Special Topics

Words into Action Guidelines

National Disaster Risk Assessment

Special Topics

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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

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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.

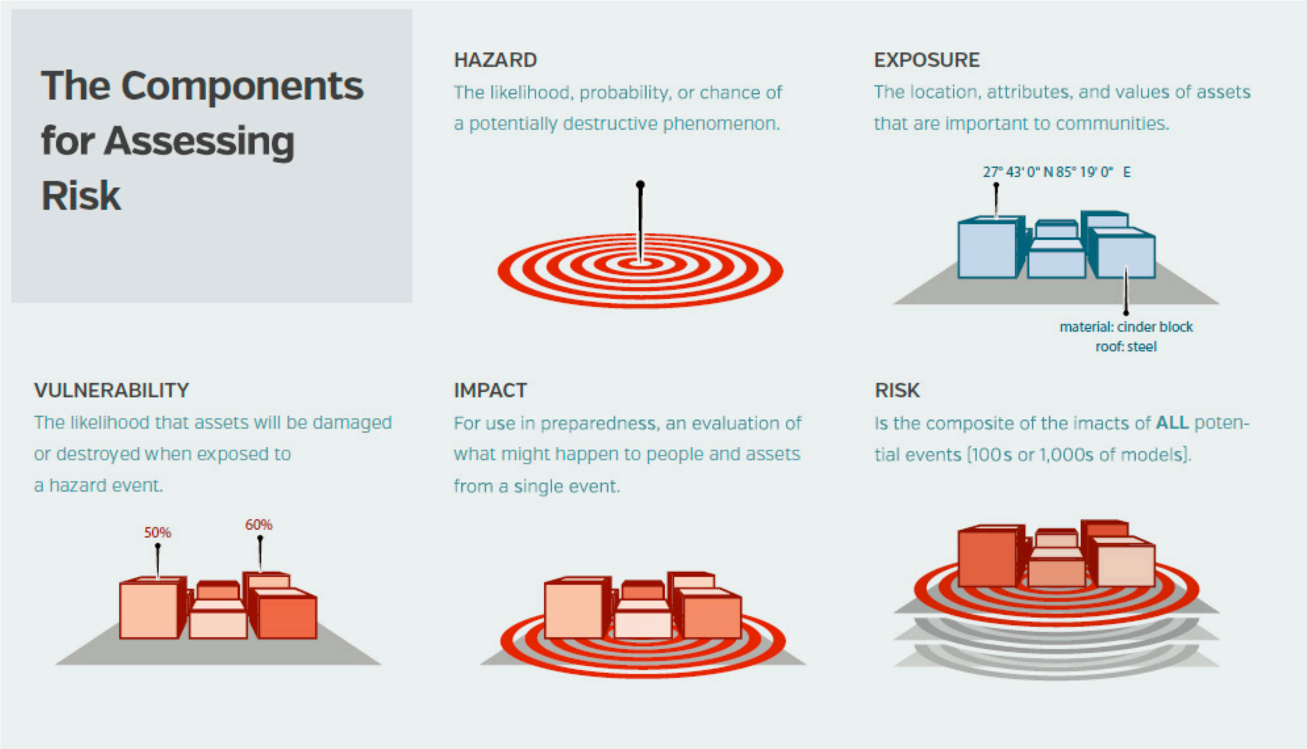

Figure 1 – Components of a risk assessment

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).

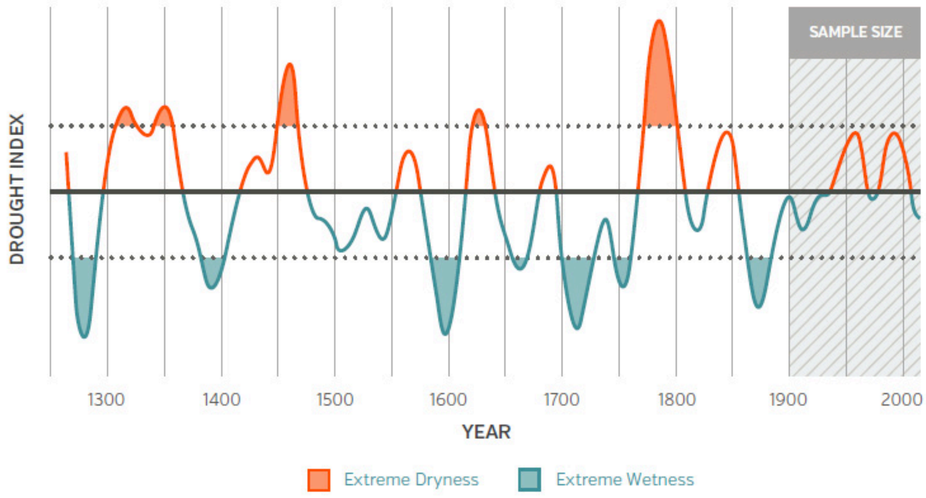

Figure 02–1
Hypothetical drought index showing periods of extreme dryness (above the dotted red line) and periods of extreme wetness (below the dotted blue line); the historical record does not capture extreme dry and wet periods experienced prior to its start in 1900.

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
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- 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

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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.

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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

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[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

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[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.

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[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.

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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*.

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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.

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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.

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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.

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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

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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).

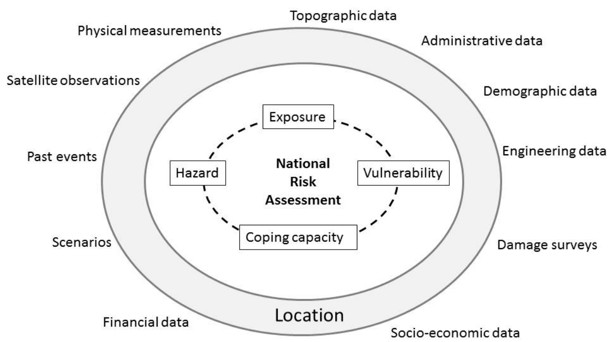

Figure 1 – Examples of the key role of spatial information in a risk assessment

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.

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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.

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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.

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[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

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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

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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

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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.

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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

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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

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[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).

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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

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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.

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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

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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

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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.

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