano (University of Bologna

10. Tropical Cyclone (To be completed soon)