Insurance Development Forum

The Development Impact of Risk Analytics

Authors

Lead authors:

Nick Moody, Editor
(IDF Risk Modelling Steering Group)

Stuart Fraser
(IDF Risk Modelling Steering Group)

Katherine Miles
(Katherine S Miles Consulting Ltd)

John Schneider
(GEM Foundation)

Contributing authors:

John Bevington
(JBA Consulting)

Christelle Castet
(AXA Climate)

Chris Ewing
(Aon Impact Forecasting)

Marc Gordon
(UN Office for Disaster Risk Reduction)

Clemens Gros
(Red Cross Red Crescent Climate Centre)

Rachel Haldane
(START Network)

Catalina Jaime Sanchez
(Red Cross Red Crescent Climate Centre)

Paul Maisey
(JBA Risk Management Ltd)

Gero Michel
(AIG Re)

Tom Philp
(AXA XL)

Carlos Sanchez
(Willis Towers Watson)

Kara Siahaan
(IFRC)

Claire Souch
(AWHA Consulting Ltd)

Maxime Souvignet
(MCII/United Nations University)

Dickie Whitaker
(Oasis Loss Modelling Framework Ltd)

Contributors of case studies and examples:

Ana Beatriz Acevedo
(Universidad EAFIT, Colombia)

Daniel Bierenbaum
(Global Parametrics)

Litea Biukoto
(Secretariat of the Pacific Community)

Adam Bornstein
(Danish Red Cross)

Hervé Damlamian
(Secretariat of the Pacific Community)

Annette Detken
(InsuResilience Solutions Fund)

Emma Flaherty
(IFRC, Risk-informed Early Action Partnership)

Adrien Gignac-Eddy
(CIMA Foundation)

Isabel Gomes
(CIMA Foundation)

Roger Grenier
(AIR Worldwide)

Lena Laux
(InsuResilience Solutions Fund)

Serena Odianose
(World Meteorological Organisation)

Daniel Raizman
(AIR Worldwide)

Anthony Rea
(World Meteorological Organisation)

Lizzy Rees
(START Network)

Roberto Rudari
(CIMA Foundation)

Acknowledgments

Thanks go to the following for their guidance and support throughout the development of the paper:

Ekhosuehi Iyahen, (Secretary General, Insurance Development Forum)

Ian Branagan, (Chief Risk Officer Renaissance Re, Chair IDF Risk Modelling Steering Group)

Marc Gordon (Head, Global Risk analysis and Reporting UNDRR, Co-chair IDF Risk Modelling Steering Group)

Jan Kellett, (Special Advisor, Finance Sector Hub, and Co-Chair, IDF Operating Committee)

Tuga Alaskary
(Advisor, InsuResilience Secretariat)

Thanks also to Jon Gascoigne and colleagues at the Centre for Disaster Protection for a very helpful peer review

Cover graph data represents annual fatalities and economic damage due to disasters worldwide 1980-2020 (EM-DAT, Centre for Research on the Epidemiology of Disasters / UCLouvain, Brussels, Belgium)

The Development Impact of Risk Analytics

A call to action for public and private collaboration

Why risk analytics matter in the achievement of the UN Sustainable Development Goals

How barriers to access can be overcome

Contents

Foreword

Achim Steiner
UNDP

Mami Mizutori
UNDRR

Denis Duverne
IDF

Even before the pandemic, progress towards the 2030 Agenda for Sustainable Development was off-track. Although the full impacts of COVID-19 are not yet known, the threat to the development of resilient systems and societies has been laid bare. The World Bank already estimates that up to 100 million more people could live in extreme poverty due to the impacts of the pandemic.[1]

Much of this was avoidable. Perhaps the timing of the pandemic was a surprise but its occurrence was not; some countries, companies and influencers had foreseen such outcomes and yet recommended measures were not adopted. Inaction prevailed. An evolved approach to understanding risk is clearly needed; we must move beyond resignation and response to risk reduction and prevention. We have to identify and act on warning signals that account for context, complexity and uncertainty.

The pandemic has not been the only recent cause of change in the profile of risk understanding. An observer at the 2019 UN Climate Action Summit looking beyond the headlines might have detected some fundamental shifts in risk policy:

- For the first time, themes of risk prevention and reduction received as much attention as the reduction of greenhouse gas emissions.
- Focus continued to move towards *ex-ante* preventative investment in preference to *ex-post* emergency response.
- The increasing value attached to public and private sector collaborations, both at strategic and operational levels. Of particular note was:
  - Cross-sector support for the InsuResilience Vision 2025 target of covering 500 million poor and vulnerable people against disaster and climate shocks through risk finance and insurance.
  - The formal connection of development programmes and private sector risk capacity in an operational collaboration between the United Nations Development Programme (UNDP), the Government of Germany and the Insurance Development Forum (IDF).

These shifts marked an important chain of thought: that regardless of any progress towards net zero emissions, we are already more vulnerable than before, that reducing risk is always better than reacting to shocks; and that if we do not pool the world's resources and expertise we will fail to respond at the scale that is so clearly required. This is as true for pandemic and other risks as it is for climate.

As the UN Secretary-General has put it: *"We must change course by 2020, or we risk missing the point where we can avoid the disastrous consequences for people and all the natural systems that sustain us.[2]"*

1 https://blogs.worldbank.org/opendata/updated-estimates-impact-covid-19-global-poverty
2 https://www.un.org/en/climatechange/un-climate-action.shtml

The practice of understanding risk is the foundation of any approach to reducing it. Risk decision-making can be a difficult process involving judgment and compromise, not least as we strive to improve our understanding of the systemic nature of risk. However, rational quantification of risk plays an important part by providing a sense of scale as well as shining a light on what is known - and what is not. There is no certainty; no risk practitioner believes that the models are fully representative of reality, but there is value in using a disciplined (and multi-disciplinary) process to examine the causes and potential impacts that so adversely affect people and society, particularly those with the least resilience.

The pandemic teaches us that even a single hazard can trigger multiple shocks across fragile human, ecological, economic and political systems. Recession, inequality, financial and digital exclusion, informal settlement and lack of empowerment all diminish a population's resilience. Systems we all depend upon such as trade, food, energy, transportation and social safety nets are revealed to be more precarious than we thought. As the UN's Global Assessment Report 2019[3] reported, we are fast approaching the point where we may not be able to mitigate or repair impacts from realised cascading and systemic risks, many of which are driven by our changing climate. The need for ambitious collective action to better understand the nature of risk, to build resilience and achieve sustainable, regenerative development has never been greater.

If these problems are to be addressed, we have to make some fundamental improvements to the way we think about and analyse risk, as well as how we collaborate across domains, scales and sectors. The insurance sector stands ready to share its expertise in supporting sustainable development; understanding risk is after all central to its business. Public-private partnership is essential if we are to improve the flow of risk finance at scale.

At the country level, risk understanding is empowering for risk decision-makers and communities, and must be inclusive of women and vulnerable groups. Risk insight is a pre-requisite for building resilience, yet many barriers prevent decision-makers from developing their own view of risk, even at the least complex levels. Open data and open access risk software offer the means to remove some of these barriers, but the capacity to realise their potential can only be developed through collaborative, cross-sector programmes.

This paper describes the value of understanding risk in the development agenda, but it is also an appeal. It is an appeal to donors and all actors involved in risk reduction and management to take specific steps to accelerate the spread of risk understanding, more clearly identify risk ownership and provide leaders with the tools necessary for the risk conversation with populations. Each step should harness the capabilities of the private sector, for whom risk understanding has become a survival skill.

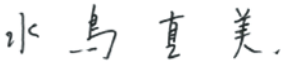
This should lead to a future where more countries:

- Have a strategic risk surveillance function that informs risk reduction and sustainable development strategies.
- Are prioritising ex-ante preventative investments that reduce existing risk and prevent the creation of new risk, including through Nationally Determined Contributions and National Adaptation Plans.
- Can better understand the price of risk to inform development financing and residual risk management strategies, including risk transfer programmes, preparedness and event response.

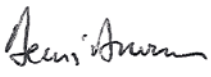
In doing so, risk decision-making will be based on the shared view of risk that is so important in protecting populations and ecosystems. And we will finally be able to achieve the Sustainable Development Goals by growing more resilient societies and economies.

Achim Steiner, Administrator, United Nations Development Programme (UNDP)

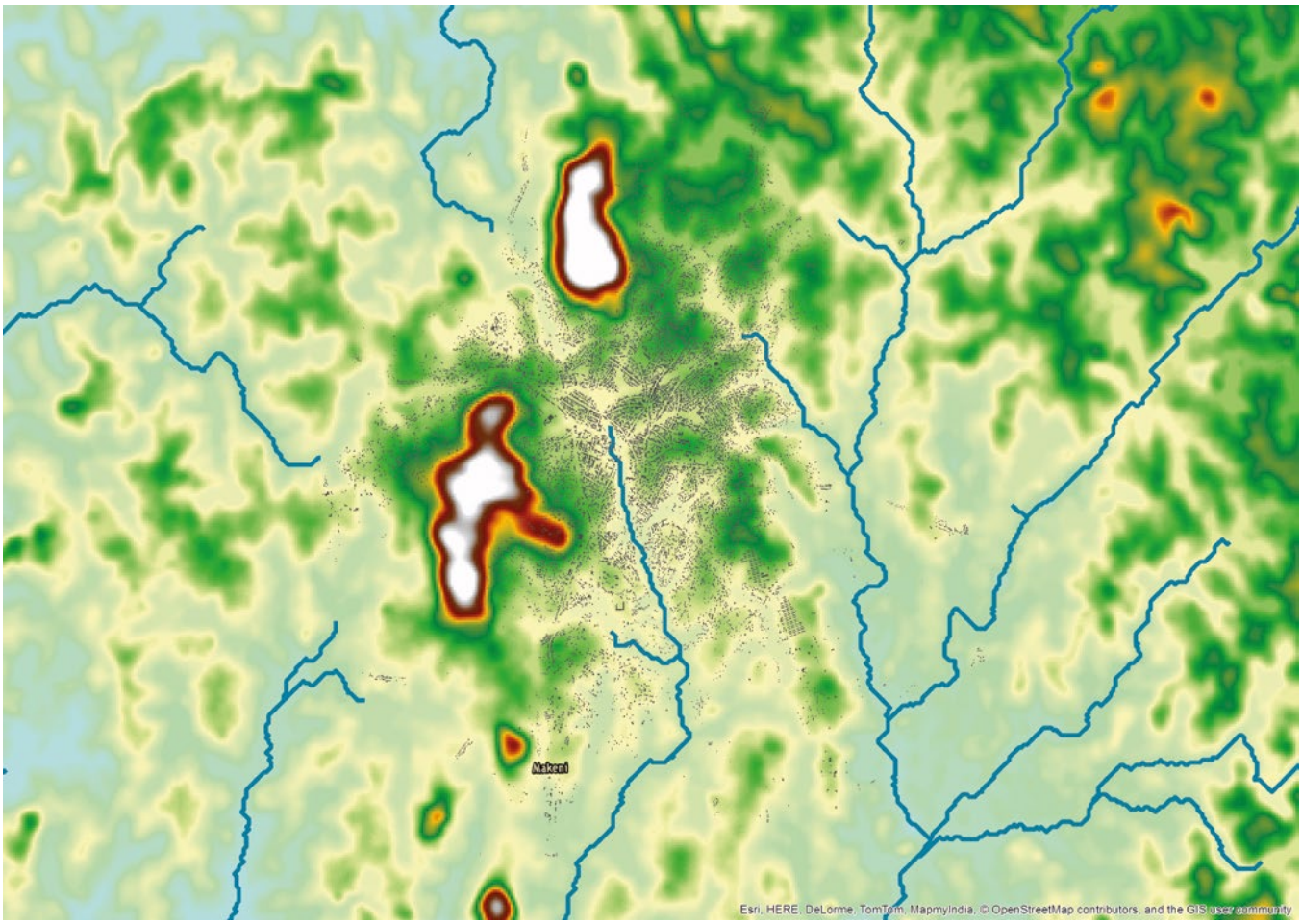
Mami Mizutori, Special Representative of the Secretary-General for Disaster Risk Reduction and Head of the UN Office for Disaster Risk Reduction (UNDRR)



Denis Duverne, Chair, Insurance Development Forum (IDF)



[3] UNDRR (2019). Global Assessment Report on Disaster Risk Reduction (GAR). Geneva, Switzerland. United Nations Office for Disaster Risk Reduction (UNDRR).



An example from Sierra Leone of overlapping data inputs used in a catastrophe flood model: elevation data (filled colours), river channels (blue lines) and building locations (black speckling). Credit: JBA Risk Management Limited / Arup / World Bank

Editor's Note

Lifting the barriers to understanding risk

This paper proposes a hypothesis – a theory of change-illustrated with evidence from country projects and literature. It is not an empirical study built on formal monitoring, evaluation and learning processes, but it is a thesis reinforced wherever possible with evidence of where things have gone right, sometimes wrong, and mostly where there are barriers to the flow of risk understanding that must be removed for the benefit of communities.

Objectives:

- To demonstrate the value of quantitative risk understanding to the achievement of the UN Sustainable Development Goals.
- To describe the benefits and challenges of building capacity for quantitative risk insight at country and city levels.
- To illustrate likely future developments, including the application of risk analytics to wider development challenges.
- To offer practical recommendations to make this both possible and effective through joint application of cross-sector strengths and resources.

Scope:

The Sendai Framework, and more recently the UN's Global Risk Assessment Framework (GRAF), teach us that the principles of risk management apply across all walks of life, all geographies and all timescales. However, in seeking to make specific, practical recommendations, the scope of the paper has been limited within certain boundaries.

The majority of reference points here concern disasters triggered by the occurrence of natural hazards (rather than man-made hazards such as cyber, chemical accident or conflict). Reference will also be made to compound risk including, for example, the impacts of pandemic combined with other sources of risk.

The paper spans many levels of risk management from a strategic, systemic view of risk to the analytics so necessary for execution of operational projects.

While anchored in finance as the means to manage risk, this paper is not only about financial mechanisms. It is about developing the trust and confidence so essential to building social, environmental and financial resilience. Reference is therefore made to potential and realised applications of disaster risk modelling beyond financial metrics.

Executive Summary

Risk insight is the foundation on which risk prevention and resilience programmes are built. The good news is that the key ingredients for widespread risk understanding already exist - the science, the computing, the satellite and ground data, the indigenous knowledge, and most of all innovative multi-disciplinary methodologies of risk understanding developed over the last three decades.

Yet the world has been unable to move away from a continuous cycle of disaster–respond–rebuild–repeat. Systemic flaws are blocking the flow of risk insight to the risk owners on whom vulnerable communities rely for protection.

The challenge for all sectors and governments is to move from managing disasters to managing the risk itself. Risk information is power and yet so much of the resource and science it is built on resides in the global north.

There is plenty of evidence that the private sector can bring substantial help to the problem of scale, in risk understanding, sustainable investment and risk transfer. For example over the last 20 years the re/insurance industry has paid out almost US$1,100 billion of losses (US$55.0 billion per year, on average) following catastrophic events.

While significant protection gaps persist, private sector expertise in analytics and risk management can help to close that gap. Public sector, private companies, academia and civil society must work together to create standards, share research and adopt replicable best practices.

Above all an inclusive, collaborative approach to modelling risk will reinforce local ownership. This will lead to improved policy outcomes and more targeted operational programmes.

Summary points and recommendations from this report:

1. **A strategic approach to risk:** The ambition for any country has to be system level, multi-hazard assessment of risk at national level, drawing all responses to risk into an overall plan.
2. **Empowerment:** Risk owners should be empowered through a partnership approach in developing national capacity in risk analysis. Empowerment must include women's participation at all stages in the process.
3. **Collaboration:** Public-private partnership should be at the heart of the risk assessment process in development.
4. **Open modelling principles:** Donor governments, foundations and climate funds should encourage adoption of a **minimum set of open modelling principles** in development programmes. Cost should not be a barrier to entry to understanding risk.

5. **Development of a scale for assessment of risk analytics capacity.**
   Risk owners should have access to a framework and advice to assess the maturity of their risk function, and select a pathway to developing it according to the risk questions they face. Availability of a 'starter-pack' of global models and data accessible on open platforms would be a major contribution.
6. **People-centric metrics:**
   Data must be disaggregated to enable a gender focus and programmes specific to the vulnerable and/or financially excluded.
7. **Risk education and communication:**
   The risk message doesn't resonate with an authority or community unless it is understood they have clear ownership. Planning in risk capacity building must include provision for sustainable risk education and communication programmes.

KEY CALL TO ACTION

The creation of a public-private partnership to accelerate the use of risk analysis for decision making in vulnerable countries, at scale.

Timing

A number of factors suggest that acting on the recommendations in this report now is more important than ever. These include:

a. The time to galvanise political will is during and after a crisis. Global public and political attention to risk has not been this high for a very long time. There is a genuine will to be proactive and not to be on the back foot again. The time to lock risk awareness and understanding into national processes is **today**.

b. The UNFCCC 26th Conference of the Parties (CoP26) is on the horizon and the link is increasingly being made between climate risk and other risks, including pandemic, both in terms of causal links and the compounding of impacts. The build-up to CoP26 offers the necessary mechanism to bring the proposed change to the attention of donors, foundations and development partners.

1 Why is change necessary?

Why is change necessary?

Key Statistics

1.3 million people killed between 1998-2017 due to climate-related and geophysical events[1]

26 million people are forced into poverty by disasters each year, on average[2]

80%+ of the world's food-insecure people live in countries prone to natural hazards[3]

1.1 From managing crises to managing risk

The brutal impact of catastrophes on vulnerable communities and citizens is well documented. More people are displaced by extreme events than by violence and conflict. Poverty, rapid urbanisation, weak governance, the degradation and decline of ecosystems and the implications of climate change are driving disaster risk around the world.

The Covid-19 emergency has shown us that the combination of our lifestyle and investment choices, interconnected global systems, and risk governance mechanisms are ill-equipped for 21st Century challenges, and cause these risks to impact societies and ecosystems well beyond the ocation, sector and moment of the initial shock.

There are also pronounced differences in impacts on individuals and communities, based on characteristics such as gender, age, ethnicity or socio-economic status.

The virus has invoked an extraordinary worldwide response, and if any positives at all can be salvaged from the crisis, it must be increased recognition of the value of understanding and addressing the drivers of risk creation and propagation. It has highlighted the critical importance of a continuous discussion between risk researchers and policy makers to drive decision-making.

At the same time, disasters and climate risk have not gone away, and their impacts will get worse if we do not act.

Almost regardless of whichever climate change pathway the world achieves in the coming decades, the science supporting the Paris Agreement tells us that in aggregate, disasters arising from natural hazards will either be more severe, or more frequent, or both.[4]

Risk is systemic and complex. Disasters are not just about initial loss of life or property or damage to infrastructure, but also about long term distress to individuals, vulnerable groups, communities and economies, be it through displacement, loss of livelihoods, psychological impacts, physical harm or disruption to basic services.

Moving from reactive to proactive

Distressing images of harm and loss in the media give rise to the necessary and commendable impulse to respond with aid. However, in many instances this reflex would be unnecessary were we to apply already available insights to prevent the creation of new risk or reduce the existing stock of risk, redressing the fundamental vulnerabilities that prevent sustainable development.

The challenge for all sectors and governments is to move from managing disasters to managing the risk itself.

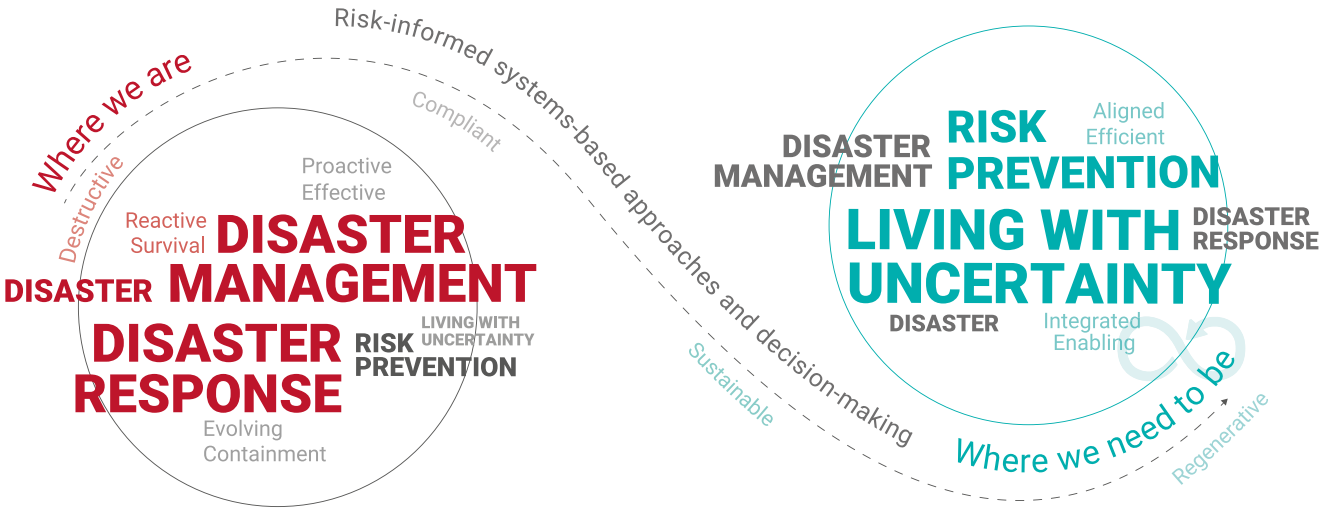
1 Centre for Research on the Epidemiology of Disasters (CRED), UNDRR, 2018

2 Hallegatte, Stephane, Adrien Vogt-Schilb, Mook Bangalore, and Julie Rozenberg. 2017. Unbreakable: Building the Resilience of the Poor in the Face of Natural Disasters. Climate Change and Development Series. Washington, DC: World Bank.

3 World Food Programme pamphlet 'Forecast Based Financing' April 2019

4 https://unfccc.int/sites/default/files/english_paris_agreement.pdf

Figure 1: Innovation curve: From destructive to regenerative approaches.
UNDRR (2019).[5]



1.2 Why is change necessary?

Risk understanding underpins good decisions

Understanding of risk is a prerequisite for regenerative, sustainable development and resilience; it enables the targeted allocation of resources and informs risk aware behaviours.

Priority 1 of the Sendai Framework for Disaster Risk Reduction[6] is 'Understanding Disaster Risk.' In adopting the Sendai Framework, UN member states recognised the need to evolve from a predominantly natural hazard focus, to one that encompasses natural and human-induced hazards and risks (to include technological, biological and environmental hazards and risks.[7]).

Furthermore, countries specifically integrated disaster risk related targets in the Sustainable Development Goals (SDGs) as part of the 2030 Agenda for Sustainable Development.

5 Global Assessment Report on Disaster Risk Reduction (GAR). Geneva, Switzerland. United Nations Office for Disaster Risk Reduction (UNDRR 2019).

6 The Sendai Framework for Disaster Risk Reduction was endorsed by the UN General Assembly following the 2015 Third UN World Conference on Disaster Risk Reduction (WCDRR), and was the first global agreement to be completed in support of the 2030 Global Agenda. (https://www.undrr.org/implementing-sendai-framework/what-sf)

7 Paragraph 15. Sendai Framework for Disaster Risk Reduction 2015-2030

NOAA Flickr
https://www

Creative Cor

In spite of this clear recognition of the challenge, the majority of vulnerable countries struggle to meet national commitments in developing disaster risk reduction strategies, including early warning and risk information[8]. As we will see in Chapter 3, the risk analysis that does take place is too often a snapshot of a single issue, developed remotely and without a strategic context. Decisions affecting the wellbeing of exposed communities are therefore, in many cases, not being made well, or worse are not being made at all.

There are many reasons why this can be the case but a foundational reason is lack of access to, and use of, risk understanding by those who need it most.

> **“Quantifying risk allows for more transparent risk ownership, shared responsibility, and accountability in disaster management – both financially and operationally.[9]”**

[8] See Sendai Framework Monitor ‘Progress of Global Targets’ https://sendaimonitor.undrr.org/

[9] Harris, C and Cardenes, I. (2020) ‘Basis risk in disaster risk financing for humanitarian action: Potential approaches to measuring, monitoring and managing it.’ Centre for Disaster Protection Insight paper, Centre for Disaster Protection, London

The good news is that the key ingredients for widespread risk understanding already exist – the science, the computing, the satellite and ground data, the indigenous knowledge, and, most of all, innovative multi-disciplinary methodologies of risk understanding developed over the last three decades. Yet there are systemic flaws blocking the flow of risk insight to the risk owners on whom vulnerable communities rely for protection.

Some observed reasons include:

- Technical and behavioural barriers to exchange of knowledge and data between sectors (public, private, civil society and academia.)
- Economic and legal barriers that keep risk science locked up in the global north behind proprietary walls, or lack of incentives to translate and share knowledge across sectors.
- Lack of integration of contextual knowledge, and in particular rich local research and data.
- A critical lack of user-friendly open platforms for the sharing and examination of different views of risk, or for building an independent local view.
- A failure to link risk analysis with the decisions being made. This may often relate to opacity about who actually owns the risk and is therefore making the decision.
- A perception of complexity - sometimes justifiable - which has to be resolved by matching the right tools to the context of both the decision being made and who is making it.

The supply of risk analytics is inefficient and ineffective. At the project (rather than strategic) level there are multiple examples of duplication and inefficiency as competing agencies work in a selection of countries that offer the most conducive conditions for partnership.

A single hazard, single transaction approach is prevalent, emphasising short term consequences in the absence of a strategic risk management policy. A lot of money is being spent, but not always in effective ways that leave a country or city better able to manage its own risk across departments for the long term.

In short, risk owners such as elected representatives and public servants rarely have the opportunity to determine and develop their own view of risk, and are instead rationed somewhat opaque output from often expensive risk models developed in the global north.

> **"Issues may also begin to emerge with multiple risk financing systems for each hazard in a single country, generating multiple depictions of risk from multiple models. This may result in uncoordinated, unphased responses, with double coverage and gaps. In a humanitarian situation, this can also cause unhelpful political and inter-agency issues. We need to find a way to harmonise at a national level – a DRF data framework that all can coordinate around within their own DRF strategies."**
>
> Start Network, RCRC Climate Centre, IFRC[10]

[10] Start Network, RCRC Climate Centre, IFRC, 'Impact before Instruments' Paper 2, 'People Centred and Transparent Risk Analytics,' November 2019

Three major themes stand out as we look at these challenges:

1. **The changing nature of risk.** Everything is connected. It is impossible to understand the potential impact of loss of infrastructure, for example, without looking at compound effects such as loss of household income or the disproportionate effects on women, girls or the less mobile. Two key drivers in this change are worth highlighting:
   a. **Human behaviour.** The choices we make are constantly creating new risks. Increased urbanisation concentrates vulnerability, yet cities will grow from housing 54% of the world's population now to 66% by 2050.[11] Hyper-connected infrastructure, transport and trade amplify shocks which reverberate across multiple systems. Discriminatory social norms prevent women from achieving parity of economic participation or equal ownership of assets, limiting their resilience to crises.

      Weak governance allows informal settlements on flood plains or on the slopes of volcanoes; whereas risk-informed governance reduces fear, builds confidence and trust and creates the conditions for investment in resilience. A systemic, policy driven view[12] can ensure that operational projects and transactions are designed within a risk-aware context.

   b. **Climate change.** While global efforts are made to reduce CO_2 emissions, the world is rapidly realising that any warming pathway will involve unwelcome changes in frequency and/or severity of extreme hydrometeorological events, whether rapid onset (flood, cyclone, wildfire) or slow (seasonal drought, decadal sea level rise). These changes must not only be understood but the knowledge must be shared and acted on.

2. **Empowerment:** At its core, development is about empowerment of communities to drive their own progress; empowerment of nations and municipalities in building their resilience, and empowerment of citizens, particularly women and girls, and vulnerable groups.

   Risk information is power and yet so much of the resource and science it is built on resides in the global north.

   In recent years, development and humanitarian sectors have stressed the absolute necessity of a whole risk management approach, moving away from the mode where disasters appear to take communities and global agencies by surprise, and where the ex-post response is usually late, inefficient, unpredictable and rarely meets the human need.

The Centre for Disaster Protection[13] describes this as 'Moving from reaction to readiness', building on previous research and experience of working on disaster risk finance in more than 40 countries[14], and the World Food Programme describes it as 'Moving from crisis response to risk management.'[15]

This change has a moral dimension, as well as making practical sense; if development is about empowerment, then clearly it is right to move from aid dependency to sustainable local capacity capable of responding to the differentiated needs of communities and genders. However it is hard for a nation to achieve that if it continues to rely on remote providers for its risk information, on terms dictated by them.

While it is practical to categorise risk (spatially, temporally, or by discipline) to delegate responsibility to organisations, governments and their agencies in all sectors will only be truly empowered if they implement integrated, multi-sectoral processes of risk assessment and decision-making.

---

11 UN Habitat report: Urbanisation and Development, Emerging Futures 2016

12 For a useful primer on approaches to assessment of risk at a systemic level, see Chapter 2 of the Global Assessment Report on Disaster Risk Reduction (GAR). Geneva, Switzerland. United Nations Office for Disaster Risk Reduction UNDRR (2019). Additionally the Global Risk Assessment Framework (GRAF) 'Fostering Systems Thinking' working group will publish a peer reviewed 'Systemic Risks' paper by the end of 2020.

13 https://www.disasterprotection.org/

14 Clarke, D. J., & Dercon, S. (2016) Dull Disasters? How planning ahead will make a difference, New York, Oxford University Press

15 'Climate Risk Financing' World Food Programme Climate and Disaster Risk Reductions Unit, November 2019

3. **The problem of scale:** The scale of the task cannot be overestimated; the following are just some indicators of the scale of risk to be addressed:

   a. There are 43 countries in the Climate Vulnerable Forum/V20 grouping of low-emitting but highly vulnerable countries. The overlap with the OECD Development Assistance Committee's[16] list of Low Income or Lower-Middle Income countries is a reminder of the consequences of disasters on economies and the difficulty of growth without prior investment in resilience. A prioritised list of developing economies vulnerable to disaster could easily exceed 70.

   b. A recent expert working group sponsored by the International Science Council and UNDRR classified more than 300 reportable hazards, a sizable number of them being hydrological, meteorological or geophysical, in addition to biological, technological and environmental hazards.[17]

   c. We also know that in some vulnerable countries a 'protection gap' of 90% of potential economic loss after disasters has to be covered by taxpayers or donors because the risk has not been prevented through risk-informed investment in resilience, or because the residual risk has not been transferred to those better equipped to bear it. Worse still the burden may manifest itself through the hardship of the most vulnerable people.

      Many of the countries with the lowest levels of financial protection are among the most exposed to risks such as climate change. For example Bangladesh, India, Vietnam, Philippines, Indonesia, Egypt and Nigeria each have an insurance penetration rate of less than 1%, placing the task of recovery on governments with very little marginal resource.[18]

   d. Neither should we think of limiting the scale of the problem to the value of assets at risk. As the World Bank's 'Unbreakable' report[19] described, poor people suffer disproportionately from disasters; the loss of assets may not feature as particularly significant in monetary terms but the loss of wellbeing is grave. Added to this some of the countries with the least resources also have the highest levels of gender inequality, compounding the risk for the most vulnerable.[20]

Having looked at these indicators of the scale of the challenge, it is only a short step to appreciate that we have to combine the resources and expertise of all sectors – public, private and civil society.

> **"The world has been unable to move away from a vicious cycle of disaster–respond–rebuild–repeat. Financing has historically focused on picking up the pieces post-disaster. However, this "band-aid" approach is not appropriate. It continues to undermine progress towards sustainable development. Risk generated by the interaction of complex human and natural systems, amplified by changes in climate, is reversing efforts to achieve the goals of the 2030 Agenda for Sustainable Development (2030 Agenda). The very survival of humans on the planet is at stake."**
>
> Global Assessment Report on Disaster Risk Reduction 2019 – GAR Distilled. United Nations Office for Disaster Risk Reduction (UNDRR 2019).

16 Organisation for Economic Cooperation and Development Development Assistance Committee

17 UNDRR/ISC Sendai Hazard Definition and Classification Review Technical Report: https://council.science/wp-content/uploads/2020/06/UNDRR_Hazard-Report_DIGITAL.pdf

18 Lloyd's 'A World at Risk, Closing the Insurance Gap'

19 Hallegatte, Stephane, Adrien Vogt-Schilb, Mook Bangalore, and Julie Rozenberg. 2017. Unbreakable: Building the Resilience of the Poor in the Face of Natural Disasters. Climate Change and Development Series. Washington, DC: World Bank.

20 Women, Business and the Law, 2020. World Bank, Washington DC. https://wbl.worldbank.org/

Alternative Finance and the 2030 Agenda:

From across the development community there is absolutely no doubt that additional and enhanced financing is required to deliver on the massive ambition and need of the 2030 Agenda, an agenda that increasingly demands a much better investment in the analysis of risk to deliver:

- **The Scale of the Need:** When the SDGs were agreed, UNCTAD[21] argued that developing countries face a US$2.5 trillion annual investment gap in key sustainability sectors, each and every year until 2030. Its 2020 report suggests that COVID-19 will cause investment to 'fall sharply from 2019 levels of US$1.5 trillion, dropping well below the trough reached during the global financial crisis, and undoing the already lacklustre growth in international investment over the last decade.'
- **Shifting from Aid:** With only US$150 billion a year of official development assistance, much of it tied up in very specific and somewhat limited development activities, *"there is a sense that we need to move from grant-making toward employing a wider range of financial tools and scaling up investment in poor countries under the Sustainable Development Goals (SDGs) financing frameworks - and that private finance has a part to play."*[22]

At the same time there is plenty of evidence that the private sector can bring very significant help to the problem of scale, both in sustainable investment and in risk transfer. For example over the last 20 years the re/insurance industry has paid out almost US$1,100 billion of losses (US$55.0 billion per year, on average) for catastrophic events.

Most insured losses have occurred in developed economies with mature insurance markets, however it is to the finance sector's advantage to diversify and grow new markets and it is steadily building a record - for example, a total payout of US$2 billion in the 2017 Mexico earthquake[23] and at least US$10 billion in the 2011 Thailand floods.[24]

21 United Nationas Conference on Trade and Development (UNCTAD, World Investment Reports, 2014 and 2020)

22 'New Financing Partnership for Humanitarian Impact,' Overseas Development Institute (ODI), January 2019.

23 https://www.munichre.com/topics-online/en/climate-change-and-natural-disasters/natural-disasters/earthquakes/mexico-city-tragic-anniversary-2017.html

24 Munich Re Topics Geo 2011 https://www.preventionweb.net/files/25635_30207225en1.pdf

1.3 The scope of development impact

Every one of the Sustainable Development Goals (SDGs) relate to risk in one way or another. SDG 17 (Partnership for the Goals) provides the core of the solution, as the effective management of risk must be built on a foundation of partnerships across sectors and geographies. In considering the application of risk analytics in development, five SDG targets in particular have been considered in this paper as drivers for change:

- SDG 1.5 Build the resilience of the poor and those in vulnerable situations…
- SDG 2.4 Ensure sustainable food production […] strengthen adaptation to climate change, extreme weather…
- SDG 5 Achieve gender equality and empower all women and girls.
- SDG 11.5 Reduce the number of deaths and losses caused by disasters.
- SDG 13.1 Strengthen resilience and adaptive capacity to climate hazards and natural disasters.

This paper considers the application of risk analytics under three categories of response to risk:

- **Risk prevention and mitigation:** for example through investment in climate adaptation measures such as strengthened infrastructure, or risk-aware planning policy.
- **Risk transfer:** the sharing or pooling of the residual risk remaining after risk prevention measures have been taken. The risk is priced and then shared with others better equipped to bear it, using financial means, usually involving the payment of a premium.
- **Anticipatory action:** mechanisms which trigger funding for pre-defined early actions when risk analysis and forecasts predict that an imminent event will have severe impacts. The distinguishing characteristic is that the planned action itself takes place before the occurrence of the event. The aim is to mitigate and reduce impact, and prepare for effective response, rather than depend on emergency response[25].

Perhaps most importantly, development and ownership of data on risks to citizens' lives and livelihoods, and individual and collective finances can empower governments and citizens as owners of risk and enable governments to take evidence-based decisions on actions to respond, prepare for, and reduce the risk to their communities and population.

> **If development and economic growth are not risk informed, they are not sustainable and can undermine efforts to build resilience. The economic losses which often ensue from the creation of new risk or exacerbation of existing levels of risk can have a significant human cost.**
>
> 'Economic losses, poverty and disasters 1998-2017' UN Office for Disaster Risk Reduction (UNDRR), Centre for Research on the Epidemiology of Disasters.

[25] For a further definition, see 'Anticipatory crisis financing and action: Concepts, initiatives and evidence' Weingartner, L and Wilkinson E, ODI 2019, commissioned by the Centre for Disaster Protection.

1.4 Risks for whom?

Understanding risk requires us to consider people's wellbeing as well as their assets. This goes beyond calculating narrow interpretations of economic loss focused on physical damage to buildings and infrastructure. Risk to people is about the impact on their lives, health and livelihoods of individuals, their families and households and the wider communities in which they reside. It is also about the ecosystems on which they depend. No single sector yet has risk expertise that spans the whole spectrum of damage, loss and harm, which in itself makes an argument for a combined approach.

Assisting the most vulnerable. Although vulnerability is not a result of poverty alone, disasters magnify existing social inequalities and further disadvantage those who are already vulnerable[26]. The Intergovernmental Panel on Climate Change (IPCC) has high confidence that *'differences in vulnerability and exposure arise from non-climatic factors and from multi-dimensional inequalities often produced by uneven development processes'*.[27] Some people are more exposed, for example given their livelihoods or geographic location, such as those relying on subsistence aquaculture value chains, living in small island states or coastal areas. Moreover, some people are more likely to be adversely affected due to factors such as their gender, class, ethnicity, age or (dis)ability.[28] At a household level, low income households and in particular those headed by women can be more vulnerable.

The need to understand different groups' vulnerabilities is not limited to low income countries – after Hurricane Katrina in 2005, African American women were among the worst affected by flooding in Louisiana in the USA. In New Orleans, there was much higher poverty among the African American population and more than half the poor families in the city were headed by single mothers.[29]

Risk to people also involves understanding capacity to recover. Many individuals and their families may have limited access to mechanisms such as insurance, borrowing, or remittances and savings on which to draw to support their recovery process after a disaster. The impacts of a disaster may cause detrimental short-term actions – for example selling assets, removing children from education – which cause harm to longer-term income, food-production, or life chances.

What do we mean by risk analytics?

We all make judgements on multiple risks, often simultaneously, balancing trade-offs, in our daily work and personal lives. Using the most complex models of all – our minds – we make frequent decisions based on our personal experience, observation of the world around us and informed views about the shape of the world to come.

The practice of risk analytics referred to in this paper is no different. The term covers the combining and sharing of knowledge, science and data to understand the most likely versions of the future. This paper concentrates on methods that quantify risk in order to create greater certainty, or to put it another way, less fear. It can range from the simplest diagram of a possible event, perhaps informed by local story-telling, to computer-intensive simulations using big data sets derived from global climate or geophysical models, high resolution digital mapping and vulnerability science.

A key point is to use the right tools for the decision being made, and nothing more, a subject explored further in Chapter 3.

None of this detracts from the value of judgement, informed by context and relational information – the qualitative view. However, risk research and analytics provides the critical function of sensing and interrogating an exceptionally complex environment. In the context of constantly changing threats and vulnerabilities, analytics can build the trust and confidence required to unlock the relationships and money needed to build resilience, and enable sustained development.

---

26 Global Assessment Report on Disaster Risk Reduction (GAR). Geneva, Switzerland. United Nations Office for Disaster Risk Reduction (UNDRR 2019).

27 IPCC, 2018. See: https://www.ipcc.ch/site/assets/uploads/2018/02/ar5_wgII_spm_en.pdf

28 IPCC, 2018. See: https://www.ipcc.ch/site/assets/uploads/2018/02/ar5_wgII_spm_en.pdf

29 https://www.bbc.co.uk/news/science-environment-43294221

1.5 Who owns the risk?

For global actors it is common to refer to 'the risk owner' almost as an abstract concept, simplifying a very complex reality. At top-level we might think of those who are expected to manage risks for the safety and wellbeing of a population and its environment by virtue of public appointment. In reality, responsibility for risk ownership varies widely between countries, and within a country ownership may be ill-defined, complicated or – for some risks – non-existent.

Governments are ultimately the insurers of last resort. This does not only mean picking up the tail of liabilities not covered by conventional risk finance, but also wider socio-economic and even psychological risks resulting from extreme events. Left under-funded, these can create inter-generational problems for governments for many years beyond the physical rebuild.

A number of countries have well developed strategic risk plans which include risk reduction, risk transfer, anticipatory action and response measures, with ownership assigned to each. For example Japan, well known for its advanced thinking about risk in the face of natural hazards, has clearly appointed responsibility at national, prefecture and municipal levels.[30] Mexico[31] and Rwanda[32] offer further examples of integrated thinking, where investment in risk prevention is the starting point.

However for many countries and the agencies that assist them the budget is still weighted towards response and it is harder to identify ownership of an overall national risk assessment and surveillance function, or a department that is primarily concerned with national risk prevention. The responsibility for a national strategy may fall to a Ministry of Finance, which owns the relevant budgets but may not have developed the risk assessment framework to match, within which ownership can be delegated. Equally, asset-owning ministries or ministries charged with social welfare may feel that they should be conducting their own analysis, which can lead to multiple, compartmentalised views of risk.

It is unhelpful to think that the risk analysis should follow once a risk owner has been identified. Risk analysis should be the start point – it helps identify and quantify the areas of gravest concern to a government and people. Risk owners can then be identified for those priority risks that can be reasonably predicted and modelled, encouraging an ex-ante policy that starts with risk prevention.

1.6 About the money

Most development decisions involve money, and in any sector it is inescapable that to finance risk you first have to quantify it. Finance provides the mechanism to execute change, whether the impacts risked by communities are financial, physical, environmental or social.

It is also the case that modelling risk using financial metrics leads to a particularly disciplined, albeit simplified way of thinking about risk and uncertainty. If adapted in ways suggested in this paper, it can become an accessible, strategic resource to national, provincial and municipal governments and cities.

Following this logic, many of the examples in this paper relate to research and metrics that can unlock and guide essential flows of finance, to fuel collaboration across actors, sectors, disciplines and across scales.

30 'Developing role-specific disaster management plans by a three-tiered administration', Japan Medical Association Journal 2016 July; 59 (1):pp 27-30

31 https://openknowledge.worldbank.org/handle/10986/26881

32 https://reliefweb.int/report/rwanda/national-disaster-risk-management-plan-september-2013

The value of private sector experience in risk understanding

At top level the private sector brings confidence. For example a wide variety of insurance and insurance-like mechanisms give the knowledge that investment – public or private – is recoverable if disaster occurs. This in turn reduces the cost of risk to governments, enables planning, creates investment and stimulates consumption.

However access to capital is not the only benefit of private sector engagement in the development agenda; the risk expertise it brings is just as valuable. A key point here is that for the private sector risk understanding is existential – unlike a public sector agency, a repeated failure to detect new risks or to understand their potential impacts will cause a company to liquidate. Disaster risk analytics and risk management more broadly has therefore become a core capability deeply rooted throughout global finance organisations, particularly in re/insurance. A system of competing risk modelling companies has grown to support this function.

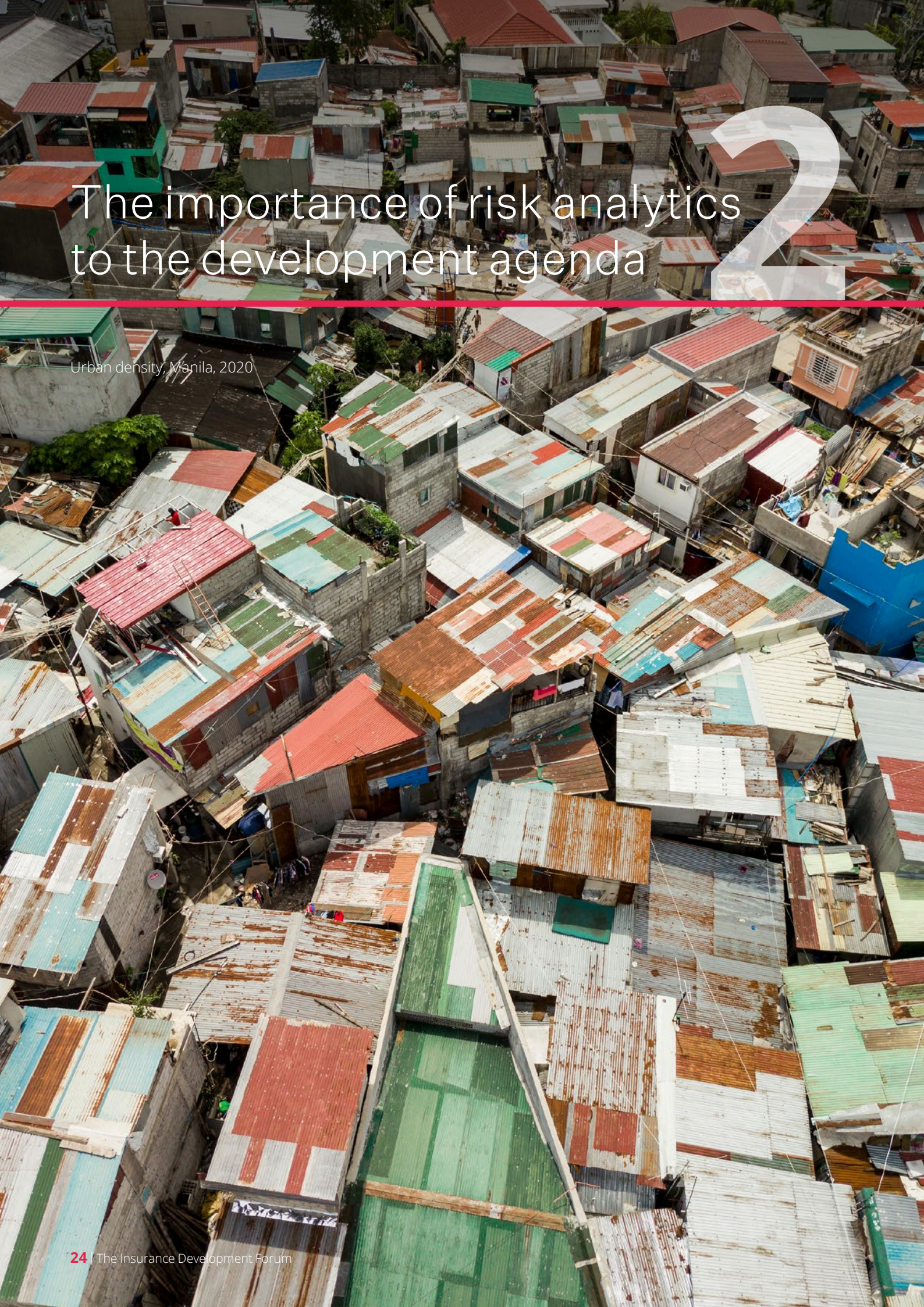
This experience can and should be harnessed by governments and their agencies seeking to manage risk. Some examples of where the private sector can help include:

- Strategic risk assessment: Global companies survive by building complex portfolios of diversified risk. This is not unlike the challenge faced by many governments wishing to develop stable financing frameworks. The private sector may not be expert in all areas of governments' risk burden, but can bring the experience of strategic management of multiple exposures and risks.
- Operational application: Perhaps the most valuable expertise of all is the industry's skill in taking academic research in multiple disciplines, as well as scientific data and observations, and applying it to make real world decisions that have to be right.
- Understanding of uncertainty: Industry has learned to spot where input data is unreliable, or which levels of uncertainty are acceptable. Having a flood map or a full probabilistic model is no use in decision-making unless the context and provenance of the analysis is also understood. Public-private partnership mechanisms offer a means to harness private sector experience and intuition.
- The language of risk: If governments and regulators wish to engage with international markets for domestic market development, they should be able to do so on an equal footing. The global private sector can help by:
  - Capacity building in partnership so that a risk-owning government is able to critique the risk judgments being made, or better still develop them autonomously.
  - Working in partnership with domestic companies to build capacity in support of national development objectives.
- Risk analytics resources: The private sector is increasingly making its experience and resources available on an open source basis, either directly or through academic investments which eventually become start-ups.

Chapters 2 and 3 expand on a number of these themes.

The importance of risk analytics to the development agenda

2



Urban density, Manila, 2020

The importance of risk analytics to the development agenda

> **Risk literacy is the basic knowledge required to deal with a modern technological society. The breakneck speed of technological innovation will make risk literacy as indispensable in the twenty-first century as reading and writing were in previous centuries. Without it, you jeopardise your health and money, or may be manipulated into unrealistic fears and hopes.**
>
> Gerd Gigerenzer, Risk Savvy: How to Make Good Decisions

2.1 Introduction to the practice of disaster risk assessment

Decision-making in disaster risk reduction (DRR) should be risk-informed, involving all sectors in a multi-hazard approach.[1]

Risk reduction strategies may be *structural* – for example investing in resilient building stock and infrastructure, or flood protection systems; *social* – warning and evacuation, social protection, anticipatory action; or *financial* – risk transfer and insurance. Risk analytics supports these investments by identifying communities, populations and assets exposed to one or more hazards, the potential for them to suffer negative impacts and the possible magnitude of those impacts.

Qualitative risk understanding may combine indigenous experience and historical records to understand the past occurrence and impacts of hazards and describe the risk. Quantitative approaches involve replicating historical events and simulating potential future events in a model to map the distribution of hazard intensity based on an understanding of physical processes.

Using those hazard maps, exposure to that hazard can be analysed and when the vulnerability of exposed assets and people are considered, we can estimate the likelihood and severity of impact from thousands of possible events. This is the premise of disaster risk models (see box).

Risk models are increasingly applied to inform the DRR activities of development and humanitarian organisations, including in implementing insurance and contingent financing, social protection schemes and anticipatory action/financing.

These analytics tools have important applications in urban development, land use planning, design of resilient infrastructure, forecasting of impacts for anticipatory action, early warning systems and evacuation planning, public health contingency planning, business continuity, environmental planning and more. Risk models have the partially-realised potential to help us better understand environmental impacts and disparities in risk along gender and socio-economic lines.

Modelling for financial metrics brings a particularly disciplined way of thinking about risk and an appreciation of uncertainty. Using models, we can provide confidence limits or upper and lower bounds on risk estimates by applying contrasting optimistic or pessimistic assumptions or by simulating multiple scenarios. By producing a range of estimates and providing transparent advice on how the range was developed, models assist decision-makers in evidence-based management of their risk. As one recent report suggested:

"Many countries are developing risk models to provide more insights into disaster risk, but financial loss models are needed to better understand uncertainty of outcomes and to more accurately determine the cost-benefit of climate adaptation measures and disaster risk financing options."[2]

[1] UNDRR Sendai Framework for Disaster Risk Reduction 2015-2030, Guiding Principle 19g. https://www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030

[2] 'Analysing stakeholder needs for climate and disaster risk data', InsuResilience Global Partnership, February 2020.

Disaster risk models

Disaster risk models are a marvel of cross-disciplinary cooperation, bringing together models and data from multiple research sources to represent the processes and impacts of disasters (Figure 2.1).

The better we can understand these processes and impacts, the more able we are to provide cost-effective mitigation to reduce human suffering and economic damage.

A **hazard** model represents the estimated distribution and intensity of events (for example flood, earthquake or wind) across a long time period, based on simulation of physical processes or statistical analysis of event severity and frequency. This provides a large set of plausible events, including severe events that have not been recorded in the recent past – a crucial advantage of using models over short and incomplete historical records/experience.

The **exposure** component of the risk calculation (the location and characteristics of structures, infrastructure and people) is drawn from a wide range of sources from local records to remote sensing. The models then apply **vulnerability** relationships – the propensity of an asset to suffer damage – to estimate the number of assets or population affected, level of damage, disruption or downtime, financial loss, number of displaced people, casualties and fatalities.

Deterministic (scenario) models estimate the impact for one or more scenario events. Probabilistic models estimate impact per simulated event or year[3] and at various recurrence intervals[4].

Disaster risk models communicate uncertainty in risk estimates: sources of uncertainty may include imperfect input data, veracity of assumptions built into the models and the chaotic nature of natural processes.

> **Risk information is the basis for planning and decision making in many areas of disaster risk management, including resilient infrastructure, pre-disaster planning and purchasing insurance**
>
> 'Innovative Finance for Resilient Infrastructure', Lloyd's, 2018

2.2 Risk analytics for risk prevention and mitigation

To effectively prevent, reduce, or mitigate risk and adapt to future climate conditions the risk context must first be understood.

Risk analytics is one of the first steps of developing national Disaster Risk Reduction (DRR)[5] and Climate Change Adaptation (CCA) plans, as it is required to build a strong understanding and evidence of the risk context. National and local investment strategies require quantification of the current baseline and future risk, the latter being driven by changes in socio-economic conditions and changes to climate.

> **You can't wish away systemic risks, it's much cheaper to deal with them up front.**
>
> Mark Carney, Finance Advisor to CoP26, UNFCCC Race to Zero launch, 5 June 2020.

Hazard and risk mapping should underpin sustainable urban development and land-use planning, and the planning of hazardous industrial activities[6,7]. By delineating hazard zones, development plans can consider the risk in different locations; and limit unplanned development in hazardous areas of available land.

Risk analysis informs mitigation strategies by estimating benefits such as economic loss prevented or lives saved[8] against the costs of for example, construction of flood protection, strengthening building codes, or applying nature based solutions.

---

3 also known as Annual Average Loss (AAL) or Annual Expected Damage (AED)

4 also referred to as 'return period loss'; which communicates the average expected interval between experiencing losses of a certain amount, or alternatively the annual probability of exceeding a certain loss amount (or other impact).

5 UNDRR, 2019

6 UNECE, 2017

7 See for example the EU Flood Directive; European Commission 2007

8 Rajput et al., 2018

2.2.1 Assisting disaster response and recovery

Risk analytics can also quantify impacts from a recent or current disaster – not only providing evidence for response and recovery, but also guidance for future risk prevention.

Using an existing risk model, the event that just occurred can be reconstructed and the impact on population and assets estimated[9,10].

This can augment information being collected 'on the ground' – such as in Post Disaster Needs Assessments (PDNA) or Disaster and Loss Assessments (DaLA)[11] – which may hold greater detail but often cannot represent the full area affected. Such assessments can guide government actions and spending to focus on the most affected sections of society, locations, and sectors objectively.

Rapid impact estimates can expedite recovery and reconstruction, which is vital because 'faster recovery minimises the disaster's impact on economic growth and poverty reduction'[12], with the ability to communicate impacts on different socioeconomic groups and economic sectors.

The post-disaster recovery phase offers opportunities not only to restore livelihoods and the built environment to their pre-disaster state, but also to increase their resilience through reconstruction – to *build back better*[13]. An event may have fundamentally altered the environment and the risk of future risks, for example by changing ground elevations1[4]. Risk analytics can quantify this adjusted risk and steer robust reconstruction (including asset-level actions and urban-scale or national planning[15]) and investment towards the changed environment and the future climate.

2.2.2 Operational instruments for investment in climate adaptation

Key Statistics

More than 300 million people living in low-lying areas will be at risk of annual coastal flooding by the end of the century[16].

Hazards are constantly evolving due to the changing climate. The signature of the Paris Agreement and the publication of the IPCC special report on the impact of 1.5°C warming exhorted the public and private sectors to take actions to better understand and limit their exposure to climate-related risks.

Knowledge gaps, including the climate risks faced by businesses, are a major barrier to bringing increased private sector investment into accelerating climate action[17]. Climate risk analytics can address those gaps by quantifying the uncertainty of impacts at a local level, identifying adaptation opportunities, and developing business continuity plans for diverse institution types encompassing MFIs, business associations and cooperatives.

In the last five years the investment community has woken up to the financial materiality of climate risk. Initiatives such as the G20 Green Finance Study Group and the private sector driven Task-force for Climate-related Financial Disclosures (TCFD) have set expectations and standards for disclosure of climate-related risk.

These new frameworks are leading companies to seek greater understanding of the increasing risk to their assets caused by climate change. Despite this the adoption of climate risk analytics within investment practices has, to date, been limited.

Two sets of challenges should be addressed to increase adoption: misperceptions regarding the ability of current climate risk analytics to inform investment decision-making (Figure 2.2), and core analytical considerations and the nature of investment decision-making (Figure 2.3).

---

9 For example, World Bank's Global Rapid Post-disaster Damage Estimation (GRADE) approach estimates property damage, sector-level damage, GDP impacts and casualties within 2 weeks after an event; Gunasekera et al, 2018

10 Michel, 2017

11 World Bank, 2017.

12 Hallegatte and Vogt-Schilb, 2017

13 https://www.undrr.org/terminology/build-back-better

14 e.g. Hughes et al, 2015

15 including appropriate land-use zoning for reconstructed or new development, strengthening building codes or ensuring reconstructed buildings adhere to regulations that improve resilience of those assets.

16 Kulp et al., 2019

17 CIF (2016)

Figure 2.1: Perceptions holding up the adoption of climate risk analytics in investment

Purpose	Metrics
The perception is that catastrophe and climate risk model development has only been tailored to needs of the re/insurance industry. Models are seen as defensive in nature, being designed for loss minimisation rather than investment opportunity. Models are complex, specialist tools. They are not flexible or accessible enough for wider finance use.	Models have been tailored for re/insurance use and reflect the exposure of a given asset at a specific moment. The language of (for example) peril, hazard, average losses does not fit with investment terminology. The value of metrics such as Annual Average Loss (AAL), Probable Maximum Loss (PML) or the Exceedance Probability Curve (EP curve) is not yet realised in calculating asset valuations.

Figure 2.2: Uncertainties in climate risk modelling for investment

Acute physical climate risks	Although sudden onset extreme events have been extensively modelled, history is not a reliable guide to the future. How will frequency and severity change?
Chronic physical climate risks	The effect of slow, progressive changes such as temperature rise, sea level rise or land degradation are more directly related to the climate signal.
Systemic risks	Relating physical climate risk to impact on regional and local GDP growth, inflation and interest rates remains difficult.
Micro exposures	Given the complexity of supply chain exposures, volatility of input costs, changing demand and distribution networks, how will physical climate risks affect earnings from a specific company, security or asset?
Time horizons	Can climate risk analytics in its current form really help with asset valuation beyond 7-10 years from now?

Climate conditioning of risk models

At COP17 in 2015, participating countries agreed to develop National Adaptation Plans (NAPs), aiming to reduce vulnerability to the impacts of climate change by building adaptive capacity and resilience, through integration of climate change adaptation into new and existing policies, programmes and activities such as development planning. Such planning must be informed by an assessment of future climate conditions.

A branch of climate research dedicated to detecting and attributing specific changes in hazard due to climate change is emerging. Using computer-simulations – general circulation models (GCMs) – to predict future changes in our climate system, these models estimate climate conditions under different greenhouse gas emission scenarios, encompassing a range of future socio-economic development and mitigation actions. Under the IPCC assessment these models are compared and their uncertainties quantified.

They are subsequently used in risk models to modify the hazard event simulations. Known as **'climate conditioning'**, some risk models already include climate change scenarios to understand the impact the change in hazard has on losses. This is becoming more commonplace in risk analysis in the development sector but there remain practical challenges to funding and running multiple projections in some projects.

The usefulness of building climate science into risk modelling was described in a landmark report from the Geneva Association in 2018. (footnote) The report identified how the conditioning of models for different climate warming scenarios could build greater resilience through stress testing, and could pave the way for new climate services. It would also be a fundamental tool in investment management, giving insight into impacts on assets and operations, and pricing in risk throughout an investment's lifecycle.[18]

2.3 Risk analytics for risk transfer

Risk transfer programmes enable a risk to be passed from one party to another better equipped to bear a loss, particularly from low frequency, high impact disasters.

The importance of risk transfer to climate resilient investment and the reduction of poverty is recognised by the InsuResilience Global Partnership Vision 2025.[19]

Goals for 2025 include:

- 500 million poor and vulnerable people protected against disaster and climate shocks by pre-arranged risk finance and insurance mechanisms;
- US$ 5 billion of risk capital offered by the insurance industry;
- 80 V20 and other vulnerable countries with comprehensive disaster risk finance strategies in place.

Additionally, climate risk transfer is a priority area for countries implementing the adaptation goal of the Paris Agreement at national level[20]: 38 countries mention climate risk insurance approaches in their Nationally Determined Contributions (NDCs) and another four countries include it in their National Adaptation Plans (NAPs). Together these countries represent more than 4 billion people, including approximately half of the world's poorest people.

There are three main models of climate risk insurance at the macro-, meso-, and micro-level in addition to alternative capital, summarised in Figure 2.3.

Quantitative risk analytics are a fundamental tool in closing the protection gap. With sovereign disaster risk financing and insurance clearly a key contributor to achieving greater resilience in low and lower-middle income countries, risk models provide a number of key inputs to determining the most appropriate solutions:

- What is the risk in terms of estimated loss severity and frequency to an asset or portfolio of assets? (understand risk and identify risk financing needs).
- What type of product is most suitable (parametric product, parametric index, modelled loss basis, or indemnity basis (see Figure 2.5 for definitions)) and in what wider framework of risk reduction tools can they contribute?
- What is an appropriate and cost-effective structure of risk transfer, including what risks are appropriate to cover, how much of that risk should be retained by the individual or government and how much should be transferred?
- What is a suitable premium for covering the risk?
- In the case of parametric products, how can we minimise basis risk?
- How can a product be most effective in addressing the risk to target sections of a population?

[18] The Geneva Association (2018a). Managing Physical Climate Risk: Leveraging Innovations in Catastrophe Risk Modelling. Authors: Golnaraghi, M. et. al. https://www.genevaassociation.org/research-topics/climate-change-and-emerging-environmental-topics/managing-physical-climate-risk

[19] https://www.insuresilience.org/wp-content/uploads/2019/09/InsuResilience-Global-Partnership_Vision-2025-with-Workplan1.pdf

[20] MCII, 2017

Figure 2.3: Models of climate risk insurance

Inclusive (micro) insurance A household, farmer or small business transfers risk to an insurance carrier, often as part of a wider micro-finance scheme	**Meso-level insurance and re-insurance** The most prevalent mode of risk transfer at municipal, provincial or sovereign levels in the development context. Programmes are increasingly based on 'parametric' instruments, as distinct from more traditional indemnity policies. These have the virtue of simplicity and immediacy as they do not rely on detailed estimation of loss after the event, but have flaws which can lead to inequitable pay-outs that must be addressed by more open and transparent risk modelling.
Macro-level regional or national risk pools Groups of organisations (usually governments) collaborate to share capabilities and buy risk coverage, usually in partnership with donors, development agencies and the private sector. The leading multi-sovereign risk pools are African Risk Capacity (ARC), the Caribbean Catastrophe Risk Insurance Facility (CCRIF), the Pacific Catastrophe Risk Insurance Company (PCRIC) and the South-East Asia Disaster Risk Insurance Facility (SEADRIF.)	**Alternative capital** Commonly known as Insurance-Linked Securities (ILS), these weather or geo-hazard related financial derivatives are increasingly issued by risk owners to share risk with capital markets. The attraction for investors is that the risk is not correlated with market performance. The most commonly traded instrument is known as a catastrophe bond.

Figure 2.4: Insurance product types in the development context

Indemnity	Pay-out based on assessed loss Assessment minimises basis risk High costs and possible delays in payment associated with the loss adjustment process
Modelled loss	Pay-out based on loss estimated by agreed risk model Basis risk is real, but relatively low Significant investment in risk analytics
Parametric index	Pay-out determined using formulae estimating loss from realisation of the hazard Hazard measured at reference points determined by formulae Basis risk lies between modelled loss and parametric approaches
Parametric	Pay-out based on a simple event definition (intensity threshold at a certain location) Triggers a rapid payment High basis risk

Extending the value of risk analytics

Risk analytics conducted primarily for risk transfer have value beyond the primary project, where those data have been made public.

For instance, exposure and hazard data created by AIR Worldwide under the Pacific Catastrophe Risk and Financing Initiative (PCRAFI) in 2013 remains in use today as a primary source of disaster risk information in the Pacific region, and the primary source of exposure data for national level assessments.

The data was used in urban planning in Vanuatu, by domestic insurance providers to extend insurance products to include disaster risks, by macroeconomists to determine the accuracy of stress testing, and by international organisation to target development policies in the region[21].

Under PCRAFI Phase 2, the Secretariat of the Pacific Community (SPC) is standardising exposure data collection in the region and in the process trained government staff to collect new data to update and improve the PCRAFI exposure data.

Effective and affordable risk transfer relies on risk being quantified in terms of the annual expected loss, and the annual probability (or return period) of extreme losses. Without accurate models the cost of transferring economic risk can be high due to the excessive 'margins-for-unknown/error' in that risk, which insurers have to offset by increasing the risk premium charged.

Such additional costs would need to be borne by the risk owner – the government (therefore taxpayers) or humanitarian organisations like the Red Cross Red Crescent. Neither can afford to pay more for risk coverage than is absolutely necessary.

Good quality and accurate models therefore reduce the cost of risk transfer to the benefit of these entire local economies.

Application of risk analytics in the global re/insurance sector

The measurement of loss in financial terms is a core capability in the private sector, which routinely applies a financial module in risk analysis to manage the implications of financial contracts[22]. The sector also brings decades of experience of using those financial outputs directly in the management of disaster risk via a range of risk financing and insurance strategies.

Now, risk analytics are embedded in many insurance sector operations: assessing potential losses from a portfolio of risks to ensure it is sufficiently diverse and that obligations to policyholders can be met in the case of catastrophic losses; ensuring profitability; and adhering to regulations that ensure companies remain solvent and able to fulfil their commitments to pay claims, and so on.

Through the application of risk analytics, the insurance industry is able to continue reliably providing insurance coverage in addition to important co-benefits including[23]:

- Quick and reliable payment of claimants/beneficiaries
- Promotion of knowledge to protect lives and property
- Mechanisms to spread or diversify risk to protect capital
- Significant social benefits by contributing to rebuilding livelihoods and economies
- Confidence to innovate, access loans, develop and participate in complex supply chains and actively deploy capital – relatively small premium payments for coverage can enable individuals to accept residual risk and put capital into activities that may otherwise have been saved to cover unexpected losses
- Investment in national infrastructure and other catalysts for economic development.

21 MCII, 2017

22 Mitchell-Wallace et al. (2017) provides more information on the fundamentals of catastrophe models.

23 https://www.iii.org/sites/default/files/docs/pdf/insurance-driver-econ-growth-053018.pdf

Throughout the risk transfer process, adequate risk quantification is necessary to allow this transfer to be fair and equitable and ensure that the appropriate premium is charged for the risk

Mitchell-Wallace, 2017[24]

Risk models are also used to inform another form of risk transfer in the capital markets: Insurance Linked Securities (ILS). These are, financial products whose value is linked to disaster losses and are attractive to investors looking for risk uncorrelated to usual capital market risks.

The most common products include Catastrophe Bonds and a recent example in the development sector is a World Bank transaction insuring the Philippines for 3 years against disaster losses of up to USD 75 million from earthquakes and USD 150 million from tropical cyclones.[25]

The private sector has extensive experience in designing (including modelling the risks), structuring and placing Catastrophe Bonds. Innovative products from the public and private sectors now go beyond the traditionally modelled hazards, providing substantial financing for risks such as volcanic eruption (see boxes).

World first – volcano parametric catastrophe bond

Worldwide, 500 million people live near 1,500 active volcanoes. Eruptions can cause significant population displacement as well as loss of life, livelihoods and property.

Unlike an earthquake which inflicts immediate loss to a specific area, the impact of an eruption is heavily influenced by tephra fallout hazard (fragments and ash), atmospheric conditions and population density of nearby communities.

When Volcán de Fuego in Guatemala erupted in June 2018, the pyroclastic flow (a dense, destructive mass of hot ash, lava fragments, and gases) resulted in nearly 200 deaths and 5,000 evacuations. The national disaster agency (CONRED) estimated that the subsequent ashfall affected 1.7 million people. This one volcano is known to have erupted 60 times since 1574 and yet 54,000 people still live within 10 kilometres of its centre.[26]

In this case UNICEF funding fell 80% short of the requirement and there is a clear need to identify a more reliable solution than emergency appeals. Through the use of risk models, volcanic risk can be priced and efficiently transferred to (re) insurance and capital markets, providing a mechanism for the rapid reduction of human suffering and economic damage.

The Danish Red Cross has partnered with Mitiga Solutions (a spin-off of Barcelona Supercomputing Centre) and REplexus to develop the world's first volcano parametric catastrophe bond, to be placed in September 2020 but already cited as an example of best practice.[27]

The multi-continental bond has a number of innovative features, including the use of an ILS blockchain developed by REplexus to reduce transaction costs by hundreds of thousands of dollars per issue. The risk analytics component is also novel, introducing hybrid triggers developed by Mitiga based on (1) the occurrence of an eruption, measured by the eruption column height of the ash plume, and (2) the direction of the wind as a function of the dissipation rate and location of the ash fall. Uniquely this makes it capable of making both ex-ante and ex-post payments. To mitigate concerns that an eruption may not trigger the bond, the risk analysis sets three plume height thresholds.

The hybrid nature of the parametric trigger constrains the expected loss to single digits while the attachment risk falls in the area of low double digits. This relationship is significant because the probability of a pay-out is greater in the event of smaller eruptions while the likelihood of complete capital loss for the investor is significantly reduced. A lower expected loss means lower premium burden on humanitarian budgets, while large placements may still be made.

"Whereas most catastrophe bonds pay out after a risk event has created a loss, our volcano cat bond can pay out before ash hits the ground and serious loss occurs [...] we've leveraged the funding attributes of insurance with the benefits of early action protocols – the world's first blended cat bond."

Adam Bornstein, Danish Red Cross.

[24] in Mitchell-Wallace et al., 2017; page 49

[25] World Bank, 2019

[26] Smithsonian Global Volcanism Program: https://volcano.si.edu/volcano.cfm?vn=342090

[27] Good Humanitarian Donorship and Boston Consulting Group 'Organizational Readiness and Enabling Private Capital for Innovative Financing in Humanitarian Contexts' pp124-125.

Pandemic Emergency Financing Facility

The Pandemic Emergency Financing Facility (PEF)[28] was launched in 2016 to provide rapid financing to the world's poorest countries to tackle cross-border, large-scale pandemic outbreaks. PEF payouts are triggered based on the number of cases of infections and fatalities, outbreak growth over a defined time period, and outbreak spread – two or more IBRD/IDA countries must be affected.

PEF funds are provided as grants to finance response efforts including a wide range of actions from supporting front line health workers, drugs and medicines, critical medical equipment (including personal protective equipment), and more. The facility paid out over $60 million to WHO and UNICEF during the Ebola crisis in DRC in 2018 and 2019.

The current insurance window matured in July 2020 with donors having paid US$107.2 million in premiums. The insurance window paid out US$195.84 for COVID-19 in funds as grants to 64 of the lowest-income countries.

The Facility became controversial during the COVID-19 pandemic. It was criticised for paying out months after the need was obvious, and for paying out not much more than the premiums donors had paid in. This followed on from criticism for not responding to the Ebola crisis in 2018. World Bank has since abandoned plans for a second PEF. Reasons for the late COVID-19 payout were partly administrative, but also the trigger conditions selected. These were partly based on a complex growth rate calculation, over-riding simpler views such as geographical spread.

There is widespread support for the principle of pandemic risk finance, but the lessons of 2020 point to the need for more responsive mechanisms. Commentary from the Centre for Disaster Protection concluded:

"Future pandemic financing should be designed much more simply, to pay out more frequently and more quickly to respond to small outbreaks rather than run the risk of coming in too late."[29]

Public assets

While the majority of risk transfer programs focus on covering damage to residential and commercial property, some sovereign-level schemes (e.g. FONDEN, in Mexico; see box) have used risk analytics to estimate and manage risk to public assets.

These include transport networks, social infrastructure, energy, water and sanitation, telecommunications supply and distribution, and natural/green infrastructure: such assets play an important part in the resilience of economies and their recovery from disasters. The IDF Guide to Insuring Public Assets shares practical information for decision-makers considering financial protection of their country, regional or municipal assets.[30]

The quantification of risk to public assets is important, but poses several challenges, including the variety in construction and vulnerability to hazards of the very different structures and network types of assets classed as infrastructure.

Very often the vulnerability data is poor and many assets present unique modelling challenges. Difficulties include modelling linear assets (roads, railways), complex sites (for example power stations) and the differential use of infrastructure by different groups such as women and children (for example schools and healthcare facilities.)

[28] https://www.worldbank.org/en/topic/pandemics/brief/fact-sheet-pandemic-emergency-financing-facility

[29] Centre for Disaster Protection: https://www.disasterprotection.org/latest-news/now-is-not-the-time-for-the-world-bank-to-step-back-on-pandemic-financing

[30] See 'IDF Practical Guide to Insuring Public Assets, IDF September 2019 https://www.insdevforum.org/resource-library

Fondo Nacional de Desastres Naturales (FONDEN)

FONDEN is regarded as a benchmark in integrated risk management for a country beset by multiple natural hazards. It was established in 1996 to provide immediate availability of financial resources after a disaster, without requiring funds from existing budget plans and public programs. It focussed on reconstruction and restoration of low income housing, public infrastructure and the protected natural areas, rivers and lagoons. However, it is much more than a fund to compensate for disaster impacts.

Its role incorporates other important activities in an holistic disaster risk management programme addressing prevention, response and recovery.

For instance, FONDEN includes a mandate for disaster prevention activities, undertakes joint state and federal damage assessments to determine the required response resources, and created state trust accounts holding FONDEN resources for specific disasters. Under FONDEN the Fund for Natural Disaster Prevention, FOPREDEN, supports federal agency and state government investments in risk identification and risk reduction. FONDEN has also sought to empower local authorities in risk management by encouraging shared responsibility and local capacity.

Risk policy has been underpinned by risk analytics, in particular R-FONDEN, a probabilistic catastrophe risk model and the use of other technologies that have emerged over its lifetime, including handheld damage estimation and an online inventory of post-disaster activities and infrastructure damage.

To achieve its goals FONDEN receives a minimum allocation of funds of the annual budget of the Mexican Ministry of Finance and Public Credit. FONDEN has been a leader in sovereign risk transfer, issuing the first ever government cat bond for coverage against earthquakes, since superseded by hurricane and earthquake catastrophe bonds and indemnity insurance.

Source: FONDEN Mexico's Natural Disaster Fund - A Review, May 2012

Only a limited number of disaster risk models account adequately for wider disruption caused to society due to damaged or failed infrastructure systems, an area that must be addressed by the inclusion of social sciences in the modelling process.

Models that are making progress in this space include: GNS/NIWA Riskscape and Geoscience Australia's Systemic Infrastructure Resilience Analysis (SIRA) which simulate disruption to electricity and water supplies as well as road networks. GEM Foundation has developed a model for assessing the downtime of a transportation network and associated business disruption[31].

The model is now being applied in collaboration with NRCAN in their DRR Pathways project to assess the downstream effects of earthquake and flood-induced failures to the transportation system in British Columbia.

Tackling basis risk

Basis risk is a key issue in the use of models to inform disaster risk financing strategies. The Centre for Disaster Protection and Start Network's excellent guide to technical solutions to basis risk suggests three causes: model error, uncertainties in basis risk can occur due to a combination of model error, uncertainties in event outcomes and miscommunication or misinterpretation of model outputs.

- The more removed a scheme is from paying out on the basis of assessed losses, the greater the basis risk associated with a payout
- Parametric products have higher basis risk than indemnity products
- When a loss occurs but a model does not trigger a payout, this can damage trust in risk financing programmes and leave the policyholder with unexpectedly limited funds in the face of a disaster response and recovery.
- Conversely, paying out more than actual loss can result in policy premiums rising and becoming unaffordable.

Efforts are made in model development to minimise basis risk for risk transfer, but still improvements in data collection and analysis are needed for better ground-truthing and to ensure products continue to be affordable and meet policyholder needs.[32]

31 2020, Costa et al, https://doi.org/10.1002/eqe.3288

32 Harris, C. and Cardenes, I. (2020) 'Basis risk in disaster risk financing for humanitarian action: Potential approaches to measuring, monitoring, and managing it.' Centre for Disaster Protection Insight paper, Centre for Disaster Protection, London.

2.4 Anticipatory action

The defining feature of anticipatory action is that some form of service or benefit is triggered by a forecast and risk analysis and is delivered *before* the occurrence of the event. Early warnings of heightened risk enable governments, humanitarian and development organisations to take anticipatory actions to protect people and assets before a disaster occurs.

It follows that the action must be designed on a basis of risk understanding. Forecasts are just one input and many actors in anticipatory forecasting use the principles of 'Impact-based Forecasting' (IbF[33]) to understand potential loss or harm.

The extent of anticipatory actions taken varies with the forecast's lead time and related uncertainty: storms and cyclones can be forecast with relatively high skill in the days preceding landfall. For example in India in 2013 as many as 800,000 people were evacuated within the 48 hours before Cyclone Phailin made landfall.

These large-scale measures are less feasible in conditions of high uncertainty. Flood is especially difficult to anticipate with confidence, particularly in data scarce areas. The Global Flood Awareness System (GloFAS)[34] has already been used to trigger early action by the Red Cross Red Crescent in Peru, Bangladesh and Uganda. It will continue to be used where this type of forecast can complement national forecasts in reducing uncertainty. Larger river basins offer some scope and encouraging examples exist, for example in Bangladesh (see box).

Anticipatory finance in Bangladesh and the Philippines

In 2017, Bangladesh experienced the worst floods in recent decades. Based on a forecast, risk analysis and pre-defined trigger level, a Red Cross Red Crescent project distributed an unconditional cash grant equivalent to USD$60 to each of 1,039 poor households in highly vulnerable, flood-prone communities in the Brahmaputra river basin between three and seven days before an early flood peak. A quasi-experimental study accompanied the intervention to assess the effectiveness of forecast-based cash assistance.

Research showed that the early cash grants distributed by the Bangladesh Red Crescent Society contributed to improving households' access to food, a 30% reduction in high-interest debt accrual of vulnerable households, and reduced psycho-social stress during and after the flood period, compared to a control group of similarly vulnerable and flood-affected communities that did not receive the forecast-based cash assistance. The intervention may also have prevented households from being forced to make destitution sales of valuable assets.

This learning and other evidence led to IFRC's establishment of a Forecast-based Action (FbA) fund by the Disaster Relief Emergency Fund. The funding mechanism and early actions were triggered in May 2020 in anticipation of Tropical Cyclone Amphan in the coastal border area of Bangladesh and India[35].

This was the first large-scale, coordinated inter-agency triggering of anticipatory actions by impact-based forecasts and warnings. The approach continues to scale up and a US$5.2m Anticipatory Action Plan including UN agencies and RCRC partners has been approved by the UN Central Emergency Response Fund, based on the Forecast based Financing approach. Most recently, the system was tested in July 2020, when a 1 in 10 year flood forecast triggered deployment of cash, waterproof storage drums, livestock feed, dignity and health kits.[36,37]

On Christmas Day 2019, Tropical Cyclone Ursula made landfall in the Philippines. Just at the beginning of the same year, Oxfam Novib, PLAN International, Global Parametrics and local partners had set up the B-Ready pilot programme to test the benefit of anticipatory cash transfers to the most vulnerable in the community of Salcedo. Risk analysis by Global Parametrics determined pre-set thresholds, which were breached 66 hours prior to Ursula's landfall in the area.

Emergency life-saving actions were taken and an immediate distribution of cash via debit cards was triggered to reduce broader social and economic impacts. The pilot includes disaggregated data to identify households with women, children, persons with disability (PWDs) elderly and other vulnerable groups living in poverty and high exposure to typhoon hazards. Its pre-disaster digital cash transfer is complemented by financial literacy training.

Women are the intended recipients of the cards on behalf of their households, to ensure the transfer is used for the intended purpose. Women's access to finance and mobile phones were accounted for in the delivery model. Further, a gender specialist is providing training to partners on gender equality to support project implementation.

---

33 IbF is promoted as a forecast view of what the weather will do, rather than what it will be. See WMO Guidelines on Multi-Hazard Impact-based Forecasting and Warning Services, due to be updated during 2020.

34 European Centre for Medium-Range Weather Forecasting (ECMWF): https://www.globalfloods.eu/

35 https://www.climatecentre.org/news/1285/ifrc-emergency-assistance-for-cyclone-amphan-includes-second-ever-use-of-early-action-funding-mechanism.

36 https://media.ifrc.org/ifrc/press-release/early-action-save-lives-bangladesh-amid-severe-flood-forecast/

37 Harrowsmith, M., Jaime, C., Coughlan de Perez, E., Uprety, M., Johnson, C., Van den Homberg, M., Tijssen, A., Mulvihill, E., Comment, T. 2020. The Future of Forecasting: Impact based Forecasting for Early Action Guide. Red Cross Red Crescent Climate Centre, Met Office.

Modelling drought for Forecast-based-Finance

A number of humanitarian organisations are building finance mechanisms for drought and consequent food security outcomes; some of these programmes fit into the category of Anticipatory Action. Risk assessment is extremely challenging, particularly in defining the most useful biophysical indicator and the thresholds that might trigger action. The link between modelled impacts, realised impacts and humanitarian need is also difficult to establish and can lead to problems of basis risk.

START Network's Drought Risk Finance Facility Lab (DRiSL) project[38] is researching these questions to assess the extent to which drought early action can be triggered with confidence. It has compared the value of a number of plausible drought metrics including rainfall, soil moisture content, the Water Requirement Satisfaction Index (WRSI) and the Normalised Difference Vegetation Index (NDVI) during modelled anticipation windows over the last ~40 years. The project is centred on the diverse geographic and socio-economic contexts of Pakistan, Zimbabwe and Madagascar, where START Network and Welterhungerhilfe have operational programmes.

So far the project has found high uncertainty in selection of indicators, particularly (as would be expected) for higher return period events and smaller spatial scales. Some merit was found in using soil moisture as an indicator in Zimbabwe, but this was less helpful in Madagascar (where rainfall is not well represented in the data) or Pakistan (where there is greater use of irrigation.) However the use of NDVI to simulate response in Pakistan's semi-arid climate showed some skill.

The greatest challenge lies in understanding the eventual impact on food security and livelihoods, largely due to a lack of historical impact data. There may be a weak relationship between biophysical metrics and human impact but it should be treated with caution as there are multiple processes and conditions at work.

The lessons from this work are:

- The best choice of metric for anticipation of agricultural drought appears to be highly specific to the region and climate regime. One model does not fit all.
- For anticipation purposes, metrics of water stress such as soil moisture may be a more useful indicator than measures of crop performance.

Some anticipatory decisions can realistically be taken within a seasonal lead time of 2-3 months, particularly in anticipation of drought or heatwave.

Institutional collaborations that have achieved some success include the Famine Early Warning System Network (FEWS NET[39]) and the Global Framework for Climate Services.

However, there is work to be done to improve drought models, not least because of uncertainty in the input data[40]. The multi-disciplinary SHEAR research programme supports the advancement of anticipatory action for drought. The START network Drought Risk Finance Facility Lab (DRiSL) project[41] is researching improved connections between models and real humanitarian impacts, through monitoring and forecasting of biophysical indicators (see box.) While the ForPaC project, lead by University of Sussex, with the Kenya Drought National Authority, Kenya Met Service, Kenya Red Cross and others, is advancing climate forecast science and forecasting of vegetation condition to develop enhanced drought warning systems and early action systems in Kenya. This research is being used by the Kenya Red Cross to develop Early Action Protocols for Drought with access to the FbA by DREF.[42]

Heatwave early warning systems tend to have longer lead times and can trigger action to reduce mortality, but these are more frequent in developed countries.

A further characteristic of the anticipatory action category is the partnership of governments and humanitarian agencies in country contexts, where there is increasing agreement that readiness to act early to reduce disaster impacts is better than concentrating resources on post-disaster response.

38 A collaboration between Start Network, University of Sussex, University of Reading, University of Columbia and Welthungerhilfe (WHH). https://gtr.ukri.org/projects?ref=NE%2FR014272%2F1 Funded by the Science for Humanitarian Emergencies & Resilience (SHEAR) programme of the UK's Department for International Development and Natural Environment Research Council.

39 https://fews.net/ Funded and managed by USAID. At the time of writing FEWSNET is monitoring the impact of Covid-19 on acute food security in already vulnerable regions.

40 The ARC Malawi 2016 example described at Annex C illustrates the point.

41 https://gtr.ukri.org/projects?ref=NE%2FR014272%2F1

42 https://www.the-star.co.ke/news/2020-07-22-kenyan-scientists-able-to-predict-drought-2-months-ahead/ and https://www.forpac.org/resources

Anticipatory action is gaining support across the international humanitarian sector, partner governments and civil society. However, the risk analysis and forecasting on which it is based would be more effective if the following improvements were made:

- **Building formal partnerships:** Distance between organisations creates problems such as lack of access to essential forecasts, exposure data and vulnerability research. Humanitarians are adept at working with what they have, for example by use of crowd-sourced mapping and proxies for vulnerability, but the solution lies in formal agreements right along a chain from risk analysis to forecasting and operational action.

  For example, Impact based Forecasting (the enabling mechanism for Anticipatory Action) depends on aligning the mandates and processes of national hydromet and geophysical agencies, development organisations, NGOs, the private sector, risk modellers and others.

  The recently formed **Risk-informed Early Action Partnership**[43] and **Anticipation Hub**[44] potentially offer significant help in bridging these gaps.

- **Improved integration of local knowledge:** Successful anticipatory action must identify deeply localised impacts, which implies the need for high resolution insight. Need is defined not only by location, but also by gender, age or economic status, adding a long-term view to immediate effects.

  Open source mapping initiatives such as Missing Maps and Humanitarian OpenStreetMap offer valuable physical exposure data in data-sparse regions, improving the prospect of effective anticipatory risk insight. Increasingly specialist NGOs such as MapAction (footnote) are helping build local capacity in mapping and information management, an important step towards sustainable local risk understanding.[45]

  If local knowledge is to be combined with global strengths, widespread use of open modelling principles and resources will help. Open platforms are already available with the infrastructure necessary to develop IbF services (for example the Indonesian InaSAFE system, and the private sector inspired CLIMADA and Oasis LMF platforms.)

- **Model re-purposing and development:** Catastrophe risk modelling offers potential to add value beyond current IbF approaches for anticipatory action, but requires a re-purposing of the methodology to deliver metrics on human, environmental and economic impacts. Also, risk modelling must be integrated further into forecast systems for better anticipation of impacts. These changes are happening, but are not yet prevalent.

- **Tolerance of uncertainty:** Forecasts are uncertain and there is always risk that early actions are taken in vain. Rainfall might not be as severe as anticipated so a flood does not occur, or a cyclone track may change and not make landfall. While funding agencies have been reluctant to finance interventions with uncertain outcomes, there is a growing evidence base that anticipatory action can reduce disaster impacts and contribute to long-term resilience, even when acting on a 'no regrets' basis. This evidence is building traction with funders.

43 https://www.gov.uk/government/news/uk-aid-to-help-protect-one-billion-people-from-impact-of-extreme-weather

44 https://www.forecast-based-financing.org/anticipation-hub/

45 www.MapAction.org

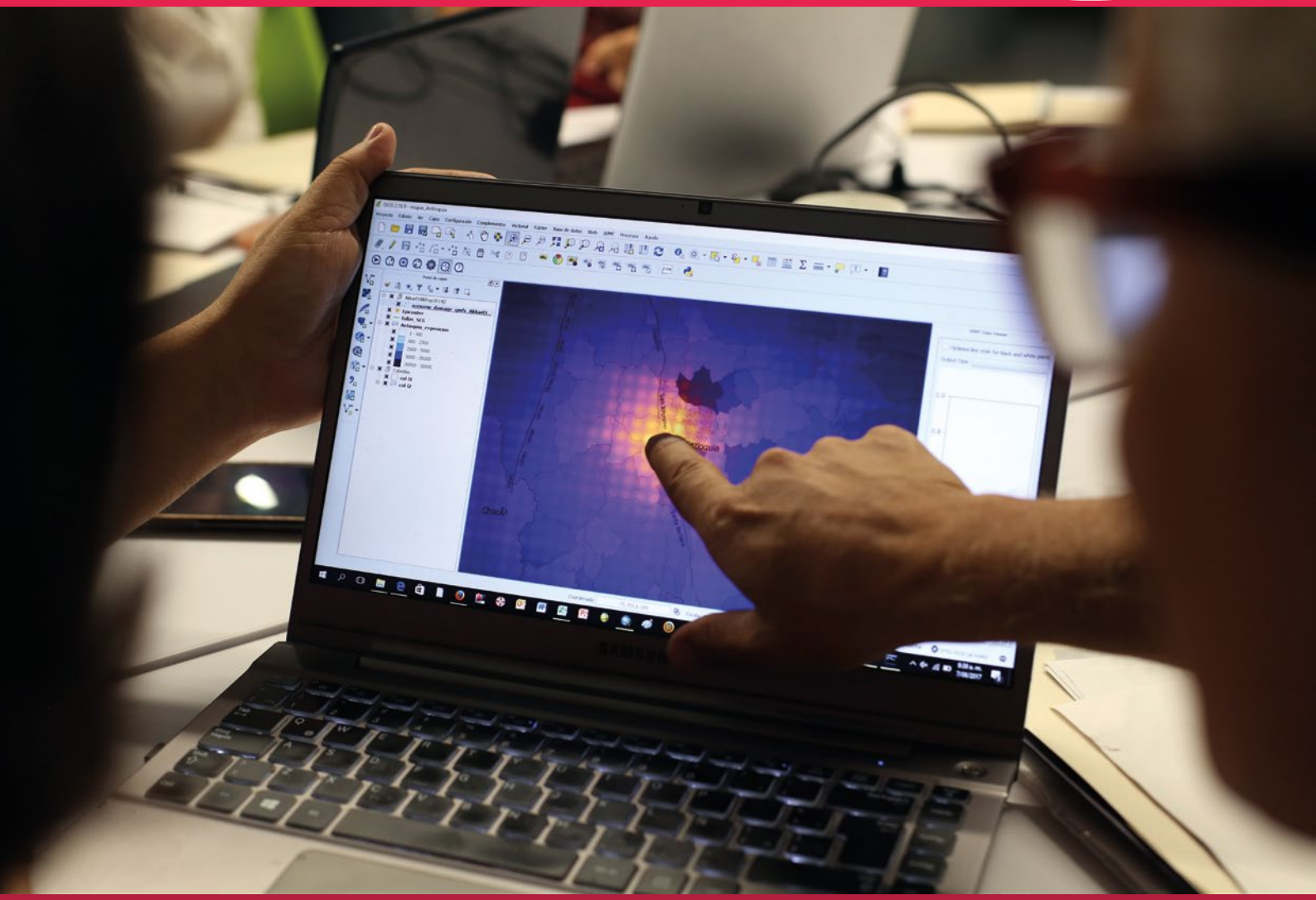
Tsunami Hazard Zone sign in Curaco de Velez village, Chile
Photo: Shutterstock

2.5 Key points

1. Risk analytics is the foundation of risk prevention and mitigation, risk transfer and anticipatory action in development. Its importance is recognised in policy frameworks and in dialogue with governments. It is a vital tool to close the protection gap and advance climate adaptation and climate financing.
2. The insurance-focussed foundation of risk analytics has so far meant a concentration on financial losses to property. However, risk modelling frameworks offer broader capabilities. Further collaboration across sectors is required to maximise the potential for development and humanitarian applications.
3. The adoption of climate risk analytics in climate risk investment practices remains limited despite greater awareness of physical climate risk on asset valuations in the investment community. Misperceptions of the relevance of common risk metrics and terminology and applications of models should be addressed to encourage greater application in climate investment. Equally, analytical challenges in existing models should be addressed – including expanding modelled time horizons and influence of climate on losses over those timescales.
4. The value of risk analytics comes not only from the end-product – the provision of risk metrics – but also from the underlying research, which provides content for risk education and the consequent building of consensus.

Demand for risk insight and the challenge of access

3



OpenQuake training workshop
Medellin, Colombia 2017
Photo: Universidad EAFIT

Demand for risk insight and the challenge of access

3.1 User demand

Understanding (and building) the demand for risk insight among risk owners is a critical first step in addressing risk prevention and the protection gap. This understanding is being developed through increasing engagement with government ministries, scientific agencies and civil society organisations.

Demand has been reflected in project discussions, open forums and surveys, but most clearly in the extensive commitment of resources by countries to developing risk information and capacity.

There is a desire in many countries to 'own' risk insights, but international support and finance is often required to realise this ambition.

Just some examples include:

- Significant investment since 2009 in building and sustaining Indonesia's national disaster management program through the Australia-Indonesia Facility for Disaster Reduction.
- Development of risk analytics capacity in the Philippines and Bangladesh, funded by the German government and enabling partnerships between national government and academia using the Oasis Loss Modelling Framework[1].
- The development of the National Risk Atlas of Rwanda by in-country experts at MIDIMAR with European Union support.[2]
- Continued long-term engagement of governments, universities and the private sector on earthquake risk in Colombia, Ecuador and Dominican Republic, initiated by the 2013-15 regional South America Risk Assessment (SARA) Project[3].

Regional forums on risk financing offer further evidence of demand. The SEADRIF initiative recently held a remote workshop on the financial protection of public assets. Over 100 participants in ASEAN countries attended; in a survey conducted at that session, 71% of participants ranked 'risk modelling capability' as the top capability needing external support or capacity building (higher than support on reinsurance broking or actuarial capability).

There is not only demand to *receive* risk insight, but increasingly to have **full understanding and ownership** of the processes and to trust the insights. This is reflected by the views of DRM professionals in public forums (see box below, 'Improving access'.) and surveys while conversations with risk managers reveal the demand for risk insight in the context of their primary function and everyday decision-making (see box).

1 https://www.international-climate-initiative.com/en/details/project/oasis-platform-for-climate-and-catastrophe-risk-assessment-asia-18_II_165-3018

2 https://www.gfdrr.org/en/publication/rwanda-national-risk-atlas; developed by Ministry of Disaster Management and Refugee Affairs with ACP-EU support.

3 https://sara.openquake.org/

Mapping and gap analysis of user needs

Significant information gaps create a barrier to developing robust risk models. The Mapping & Gap Analysis Working Group of the UNDRR Global Risk Assessment Framework (GRAF)[4] conducted a survey of national focal points for disaster management, producing indicative results from eight developing countries (Indonesia, Bolivia, Colombia, Paraguay, Costa Rica, Nicaragua, Guatemala, Dominican Republic).

Most countries reported a complex set of sectors and institutions contributing and interacting, with varying and often fragmented degrees of coordination. Countries also reported that their expertise is typically in deterministic (or scenario) analysis, often based on expert judgement to extrapolate from historic events. Few countries have the capability for probabilistic risk analysis at the national scale.

Specific needs identified in the survey include:

- Access to more (and better) models and data.
- Greater capacity and knowledge at the local level.
- Access to open data and tools.
- A more centralised or coordinated body to perform risk analysis.
- Better connection between science and industry, and between science and policy.

In many countries institutional risk education may not yet be sufficient to determine the specific requirements of complex risk analytics, reflected in the dominant mode of engagement – that is, contracting international expert consultants to perform analytical work.

Certainly though the skills, local knowledge and demand to participate in projects do exist. Contributing to risk analytics and developing risk expertise in this way can only improve management of risk at all levels.

Improving access

At the 2015 Understanding Risk + Finance Conference, government disaster management professionals from Malawi, Uganda, Rwanda, Ghana and Mauritius voiced their requirements on risk insight, reflecting the demand and the need to improve access:

- *communication:* Data providers must explain the risk assessment process and how to respond to risks and adapt policies based on the results.
- *establish ownership and a purpose:* End users should be engaged at the project design stage so the communication products can be tailored to them.
- *using and improving local capacity:* While international expertise is valuable it is vital to build local capacity to maintain ongoing activities.
- *improvement of technical capabilities:* Particularly information management systems, including coordinated databases for collection, storage, and sharing of data
- *formalising the process within governments:* Where risk assessment is an essential component of budgetary processes risk assessment is more likely to be resourced adequately and results more likely to be incorporated into contingency plans. Further, policymakers will be more motivated to take action based on the information.

Fraser and Nkoka 2015, Understanding Risk + Financing Conference; panel discussion

[4] https://www.preventionweb.net/disaster-risk/graf

Risk insight for city planning

City planners must consider risk in the context of their primary responsibility – maintaining services or infrastructure operation for their citizens. This is a key influence on the types of risks and the timeframes they focus on.

City planners in Cape Town apply qualitative risk mapping for stresses and shocks to specific sectors (e.g. urban settlement, IT). This incorporates six hydrometeorological hazards at three time horizons, and 35 indicators of vulnerability and resilience. As well as climate risks, the risk mapping exercise includes changes in technology, regulatory climate, ageing and insecure infrastructure and urban development patterns. The risk mapping informs 20-year plans for each sector, outlining development principles and project pipelines.

Albert Ferreira, Strategic Policy, City of Cape Town.

3.2 Choosing the analytics approach to meet the need

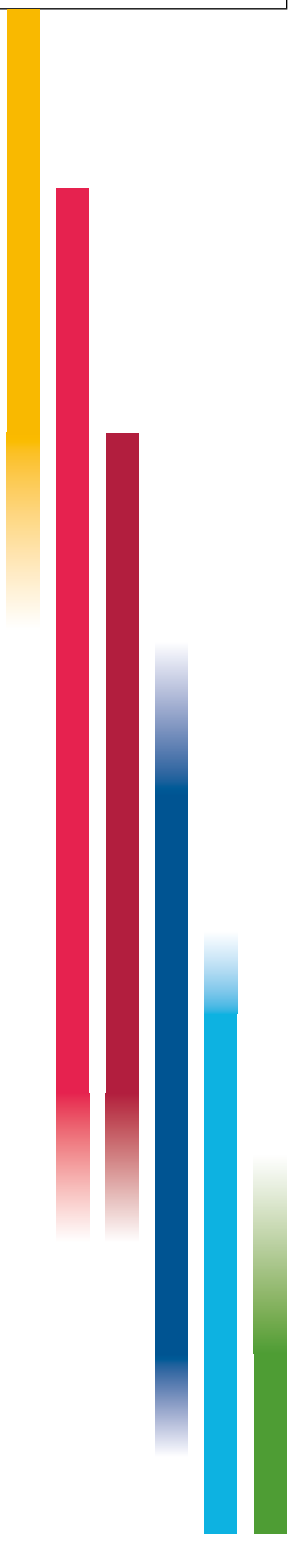
The risk problem being researched should determine the tools to be used. Realised risks may range from the impacts of frequently occurring local hazards where uncertainty is relatively low, to extremely complex compound risks causing cascading, system-level impacts at national or international level.

The array of possible analytics solutions can be daunting and it is helpful to have a framework for users to find the best approach for their risk question. **Table 3.1** offers a selection of methodologies and tools, relating to the risk problem and application.

The framework begins with risk problems where experience has reduced uncertainty to a low level, and ends with grave systemic risk where the uncertainties are far greater than the known risk. In this evolutionary chain the levels are cumulative – each analytics approach provides a building block that is useful for the next.

Table 3.1: Choice of risk analytics approaches

Risk management application	Financial risk layering	Example risk context to be analysed	Primary risk analytics methodology
Local response planning Community education and alerts	Setting local contingency funding	Low severity event with very local impact e.g. flood event with 1-2 year return period.	
Social and environmental protection measures eg building code development	Setting national contingency funding, contingent credit Insurance and other risk transfer instruments based on single hazards Humanitarian anticipatory finance	Moderate-severity events. Risk knowledge is generally greater than uncertainty. e.g. 5-20 years return period losses for a coastal storm affecting a limited number of communities	
National response planning Infrastructure adaptation projects	Cost/benefit analysis of risk prevention projects. Determination of threshold where investment in risk prevention is more cost effective than residual risk financing. Insurance and risk transfer instruments based on multiple hazards. Regional risk pools.	Low frequency single hazards or higher frequency compound hazards. Large to profound impacts on local infrastructure and economies requiring provincial to national scale government intervention e.g. 20-50 years return period losses at provincial/state level for an earthquake causing significant loss of life and damage	
Development of national strategic risk plans Continuous national risk Surveillance and reporting Critical infrastructure systems design	Development of national risk financing strategy	Profound impacts on local infrastructure and population and provincial to national economies requiring national scale intervention. Uncertainty is greater than known risk. e.g. 50 return period losses at national level	
		Major event at regional scale such as volcanic eruption with major local impact and widespread effects such as volcanic ash dispersed over a wide area. Such compound risk events with transboundary impacts require, regional and international cooperation and often significant international aid.	
Intergovern-mental strategic risk planning (SDG, SFDRR, COP...)	Global financial cooperation and strategies	Truly systemic events on a global scale Return period may not be high, for example 10-50 years, but with very high uncertainty about the nature and systemic impacts of the event	



Legend

- Hazard maps, hazard observations record, live observations, local impact records, indigenous knowledge
- Probabilistic catastrophe models. Models are improved if calibrated to local vulnerabilities, and hazard and loss experience. Metrics may include risk to property, crops, population.
- Catastrophe models conditioned to reflect frequency and severity under different climate warming pathways. 'Resilience models' reflecting the benefit of risk prevention measures. Cost / benefit analysis of investment in adaptation eg: Economics of Climate Adaptation studies.
- Use of scenario analysis to complement probabilistic approaches
- Parsimonious scenario approaches, use of contradictory assumptions including behavioural models
- Novel decision-making approaches for conditions of deep uncertainty: eg behavioural/agent-based modelling, game theory, dynamic adaptive approaches. See for example Marchau et al, 2019[5]

At the entry level there is clear demand from countries for uncomplicated, intuitive tools such as hazard maps or scenario impact maps. For international actors this should be seen as an opportunity to start on a collaborative journey of local capacity development. Moving up the scale, use of probabilistic risk models must be the ambition for the understanding of loss and harm, and is indispensable if risk finance instruments are part of the plan. **User-centric open risk modelling platforms offer an accessible means to get started.**

At these levels modelling approaches which may have their genesis in estimation of property loss are increasingly used to understand impacts on people and livelihoods. As Chapter 5 shows, where population exposures and vulnerabilities are modelled, a disaggregated approach is essential for decisions that affect women, girls and vulnerable groups. Other considerations in model and data selection include the sectors at risk, asset types and the granularity of the analysis required. These modelling approaches build upon those used for the preceding levels.

Further up the scale, levels of uncertainty and potential impact are higher and model approaches originally designed for short term outlooks must be further developed. These offer a longer-term view by incorporating projection of future climate conditions, accounting for the impact of climate change on disaster loss frequency and severity, or showing the costs and benefits of adaptation programmes (known as 'Resilience models.') This approach is particularly helpful as countries develop a more holistic risk strategy, for example considering the value of risk-aware investment alongside risk transfer mechanisms.

Problems of national or international systemic risk are at the highest end of this scale and require the greatest breadth of thinking and methodologies. They are characterised by very high levels of uncertainty and severity of impact, requiring multiple approaches to understand the uncertainty. (See box.) Counter-intuitively such events may have high return periods – experience tells us that major systemic events are all too common. The uncertainty lies in the nature of the event and the response of fragile systems.

This paper recommends that countries should have the ambition to develop a risk assessment and surveillance function capable of monitoring systemic risk. As the box shows, this is a complex undertaking and methodologies are the subject of considerable work being undertaken across sectors. The UN Global Risk Assessment Framework (GRAF, see Chapter 6) will offer guidance and is shortly to be piloted in a small number of countries. The private sector is also taking steps to contribute within its areas of competence[6].

However for most countries it may be necessary to start with the building blocks and this paper largely concentrates on principles and practical steps needed for the earlier levels; these are a very necessary foundation for the responsible fulfilment of many government and private sector functions.

Modelling systemic risk

Systemic risk is the risk of collapse of an entire system or market where the failure of a single entity causes cascading failures in others. With ever more complex and interconnected systems the old assumption that causal links between actions and events can be known may be redundant. Examples of extreme systemic risk events include the 2008 financial crisis and the 2020 coronavirus pandemic. Systemic risk may be amplified by behaviours such as rules or economic pressures which concentrate populations, centralized regulation demanding sameness in risk measures, or interdependence of government decision making. Just one example is the creation of new risk when communities displaced by flood or earthquake come together and are exposed to infection.

Systemic risk modelling should identify systems operating closer to their breaking points than previously imagined. The Thailand floods and Fukushima disasters of 2011 showed that complex global supply chains are vulnerable without built-in redundancy[7]. Systemic risk research should look for potentially cascading risk chains, as well as opportunities to simplify knowledge systems, increase transparency, and build modularity into decision design, software, models, technology or local and global dependencies.

Disaster risk models are helpful in identifying potential hazards and estimating a limited set of physical impacts, but systemic modelling must include behavioural aspects such as policy responses to social impacts or the widely varying responses of economies to catastrophe. **This implies forging new collaborations across disciplines, between academics, practitioners and policy makers; something at which the risk modelling community has become increasingly adept.**

‹ Footnote for p44

5 'Decision making under deep uncertainty: From Theory to Practice,' Marchau, Walker, Bloemen and Popper (Springer Nature, 2019.)

6 For example Lloyd's of London 'Open Source Framework for Systemic Risk', July 2020

7 See for example Slobodan Simonovich's (2018) "three Rs", Redundancy, Resourcefulness, and Rapidity

3.3 Barriers to access

There is a critical lack of access to risk insight by those who most need it. We are generating more risk intelligence, data and models than ever before but several problems create drag in the supply of risk understanding. This is due to a combination of issues, including complexity, cost, data availability and model accessibility.

3.3.1 Complexity and cost

The complexity and cost of many risk models are a barrier to development of risk understanding in under-served regions. Cities and countries are grappling with a lack of knowledge about which models, data, resolution and standards they should use. This is not only due to knowledge barriers but also due to the high costs associated with setting up and maintaining current models.

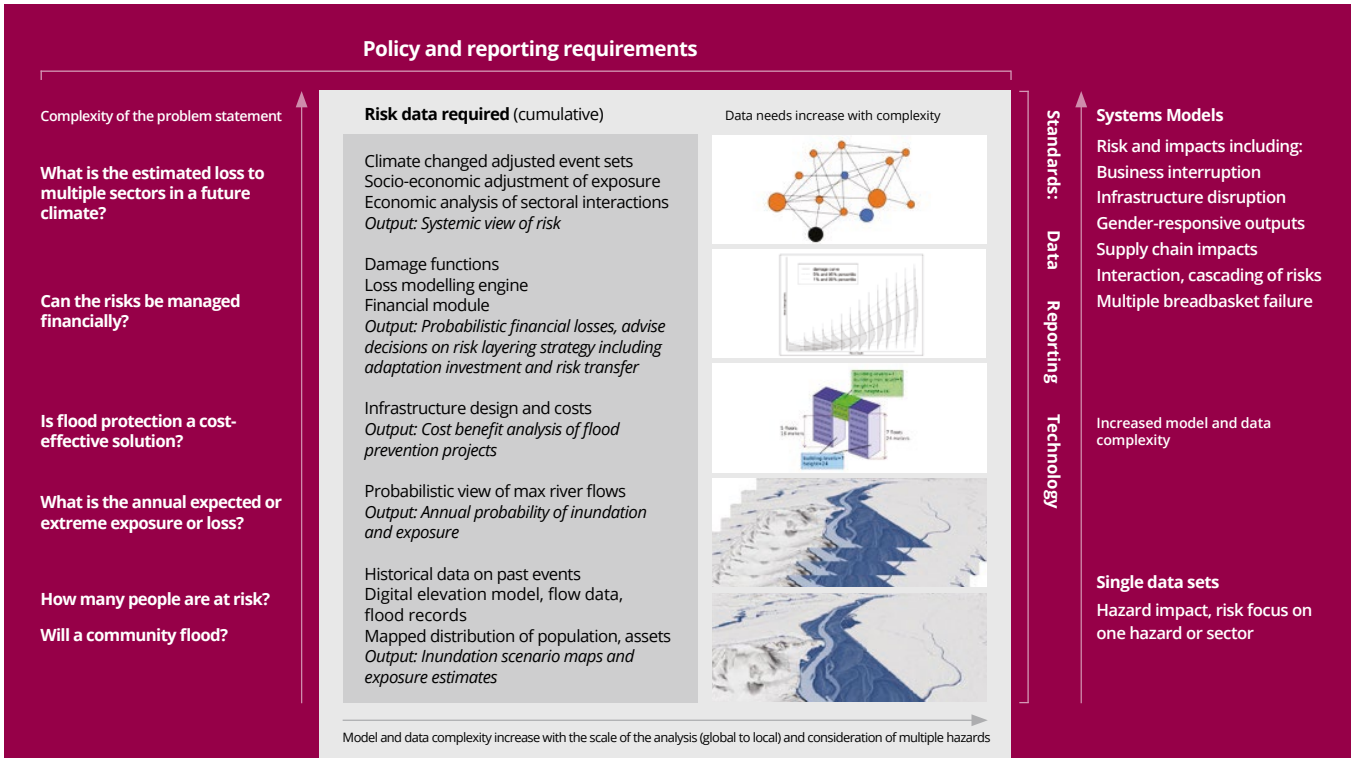
Figure 3.2 offers an applied example consistent with the hierarchy shown at Section 3.2. This practical view illustrates the following key points:

- It is possible to start the journey at relatively uncomplicated levels and grow from there. Simpler and partial risk analytics solutions are increasingly available from niche risk modelling vendors, meeting a clear demand from countries. Peril-specific hazard maps are a good example, leaving the user to decide on the exact implementation of the map or hazard layer in conjunction with potentially important, unique and local knowledge of a specific user[8].
- Complexity and data management increases with each increase in the detail (resolution) required by the risk question.
- The challenge of increasing complexity can be mitigated by the adoption of standards for interoperability and use of open source technology.

It is important to recognize that the problem statement is itself influenced by government policy and international reporting requirements. For the avoidance of bias, diversity of gender and socio-cultural views in the process is critical, and is known to contribute to improved disaster risk management outcomes (see Chapter 5.)

[8] This is the principle behind community mapping: engaging communities in formalising the information they already have to hand can demonstrate its value and engage participants in further use of that information. Community-level risk summaries can build understanding and awareness of risk, which can subsequently develop into more complex analytics and applications.

Table 3.2: Model and data complexity increasing with the complexity of the problem statement, using the example of flood.



Example flood extent maps and flood damage curves courtesy of Aon Impact Forecasting

Applying a cost-benefit analysis to each different level of the above framework and providing risk analytics increasingly modular to address the different levels of analytics as needed could provide users with a more accessible vision and entry point, with control over how complex the modelling chain becomes (Box 3.3).

Cost-benefit analysis of risk analytics

A movement to a modular and decision-focused view of risk thinking, including embedding cost-benefit analyses into a future modelling ecosystem, may reduce the cost of risk analytics.

There is a high level of "primary" uncertainty in risk analytics - a level of irreducible uncertainty in model output due to fundamental scientific uncertainty and disagreements in the research community. Uncertainty involves subjectivity, as it relates to satisfaction with existing knowledge, which is influenced by the values and perspectives of the decision-maker[9]. While models become more complex in an effort to model and communicate the uncertainty for decision-making, this uncertainty may never be eliminated. Therefore by introducing limits on the complexity of the modelling through cost-benefit analyses, one may not limit the value of the modelling at all.

[9] Marchau et al, 2019.

3.3.2 Availability of data inputs

The usefulness of models is directly influenced by the input data needed to develop and calibrate them – but availability remains a challenge. There is a pressing need to channel the right input data for risk models. Examples of necessary data sets include observations from past disasters (e.g. wind speeds, flood depths, and damage sustained), environmental conditions, (e.g. land-use, elevation), socio-economic status, and locally driven factors which influence rebuilding costs and recovery times.

Remote sensing and citizen mapping provide increasing amounts of information on the distribution of structures and infrastructures but detailed attribute information is still difficult to access in many regions. Lack of data on social vulnerability is also a key limitation on relating the occurrence of hazards to their impacts on livelihoods, welfare and differential impact in the population[10].

Difficulties with data access, completeness and granularity are particularly pronounced in regions beset by conflict, where some of the most exposed and vulnerable populations live.

Model metadata and transparency

It is often difficult for users to discern what models are available and what their provenance and capabilities may be. The IDF[11] has created the publicly available "Catrisktools" repository of model information on the Oasis Hub, but a wider community agreed standard of information would bring efficiency to the matching of supply to need. Metadata on a model is typically less than would be found in a peer-reviewed research paper outlining research methods, but would be more accessible to practitioners outside of academia.

This touches on the question of model and data transparency, a principle advocated throughout this paper. A level of transparency around methodology, technologies and assumptions, agreed by the model developer community, will help users understand the the approach used, and in particular the uncertainties underlying the decisions they are supporting.

From commercial modellers' perspectives, the balance to be struck weighs the genuine wish to engage and inform end users by explaining methods and tools against the very significant risk to companies of exposing IP on which the value and, possibly, existence of some companies is built. Bringing together stakeholders from across the spectrum of users and suppliers could help to foster understanding of the concerns and requirements of all parties, identify the real and perceived issues and build a pragmatic framework for sharing data, models and knowledge that meets the needs of all.

Examples of good practice include:

- Fathom, from Bristol University in the UK, which has published the entire methodology of its global flood hazard model.
- FITTER, a probabilistic tsunami risk model for Indonesia, developed by a consortium led by University College London in partnership with the Insurance Development Forum (IDF), built on the Oasis LMF modelling platform[12]. Funded by Lloyd's of London and the Lighthill Risk Network, the project is co-defined with Indonesian partners and the methodology and data sources are transparent throughout.

[10] See also Chapter 5 on the availability of sex-disaggregated data

[11] https://catrisktools.oasishub.co/

[12] https://iris.ucl.ac.uk/iris/browse/researchActivity/29005. The project is funded by the Lloyd's Tercentenary Research Fund, the Lighthill Risk Network and the Turing Institute.

A global exposure database would be a helpful start point for many users. This could be a part of a public good 'starter pack' for countries developing capacity, providing a basis for collaborative development of higher-resolution, localised data.

While several global population datasets such as Worldpop, the High Resolution Settlement Layer (HRSL) and the Gridded Population of the World (GPW) datasets are available, there are fewer equivalents for the built environment. However the GED4GEM exposure database[13] is a leading example for representation of buildings, and there are also several global databases for road networks including GRIP[14] and Facebook AI Roads.[15]

While GED4GEM was created for earthquake risk assessment, it has been supported by the DfID-GFDRR Challenge Fund to produce GED4ALL[16] - a widely usable exposure data schema with extended attributes pertinent to multiple hazards. One of the recommendations of this paper is the creation of a populated global exposure model to support capacity building in countries; the GED4ALL schema is the obvious framework to use in starting this work.

Data from historical events is essential for developing and calibrating models, but the absence of consistently presented historical disaster losses continues to present difficulty[17]. In particular a lack of household level loss data and sex-disaggregated data limits analysis of welfare and gender-specific impacts.

The Sendai Framework[18] emphasises the importance of recording disaster loss data, and the need is underlined by the increased use of Post-disaster Damage and Loss Assessments.[19] Private sector companies such as Munich Re, Swiss Re and Aon all invest heavily in capturing loss data, and industry has collaborated to aggregate loss data through the PERILS[20] non-profit service.

The International Science Council cites collaboration across public and private sectors, and interoperability as key policy recommendations in improving availability of disaster loss data[21].

> **"Disaster data archives and loss data collection are fundamental to comprehensive assessment of socially, temporal and spatially disaggregated impact data. Risk interpretation, with standardised loss data, can be used to provide valuable opportunities to acquire better information about the health, economic, ecological and social costs of disasters, and provide risk based information for policy, practice, and investment."**
>
> Fakhruddin et al., 2019

Improving hazard data: Increased resilience through improved weather prediction

In recent decades there has been a significant improvement of short-term forecasting globally. This has led to a significant amount of risk mitigation and reduction in loss and harm.

he evolution of tropical cyclones track forecasts means that we can now predict track position with greater accuracy and with greater lead times. These improvements in forecasting skill means that today, anticipatory decisions can now be taken with confidence days before landfall; this was not possible in the past. The population is now informed with an increased lead time and operational measures can be taken at an earlier stage with higher precision. Effects of this include reducing costs of unnecessary evacuation.

Numerical weather prediction (NWP) is the backbone of weather and climate services. Reliable, real-time access to observational data from the entire globe is critical to the quality of the output from these systems. However, the coverage of in situ observations (i.e. recorded by weather stations) is uneven across the globe, with impacts on the quality of NWP outputs both locally and globally.

The World Meteorological Organisation (WMO) proposes the completion of a Global Basic Observations Network (GBON), filling the gaps in ground observations that meet or exceed a minimum sustainable data standard. If data-sparse countries were to achieve this level of compliance, WMO suggests there would be a significant improvement in forecast skill not only locally but in global models.[22]

13 https://www.globalquakemodel.org/gempublications/Global-Exposure-Database-for-Multi-Hazard-Risk-Analysis
14 https://datacatalog.worldbank.org/dataset/grip-global-roads-inventory-dataset-2018-road-density
15 https://ai.facebook.com/blog/mapping-roads-through-deep-learning-and-weakly-supervised-training/
16 https://www.gfdrr.org/sites/default/files/publication/Exposure%20data%20schema_final%20report.pdf
17 InsuResilience Global Partnership, 2020
18 e.g. https://www.undrr.org/news/sendai-framework-disaster-loss-data-released-mark-5th-anniversary
19 See for example the World Bank's approach at https://www.preventionweb.net/publications/view/18844
20 www.PERILS.org
21 Fakhruddin B., Murray V., and Gouvea-Reis F. 2019.
22 At the time of writing WMO has assigned working groups to quantify the scientific and economic benefits resulting from investment in GBON.

For data to be useful it has to be collected in the right places, for example in areas of greater vulnerability such as dense centres of population. It also has to be made available, ideally under open and free to use licenses.

However some factors compromise this ideal:

- Even some public entities are under pressure to monetise their data.
- Some governments and other agencies have security concerns about sharing data which may be sensitive such as location, construction and vulnerability details of key infrastructure.
- Data may often be collected and not distributed by private entities.
- Where data is available it may not be in a readily-usable (machine readable) format.

Standards for data collection and sharing could go a long way to unlocking data and improving transparency. A number of initiatives are underway to address these issues. IcebreakerOn[23], described in Chapter 3, brings experience of developing open data standards in the banking sector to develop a culture of data sharing in other sectors - initially insurance, energy and transport.

World Bank GFDRR has led development of the Risk Data Schema, which gives risk experts a single language to describe hazard, exposure, vulnerability and modelled loss datasets. This brings an consistency that makes them highly interoperable and easily read by both people and machines. Key metadata fields are provided with the data, making it easier to identify datasets without relying on external files or descriptions. The Risk Data Schema is part of the Risk Data Library[24] project, which ultimately aims to create an effective library system designed for storing, finding, editing and exchanging data for disaster risk assessments.

> **Accountability and transparency in decision-making are core requirements for the humanitarian sector, irrespective of how decisions are taken [...]. It should therefore be non-negotiable that all data and analytics (along with the decisions and outputs they provide) are clear and transparent, and that efforts are made to communicate the complexity in an accessible way.[25]**

Recent private sector initiatives around data standards include the Open Exposure Data (OED) format and Risk Data Open Standard (RDOS), adding to the already-available Catastrophe Exposure Data Exchange (CEDE) format. Open tools are also being developed to maximise valuable interaction with these standards, including IDF's development of an open-source exposure data transformation tool.

Currently available metrics are only a subset of what is needed. Most risk model outputs have been developed for insurance or financial use, and have been applied in the development sector to provide a first-view of risk with little adjustment to specialist metrics and communication materials. Despite the acknowledgement that this can be a problem, no suitable alternative to the most common metrics (annual average loss (AAL), exceedance probability (EP) curves or return period (RP) losses) has been applied at scale.

The development and humanitarian sectors have made significant advances in risk metrics beyond risk to physical assets, for example in disaggregation of impact by gender, age and ethnicity and addressing peril-model gaps.

[23] www.icebreakerone.org
[24] riskdatalibrary.org
[25] Harris and Jaime. 2019

3.3.3 Model accessibility

Lack of access to risk insight raises the danger of poorly informed decisions. If risk owners in positions of national or local authority do not have access to the logic of the risk analysis, through no fault of their own they may make uninformed decisions and will have no rationale on which to base their conversation with the public.

Constraints include:

- Models developed commercially, such as those used extensively in the re/insurance market, are often not affordable or easily accessible by public sector decision makers.
- Even for licensees, models may come with some restrictions on access to the core assumptions and data used within the model due to Intellectual Property and commercial protection issues. This creates a barrier to understanding of uncertainty in the model.
- Risk models are delivered on a huge range of different platforms and in different formats, and most are not interoperable with each other. Input data has to be reformatted each time to work with models from different providers. This burden dramatically restricts the choice of models and their usage outside of a relatively small number of specialists.

Access to even basic risk understanding outside these institutions is challenging, especially for more excluded sections of the population such as low income earners and financially excluded women.

Today risk models commissioned by the international development sector are usually run by consultants on behalf of donors or decision-makers and give a snapshot of the risk at a specific point in time.

However, these outputs rarely give the end-user real intuition about their risk in the way that an expert within a re/insurer will be able to obtain through regular model use: sensitivity testing, updating input data on an ongoing basis and making adjustments to the model to reflect specific and unique characteristics about their exposure.

> **"In the past, Pacific Island countries have relied on consultants to provide specific risk advice and products, but the products are not scalable and interactive. Strengthening local capacity of women and men in key functions to undertake risk assessment is a long term goal for Pacific Island Countries. There are agencies in each country that are best placed to undertake community scale risk assessment given their understanding of community perception and values. Building capacity in risk assessment will allow agencies to provide timely advice to policy and decision makers."**
>
> Hervé Damlamian and Litea Biukoto, SPC Geohazards Division, Suva, Fiji

Such analytics (often commissioned for single projects or transactions) are unlikely to transfer any lasting level of knowledge to risk owners in a vulnerable country. This remains a fundamental paradox – that the centre of gravity for risk science and understanding remains distant from the actual risk owner.

If effective risk management decisions are to be made, end-users must understand the data and assumptions in the models used. The private re/insurance market has learned this over the past 30 years, and has notably improved its ability to prepare for losses from major catastrophe events as a result. **To empower risk owners in this way, there has to be a dramatic improvement in accessibility.**

Such a shift could be achieved through a series of entirely achievable changes:

- Increasing interoperability between models and data standards for input and output data.
- Significant capacity development in the understanding of risk, use of models and their outputs.
- Access to risk insight on open platforms so that countries can monitor their own disaster and climate risk.
- New technology solutions to make complex models accessible from desktops, when previously computer intensive environments have been necessary.

Solutions to these challenges are already available or in development, a number of which are shown in Chapter 6. More focus is needed particularly on the delivery of open, climate-related risk models on platforms that are practically and technologically accessible to end-users in the most vulnerable locations. Many global and particularly local models already exist which could be converted to be interoperable with these platforms; the investment required is modest if the collaborations can be made possible.

The Insurance Development Forum (IDF) is leading industry efforts to address many of these issues. Industry has funded the development of Oasis LMF, is developing common open data standards for exposure and risk model results and is proposing a public-private partnership to make open model and data content available to risk owners in vulnerable countries at scale.

With the increasingly broad range of potential users, the ecosystem and any internal analytical components must be flexible enough to be able to distinguish between different types of end-users, such that the outputs can be used for different risk mitigation and adaptation purposes.

3.3.4 Education and communication

Institutional education and communication

Making education across disaster reduction and risk analytics more available will build capacity for the future. The majority of skills that are applied in risk analytics are gained in Science, Technology, Engineering, and Maths (STEM) subjects.

Expertise in climate change and risk may vary greatly depending on education levels and integration of these fields into a national curriculum. Gender disparities and limited interdisciplinarity in education drive limitations in professional level capacity and result in blindspots in risk analytics.

Capacity building approaches that engage women and men from diverse backgrounds and skillsets are needed to ensure the maximum value of risk analytics can be achieved, and that its processes and outputs can be put to use most effectively at the institutional level.

The engagement of local universities in risk analytics is one efficient way to use existing structure, build on valuable local knowledge, and to enhance them to achieve this goal.

For instance, in 2015, KfW produced in collaboration with the government of El Salvador a lighthouse study on climate finance applying the Economics of Climate Adaptation framework[26] supported by the CLIMADA platform[27], which aimed at defining a complete portfolio for the capital city of the country. Local universities co-developed teaching modules for the government but also for post-graduate students and government staff. In 2017, the Minister of Environment of El Salvador featured the methodology in its contribution to the COP23.

Strong ownership at the start of a project between beneficiaries, development banks and private sector partners can promote collaboration and strengthen institutional education and communication. Chapter 4 provides good examples of such partnerships and the importance of ownership of the project from the start.

Communication between governments and citizens

In the space of a few months the parameters of pandemic modelling (e.g., the 'R' number) have become a key concept in public discourse in some countries, around which the plan can be explained and the public's consent can be gained.

We must lock in this type of learning. The research and epidemiological models being applied are complex, but the concept and the language around them are not. In the context of disasters caused by hydrological, meteorological or geophysical hazards, the concepts of frequency, severity and probability are not difficult to comprehend or communicate and should be key in gaining the confidence and consent of people exposed to their risks.

START Network cites the importance of science communication in ensuring modelled outputs – the representation of impact – are relatable to users' or community decision-makers' reality rather than using proxy indicators that are difficult to interpret and query.

The use of household economic models is one approach being used to enable people at risk to recognise their impact profile and in doing so being able to validate or refute it[28]. If people are able to validate or feed back on their reality compared to models, this could potentially provide a wealth of data to improve those models.

Additionally, the culture of risk in different communities must be taken into account when promoting risk education. If risk analytics can adjust its reliance on the traditional insurance metrics, and speak directly to citizens, it can become a more useful tool for citizens to understand their risk.

[26] Souvignet et al., 2016; Wieneke and Bresch, 2016

[27] Aznar Siguan and Bresch, 2019

[28] Harris and Jaime, 2019

3.4 Key points

1. There is demand for greater access to risk models and data including access to open data and tools to support local capacity building. There is also demand for integration of local research into the process.
2. Risk analytics must be made relevant by understanding the responsibilities and the decisions that risk managers/owners must take; this should influence the information products and metrics provided, and the scope, scale and granularity of analysis. No framework exists to help align end users with the relevant standards and modelling techniques. A project is needed to analyse the core needs of a diverse set of users to define a common framework.
3. Developing a risk analysis function is an evolutionary process. As users gain experience, more complex methods and tools may be used, more local research may be integrated and decisions become increasingly well-informed.
4. Access to risk analytics is restricted by several factors:

a. complexity, cost and lack of risk education limit the opportunity to build and use models locally;

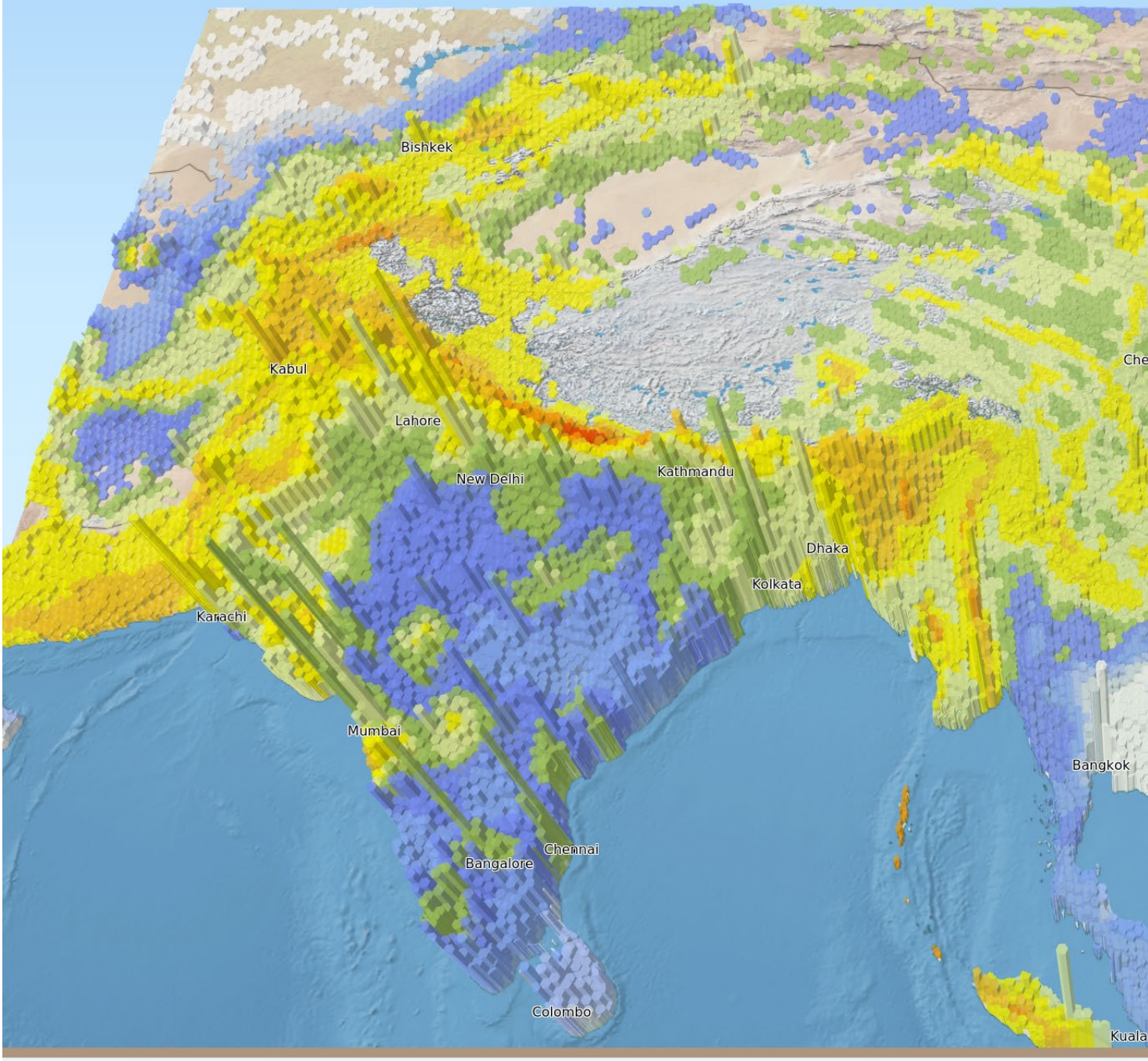
b. lack of systems to monitor, measure and manage environmental or hazard information limit the ability to build accurate models;

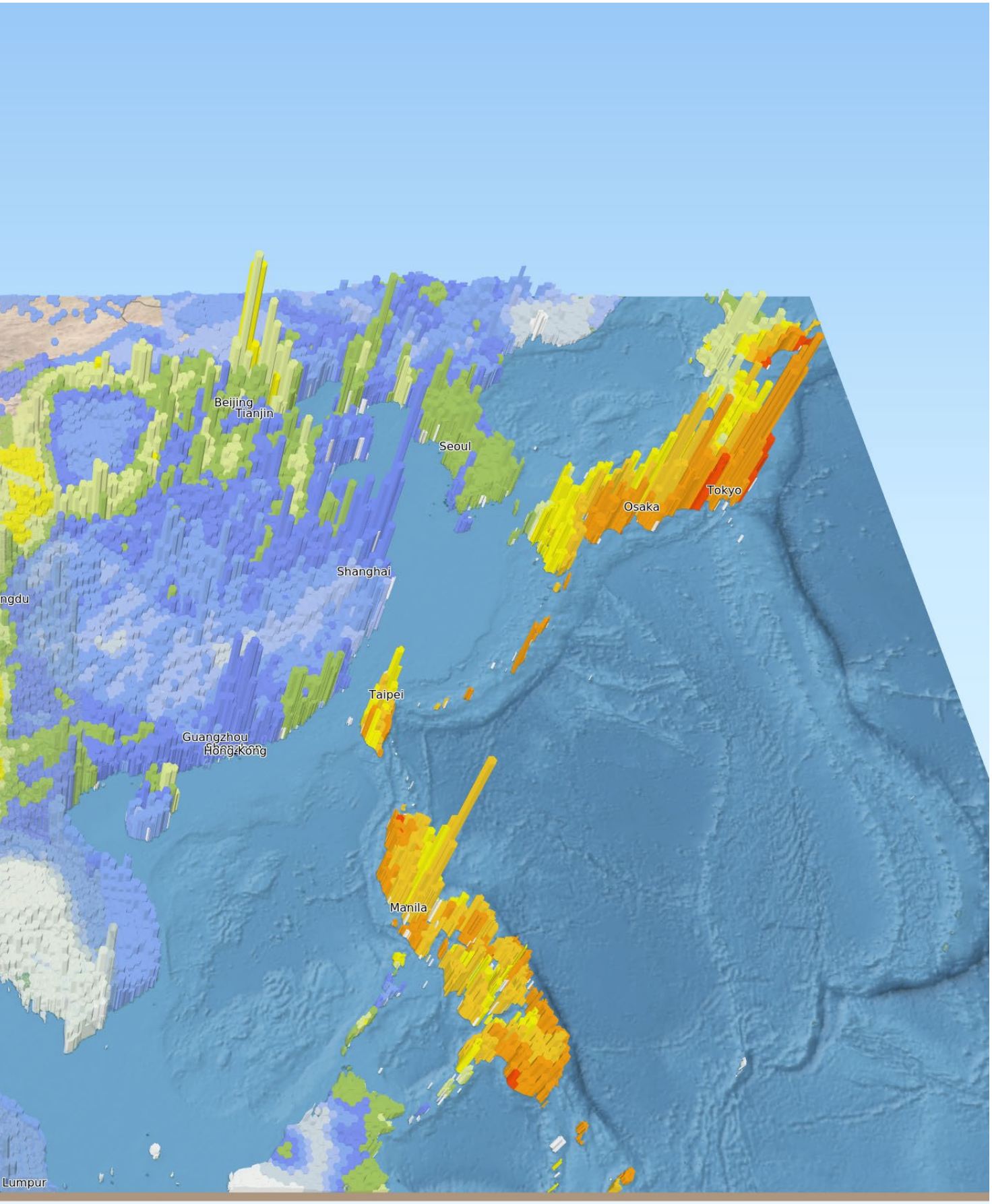
c. lack of standards and guidelines cause inefficiencies or lead to costly duplication of effort; and

d. risk metrics do not cover the full scope of development sector needs.

5. To increase access to models we must increase interoperability, transparency of methods and assumptions, and provide users with the means for continuous access to model frameworks.
6. Capacity in risk education must be integrated into any programmes funded to build capability in risk analytics.

Illustration of the built environment exposure to earthquake hazard.
The vertical bars represent exposure, with greater height corresponding to greater concentration of buildings and population. Colours indicate the level of seismic hazard, with warmer colours corresponding to a higher level of hazard. The Himalayan belt, eastern Japan and the Philippines are characterized by high exposure to significant levels of seismic hazard. These hazard and exposure layers are key components of the Global Earthquake Risk Model developed by GEM Foundation (https://maps.openquake.org/map/global-seismic-risk-map/)




Beijing
Tianjin
Seoul
Tokyo
Osaka
Shanghai
ngdu
Taipei
Guangzhou
Hong Kong
Manila
Lumpur

The benefits of building risk analytics capacity in country

4

Sichuan Province after 2008 earthquake. China.
Photo: © Wu Zhiyi / World Bank

The benefits of building risk analytics capacity in country

4.1 Overview

In many countries risk analytics capability is nascent. Using a number of case studies, this chapter highlights the importance of local context, and the benefits of more open and inclusive, 'bottom-up' approaches to model development. We will show that the co-development of risk models through collaborative, transparent and open processes leads to better understanding and ownership of the risk at the local level, empowering local institutions to inform, promote and execute disaster risk prevention, risk transfer and anticipatory action.

> **"Developing countries, in particular the least developed countries, small island developing States, landlocked developing countries and African countries, as well as middle-income and other countries facing specific disaster risk challenges, need adequate, sustainable and timely provision of support, including through finance, technology transfer and capacity building from developed countries and partners tailored to their needs and priorities, as identified by them"**
>
> Guiding Principle M, Sendai Framework for Disaster Risk Reduction, 2015

> **"Countries and communities will welcome new methods and tech-based solutions to their data gaps.**
>
> **"Governments are able to raise the necessary resources to build capacity and integrate tech-based solutions to their data gaps.**
>
> **"Academia, civil society and private companies will work together to create standards and identify replicable best practices."**
>
> UN Sustainable Development Solutions Network, 'Counting on the World to Act', 2017[1]

[1] https://countingontheworld.sdsntrends.org/2019/theory-of-change/

4.2. Case studies in building country risk analytics capability

Four case studies are shown at Annex A, covering diverse applications in Asia, Africa and South America. They illustrate how models can be successfully developed and applied through partnership between the modeller/provider and stakeholder/user.

They show how application of six key principles contributes towards achievement of SDG goals and Sendai Framework (SF) targets, particularly: SDG 13.1 to strengthen resilience and adaptive capacity; SF Target E to implement DRR strategies; and SF Target F to enhance international cooperation. These enabling principles are:

- Integration of local knowledge and vulnerability and exposure data
- Open sharing of research and transparent communication
- Clear methodology linking to international standards and best practice
- Good governance – organisational, information management
- Collaboration at multiple levels across sectors
- Capacity building through training and education

4.2.1. Integration of local knowledge and data

Evidence drawn from the case studies is shown below, under the headings of each of these principles.

> **Data is traditionally the province of the equipped and the funded. Many national governments do not have the capacity to analyse and use data, even if they have the means to collect it. Development actors and the private sector have the capacity, but the true dividends of interoperable, convergent data and analytics are missed.**
>
> **[…] It is critical that momentum is not lost, and that coordinated integrated global and national efforts strengthening data generation, statistical capacity and reporting continue.**
>
> UNDRR (2019)[2]

The act of gathering and organising local data provides a useful focus in building institutional capacity. It demonstrates the application of data to models, and the value of local research. **Case study 1** (drought risk in Zambia, Tanzania and Angola by Rudari, Gignac-Eddy and Gomes, see **Annex A**) was conducted in two phases. The focus in the second phase was on local participation in developing and using the risk results to develop policy recommendations. The result was increased ownership of the risk profiles, especially when compared with the first phase of the project, when local engagement for data collection could not take place. The approach resulted in new risk transfer mechanisms, and improvements in government policy and risk awareness.

In the development of the Pacific Risk Information System (PACRIS) for natural hazards in Pacific Island Countries (PICS), the Pacific Catastrophe Risk and Financing Initiative (PCRAFI) involved co-development of country risk atlases and other knowledge products to communicate risk information to policy and decision makers[3]. The database is now being used as a tool for Pacific Island nations as a fundamental data set for a wide range of risk assessments and DRR applications.

Similarly, the Rwanda National Risk Atlas brought available information for five hazards (drought, flood, landslide, earthquake and windstorm) and six elements at risk (population, buildings, roads, schools, hospitals and crops) together to generate evidence-based risk information to guide national and sub-national development planning and investment.

A UNDP policy specialist reported the value of this project in building local risk understanding, pointing out: *"Many expressed concern that this very technical process would deliver complex outcomes, with limited scope for real-world application in development decision-making. This could not be further from the truth."*[4]

[2] Global Assessment Report on Disaster Risk Reduction 2019 – GAR Distilled. United Nations Office for Disaster Risk Reduction (UNDRR 2019)

[3] https://www.gfdrr.org/en/pacific-catastrophe-risk-assessment-and-financing-initiative-phase-3

[4] https://www.undp.org/content/undp/en/home/blog/2018/The-only-way-to-reduce-risk-is-to-understand-it.html

4.2.2. Open sharing of research and transparent communication

Open software tools and information systems (for example OpenQuake, Oasis LMF, CLIMADA, InaSAFE, Rasor[5]) are used by disaster managers worldwide at local, provincial and national government levels to understand risk and to develop risk reduction strategies and contingency plans for response and recovery. They could be used so much more.

Case study 2 by Acevedo and Schneider (Annex A) describes how GEM has engaged scientists and engineers across academic, public and private sectors, and from local to national government in Colombia and elsewhere in South America.

Starting with the South America Risk Assessment (SARA) project in 2013, and continuing to the present Training and Education for Earthquakes (TREQ) projects, an ecosystem of projects and partnerships has informed a wide range of DRR activities, including building codes, insurance, national disaster management, and local urban planning.

This level of communication and support across sectors and for a wide range of applications is the product of nearly a decade of investment in capacity building projects.

Case Study 3 (Souvignet, Annex A) explores further use of open source modelling to build a shared view of risk between governments, their agencies and their partners. The context is the use of the Economics of Climate Adaptation (ECA) methodology[6] to analyse the impact of climate change on an economy, in this case in San Salvador. The CLIMADA open risk modelling system is used to analyse the costs and benefits of specific adaptation measures, helping a government to prioritise its investment in risk management. A further case study on San Salvador (Detken[7]) demonstrated at city level the financial value of combining risk transfer and risk prevention in an overall risk layered strategy.

A range of open tools has also been developed mainly for scenario planning by disaster managers and local government officials. InaSafe, together with mapping tools like QGIS and Open Street Map (OSM), have been used effectively to increase the uptake of science by disaster managers in Indonesia in a project funded largely by the Australian Government[8].

The success of InaSafe in Indonesia led to GFDRR applying the same approach to develop WebSAFE in the Philippines, and PacSafe in the Pacific, which is now being used as a training tool by the SPC in Tonga/Fiji.

These tools may be combined with local exposure and vulnerability data to provide a more sophisticated probabilistic risk analysis. A good example of this can be found in Riskscape, a multi-hazard risk modelling tool developed by the New Zealand government, which has been used to train government disaster management officers in Samoa and Vanuatu in the MFAT PARTneR project[9]. As exemplified by the PCRAFI initiative in the Pacific, the benefits of these tools are diminished if there is no underlying local data.

---

5 These model platforms are described in Chapter 6

6 The Economics of Climate Adaptation (ECA) methodology combines state-of-the-art probabilistic risk modelling techniques with a bottom-up and in-depth inter-sectoral dialogue between all local stakeholders of an investment project (Box 4.5). The methodology was designed to be flexible and adaptable to a wide range of user needs and applications for climate adaptation financing. The ECA methodology was first applied in a project in El Salvador (Souvignet, Annex A) and is now being extended by the InsuResilience Solutions Fund (ISF) in collaboration with the United Nations University (UNU-EHS) to projects on drought and flood risk in Honduras, Vietnam and Ethiopia. Information on CLIMADA may be found at https://wcr.ethz.ch/research/climada.html

7 https://www.insuresilience-solutions-fund.org/content/4-news-events/9-understanding-climate-risks-what-does-it-mean-for-san-salvador/understanding-climate-risks-pdf.pdf

8 https://www.dfat.gov.au/about-us/publications/Pages/aus-indonesia-facility-disaster-reduction-completion-review

9 https://niwa.co.nz/natural-hazards/research-projects/partner

Capacity building in partnership

In 2018, The German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMUB) awarded a 2-year project from its International Climate Initiative (IKI) for the co-development of robust, open and transparent catastrophe risk models in Bangladesh and the Philippines on the Oasis LMF platform and to make the available to in-country stakeholders along with the knowledge and tools on how to update them.

This 2-year project brings together a consortium of international experts in catastrophe risk modelling, risk finance and climate change impact analysis with in-country scientific agencies, universities, the private insurance market and national and local government stakeholders responsible for disaster risk management and Ministry of Finance[10]. A key goal is to create end-user ownership and long-term in-country sustainability of catastrophe modelling and risk management and finance, bringing together the scientific community with the finance sector.

The project provides a template for other countries to follow, if risk transfer transactions are to be based on an equal understanding of risk.

4.2.3. Clear methodology linking to international standards and best practice

> **If you [the private sector] engage us with know-how, technology and data then we have a win-win situation.**
>
> Dr Abbas Gullet, former Secretary General, Red Cross Kenya, speaking at Aon's 'Collaboration to close the protection gap' conference, London February 2020.

In **Case Study 4** global risk modelling expertise and standards (GEM's OpenQuake open platform and AIR Worldwide's model) were combined with local expertise and data to build a national probabilistic earthquake hazard model and seismic zonation map.

The resulting outputs were leveraged in the development of a revised national building code for Armenia[11] and national capacity for building and maintaining the model.

4.2.4. Good governance – organisational and information management

Technology solutions are seldom successful on their own in removing barriers to sharing information (Box 4.6). Technology may form part of the solution, preferably as part of a wider approach that facilitates sharing of information, including by way of significant investments in nurturing partnerships, network strengthening and building trust[12].

As we have seen so far throughout this report, collaboration is key. For instance, the Australia-Indonesia Facility for Disaster Reduction (AIFDR) was formed in 2009 as collaboration between governments of Australia and Indonesia to help develop technical capability for Indonesia's national disaster management program, which was newly formed in 2008.

Geoscience Australia facilitated the inter-agency science collaboration that led to the clarification of mandates of five key science agencies, and establishment of robust governance arrangements for the development and revision of national earthquake hazard maps[13]. It is important to note that the mandates resulted because of the trust that was developed through collaboration and capacity building across the relevant agencies.

Without these mandates, the resulting hazard maps would never have been used to revise the guidelines for building and infrastructure design and construction.

In the development of the Armenia earthquake hazard map in **Case Study 4**, the existence of an agency with a clear mandate for seismic risk mitigation[14] ensured that the new hazard maps were (i) approved by government, and (ii) adopted by the Committee of Urban Development for inclusion into the seismic building code after the project was completed.

Finally, in **Case Study 1** (Annex A) Rudari et al regard the "integration of data from hydrological, meteorological, and statistical agencies into decision-making" as fundamental to achieving policy outcomes.

[10] The project is jointly implemented by Oasis Loss Modelling Framework, Potsdam Institute for Climate Research Impact PIK), Met Office, KatRisk, and multiple partners at national level in Bangladesh and the Philippines. Additional information is available at: https://oasislmf.org/application/files/7215/5897/4850/Climate_and_Catastrophe_Risk_Assessment_in_Asia.pdf

[11] In 2019 Armenia updated all their Building Codes which now exist in draft form and are now going through the Government approval process.

[12] https://www.mfat.govt.nz/assets/Aid-Prog-docs/Research/Climate-Change-and-DRR-Synthesis-Report-Final-v6.4.pdf p. 27

[13] https://www.dfat.gov.au/about-us/publications/Pages/aus-indonesia-facility-disaster-reduction-completion-review

[14] the Armenian National Survey for Seismic Protection (NSSP) under the Ministry of Emergency Situations (MOES).

Regional guidelines for risk assessments are being developed for application at different scales (community, urban and country) with national counterparts and will be socialised through participatory workshops and case studies.

The use of tools to contextualise natural hazard risk have been tailored and tested across a number of countries and applications. Of these, InaSAFE and RiskScape were trialled; however, the gaps in hazard, exposure and vulnerability data for target areas have hindered their uptake. The data gaps are being addressed through various initiatives. In addition to this, the routine processes of government in approving development and making decisions needs to be understood so that the use of the tools can be seamlessly integrated and used by duty officers.

Hervé Damlamian and Litea Biukoto, SPC Geohazards Division, Suva, Fiji

4.2.5. Cross sector and multi-level involvement, public-private partnerships

Historically, the public sector has primarily taken responsibility for developing hazard monitoring systems, databases and associated models for hazard assessment, and their applications to building codes or other safety regulations.

In parallel, the private sector has focussed on risk assessment, particularly for risk transfer/retention mechanisms such as (re)insurance. Governments have either been self insured or relied on post-disaster aid.

This separation of public and private roles has been exacerbated by the lack of open information on the public side as well as the desire to protect commercial interests and intellectual property for commercial benefit. The barriers are gradually lifting in recognition that public and private sectors must work together to fully assess risk and incorporate risk-based decisions into planning and sustainable development.

The formation of the GEM (Global Earthquake Model) Foundation as a public-private partnership between national government organisations and (re)insurance companies in 2009 was a major step in this direction for the catastrophe modelling industry (Keller and Schneider, 2015)[15].

GEM has institutionalised the public-private partnership as part of its statute, with clear roles and responsibilities of members to share a common vision and principles[16]. The InsuResilience Solutions Fund applies the ECA methodology as a catalyst to foster public-private partnerships for developing and implementing new risk mitigation and risk transfer options (see box). As noted by Souch and Whitaker in the Oasis LMF project in Bangladesh and the Philippines, it is necessary. to bring together the scientific community with the finance sector in order to achieve sustainability of catastrophe modelling for risk management and finance.

Doing so within an open source framework benefits everyone and helps build trust between public and private sectors.

[15] Keller, N. and Schneider, J. (2015): Working together to assess risk from global to local: lessons from the Global EarthquakeModel. In: Planet@Risk, 3(2): 255-259, Davos: Global RiskForum GRF Davos. Available at https://planet-risk.org/index.php/pr/article/viewFile/215/415

[16] https://planet-risk.org/index.php/pr/article/viewFile/215/415

4.2.6. Training, education and sustained commitment

Training, education and long-term commitment is fundamental in all of the case studies shown.

As noted above, open tools and international-local partnerships for knowledge sharing are also important facilitators for training, but they cannot substitute for the long-term commitment to education and sustained engagement from all stakeholders to achieve success[17].

Most current projects in fact are building on capacity development projects conducted over the past decade or more, such as those summarised by GFDRR in its volume of case studies (Simpson et al, 2014)[18].

For instance, in the Philippines, there is quite a long history of development aid supporting science and technology capacity building for natural hazards, which has led to a wide range of tangible outcomes: improved cyclone and volcano forecasting used in evacuations, multi-hazard risk assessment used in local planning[19], and a new national probabilistic earthquake hazard model[20] under evaluation for revisions to the seismic provisions in the Philippine building code.

The Oasis Phiippines and Bangladesh project is able to build upon a history of development. This started with improvements in data collection and monitoring for hazard warnings and impact scenarios, and in turn fed into formal probabilistic hazard and risk assessment. Now, the project is developing capacity in full probabilistic risk modelling. So far more than 100 participants across 30+ institutions spanning the financial sector, government, NGO and academia have attended workshops and online training. Several Philippine scientists have spent extended periods of time (3-months) embedded within the project team at the Potsdam Institute of Climate Impact Research (PIK) to further develop their expertise in climate change impact modelling.

Similarly, GEM's current work with local governments on urban risk assessment in three cities in Latin America leverages previous work to develop collaborations at the national level and to develop necessary partnerships with academic institutions (**Case Study 1** and Box 4.9.) In this way, the work has evolved from developing seismic catalogs and hazard models at the national level to detailed risk assessments that include other hazards and cascading impacts necessary to develop integrated risk assessments and urban planning.

Building local risk understanding in South America

The South America Risk Assessment project (SARA, 2013-2015), funded by the Swiss Re Foundation, brought together international best practice tools and methodologies with local expertise and knowledge needed to establish local ownership and define risk assessment objectives and priorities. GEM Foundation combined these elements and focussed on developing local capacities across sectors (academic, public and private), across technical disciplines (e.g., hazard, risk, IT), and through the implementation of disaster risk reduction policies and programs.

GEM provided its OpenQuake earthquake hazard and risk analysis software and other tools and databases freely and openly to all participants. More than 50 of the region's experts across 17 institutions collaborated to produce critical data sets, develop common approaches, and develop open-source tools for both data collection and interpretation.

Ana Beatriz Acevedo, EAFIT University, Colombia; and John Schneider, GEM Foundation

17 https://www.insuresilience.org/wp-content/uploads/2020/03/InsuResilience_Analysing-Stakeholder-Needs_Risk-Data.pdf p. 50

18 https://www.gfdrr.org/sites/gfdrr/files/publication/Understanding_Risk-Web_Version-rev_1.8.0.pdf

19 https://reliefweb.int/report/philippines/enhancing-risk-analysis-capacities-flood-tropical-cyclone-severe-wind-and

20 https://journals.sagepub.com/doi/full/10.1177/8755293019900521

4.3 Key points

Application of six key principles is essential for the development of risk assessment capability in country, to assure that risk information is usable, useful and used for risk reduction:

1. local knowledge and vulnerability and exposure data, supported and maintained by data monitoring, management and analysis infrastructure;
2. open information and transparent communication, which are essential to developing trust in the information and ownership of the risk;
3. clear methodology linking to international standards and best practice, bringing together the scientific community with the finance sector, and assuring the credibility of the products
4. good governance in terms of the institutional responsibilities and authority, as well as sharing of data through open policies, which together assure that results will be accessible, and information will be used to inform policies;
5. cross sector and level involvement, linking public and private sectors, as well as academic with national to local institutions to maximise buy-in by all stakeholders; and
6. training and education, which is the foundation of all capacity building, and which must be approached with a long-term, sustainable approach in order to achieve development goals.

How climate and disaster risk insights can drive gender-responsive action

5

Future climate risk decision-makers?
Photo: © UNICEF / Noorani

How climate and disaster risk insights can drive gender-responsive action

1. Introduction

Risk exposure and vulnerability to disasters can vary based on gender, with women and girls often more severely and differentially impacted.

Figure 5.1: Women and girls are more vulnerable to disaster risk

- Climate change and disasters generally hit women harder
- Women have lower levels of formal financial inclusion and are less formally employed
- There are gender differences in risks, needs, constraints and enablers
- More women are employed in agriculture

Female death rate (percentage of total)[1]

91% in 1991 cyclone in Bangladesh

61% in 2008 Cyclone Nargis Myanmar

70% in 2004 Asian tsunami

Boys are likely to receive preferential treatment in rescue efforts (data from 141 countries)[1]

Lower labour force participation rate of women than men in all regions[1]

980 million women are excluded from the financial system. There is a **9%** gender gap in financial access in developing economies[1]

39 economies prevent daughters from inheriting the same proportion of assets as sons[1]

Women can take on up to an extra **ten** or more weeks per year of unpaid care[1]

Gender considerations must be integrated into risk research to inform differentiated responses for women and men. However such integration is currently the exception.

Sex-disaggregated and gender risk data and analysis, gathered through quantitative and qualitative methods add depth and granularity to climate and disaster risk management and response.

In doing so, the insights can accelerate progress towards the Sustainable Development Goals (SDGs), specifically SDG 13 and SDG 5. This chapter explores the questions of how these climate and disaster risk insights can drive gender-responsive action towards these goals.

[1] Yellow box: Ikeda, 1995. Cropper and Sahin, 2009; Baez, de la Fuente & Santos, 2010; Soroptimist International of the Americas, 2008; APWLD, 2005; UN,2015b. Light blue box: Swarup et al. 2011. Green box: ILO LFPR database. Dark blue box: Demirgüç-Kunt et al., 2018. Brown box: World Bank, 2020. Red box: ODI, 2016.

5.2 Why do we need disaster risk analytics to be gender-responsive?

Gender influences vulnerability and exposure to disasters (Figure 5.1). Disaster losses disproportionately affect poor people with an impact on their wellbeing equivalent to an estimated $520 billion a year in consumption losses.[2]

The severity of the impacts of disasters strongly depends on an individual's level of vulnerability and exposure which varies based on factors including gender, disability and ethnicity.[3,4] The importance of gender is recognised in international policy frameworks, such as UNFCCC Gender Action Plan,[5,6,7] the Sendai Framework and the 2030 Agenda for Sustainable Development. SDG 1, target 1.5

International policymakers have called for more and better collection and use of sex-disaggregated and qualitative data to inform risk understanding.

The IPCC acknowledges that probabilistic metrics are important measures and techniques for vulnerability and risk analysis but call for complementary qualitative approaches.[8] The UNFCCC has identified the action to enhance capacity-building for governments and other relevant stakeholders to collect, analyse and apply sex-disaggregated data and gender analysis in the context of climate change.[9] Moreover, global guidance on monitoring and reporting on progress of the Sendai Framework recommends data disaggregation by sex.[10]

International development partners call for the prioritisation of gender equality and social inclusion (GESI) in private sector development (PSD) programming in recognition of the multidimensional nature of poverty, gender equality, exclusion and vulnerability.

This includes programming related to climate disaster risk management and financing that does not principally focus on GESI outcomes. GESI recognises that gender-based risks are intersectional, that is, based on other aspects of an individual's identity e.g., their economic status, ethnicity, age or the geography where they live. These aspects form multiple layers to an individual's social identity, each with implications for the risks faced and access to power, resources and decision-making. Such concerns must form an integral part of the design, implementation and M&E of programmes.[11]

There are gender differences in disaster risks to life. While deaths by gender can vary by country and disaster type[12], sex-disaggregated data shows that women and girls in developing countries are more likely to die in a climate change related disaster.

The female death rate was 91% in the 1991 cyclone in Bangladesh;[13] 61% from Cyclone Nargis[14]; and 70% in the 2004 Asian Tsunami.[15] Social norms, such as that women are more likely to prioritise their children's safety over their own, may be less likely to be able to swim, or have less access to information from early warning systems, can explain some of these vulnerability differences.[16] **SDG 1, target 1.5. SDG 13, target 13.1**.

Women can experience a higher mortality rate and face different disaster risks to health related to females' reproductive differences with males.[17] These risks relate to their sexual and reproductive health, such as the lack of access to emergency delivery and obstetric care, and feminine hygiene products.[18] For example, the Ebola outbreak in Guinea, Liberia and Sierra Leone led to a 75% increase in maternal mortality, across an 18-month period. [19]

Yet, a gender approach to understanding risks to life is not about an exclusive focus on women. Men have a higher incidence of death from the Covid-19 pandemic, despite similarities in cases between women and men, with potential contributing factors being sex-based immunological responses and social norms driven differences in behaviour (e.g. smoking).[20] **SDG 3 and targets 3.1, 3.2. SDG5, target 5.6**

There is a heightened risk of violence against women and girls post a disaster. In 2011 after two tropical cyclones hit Vanuatu a 300% increase in new domestic violence cases was reported.[21] In Sierra Leone gender-based violence and rape increased during the Ebola epidemic[22] and the economic impacts led to increases in child marriage and transactional sex.[23,24]

In New Zealand after the Canterbury earthquakes, overall crime levels decreased with the notable exception of domestic violence involving persons known to each other and/or the use and abuse of alcohol.[25] More recently, the COVID-19 lockdowns have led to widely reported increases in domestic violence worldwide.[26,27] **SDG 5 and targets 5.2 and 5.3**

2 Hallegatte et al, 2017.
3 IPCC, 2012.
4 Hallegatte et al, 2017.
5 UNFCCC, 2019b.
6 In 2014, the UNFCCC created "The Lima Work Programme on Gender" (LWPG) to implement gender-responsive climate policies and mandates across all areas of climate negotiations. In 2017 at COP 23 in Bonn the adopted the Gender Action Plan based on the earlier Lima Work Programme.
7 UNFCCC, 2019a.
8 IPCC. 2012.
9 UNFCCC, 2019b.
10 UNISDR, 2017. Technical Guidance for Monitoring and Reporting on Progress in Achieving the Global Targets of the Sendai Framework for Disaster Risk Reduction. https://www.preventionweb.net/files/54970_techguidancefdigitalhr.pdf
11 Government of Nepal, 2014; GESI Working Group, 2017.
12 Cropper and Sahin, 2009.
13 Ikeda, 1995.
14 Cropper and Sahin, 2009; Baez, de la Fuente & Santos, 2010.
15 Soroptimist International of the Americas, 2008; APWLD, 2005; UN,2015b.
16 WHO, 2011; IPCC, 2014; Araujo A. et al, 2007.
17 Strand et al., 2012 and Van Kerkhove et al., 2011, Diboulo et al. 2012 in IPCC, 2014.
18 https://www.unfpa.org/emergencies
19 Davies and Bennet, 2016.
20 Wenham et al, 2020.
21 UN Women, undated.
22 Save the Children et al, undated.
23 https://www.girlsnotbrides.org/child-marriage/sierra-leone/
24 Care, 2020.
25 Breetzke, King & Fabris Rotelli, 2018.
26 https://www.bbc.co.uk/news/world-asia-51705199
27 https://www.nytimes.com/2020/04/06/world/coronavirus-domestic-violence.html

There can be gendered differences in risks to livelihoods and incomes. Women are more likely than men to be poor, and are at greater risk of poverty if they are separated, widowed, or single mothers.[28] Many of the world's poorest women work informally in subsistence agriculture where they make up half of the labour force in a sector most impacted by climate change.[29,30] Overall women undertake a larger share of unpaid care work[31] with the monetary value globally of at least $10.8 trillion annually.[32]

This has implications for their vulnerability. It restricts women's economic participation rate and in turn the accumulated assets they can draw on at times of disaster. Women's unpaid care burden also contributes to the level of formality of their work, with more women than men working informally in a majority of countries.[33]

Lower economic participation rates mean women can experience lower levels of access to social protection to build resilience and recover from disasters. Women are disproportionately excluded from social protection schemes, out of the 4 billion people unprotected.[34] **SDG 1, target 1.3; SDG 5, target 5.4**.

If childcare infrastructure and services are closed after a disaster, then childcare responsibilities are more likely to fall on women. Such facilities are often deprioritised in post disaster reconstruction. This further restricts women's opportunities for employment and entrepreneurship in economic reconstruction efforts. Certainly, this has been a widely reported risk to women resulting from the COVID 19 pandemic.[35, 36, 37] **SDG 5 target 5.4**.[38]

There are gender differences in micro, small and medium sized enterprise (MSME) ownership and labour force composition in specific sectors, with geographic variation within and between countries.[39] For instance, women make up the majority of the garment manufacturing workforce in Myanmar.[40] If a disaster disproportionately impacts an economic sector, women or men may be more impacted depending on its gender composition. **SDG 5, target 5.5**.

Women have a lower capacity to invest in preventative measures and draw on during post disaster recovery with implications for their vulnerability. Additional to lower levels of asset accumulation from paid employment or entrepreneurship, gender-discriminatory inheritance rights constituted in law or due to customary practices mean women are less likely to have land or property assets registered in their name.[41] Consequently, women's risk profile in terms of exposure as property owners will be different to men's when considering property loss. **SDG 5, target 5A, SDG 1, target 1.4**

Women's lower levels of economic participation and the gender wage gap can further restrict their asset accumulation and undermine their insurance purchasing power. For instance, more than two-thirds of economies can improve legislation affecting women's remuneration, and where the law ensures greater equality of economic opportunity between women and men, female labour force participation is higher. Moreover, there is a correlation between such legal reform and a reduction of the wage gap.[42] This suggests that women in countries with less gender equality in the law may have less resilience at times of a disaster. **SDG 5, target 5.1**

Women face barriers in access to information and finance, critical to build resilience and recover from disasters. Mobile phones can be a valuable asset to receive climate information or receive cash transfers or insurance pay-outs. Yet, GSMA's 2020 data indicates that women in low and middle-income countries are on average 8% less likely than men to own a mobile phone, and 20% less likely to use the internet on a mobile than men, and 20 % less likely to have a smart phone.

They also have lower levels of access to insurance including climate risk insurance, in a wider context where 980 million women are excluded from the financial system, representing a 9% gender gap in financial access in developing economies.[43] **SDG 5, target 5B, SDG 1, target 1.4**

Women and men are not homogenous groups and different women face different risks.[44] For example, a widowed woman may face different risks to either a divorced or unmarried woman with young children, or a pregnant married woman. Moreover, a woman working informally in a home based enterprise will face different risks to a formally employed woman or a woman SME owner with a registered enterprise. These can vary based on an individual's life cycle stage and economic strategies.[45]

Gender-based risks are intersectional, that is based on other aspects of an individual's identity. For instance, their economic status, ethnicity, age or geography.[46] These risks and vulnerabilities can also vary for gender minorities, beyond the binary definition of gender.[47]

28 UN Women, 2015.
29 World Bank, 2012.
30 UNDP, 2019.
31 UNDP, 2019.
32 Oxfam International, 2020.
33 WEIGO and ILO, 2019.
34 ILO, 2019.
35 UN Women, 2020.
36 https://www.cgdev.org/blog/how-will-covid-19-affect-women-and-girls-low-and-middle-income-countries
37 Lewis, 2020.
38 SDG 5, target 5.4: Recognize and value unpaid care and domestic work through the provision of public services, infrastructure and social protection policies and the promotion of shared responsibility within the household and the family as nationally appropriate
39 GIZ, 2019.
40 ILO, 2018.
41 World Bank, 2020.
42 World Bank, 2020.
43 Demirguc-Kunt, A. et al, 2018.
44 IPCC, 2012.
45 UNCDF, 2017.
46 UNDP, 2019.
47 Rushton et al, 2019.

Identifying the financially vulnerable

The UK's Chartered Insurance Institute (CII)'s Insuring Women's Futures initiative to improve women's financial resilience, has taken a lifecycle approach to understanding women's risks, exposure and resilience to risk in life.[48,49] Meantime, AXA and the IFC took an economic segmentation approach to sizing the women's insurance market identifying five segments of women based on their socioeconomic bracket, dependents, and income status: salaried women without children; working mothers; retirees; women entrepreneurs; and low income customers.[50]

In this context, climate and disaster risk data can provide insights on these gender and other identity factors which influence differential climate change and disaster risks and impacts, and coping capacity. Recognising the role of gender, the Sendai Framework calls for a richer understanding of exposure and vulnerability within risk understanding.[51] The multidimensional aspects of risk exposure is emphasised by the UN which calls for a holistic and people-centred approach to vulnerability.[52]

Gender-responsive risk analysis requires a move beyond analysis of loss of physical assets. If it is to contribute to SDG goals it must study risk to people's health and wellbeing, and point to measures for economic resilience.

5.3 How can disaster risk analytics be gender-responsive?

5.3.1 How to build gender considerations into the risk analytics process

Gender considerations are relevant to all aspects of the risk understanding process. Each step of this process can be influenced by and influences gender norms – the dynamics of socially constructed behaviours, norms and relationships between men and women. This includes indicator development, quantitative and qualitative sex-disaggregated and gender data collection and research methods.

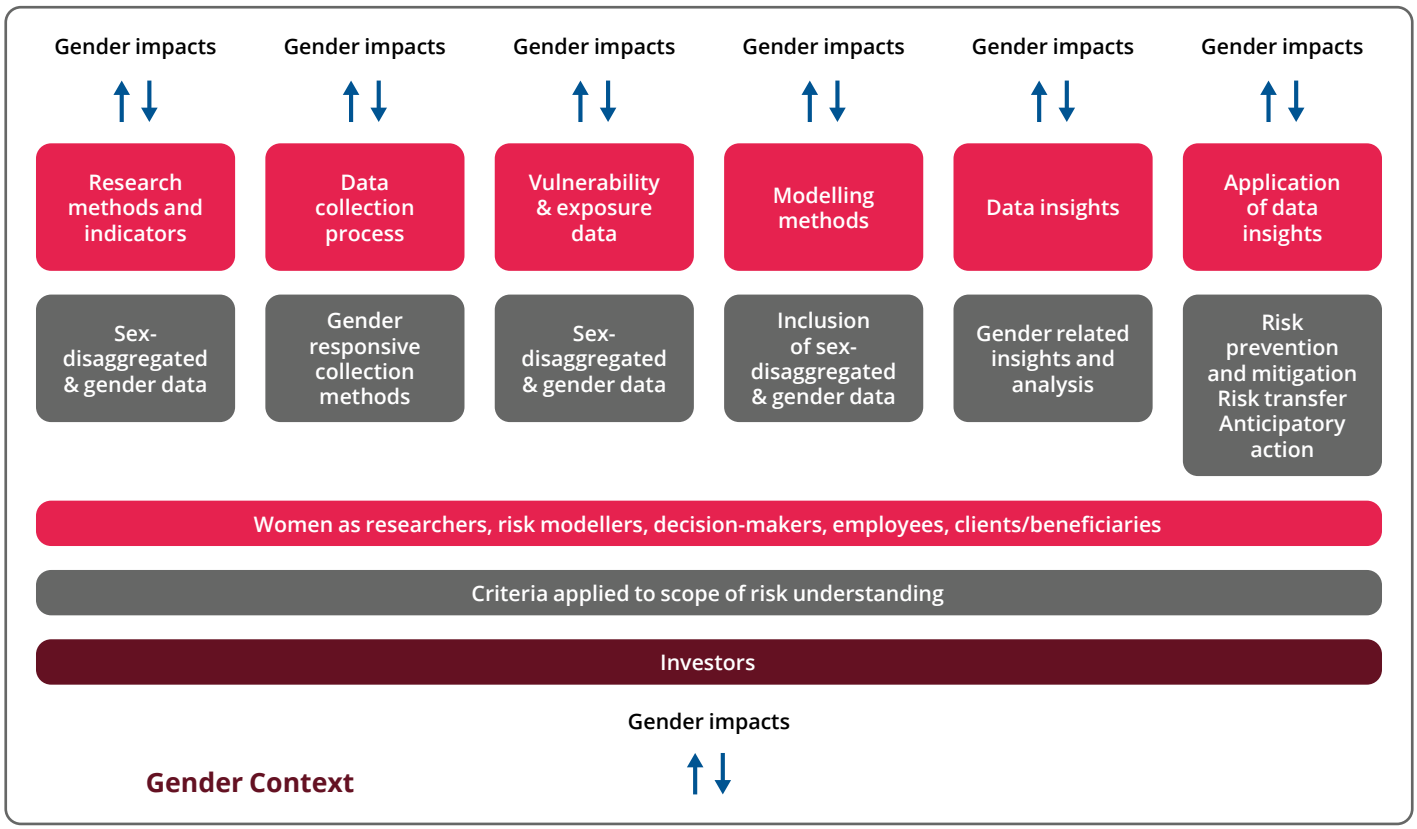
For example, sampling strategies and responses can vary depending on the gender of the enumerator, and how data is recorded, and the timing of data collection or focus group. Using qualitative approaches, researchers may elicit different information based on whether focus groups are single sexed or mixed.

Social norms can also influence the incorporation of gender in different risk modelling methods and capture within data platforms. Social norms also influence the criteria applied by institutional investors and/ or multilateral and bilateral development financial institutions that commission risk understanding, and they will influence their priorities for analysis of different intersecting components of risk and the application of the resulting data insights.

Further, women and men's respective levels of engagement can also differ within each stage of the process, as employees, regulators, or customers or/and beneficiaries. (Figure 5.1)

48 Portas and CII, 2020.
49 Portas and CII, 2019.
50 AXA, Accenture and IFC, 2015.
51 UN, 2019.
52 UN, 2019.

Figure 2: Gender is relevant at every stage of risk analysis



5.3.2 Gap Analysis

National survey datasets, key sources of information for vulnerability and exposure data, can and do include some gender data. Census data plays an important input to most risk models to inform national vulnerability understanding. Sex-disaggregated data is available within this national census or economic survey data, e.g. approximately 80% of countries collect it for labour force participation.[53]

This sex-disaggregated type of census and economic survey data can be drawn on for risk understanding about resilience levels and long term distress to individuals post a disaster.[54] Increasingly a wider range of data sets inform vulnerability and exposure risk understanding.[55] For example longitudinal data sets can add value to understanding gender differences in vulnerabilities in terms of resilience capacity and longer terms impacts of a disaster.[56]

The General Statistics Office in Vietnam collects sex, age and geographically (urban/ rural and province) disaggregated data on the proportion of the population to whom knowledge about flood and storm prevention and disaster risk reduction is disseminated.[57]

53 World Bank, 2016.
54 InsuResilience, 2020.
55 UN, 2019.
56 The first multi-disciplinary longitudinal study of childhood poverty to be carried out in more than one developing country: https://www.younglives.org.uk/content/about-us
57 InsuResilience, 2019.

Inclusion of gender data in public or private sector disaster risk modelling is not yet the default practice. The World Bank incorporates gender breakdowns in some exposure data sets, but not in vulnerability data.

However gender vulnerability data is being included in the 'Future of Indonesian Tsunamis: Towards End-to-End Quantification of Risk' (FITTER) project (see box.) The project is a cross-sector collaboration adding people-centred metrics to a catastrophe risk modelling approach.

Future of Indonesian Tsunamis: Towards End to End Quantification of Risk (FITTER)

University College London, Oxford Brookes University, Brunel University the Bandung Institute of Technology, Indonesia, and the **Insurance Development Forum** are collaborating on an innovative project convened by the Insurance Development Forum to model the impacts of tsunami in Indonesia. The project is co-developing with local stakeholders and experts, an innovative end-to-end catastrophe model on the open modelling platform Oasis.

The hazard component breaks new ground with high resolution bathymetry and wave modelling across the archipelago, but the model goes beyond traditional catastrophe modelling, with innovative elements including vulnerability functions that account for household welfare loss, and estimation of the secondary impacts of infrastructure on the local economy. This open model will be of use to both the government and insurance industry and enable modern disaster risk financing for Indonesia.

The project was convened by the **Insurance Development Forum** and is funded by Lloyd's, the Lighthill Risk Network and the Turing Institute.

Composite indicators and indexes can also be drawn on to understand both exposure and vulnerability to different types of hazards. The Global Earthquake Model Foundation (GEM) has sex-disaggregated data, such as on the head of household, in its social vulnerability data set and it draws on this when modelling its social vulnerability and recovery indexes.[58]

Data or information on social vulnerability is recognised as severely underdeveloped and a priority area for expanded work within the UNDRR – facilitated Global Risk Assessment Framework (GRAF). The GRAF anticipates that 'real reductions in risk will be through understanding and addressing patterns of vulnerability and exposure'.[59]

The GRAF acknowledges various dimension of impacts within its impact cube (e.g. human and economic) but it does not acknowledge gender related risks and impact as cross cutting themes within its framework, nor the value of sex-disaggregated data. The gender balance of individual representatives was a criterion in its selection of expert group members but not gender expertise per se. As such, going forward the integration of gender within this framework drawing on such expertise is urgently required.

The quantity of sex-disaggregated data in national data sets is increasing but there are issues of data quality and gaps, which need to be urgently addressed to enhance gender-responsive risk understanding. For instance, data may be incomplete, inconsistently collected, or not digitalised.[60] Gender data gaps include:

- Disaggregated data on damages and losses as these are usually recorded in terms of productive resources which tend to be owned by men;
- Losses related to reproductive activities of women, such as increases in unpaid care;[61]
- Material loss at household level broken down by male and female headed households;[62]
- Intra-household data to measure resilience and well being losses by gender.[63]

This means that there is sometimes insufficient granularity of data to provide a picture of womens' vulnerabilities and exposure to hazards to inform risk understanding. Over 70% of data for 58 SDG indicators linked to gender equality and women's empowerment is missing.[64]

There can be gender data gaps due to the design of data platforms, including disaster loss platforms as these systems may not allow sex-disaggregated data to be inputted. Indeed, the gap in financing to sustain a core gender data system in lower-income countries is between $170M-$240M a year between now and 2030.[65]

Even where gender data is included on data platforms, issues of accessibility prevent its use as an input to risk models. This is due to a lack of transparency, which must be addressed through greater use of open modelling principles.

58 https://index.opendri.org/dataset_list.html?idcountry=AA
59 GRAF, 2019.
60 UNDP, 2019.
61 ECLAC, 2003.
62 UN, 2015b.
63 Hallegatte et al, 2017.
64 UNDP, 2019.
65 Dat2X, 2019.

Freely available gender risk data and composite indicators are being overlooked. Data points related to monthly income, gender differences in education levels and formal SME ownership, financial access, or extent of gender legal differences could be considered. Existing indexes that provide insights into gender-differential vulnerabilities and exposure may also be drawn on such as Equal Measures 2030[66] SDG gender index[67] UNDP's Human Development Report's Gender Inequality Index (GII), and the World Bank's Women Business and the Law index.

There is scope to increase the integration of such information in different types of risk models to support more targeted allocation of resources. This is a matter of choice and awareness. Indexes draw on multiple data sets and choices are made as to which data sets to include and exclude. These choices reflect investor priorities depending on who is asking for and paying for the information, with implications for the emerging insights.

5.4 How can gender-responsive climate and disaster risk analytics be applied?

Climate and disaster risk insights can inform gender-sensitive[68] and also gender-responsive[69] risk understanding and responses. Gender-related insights may result in actions that focus on responding to the specific risks and needs of women and girls but can also focus on men and boys.

Nevertheless, responses may involve a specific focus on women and girls, given existing imbalances in society whereby they have been disadvantaged due to discrimination and social norms.

The greater vulnerability and exposure they can face due to their gender, may mean that deliberate resilience building actions are needed focused on women and girls.[70] Improved understanding on the gender dimensions of risk can inform both public and private sector stakeholder responses at different levels across risk prevention and mitigation; risk transfer; and anticipatory action.

Gender-responsive climate and disaster risk insights can be used by diverse stakeholders. Development partners may use this information to inform their financing and programme decision making at an international, regional or national policy level and in terms of its engagement in private sector and market development activities in multiple cross cutting thematic areas.

This is in the context of their institutional gender policies, such as the World Bank's Gender Strategy 2016-2023 – Gender Equality, Poverty Alleviation and Inclusive Growth.[71] Gender risk insights can also inform decision making within international climate finance funds such as the Green Climate Fund[72], the Adaptation Fund[73], and the Climate Investment Fund.[74] International climate financing mechanisms have varying approaches to their institutional gender strategies in a wider framework of their environment, social and governance lending and investment policies.

All incorporate some gender risk data to inform investment decisions.[75]

In the private sector, some insurance companies are using gender risk data to inform product design and delivery.[76] For example Swiss Re and AXA Egypt have worked with Women's World Banking in Egypt to offer insurance to low-income women entrepreneurs through Hemayet Lead in its design of 'solutions that are tailored as closely as possible to the reality of women's lives'.[77,78]

Moreover, the International Finance Corporation (IFC) is working to help insurers to design solutions that improve the financial security of women in emerging markets (See Annex B).

66 https://www.equalmeasures2030.org/

67 https://data.em2030.org/

68 Gender sensitive responses acknowledge the gender differential vulnerabilities between men and women due to the dynamics of socially constructed behaviours, norms and relationships, and consider evidence of factors that can result in gender differences and in doing so these approaches go beyond doing no harm to existing levels of gender equality.

69 Gender-responsive responses incorporate approaches that overcome historic gender biases to diminish gender inequalities.

70 UNDP, 2019.

71 World Bank, 2015.

72 https://www.greenclimate.fund/document/gender-policy See a library of its gender assessments here: https://www.greenclimate.fund/publications/documents?f%5B0%5D=field_subtype%3A342

73 https://www.adaptation-fund.org/wp-content/uploads/2016/04/OPG-ANNEX4_Gender-Policies-and-Action-Plan_approved-in-March-2016-1.pdf

74 https://www.climateinvestmentfunds.org/knowledge-documents/cif-gender-policy

75 DCED, 2019.

76 https://www.axa.com/en/magazine/why-do-we-need-a-specific-approach-for-the-womens-market ; https://www-axa-com.cdn.axa-contento-118412.eu/www-axa-com%2F67e42579-84bf-41f0-9cd9-925f1a6582f5_women-in-insurance-vdef.pdf

77 https://reports.swissre.com/2018/business-report/predict-prepare-protect/expanding-protection-online-only/enabling-women-entrepreneurship-in-egypt-online-only.html#

78 https://www.axa.com/en/magazine/why-do-we-need-a-specific-approach-for-the-womens-market

5.4.1 Gender analysis in risk prevention

National Planning: Climate Change and Disaster Risk Reduction Strategies

Gender climate and disaster risk insights can inform national climate change and disaster risk reduction (DRR) plans and strategies and related financing approaches. The forms these take vary between countries and may include standalone national disaster risk reduction (DRR) strategies and national climate change related strategies – NDCs – operationalised in diverse formats. **SDG 1, target 1.5, indicator 1.5.3**.

Guidance is available. The Sendai Framework implementation guidance[79] advocates the development of gender-responsive approaches to national DRR and under Priority 4 'Build back better'. It recommends drawing on sex-disaggregated and qualitative data on gender differences related to hazards, exposure, vulnerability, capacity and risk information.[80]

Furthermore, it suggests that any disaster loss databases collect data disaggregated by gender and advocates that the process for development of DRR plans and responses should be inclusive and participatory and include consultation with women and women's groups.[81] The Global Facility for Disaster Reduction and Recovery (GFDRR) also provides guidance on how to integrate gender risk information into DRR strategies[82] and in Post-Disaster Needs Assessments (PDNAs).[83]

Gender risk insights incorporated in such plans may include gender differences in vulnerabilities to disasters within populations and gender-differential impacts of previous disasters, for instance related to violence against women or access to reproductive health. They may further include gender context information that highlights differences in climate or and disaster risk vulnerability or exposure. For example, economic participation rates of women versus men in different sectors, which may inform gender-equitable economic reconstruction priorities.

There are examples of sex-disaggregated risk data and insights being incorporated within disaster risk reduction strategies, such as in Mozambique and Kiribati (see box). Gender risk insights and the collection of sex-disaggregated risk data, are also being incorporated into the development of gender-responsive national climate change strategies. The International Institute for Sustainable Development (IISD) has worked with the Governments of Benin,[84] Togo,[85] to undertake a dedicated gender analysis to support their NAP process.[86,87,88] The International Union for the Conservation of Nature (IUCN), has supported governments[89] to create climate change gender action plan (ccGAP) including in Peru, Zambia[90] and Tanzania.[91,92]

As Monitoring and Evaluation systems are being established to track implementation progress of these strategies and track the gender responsiveness of these investments, governments are increasingly collecting sex-disaggregated data with the intention of conducting a gender analysis on the data.[93] For example, UNDRR (formerly UNISDR) provided support in the development of national disaster risk reduction strategies in Argentina, Chile, Guatemala and Paraguay and incorporated sex-disaggregated indicators.[94]

Nevertheless, there are gaps in the integration of gender- risk data into these strategies and plans. For example, there is a need for greater focus on risks related to the unpaid care responsibilities women face, in particular related to childcare, as well as to address security risks posed due to the levels of violence against women. In part low levels of gender diversity within the groups that develop such strategies, and insufficient consultation with women's groups and gender experts have been identified as enablers.

79 The UN agency that supports countries and societies in its implementation, monitoring and review of progress against the framework.

80 UNISDR, 2019.

81 UNDRR, 2019.

82 GFDRR, 2018.

83 GFDRR, 2017.

84 http://napglobalnetwork.org/resource/pour-un-processus-de-plan-national-dadaptation-pna-qui-reponde-aux-questions-de-genre-au-benin/

85 http://napglobalnetwork.org/resource/orientations-pour-la-prise-en-compte-du-genre-dans-le-processus-de-pna-du-togo/

86 http://napglobalnetwork.org/2020/01/naps-and-the-gap-five-ways-national-adaptation-plan-processes-can-support-implementation-of-the-enhanced-gender-action-plan/

87 Dazé and Dekens, 2018.

88 Dazé and Church, 2019.

89 See full details here: https://genderandenvironment.org/works/ccgaps/

90 https://genderandenvironment.org/resource/zambia-climate-change-gender-action-plan-ccgap-report/

91 United Republic of Tanzania, 2013.

92 IUCN, 2012.

93 http://napglobalnetwork.org/2020/01/naps-and-the-gap-five-ways-national-adaptation-plan-processes-can-support-implementation-of-the-enhanced-gender-action-plan/ and http://napglobalnetwork.org/2020/03/unpacking-gender-responsive-adaptation-finance-key-issues-and-the-way-forward/

94 UN, 2019.

Gender within a national climate change and disaster risk management plan

Kiribati has a joint implementation plan for climate change and disaster risk management (KJIP) 2019-2028.[95] To inform this policy it undertook an analysis to strengthen gender considerations in its NAP process[96] Gender equality is one of the key guiding principles of the development and implementation of the KJIP which is aligned to the National Policy on Gender Equality and Women's Development. The plan states that programmes should generate sex-disaggregated data to help ensure equitable access to financial resources and other benefits (e.g. technologies and services, climate information, capacity building on climate risk management) for women and men resulting from investments in adaptation and the differentiated impacts of climate adaptation actions on women and men should be monitored. Moreover, that the gender balance in participation and influence in decision making shall be sought and achieved for all projects' governance.

Furthermore, it includes a dedicated analysis of women's role in the economy and acknowledges the importance of women's participation and influence in planning and implementing CCA and DRM measures, and that it seeks to ensure the allocation of financial resources is gender-equitable.[97]

Operational Instruments

An increasing number of investors value gender climate and disaster risk insights to inform their investment decisions in a broad range of asset classes and financial instruments. For instance, representatives of family offices, foundations, banks, Development Finance Institutions (DFIs), other institutional investors, fund managers, that are members of the GenderSmart Climate Investment Working Group.[98] Yet, despite this growing demand, the supply of climate and gender responsive investment vehicles is limited, as is the underlying gender risk data.

Institutional investor groups focused on climate change need to incorporate gender-risks insights into their dialogue and actions, such as the Global Investor Coalition on Climate Change, and the Coalition for Climate Resilient Investment. Global investment governance initiatives should offer standards on gender related disclosures. Examples include the FSB Task-force on Climate related Financial Disclosure (TCFD)[99], the Global Reporting Initiative and also investment data platforms such as Bloomberg.

95 Government of Kiribati, 2019.

96 http://napglobalnetwork.org/resource/strengthening-gender-considerations-kiribatis-national-adaptation-plan-nap-process/

97 Government of Kiribati, 2019.

98 https://www.gendersmartinvesting.com/gendersmart-blog/2020/4/24/dont-let-the-urgent-crowd-out-the-important-covid-19-gender-and-climate-change

99 https://www.fsb-tcfd.org/about/

5.4.2 Gender analysis in risk transfer and anticipatory action

Irrespective of investment in risk prevention, some residual risks remain. In this context, financial instruments for risk transfer, such as climate risk insurance and social protection schemes, can be built into disaster management plans and provide some security against the loss of assets and livelihoods as part of a wider package of resilience building measures.

Gender risk insights can inform design and implementation of climate and disaster risk transfer mechanisms at the macro, meso and micro levels. This is in the context of the business case for the evidence of the commercial benefits of integrating women as corporate clients, leaders, employees, and investors into private sector business models.[100] The use of gender risk insights may vary by model as there are differences between the business models of such insurance.

Macro

Regional and national sovereign climate risk transfer mechanisms[101] can consider gender risk insights in the policies and criteria within investment decision making and financing agreements.[102] For example, at a multilateral level GFDRR applies the World Bank's gender strategy operationalised through its Gender Action Plan 2016–2021 in its portfolio of investments. Bilaterally, Canada's Feminist International Assistance Policy (FIAP) has made inclusion of gender considerations a condition of its investment in ARC (see box.).

Development and private sector climate risk finance should also incorporate gender risk criteria in investment decision making. For example, the InsuResilience Solutions Fund (ISF) provides grant co-funding to develop or scale up climate risk insurance. It has an evaluation grid for proposals which assesses among other criteria the extent to which the concept targets the most vulnerable people (< 15 USD PPP per day) and incorporates dimensions of social vulnerability (e.g. gender, age, disability).[103]

Macro level climate risk insurance schemes can consider gender risks to inform product design for cash transfer schemes and payout priorities for institutional sectors. But this is dependent on the extent to which sex-disaggregated data is collected by national statistics offices and other sources to inform an understanding of these risks, as well as the gender-responsiveness of the national disaster management plans. In turn there are dependencies with the level of gender inclusivity of any participatory process to inform the development of sovereign scheme payout criteria.

The integration of gender risks in contingency planning

A specialised agency of the African Union (AU), African Risk Capacity (ARC) aims to link early warning systems with contingency planning, supported by risk information and parametric insurance. ARC requires member governments to undergo capacity building measures and develop detailed contingency plans prior to issuing an insurance policy.

There is a requirement to set up a gender subgroup, the Gender Advocacy and Communication Group in the Technical working groups responsible for developing these plans.

Moreover, ARC requires these groups to conduct a gender analysis using a gender audit methodology with involvement from the respective Ministry of Women's Affairs. In turn, recommendations of the gender audit are expected to contribute to the development of sex-disaggregated data for risk profiling and define gender specific priorities for the Contingency planning and each country's Final Implementation Plan. In 2019, ARC adopted a Gender Mainstreaming Strategy.

As part of this ARC is mobilising DRM partners and practitioners, to develop continent wide innovative approaches to fill the knowledge gap on gender and DRM. It also seeks to strengthen institutional and individual capacities and tools for gender transformative DRM capacity building and standards for gender transformative contingency plans and gender-sensitive M&E.[104]

100 InsuResilience Global Partnership, 2019.; BMZ, GIZ, IFC and WWB, 2017; IFC, AXA and Accenture, 2015.

101 where government is the policy holder

102 InsuResilience, 2019.

103 https://www.insuresilience-solutions-fund.org/call-for-proposals

104 InsuResilience, 2019.

Meso and Micro

Meso and micro models of climate risk finance and insurance can incorporate gender risk insights to inform gender-responsive product design and delivery. This is needed to close the protection gap in line with international commitments under the InsuResilience Global Partnership to provide climate and disaster risk finance and insurance (CDRFI) to 500 million poor and vulnerable people in developing countries. It is also in line with its Partnership commitment statement on gender pending approval of its highest steering body, the High Level Consultative Group.[105]

Gender risk insights are necessary to support micro insurance to untap the market potential of women clients. A 2015 study by AXA Group, Accenture and IFC estimated that by 2030, insurance companies are expected to earn up to $1.7 trillion from women—half of that in just 10 emerging economies.[106]

How these gender risk insights inform these models will depend on the product type and whether it is parametric, parametric index, modelled loss, which estimate the loss and payout, or indemnity -based products which pay out on actual loss. This gender risk data may not be incorporated in risk modelling for these products nor change the triggers of parametric products. But gender risk data can inform the design and delivery channels of the products to address climate risk, what the payout can be used for, and consequently the content of the insurance contract (see box).

Doing so would enhance product design as it would better meet the needs of women customers, as has been demonstrated through microinsurance tailored for women. Products can be designed that only focus on women clients to address their specific protection needs – which are lacking currently more generally for CRI.

For example, Women's World Banking has developed the Caregiver initiative, a health insurance programme designed to meet the unique health financing needs of low-income women.[107]

Within the scope of meso-models there are opportunities to use gender risk insights to inform anticipatory action design. (see box) For instance, it can inform understanding about gender constraints in accessing potential payouts, such as access to mobiles, to inform the design and distribution of anticipatory action. There is a significant opportunity for gender risk insights to inform inclusive product design in the recently announced UNDP and the German Federal Ministry for Economic Cooperation and Development (BMZ) announced a joint initiative to drive inclusive insurance in seven countries from 2020 to 2023.[108]

Sex-disaggregated client data can be used to establish which clients are currently being served, and the extent to which their gender diverse risks and needs are being met through existing CRI products. For example, Agriculture and Climate Risk Enterprise Ltd (ACRE) have gathered this data and conducted a gender-analysis of the affordability and payouts of its products. It found that women were less likely to make large one off payments for insurance, and instead made regular smaller payments of varying amounts. Women were also found to be more consistent at paying in instalments.

Gender data can also support the M&E of the gender impacts of CRI payouts on direct and indirect beneficiaries. For example, an impact assessment of the R4 Rural Resilience Initiative in Senegal found that households with insurance spent more on productive agricultural inputs than those without insurance, and strengthened social bonds and women's empowerment.

Separately, R4 compared the differential impacts between male and female headed households, finding that women's decision making increased, as did their ability to save and acquire small loans for income generation.[109]

Gender risk insights can also inform regulatory action by insurance supervisors in their oversight of meso and micro models of risk transfer and anticipatory action. This may contribute to enhance women's access to and usage of insurance, as is being recognised by IAIS and A2ii to achieve inclusive insurance.[110] For example, in 2019, in partnership with Superintendencia de Seguros de la Nación (SSN), IAIS and A2ii held a roundtable on insurance for women for insurance supervisory authorities, practitioners and policy makes in Argentina who have a strategic focus on enhancing women's access to insurance.[111]

105 InsuResilience, 2019b.
106 AXA, Accenture and IFC, 2015.
107 IAIS and A2ii, 2019.; BMZ, GIZ, IFC and WWB, 2017.
108 BMZ et al, 2019.
109 InsuResilience, 2019.
110 IAIS and A2ii, 2019; A2ii, 2017.
111 IAIS, A2ii and SSN, 2019.

MiCRO risk transfer

Microinsurance Catastrophe Risk Organisation (MiCRO) is a reinsurance company specialising in the design and implementation of natural hazard risk transfer solutions for vulnerable and low-income segments of the population, with a target for 55% of its clients to be women.

It has used gender risk insights gathered through gender-balanced focus groups and surveys to inform its product design – a credit linked business interruption index insurance. Recognising that the most vulnerable may not experience direct asset loss as a result of a hazard, they focused on payouts to cover productive asset loss. Gender risk insights also have informed the choice of partners in Colombia and Guatemala.

Since access to its products are dependent on clients being eligible to access credit, its partners are those whose business models and credit products address womens' constraints in credit access such as a lack of collateral.

MiCRO requires its distributing partners to provide data on the gender-breakdown of their clients and amount of the loan activity. It considers gender differences in climate risks and impacts in its value-added programme. In Guatemala with the World Food Programme (WFP) it is incorporating women's specific needs within the value-added components of its climate risk insurance.

While the risk of drought is the same for all clients, risk coping strategies are different based on gender. Given that women play a more prominent role in catering for the nutritional needs of their families at times of drought, nutrition advice is being integrated into climate information services targeting its women clients.

Meanwhile in El Salvador, MiCRO has incorporated gender, income level, customer loyalty and as well as loan size, into a points system to determine which clients are entitled to premium subsidies. While women are only 30% of the client base of the partner bank, disproportionately more women qualify due to their lower incomes and assets.

Gender based cash transfers

The B Ready Programme, implemented by Oxfam Novib and its partners PLAN International, Global Parametrics with local partners, is piloting the impact of forecast based cash transfers through debit cards on the resilience of the most vulnerable people before a typhoon hits in the Philippines. Based on gender risk insights, the programme has integrated gender vulnerability considerations in the delivery model of this forecast based financing product.[112]

The project focuses on households with women, children, persons with disability (PWDs) elderly and other vulnerable groups living in poverty and high exposure to typhoon hazards.[113] Its pre-disaster digital cash transfer is complemented by financial literacy training.

Women are the intended recipients of the cards on behalf of their households, to ensure the transfer is used for the intended purpose. Moreover, their access to finance and mobile phones were accounted for in the delivery model. Further, a gender specialist is providing training to partners on gender equality to support project implementation.[114]

Agri-focused micro CRI product design decisions can be informed based on the gendered profile of who grows which type of crops and the risks faced based on their role in the wider value chain. For example, GIZ has conducted a gender value chain analysis to understand the different levels of participation and roles of women at play at different stages of honey, vanilla, cloves, fish value chains and to design gender-specific and gender-sensitive climate risk insurance.[115] IFAD has recently published a checklist for the design and implementation of agricultural and climate risk insurance with a focus on including the female farming community.[116]

112 https://www.oxfamnovib.nl/donors-partners/about-oxfam/projects-and-programs/b-ready

113 https://pia.gov.ph/news/articles/1020293

114 https://www.unjobnet.org/jobs/detail/10052891

115 DCED, 2019b.

116 IFAD, 2020.

5.4.3 Overall

Currently there are still low levels of women participation in technical and leadership positions in risk understanding and in insurance companies. Based on the Institute and Faculty of Actuaries' 2019 annual report data only 35% of its members were women.[117] This is despite a gender diverse workforce holding potential for enhanced risk understanding and management. There is the opportunity for the actuary profession to encourage more women to train in the sector. (see Annex B).

The International Monetary Fund (IMF) indicates that the presence of women, as well as a higher share of women on bank boards and on boards of banking supervision agencies, are associated with greater bank stability and financial resilience.[118, 119, 120] Moreover, women employees are recognised to play a key role in understanding the risks faced by women and to design and distribute CRI to and service female insurance clients.[121] **SDG 5 targets 5.1 and 5.5**.

There is a need to ensure women are involved in the key ministries involved in the design and implementation of disaster management, and the supervision of climate and disaster risk transfer mechanisms. Notably, financial regulators and insurance supervisors are increasing women's participation and leadership within their workforce through training initiatives (see annex).

Since financial regulators play a pivotal role in directing financial resources as part of disaster risk responses and increasing the gender-diversity of these institutions can increase the integration of gender within these responses and payout priorities with sovereign risk transfer schemes (See Annex B).

Governments are promoting private sector action to boost gender diversity including among insurance companies. For example, in the UK, HM Treasury has created a Women in Finance Charter – a pledge which requires signatories to commit to internal targets for gender diversity in senior management and annually report progress.[122] In response, sector level and institutional level initiatives have emerged to address diversity in the financial sector.

For example, Lloyd's of London has implemented initiatives for the reinsurance market (See Annex B). AXA has a Women in Insurance Industry Initiative and Zurich Insurance Company has a diversity strategy and has undertaken gender pay gap audits. Both Zurich and AXA participate in the Bloomberg Gender Equality Index (GEI), which tracks the performance of public companies committed to transparency in gender data reporting.[123]

Beyond women's participation and leadership, it is essential to build the capacity of both women and men working in climate and disaster risk analytics on the value of gender-information and sex-disaggregated data to inform their work. For example, the World Bank offers a self-paced e-learning course on an Introduction to Gender and Disaster Risk Management.[124]

Moreover, United Nations Capital Development Fund (UNCDF) and the Alliance for Financial Inclusion worked with financial sector regulators to create of global guidance on the theme,[125] and UNCDF has worked at an institutional level to encourage the use of sex-disaggregated supply side financial data to inform financial risk understanding.[126]

---

117 http://fr.zone-secure.net/18541/1026770/#page=1

118 IMF, 2017.

119 IMF, 2018.

120 https://blogs.imf.org/2018/09/19/women-in-finance-an-economic-case-for-gender-equality/

121 BMZ, GIZ, IFC, WWW, 2017.

122 UK Government, HM Treasury, undated.

123 https://www.bloomberg.com/gei/about/

124 https://olc.worldbank.org/content/introduction-gender-and-disaster-risk-management

125 AFI, 2017.

126 UNCDF, 2019.

5.5 Risk insights for gender responsive policy and action to deliver on the SDGs

There is a clear imperative to enhance the gender responsiveness of risk understanding in both public and private sector. There are significant opportunities for the wider application of gender-responsive climate and disaster risk analytics to contribute to gender dimensions of multiple SDG outcomes in those economies most vulnerable to climate and disaster risk.

As this chapter has indicated, there is potential to enhance the gender-responsiveness of risk understanding around vulnerabilities and exposure to a range of climate change related disaster risks to life, health and livelihoods immediately and longer term after a disaster. Doing so can enhance resilience building of women in the face of risk, with implications for their overall empowerment and SDG5.

Importantly it will have the potential to reduce the heightened violence against women' and girls in the face of disasters, as well as advance women's economic participation and therefore their empowerment.

Public and private sector collaboration is key. Without a cohesive approach, gender climate and disaster risk insights will be unable to deliver action to protect and build the resilience of the most vulnerable individuals. The private sector offers innovative solutions to address the gender dimensions of climate change and disasters through designing and scaling up customer-including women - centric risk transfer products at the meso and micro levels.

But there are limits to their reach, as the most vulnerable may not necessarily be direct beneficiaries, perhaps for reasons of affordability. This is where social protection measures within gender-responsive macro models of CRI insurance will play a critical role to protect the most vulnerable in the face of disasters.

Public private partnership will be necessary to inform and implement gender-responsive national planning for climate and disaster risks, and to deploy development financed operational instruments. As a result, gender considerations need to be meaningfully integrated into donor investments in public-private collaboration to further risk analytics to support development outcomes.

5.6 Key points

This chapter has indicated a number of opportunities and a clear need for institutional capacity building across several dimensions of the climate and disaster risk understanding process, as well as advocacy with diverse stakeholders.

- Firstly, at the level of tool design and implementation, to incorporate gender considerations and use sex-disaggregated risk data in existing approaches to risk management, risk modelling, and disaster databases.[127]
- Secondly, capacity building programmes should increase women's participation in risk analytics and decision-making in the public and private sectors. Programmes should advocate this agenda with influential organisations working in risk prevention and risk transfer. These include (but are not limited to) ministries, scientific agencies, donor finance institutions, commercial investors and the re/insurance sector.[128]
- Practically, there is a need to provide technical assistance to ensure the collection of sex-disaggregated disaster data by V20 countries to report to the Sendai monitor platform and ensure the system can publicly display this data.
- This can be done by building on the forthcoming InsuResilience Global Partnership's Gender Commitment Statement to advance efforts in collecting sex-disaggregated data as part of the Partnership's annual monitoring and evaluation efforts across all its programmes.
- The design of open source platforms, including those described in this paper, must be capable of sex-disaggregated data inputs.
- As a next step there is the opportunity to task the InsuResilience Global Partnership Gender Centre of Excellence, planned to be launched in November 2020, with the development of guidance material and research to inform standards and approaches for advancing gender-responsive data analytics.

127 InsuResilience, 2019.

128 https://a2ii.org/en/knowledge-center/the-role-of-insurance-regulation-in-promoting-inclusive-insurance-for-women

Looking ahead: Indicators of the accelerating spread of risk understanding

6

Plume from the Eyjafjallajokull crater
Photo: Olafur Sigurjónsson Forsæti III from the Icelandic Meteorological Office

Looking ahead: Indicators of the accelerating spread of risk understanding

6.1 A target open risk modelling ecosystem for use in development

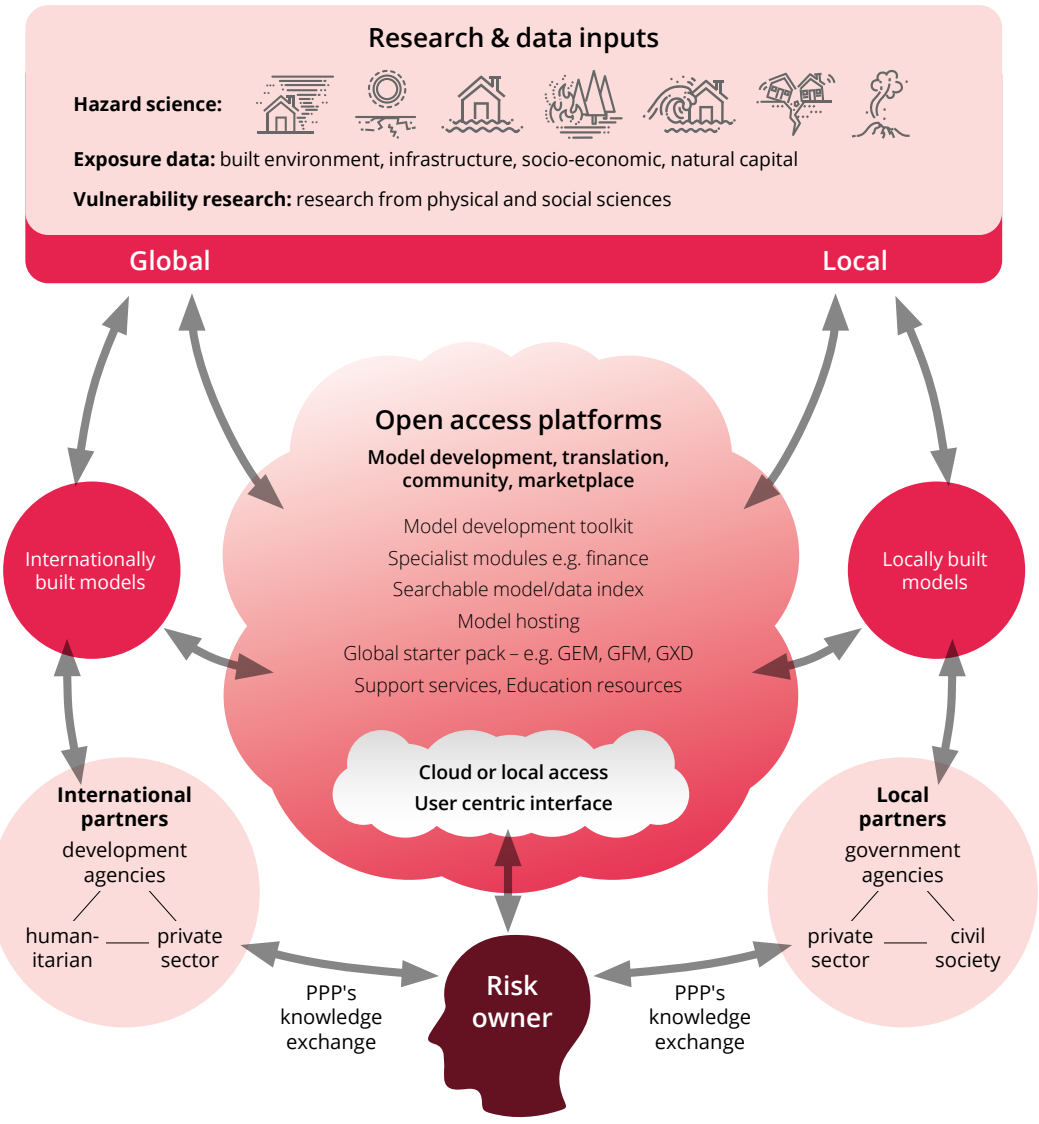


Figure 6.1 summarises many of the themes described earlier in this paper, illustrating the collaborations, tools and principles necessary to support the risk owner's duty to understand her or his risk.

The vision for this target open risk modelling system is further explored in a proposed **Theory of Change, shown at Annex A**, using the example of risk transfer. The theory of change follows on from the question in Chapter 1 'Why is change necessary?' and draws together the principles developed in further chapters and highlighted in Figure 1. In summary these principles are:

- **Accessibility:** Access to a wide range of global and local risk data and models from across all sectors on open source platforms. Accessibility includes affordability; price should not be a barrier to understanding and quantifying risk. Large investments in complex computer hardware environments and proprietary platform licences may be a choice for commercial companies and even for development banks, but this is not an option available to many risk owners[1].
- **Usability:** At its most advanced, risk analysis can be a very complex and computer intensive undertaking. However, as seen in Chapter 3, a spectrum of tools can be made available at different technical levels according to the context of the decision being made. At a minimum, capable staff – both women and men – should be able to access and interrogate risk information in the cloud through user friendly interfaces without the need for deep coding skills.
- **Transparency:** It is essential that users can see input data and the assumptions behind the model and are able to reproduce model results. Even better they should be able to validate the model with historical data during the design and testing stages. This is foundational to understanding the level of uncertainty during the decision-making process.
- **Choice:** The adoption of common data standards promotes choice. Care must be taken when comparing model results; the user must be able to tell good from bad, and when mixing sources might lead to nonsensical outcomes. However that skill may never be developed if the choices are not available. A good starting point is choice in exposure data sets, where some leading data formats are already being made interoperable on open platforms.
- **Collaboration:** As shown in previous chapters, there is not enough resource in the development system to address the global challenge of the 2030 agenda. This is equally true for the process of risk understanding. The private sector has developed risk assessment and management as a survival skill; development programmes should take advantage of this experience through partnership with the private sector and research institutions.
- **Ease of interpretation:** Models are often complex undertakings, but the output metrics and uncertainties must be comprehensible to decision makers. Caveats around the results are as important as the model findings.
- **A sustainable, flourishing market for risk understanding:** Where all model and data providers can exchange knowledge and services in an interoperable and accessible system, while rewarding their investment.

Implicit in these principles is the building of capacity among risk owners in countries, as we have seen in Chapter 4. It is suggested that the way to do this is through practical, collaborative projects – by co-defining risk assessment projects and co-developing models using the skills and resources of all sectors, with a view to creating sustainable capacity.

The value of the theory of change is in telling a story of a possible future through a diagram and narrative. Box 1 (below) is an indication of just how much support there is across sectors for the principles being advocated.

[1] Open source platforms do not imply that models and data are free. They may be free to certain users as part of public goods programmes, but licensing should preserve the value of intellectual property in sales to those who can afford it.

Evidence of cross-sector support for the principles being advocated

> **Demand-side stakeholders want better data, better models, better communication and training on how to use models. These stakeholders demand peer users to assist with training on how to understand the data, how to get more from the data, and how models could influence better use of climate adaptation methods to improve resilience.**

InsuResilience 2020[2]

> **The creation of risk information should be broadly inclusive, OpenDRI engages stakeholders from the government, scientific and technical agencies, the public, civil society organisations, and at-risk communities at multiple stages of the data creation and implementation processes.**

OpenDRI[3]

> **[Recommendation 1...] Invest in open-source models that provide a long-term view of climate risk and link to insurance solutions.**

Global Commission on Adaptation background paper, 2019[4]

> **Accountability and transparency in decision-making are core requirements for the humanitarian sector, irrespective of how decisions are taken. It should therefore be non-negotiable that all data and analytics (along with the decisions and outputs they provide) are clear and transparent, and that efforts are made to communicate the complexity in an accessible way.**

Start Network, Red Cross Red Crescent Climate Centre. 2019[5]

> **Risk models need to be open, and the logical steps for decision-making clear to specialists and non-specialists alike**

Centre for Disaster Protection, 2020[6]

> **Countries and communities will welcome new methods and tech-based solutions to their data gaps. Governments are able to raise the necessary resources to build capacity and integrate tech-based solutions to their data gaps. Academia, civil society and private companies will work together to create standards and identify replicable best practices**

UN Sustainable Development Solutions Network 2019[7]

> **Behavioural scientists have suggested that much can be gained from keeping things simple: ensure that plans and any decision making they entail are kept as clear and simple as possible. Well-designed, intelligent decision rules and triggers will make the difference**

Dercon and Clarke, 2016[8]

A number of encouraging trends in open risk analytics point to the possibility of increased empowerment of risk owners to access, develop and apply risk information in disaster reduction and mitigation, risk transfer, and anticipatory action.

This chapter looks at emerging trends in organisational collaboration, advances in technology, data and models and can improve collaboration and empowerment – and lead to better development decisions.

2 InsuResilience Global Partnership 'Analysing Stakeholder Needs for Climate and Disaster Risk Finance Data, Feb 2020.

3 www.OpenDRI.org

4 'Insurance for Climate Adaptation: Opportunities and Limitations', Jarzabkowski, P., K. Chalkias, D. Clarke, E. Iyahen, D. Stadtmueller & A. Zwick. 2019.

5 Harries, C., and Jaime, C., (2019) Impact before Instruments: People -centred transparent risk analytics' discussion paper. Start Network and Red Cross Red Crescent Climate Centre.

6 'Basis risk in DRF for humanitarian action', Centre for Disaster Protection, 2020

7 UN 'Counting on the World to Act' Theory of change, 2017: https://countingontheworld.sdsntrends.org/2019/theory-of-change/

8 "Dull Disasters. How Planning Ahead Will Make a Difference." Dercon and Clarke, OUP 2016

6.2 Emerging organisational collaborations

6.2.1 Collaborations between public and private sector organisations

There is a notable increase in collaboration between public international development organisations and the private sector in responding to risk – As evidenced already in this paper, the need is clear. A recent series of Geneva Association papers on building flood resilience reinforces the point.(footnote) Floods are the most costly weather-related event globally and are likely to increase in frequency and severity. The only way to manage the threat is through a system-wide approach involving those who are managing risks, those who are at risk, and those involved in creating the risk.[9]

Access to private sector expertise in risk management brings the benefit of decades of experience in use of models for critical decision making. This includes, for example, the ability to tell good data sources from bad, and the ability to judge and communicate levels of uncertainty in the analysis.

It also unlocks private sector mechanisms and capital for risk prevention and risk transfer, with consequent benefits in resilience and market development. In response to the need to bring cross-sector expertise and resources to bear on SDG challenges, a number of important cross-sector collaborations have emerged.

These include:

- **The InsuResilience Global Partnership[10]:** a public/private partnership of V20 and G20 countries, multilateral organisations, private sector, civil society organisations and academia working towards strengthening the resilience of the poor and vulnerable, with a particular emphasis on women and girls, through the scale-up of disaster risk financing and risk transfer solutions. Through its collaborative delivery vehicle, the Program Alliance, members ensure better coherence in channelling donor support to vulnerable countries. Its *High-Level Consultative Group* brings together high-level government representatives, CEOs, and heads of agency to ensure political leadership and visibility of the initiative. The *Partnership Forum* is the annual flagship event of the climate and disaster risk finance and insurance community through which the Partnership promotes a thriving collaboration, knowledge creation and exchange for enhanced impact on the ground.
- **The Insurance Development Forum[11]:** a public/private forum launched in 2016; the IDF is led by the insurance industry and supported by international development organisations. Its Steering Committee and Operating Committee are led by insurance industry leaders, UN agency leaders including UNDP and UNDRR, international institutions including the World Bank, regulators, humanitarian NGOs, and many others. Since its inception the IDF has led several projects in which multiple private companies are successfully combining their expertise for the first time in their history. This has led to collaborations on best practice guidance for development financing and close engagement on systemic risk assessment with UNDRR GRAF. Now a legal entity, it is moving to an operational basis to add to its earlier functions. It has begun to establish **formal PPP agreements**, such as the **Tripartite Agreement** between the German government, UNDP, IDF and country governments, in support of the InsuResilience Vision 2025[12]. Formal agreements are an important mechanism to provide a route to engage private sector capability while building trust in a planned and collaborative workstream.
- **The Coalition for Climate Resilient Investment:** In the arena of risk prevention and mitigation, the Coalition for Climate Resilient Investment is *"A first-of-its kind private sector led coalition [...] comprised of companies from across the investment value chain with US$5trillion of assets under management, alongside Governments and multilateral organisations"*[13]. Led by the governments of Jamaica and UK, the World Economic Forum, Willis Towers Watson, and the Global Commission on Adaptation, it

9 https://www.genevaassociation.org/building-flood-resilience

10 www.InsuResilience.org

11 www.InsDevForum.org

12 The InsuResilience Global Partnership Vision 2025 includes ambitious targets to protect vulnerable people from shocks due to climate and disaster risk, with a target of reaching 500m people by 2025. InsuResilience Global Partnership, 2019.

13 https://www.adaptation-undp.org/sites/default/files/uploaded-images/coalition_for_climate_resilient_investment_cas_launch_.pdf

aims to integrate climate resilient decision-making in infrastructure investment, leading to more climate-resilient economies. Development of climate and disaster risk assessment will necessarily be part of its work - investors are very risk-aware when considering factors such as credit risk or political risk, but pricing the risks caused by climate change and disasters in asset valuations is still a very new concept.

- **The UN Global Risk Assessment Framework (GRAF):** UNDRR is leading this open and collaborative initiative on behalf of the UN system, bringing together experts from across private and public sectors. UN GRAF is a community and an operational programme seeking to understand the dynamic nature of risk and how the increasing complexity and interconnectedness of society can further amplify impacts. The Central GRAF Steering Group drives a series of working groups and guides a community of over 150 experts from across risk, science, investment and policy-making and communication. In line with its commitment to collaboration the Steering Group aims to balance technical, operational and strategic backgrounds of relevance to the operationalisation of the GRAF; geographic representation; gender; and major stakeholder groups, including public and private sectors, civil society, national/local government, research funders.

  The operational programme will start with five demand-driven national pilot projects, with ambitions for significant growth by 2030. It will involve all sectors in a partnership with governments using an online collaboration platform. Governments will be both risk information providers and users.

- **The Global Earthquake Model (GEM):** The contribution of GEM to building country capacity has been described in Chapter 4. Its growth is proof of the benefits that arise when developing and applying knowledge is treated as a cooperative endeavor. GEM was created specifically as a public-private partnership because its founders realised that combining the interests of public and private sectors in common vision to reduce earthquake risk worldwide mission was critically needed.

  GEM's formal partners include 13 private companies, 15 public organisations representing nations, and 9 international organisations. Various other associate participants and organisational members of international consortia also deliver global projects. The partnership works because both sectors seek the same outcome: credible, accessible risk information that is widely used and understood.

  "The perspectives and positions of the two sectors do not differ as widely as GEM's founders initially anticipated. In practice, differences in perspective varied within each sector as much as or more than they did across sectors"[14].

6.2.2 Collaboration between model providers and users

The best models are built in partnership with users and combine hard science with local historical and real-time data. A growing number of risk assessment projects integrate co-definition and co-development from the outset, meaning that there is no final 'handover' because the project was the user's throughout.

The humanitarian sector and international risk pools offer examples of best practice. Evaluation of historical impacts, validation of model approaches and development of early action plans are increasingly aligned with the capabilities of governments and local agencies.

> **"...analytics and models need to be co-designed and co-developed by scientists and modellers, operational disaster managers, responders and financiers – and communicated to ensure accountability in those models and decisions to people at risk. The design modellers use must be fit for purpose for all for the DRF system to achieve impact and accountability."**
>
> Harris, C. and Cardenes, I. (2020) 'Basis risk in disaster risk financing for humanitarian action: Potential approaches to measuring, monitoring and managing it.' Centre for Disaster Protection Insight paper, Centre for Disaster Protection, London.

[14] 'Understanding Risk: The evolution of disaster risk assessment since 2005': UNISDR (now UNDRR) 2014, preparatory report for the 2015 Global Assessment Report.

Improving the consistency and interoperability of risk data

There is a recognised need to improve efficiency in sharing risk data – between project partners, between organisations in the chain of risk transfer, or for users to pick up and build on data created in previous unrelated projects. A good, practical starting point for public-private technical collaboration is the development and sharing of interoperable exposure data sets.

The Open Exposure Data[15] (OED) format was developed through working with (re)insurance industry users to design an open and fully documented exposure framework. It provides standardisation and greater transparency in exposure data and can facilitate greater use of multiple models.

Based on wide consultations[16] in the GFDRR-DFID Challenge Fund, a new open-source multi-hazard exposure, hazard, vulnerability and modelled loss data schema has been developed. The Risk Data Library[17] improves efficiency in sharing, finding, reviewing and applying risk data in the development sector.

The insurance industry, through the IDF Risk Modelling Steering Group, has developed an open-source exposure data transformation framework, to improve interoperability of industry exposure data. This enables more efficient use of data between models (including the potential to share data between the private and public sectors) and improved transparency of assumptions.

6.2.3. The role of procurement

Positive outcomes and lessons learned from current collaborations - such as those described in Chapter 4 - provide the evidence for donors and commissioning agencies to lock in collaborative behaviours. It is not difficult or costly to specify these principles in project terms of reference and the result will be a lasting transfer of knowledge, processes and tools. Project terms of reference can also prescribe the nature and granularity of financial and socio-economic metrics, including sex-disaggregated risk estimates.

Public good procurement rules should promote further desirable behaviours by default. A check list might include a minimum level of gender-diverse participation in the project. It should also include standards for accessibility on open platforms, and for transparency of methodology, assumptions and uncertainties. This will allow users a better understanding of basis risk, improved design of anticipatory triggers and awareness of model limitations.

6.3 Technological advances

Advances in technology will democratise access to risk insight. The proposed modelling ecosystem must be able to make the most of recent developments in open platforms and in new high resolution data sources.

6.3.1 Open source modelling platforms

In recent years initiatives from academia, development and industry have produced open software platforms - on which users can develop their own analysis and run multiple models (see **Table1**). They are based on open source code and are free to use, providing an alternative to commercial or other proprietary platforms. The most versatile have also become cross-sector market places and communities where users can find multiple models and data sets and can receive guidance and support. With sufficient expertise it is possible to use such platforms to develop a view of risk without the need to pay platform licence fees or become locked into a proprietary format.

15 https://www.nasdaq.com/solutions/open-exposure-data-oed

16 GFDRR, 2016.

17 risk-data-library.github.io/

Table 1: Examples of open source modelling platforms

Platform	Genesis	Purpose and key features
Oasis Loss Modelling Framework	Industry funded + Climate KIC + European Union's Horizon 2020	Developed by insurance industry experts, but suitable for wider application. Oasis LMF is a versatile free-to-use platform for model building, but does not produce models of its own. It is open to all model providers, with source code and documentation being openly available onGithub. Oasis LMF's architecture offers wide compatibility, enabling use of the financial module with diverse exposure, hazard, and vulnerability inputs. The Oasis calculation 'engine' underpins an ecosystem of other platforms e.g. Nasdaq Risk Modelling for Catastrophes, Exceedance, Fractal. Oasis is also positioned as a community, information hub and marketplace for providers and users.
OpenQuake	Flagship software platform of GEM Foundation	Free, open-source software platform for scenario or probabilistic hazard and risk assessment. Originally designed for earthquakes, the risk engine can be used to assess risk for any spatially varying hazard by importing hazard footprints. Modules currently exist for flood, volcanic eruptions, and earthquake-triggered landslide and liquefaction. Source code, extensive user manual, and specialised toolkits for building models are available on Github. Runs on laptops with QGIS plug-in, through to super computers for complex analyses. Outputs include a wide range of hazard and risk metrics including ground-up loss for input to insurance loss calculations.
CAPRA	Developed with support of the World Bank, Inter-American Development Bank and UNISDR.	Free open source software platform originally developed for Latin America and used in UNDRR's Global Assessment Report. Includes hazard modules for earthquake, earthquake and tsunami (combined module), volcano, flood, cyclone, and landslide. Capable of probabilistic and deterministic (scenario) analysis. Associated GIS platform and financial applications.
CLIMADA	Development funded, genesis in academia with re/insurance context, based on industry modelling principles	Designed to quantify the impact of climate adaptation projects at an aggregate level, through cost/benefit analysis in the risk context. CLIMADA is the preferred platform for Economics of Climate Adaptation (ECA) studies referred to in Chapter 4, offering a ranking of investments and suggesting a pivot point where transfer of residual risk offers a better return. Offers probabilistic and scenarios approaches. Source code and documentation are openly available on Github. Models are climate conditioned through adjustment of frequency and severity assumptions. CLIMADA generally uses global approaches which will work at aggregate level, but are less suitable for local modelling or operational instruments.
InaSafe	Developed jointly by Indonesia (BNPB), Australia (Australian Government) and the World Bank (GFDRR)	Simple but rigorous approach combining hazard scenario footprints with exposure data and vulnerability curves. Strength in bringing together data from scientific agencies, local governments and communities. Does not offer probabilistic modelling and is therefore not designed for operational instruments or quantification of uncertainty.

Open source platforms are critical to the ideal risk modelling ecosystem because they enable **collaboration and co-development between users**. They give access to a **broader spectrum of data and models** than can be offered from a single proprietary platform, while maintaining a single interface.

There is growing use of open platforms in the private sector, with an increasing number of models being made available via Oasis LMF or Nasdaq Risk Modelling for Catastrophes (previously MODEX)[18]. Risk assessments commissioned by international development organisations are increasingly looking to ensure access to models for their clients, through the use of open models and frameworks in their projects.

Expected technical developments in open platforms include expansion of risk scope, for example to be able to characterise socio-economic risk (as OpenQuake is doing) including disaggregated gender risk and pandemic risk in support of the broadening systemic risk agenda.

[18] https://www.nasdaq.com/solutions/nasdaq-risk-modelling-for-catastrophes

6.3.2 Web services and cloud-based solutions

Cloud computing reduces technical and financial barriers for users with limited resources, through:

- Access to significant processing power to run complex models without the cost of developing that internally.
- Affordability of shared hosting on servers to reduce operational costs.
- Improved interfaces and a reduced requirement for deep coding expertise among users.
- Transfer of data from one system or platform to another via API technology, giving users the opportunity to access real-time information and to draw on multiple sources of risk information into a single system.

Cloud access also provides infrastructure for 'always-on' services such as risk forecasting and monitoring. Procuring model-as-a-service or data-as-a-service means specialist model vendors can configure, deploy, run, support and maintain the service on behalf of the user, performing a service role that may not be available to the user internally.

Real-time services, such as earth observation and weather data feeds, can characterise hazards during an event (e.g. flood extent) or disaster impacts shortly after an event and over a large area. Real-time weather data can now be fed into models, including highly localised data from multiple sources. This offers improvement over the sometimes incomplete or low-resolution public data available from some national networks. Real-time data can also be integrated into forecast models though 'Data assimilation'[19] to further refine and calibrate the next set of model forecasts, contributing to reduced basis risk.

6.3.3 Ever-improving data sources and processing

Enhanced earth observation satellite capabilities, computing power and advances in data sciences are making many new datasets available. Earth observation data acquired from new satellites, or incremental improvement and combination of existing data, have resulted in improvements to regional and global exposure data. For example, Facebook and CIESIN have developed a high-resolution (approximately 30 metre) population layer using recent census data, 0.5 metre resolution satellite imagery, night-time lights data and computer vision processing (a type of machine learning) while MAXAR can now provide building footprint data over large areas.

Satellite imagery can now be combined with street-level images captured by vehicle-mounted cameras, and processed with computer vision techniques to classify exposure type (e.g. residential, commercial) and estimate building height, on the basis of the building facade, or identify specific vulnerabilities[20]. This can already be performed at city level and as these techniques develop further, they hold great potential for improving exposure datasets at scale.

Machine learning can also augment traditional models to assess likely hazard and levels of damage sustained in events. While these applications are still relatively few and limited in scope and scale, already early exploration of ML-based damage estimation is being trialled[21].

Use of machine learning must be tempered with consideration of the availability of input, training, validation and testing data, and biases within the data that need to be controlled in analysis. These can be social (for example gender, ethnicity, wealth biases) or structural (over-representation of certain types or quality of construction).

There continues to be considerable investment in Digital Elevation Models (DEMs,) which characterise topography for risk analytics. An accurate DEM is vital for estimating flood risk in particular[22]. Vertical accuracy has been a major limitation in estimating broad scale flood inundation but the reduced cost of LIDAR technology in particular offers improvement, which in turn will improve risk estimates.

[19] e.g. Hostache et al 2018
[20] Antos and Triveno, 2018
[21] GFDRR, 2018
[22] GFDRR, 2014

Advances in hydromet monitoring

Improving the density of weather observation networks is a key task in improving weather monitoring, forecasting and early warning, and also analytics for hydro-meteorological risks. Encouraging developments include:

*** 3D-printing technologies** are being used to overcome the issue of sparse weather observation networks. 3D-printed automatic weather stations (3D-PAWS) can be largely printed locally (and re-printed in case of needing to be fixed/replaced) by a national hydro-met agency for a fraction of the cost of a standard weather station. The CREWS Initiative has funded the Afghanistan Meteorological Department to create a network of 3D-PAWS. It provides cost-effective improved weather monitoring and communication[23], builds technical capacity and enables a sustainable monitoring system with inputs to national and regional forecasting, agricultural and health monitoring, and alert and decision-support systems.

*** Sensor technology** is already being used by some private weather forecasting firms to improve accuracy and provision of forecasts beyond the network of observations provided by National Meteorological and Hydrological Services (NMHSs). Sensors include cell tower signals, smart vehicle sensors, and networked weather gauges.

* The development of **global observational data availability** for higher quality weather and climate products and services at global, regional, national and local levels. Many countries are current or potential targets of internationally funded development projects that are "country-driven", and based on national weather and climate risk information, and national observing capabilities. This approach risks ignoring the inherently trans-boundary nature of weather and climate. Developing countries' compliance with the requirements defined by the Global Basic Observing Network (GBON, also see Chapter 3) would deliver a major strengthening of global observational data availability.

Since the link between local observations and the local quality of numerical weather prediction (NWP) outputs is often poorly understood, data delivery to global systems often falls short. WMO proposes the Systematic Observation Financing Facility (SOFF) to fund GBON compliance in developing countries. This will improve inputs to global numerical weather prediction models, delivering both global and local benefits. National meteorological and hydrological services will be supported to understand the national benefits of international data exchange. Countries will have access to better forecast products, leading to improved services and increased economic productivity.

Harvesting of mobile phone location and natural language processing of message text are being increasingly used to provide rapid situational awareness in the minutes and hours during and following disasters. In addition to remote sensing imagery capturing the disaster and its impacts faster and in more detail than before, changes in mobile use can indicate distribution of power outages, and movement of people while message text can add crowd-sourced context.

[23] CREWS, 2020

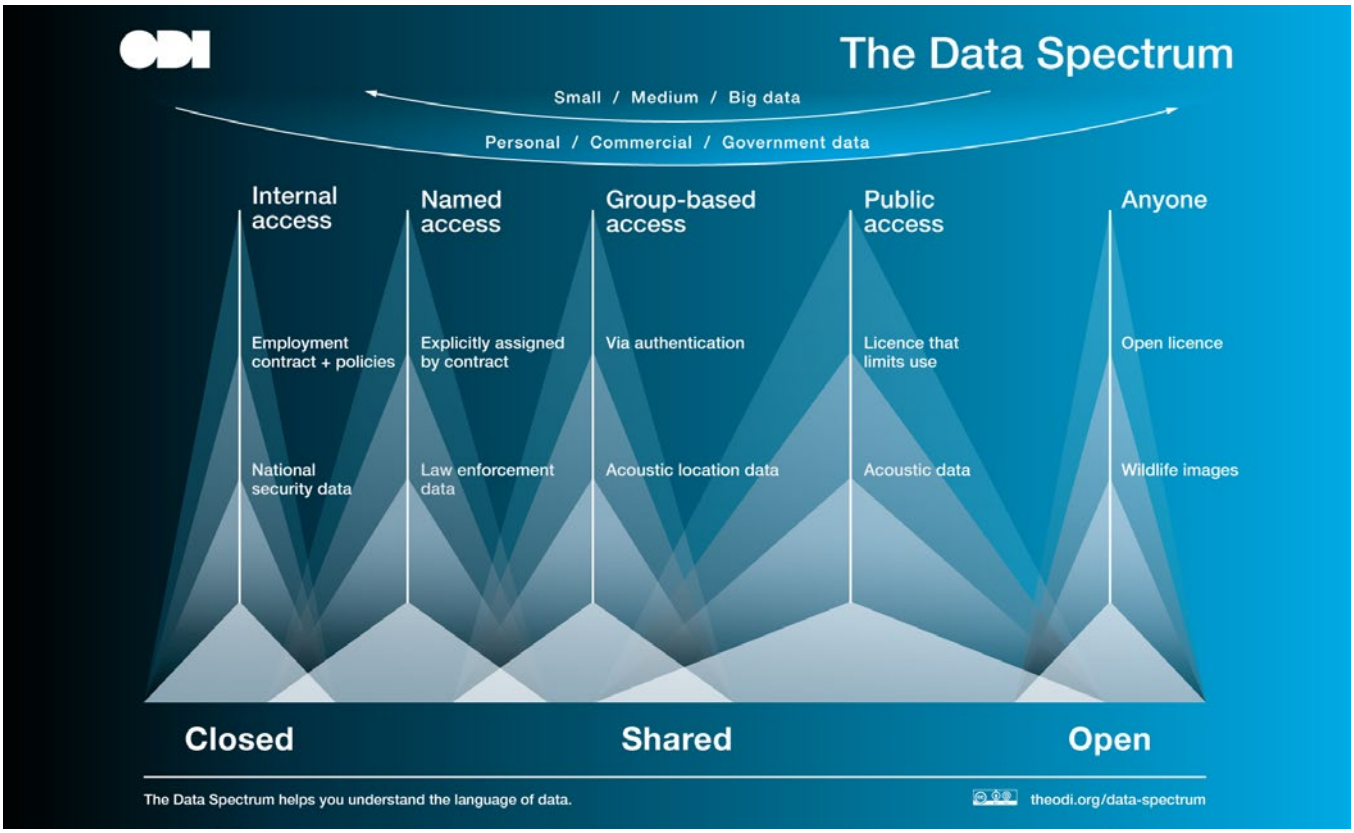
6.4 Data and model governance

> **Improved risk data and analysis of the impact of climate change are essential to increase understanding about the risk profiles of different countries, regions, assets and populations. These risk data should enable modelling of the frequency and severity of different climate events, geographic exposure, vulnerability and potential financial losses. [...] Such models should not be proprietary, but rather should be open and widely available.**
>
> Jarzabkowski, et al. 2019.

6.4.1 Licensing

The Open Data Institute[22] divides the data spectrum into open, shared or closed data, depending on how it is licensed (see Figure 2). Most data in the risk modelling world is in the 'shared' category, in that it may be licensed for usage subject to conditions. This is an important mechanism, allowing the value of investment in research to be realised, although it necessarily limits re-use or gradual improvement of the data by the wider risk community, especially risk owners with limited budgets.

Figure 2: Illustration supporting the Open Data Institute's definition of the data spectrum



[22] www.theodi.org

An increasing amount of data is being released as 'Public access' data (a form of Shared Data subject to licences that limit use) or even 'Open' (anyone can access).[23] Open data enables a common understanding of inputs to models. The open sharing of model results is to be encouraged in publicly funded programmes. Some governments may be reluctant to release risk data, for security or other reasons, but access to the sources behind decision making does enable comparison between models and a healthy discussion of uncertainties.

Sharing data has been found to be valuable in stimulating innovation across a sector, enabling a community of data providers to address common challenges that one organisation cannot solve alone. Increasingly, data generated in the development sector are being shared, through initiatives such as OpenDRI, Humanitarian Data Exchange, GEM Foundation and other international, regional and national institutions recognising the value of sharing risk data on open spatial data platforms. For instance, GeoNode platforms set up through development projects with the World Bank and others are now used by dozens of country governments[24] to share risk data, in addition to UNESCO, ADB, World Bank and others using the system.

The future risk analytics ecosystem for development impact should ensure inclusivity, understanding and sustainability of data production and use. One way to achieve this is to follow the OpenDRI principles for disaster risk data and open data and projects. These specify that open data should be:

- Open by default (open unless its release would have justifiable negative implications)
- Accessible, licensed and documented
- Users can make the most effective use of datasets that: are in standard, machine-readable formats; are distributed with reference terms of use; and provide information that enables users to understand what the data is and where it came from
- Co-created with stakeholders (government, technical agencies, public, civil society, and at-risk communities) engaged at multiple stages of data creation and implementation
- Locally owned, developed and managed at the scale it serves
- Communicated in ways that meet the needs of diverse users via simple tools or outputs tailored to the specific needs of a context

Practically, and understandably, NGOs would always choose open and free data as their first option. This is not just to make donor funding go as far as possible, but also to encourage the trust that can be built through transparency and an open, collaborative approach.

There is also a moral dimension; humanitarians may be less constrained by the commercial value of IP, but also have an instinctive dislike of opacity. Just some examples of open data sets currently in use by Start Network and the Red Cross include:

- Pakistan heatwave model – Freely available historic station data to set temperature trigger levels.
- Pakistan Flood model – Validation of hazard models using satellite images and population modelling using widely available humanitarian estimates of the number of people affected.
- Madagascar drought – Validation of historic bad years using agricultural yield data, health indicators such as mortality and malnutrition rates, and macro indicators such as imports, food aid etc – all openly available.
- Pakistan drought – Use of free NASA satellite data to test NDVI (a 'greenness' measure) as a food insecurity predictor.
- The Africa RiskView drought model from ARC is fed with freely available rainfall estimates such as ARC2 and RFE2.
- Red Cross Forecast based Finance trigger models use open source data, for example:
  - Philippines typhoon using Open Street Map (OSM) data
  - Indonesia InaSAFE-FbA using GloFAS and OSM
  - Peru cold wave: Using government level open data at all levels
  - Uganda: Using GloFAS and Government level data.

[23] Examples of open licences are those conformant with the OpenDefinition for example CreativeCommons Zero, Attribution and Share-alike; these licences for content or data enable any type of derivative use. CreativeCommons no-derivative and non-commercial licences would be examples of licence for shared public access data (but not open data), as they place restrictions on use.

[24] including http://www.masdap.mw/, https://geodash.gov.bd/, https://disasterrisk.af/

Government statistical offices will] work with Chief Data Officers, private companies, citizen groups, NGOs and academia to generate data through a more collaborative model that does not impose a strict divide between 'official' and 'non-official' data sources. Open data, data privacy and data interoperability are norms rather than exceptions.

Theory of Change, UN Sustainable Development Solutions Network[25]

Private sector data sharing

Data sharing has been a harder sell in the private sector, as data and Intellectual Property Rights (IPR) are so tied to commercial competitive advantage.

Although this should be one of the first conversations to have with a prospective provider of a model, modelling service or data service, it is too frequently overlooked. Issues of vendor or embedded third party intellectual property can result in limited access and increased costs for subsequent analyses.

The Icebreaker One initiative (also referred to in Chapter 3) brings experience of open data development in the banking sector. Its purpose is to accelerate data sharing in wider financial sectors through clarification of standards and licensing terms. In doing so it promotes the importance of change in culture, business models and incentives.

6.4.2 Data standards

A future ecosystem should maximise **interoperability**, increasing the efficiency of exchanging data between models to reduce duplication in data development, and encourage the community to contribute to improvement of existing data. Key in this is developing tools to help users translate exposure data between different models, and creating environments where multiple models can operate using a common framework.

The IDF Interoperability Technical Working Group (ITWG) and Oasis LMF have led development of a new open-source exposure data transformation tool to assist data transformation in the insurance sector between multiple models (with OED at its centre).[26] A nascent community steering group will develop this prototype tool to accommodate an increasing number of models to increase efficiency and transparency on data conversion in the market. The Risk Data Library Project, managed by GFDRR, has created an open-source risk data schema for the development sector[27], with GED4ALL to structure exposure data. GED4ALL will be linked to the OED via the ITWG transformation tool, enabling more effective sharing of exposure data betwen the insurance and development sectors for development-focussed risk analytics with both built environment and socio-economic focus. The interconnection of technology standards and interoperability play a key role and impact many parts of the modelling process. Table 2 gives four key areas and some examples.

Table 2: Key standards in risk analytics

Model component Standards	Messaging Standards
Hazard – local conditions, topography, soil type Exposure / Vulnerability functions – occupancy and construction codes, building age, secondary modifiers Geocoding – Long/Lat coordinates, centroids, Financial calculations: Policy structures	OED – standardised column headers for exposure data RDO – standardised open exposure and results data format CEDE– standardised open exposure and results data format
Catastrophe Methodology Standards	**Interoperability Standards**
Model settings – metadata, uncertainty, demand surge, sampling Monte-Carlo sampling vs distributional calculation for loss calculation Distribution assumptions for vulnerability curves and hazard uncertainty Correlation	User interface APIs Multi-models Exposure Management processes

[25] Counting on the World to Act', UNSDSN, 2019. https://www.unsdsn.org/counting-on-the-world-to-act-2019

[26] (footnote: https://github.com/OasisLMF/OasisDataConverter)

[27] https://github.com/GFDRR/rdl-data/; riskdatalibrary.org

6.5 Key points

1. The direction of travel in risk analytics is positive in terms of organisational collaboration, technological advances, and data and model governance. It is encouraging that many of the issues we strive to address in a future modelling ecosystem are already underway in the private sector, public sector, or both.
2. We must continue to develop organisational capacity through co-design and co-development of projects and technical collaboration between risk owners and international partners. To reduce technical barriers, clear and transparent guidance is required to describe appropriate uses, assumptions, limitations, data requirements, possible outputs and necessary inputs of different models. In providing more risk information model providers must be able to describe the capabilities of different models without generating confusion.
3. Procurement processes should incorporate open modelling principles and practices to mandate their application in risk analytics projects and drive the adoption of an improved modelling ecosystem. Co-design and co-development, the application of best-practice data and model governance and standards, gender-responsive analytics, and adoption of transparent licensing and documentation should become a consistent feature of all risk analytics projects. The role of donors and commissioning agencies in driving these trends is vital through careful definition of project terms. Clear data and model governance must be developed to produce maximum access for risk owners while promoting sustainability of the risk analytics community.
4. Areas in which risk analytics has not made much progress include people-centred risk metrics, and in particular in gender-responsiveness. As users' decisions are reliant on these being improved, risk analytics capabilities must evolve to respond. Investment should match the ambition, not only in gender sensitive models and data but also in gender-diverse participation in the process.
5. Technological advances are hugely important to achieving more open and democratic access to risk information. The private sector is harnessing the potential of open modelling and cloud-based solutions for risk analytics, but the benefit can only be shared with vulnerable countries and development programmes through firm public-private partnership.

7

Bringing it all together

Market place in Banda Aceh, Indonesia, March 2019.

Bringing it all together

7.1 Perspective in risk decision-making

In 2005 a Swedish academic paper described 'Seven Myths of Risk[1].' Two of these myths were:

- That risk should be judged primarily by the probability and severity of the outcomes.
- That risk decisions should be made by experts, not by the lay person.

In this paper we have highlighted the importance of the quantification of risk as a foundation for development decisions, but we do not for a moment suggest excessive adherence to the numbers.

It is wrong to ignore values such as rights, consent, social justice and social norms, much of which cannot be quantified. As we have described, it would also be wrong to make decisions on the numbers without understanding the uncertainties behind them, which requires a level of judgment built through experience. These considerations are central to rational decision-making and risk communication, which are the tasks of the politician, public sector manager or business leader.

Risk decision-making involves bargaining and compromise under conditions of uncertainty and bias. Where risk analytics can make a fundamental contribution is in the reduction of that uncertainty and bias, and in the description of choices to inform the debate.

The authors suggest that the decision-maker will be more assured and empowered if there is a sense of deep involvement or ownership of the analysis. This leads to recommendations around open access, affordability, use of local knowledge (from women as well as men) and capacity building of diverse stakeholders in the risk analytics value chain.

7.2 Vision

All actors working on risk programmes in support of the UN SDGs, especially risk owners in countries and their agencies, should have access to an open ecosystem of platforms and data in common use across sectors, and the skills to use them.

Empowerment of risk owners through risk understanding is critical not only for sovereign governments and market development, but also for socially just and inclusive outcomes for all of their citizens. It will also help to focus the combined efforts of all sectors for resilience and economic development at scale.

In researching this paper it has become very clear that many governments, development agencies, INGOs and private sector actors share a common view of how risk analytics should be done.

Risk-owning governments, their development, humanitarian and private sector partners would benefit from a common approach to risk assessment and quantification, using the common set of core principles shown in previous chapters.

[1] Risk Management: An International Journal, Vol 7, No 2 (2005), 'Seven Myths of Risk', Sven Ove Hansson

7.3 Summary points and recommendations

1. A strategic approach to risk:

The start point for any country has to be a system level, multi-hazard assessment of risk at national level, drawing all responses to risk into an overall plan. Risk prevention must be the first priority in any national risk strategy. A key principle is the understanding of complex, systemic risk – looking at a single hazard is of little use at the strategic level if the reality is the risk of multiple breadbasket failure, or pandemic overlaid with economic recession and drought. Implicit in this is that the analysis must reflect how human behaviours contribute to disasters through creating vulnerability. The UN system is leading the development of frameworks for governments to employ. Recommendations include:

a. Integration of cross-sector risk assessment capability in key government frameworks, assisted by (but not limited to) the UN Global Risk Assessment Framework, Integrated National Finance Frameworks, and gender-responsive National Adaptation Plans and Disaster Risk Management plans.

b. The authors echo calls for development of strategic risk surveillance functions at international and national levels[2] and suggest that these should draw on cross-sector capabilities from the outset.

c. The private sector is ready to play its part in development of such frameworks. Operational commercial instruments for risk prevention and risk transfer should sit consistently within this national assessment.

2. Empowerment:

Risk owners should be empowered through a partnership approach in developing national capacity in risk analysis. Specific recommendations include:

a. Objectives for development programmes in risk prevention, risk transfer and anticipatory action should include creation of sustainable risk analysis function. On the principle of learning by doing, this includes co-definition and co-development of risk analysis projects.

b. International public and private sector organisations should promote learning about, and use of, service-based open risk analytics platforms and data. The point here is accessibility on both demand and supply sides. On the supply side this is about opening up the market to important, translated research at local and global levels; on the demand side it is about removing barriers to access.

c. National empowerment is not just about creating capacity in government departments. National science and financial institutions (such as national reinsurers) must be included in the process, as should a range of private sector partners.

d. Capacity building programmes should promote women's participation at every point of the chain in risk analysis, decision-making and communication, across public and private sectors.

[2] See, for example, 'The Future of Crisis Financing: A call to action', Poole, L., Clarke, D., and Swithern, S. (2020) Brief, Centre for Disaster Protection, London.

3. Collaboration:

Public-private partnership should be at the heart of the risk assessment process in development. There is not enough resource in the development system to address the global challenge of the 2030 agenda. This is equally true for the process of risk understanding. The private sector has developed risk assessment and management as a survival skill; development programmes should take advantage of this experience. Public-private partnerships offer access to this resource, while also offering introduction of commercial interests to markets in a controlled manner. Recommendations include:

a. The default setting in public sector programmes in risk assessment should be inclusion of industry, rather than exclusion. There will always be circumstances where it is not appropriate for the private sector to be engaged, but this should be the exception rather than the norm.

b. **Creation of a non-profit public-private entity with a mandate to promote and implement the principles of open risk modelling and capacity development with countries and international partners.** Such an entity would be aligned to the InsuResilience Global Partnership's Vision 2025, and should work in collaboration with UN and multi-lateral country development programmes. It should work in partnership from the outset with complementary programmes and organisations[3]. The capabilities of such an entity would include:

    1. Capacity building in deployment and use of open model platforms, including existing model and data resources, and advice on open data standards. Many practical opportunities for such collaborations are available, but the entity to execute them for public good does not yet exist.
    2. Identifying and filling model and data gaps where the current market is not providing. Very often this will involve translation of existing (but previously inaccessible) research for access on open platforms.
    3. Capacity building in model commissioning and long-term development.
    4. Curation of models and data across open platforms.

c. Recognition by risk owners that public-private partnership within countries is just as important. For example, domestic financial companies can play a pivotal role in building national capacity for risk understanding.

4. Open modelling principles:

Donor governments, foundations and climate funds should encourage adoption of a **minimum set of open modelling principles** in procurement by development agencies, countries and private sector partners. The purpose is to enable a flourishing market on both demand and supply sides – for example science institutions and academia are able to supply translated research and, on the demand side, users gain affordable access while rewarding investment in intellectual property.

Cost should not be a barrier to entry to understanding risk, there is room in the market for many different types of provider. Large investments in complex computer hardware environments and proprietary platform licences are a valid choice for commercial companies and even for development banks, but this is not an option available to many risk owners. Principles to be encouraged and built into public procurement processes should include:

a. Compatibility of models and data with open source platforms meeting a minimum set of requirements for access and usability.

b. Open data standards, including a minimum standard of interoperability of data inputs and model results. The adoption of common data standards promotes choice. Care must be taken when comparing model results; the user must be able to tell good from bad, and when mixing sources might lead to nonsensical outcomes. However that skill may never be developed if the choices are not available. A good starting point is choice in exposure data sets, where some leading data formats are already being made interoperable on open platforms.

c. Inclusion of local research and knowledge in the analysis.

d. Transparency of data sources and assumptions forming the basis of the analysis. It is essential that users can see input data and the assumptions behind the model and are able to reproduce model results. This is foundational to understanding the level of uncertainty during the decision-making process.

[3] For example the Centre for Disaster Protection (www.disasterprotection.org), the GEM Foundation (www.globalquakemodel.org) and global centres of science expertise (www.GADRI.org)

5. Provision of a capability assessment framework, and a supporting public good 'starter pack':

No frameworks exist to identify the standards and appropriate modelling techniques that best match a user's needs. A project is needed to describe the core needs of a diverse set of users in a common framework aligned with the UN Global Risk Assessment Framework (GRAF.)

The framework should build on the outline model proposed in Chapter 3. Users would then be able to assess the maturity of their current capability and plan their next steps in capacity building.
The framework should be reinforced by access to a limited, standard set of models and data, accessible on open platforms, as a foundation for developing a risk assessment function to the complexity required by the risk owner. This work could be executed by the PPP in Recommendation 3. Necessary tasks include:

a. Design and implementation of the capability assessment framework.

b. Identification of model and data gaps that limit countries' ability to take a strategic, *ex-ante* view of risk.

c. Translation of existing global peril models: Global hazard models exist for most perils but investment is required to go the 'last mile' by formatting them for use on open source platforms. The conversion of the Global Earthquake Model (GEM) to the Oasis LMF format for insurance applications is a good example.

d. Global Exposure Database: As seen in Chapter 6, the schema for a global exposure database for use across sectors already exists and is ready for use[4]. A multi-tier approach using this schema would make a starter version freely available while protecting the intellectual property value of higher resolution research.

6. People-centric metrics:

For the achievement of many SDG targets, much greater investment must be made in **people-centric metrics**; data must be sex-disaggregated to enable a gender focus and programmes specific to the vulnerable and/or financially excluded. Specific recommendations include:

a. Capacity building to enable default incorporation of gender considerations and sex-disaggregated data in risk analysis for operational risk prevention, risk transfer and anticipatory action programmes. This includes facilitating the collection of sex-disaggregated disaster data by V20 countries to report to the Sendai monitor platform and ensure the system can publicly display this data.

b. Inclusion of wider gender-based vulnerability data sources in key frameworks, for example women's time-use surveys, financial inclusion, gender-based violence and gender legal differences.

c. Engagement with investors and grant-makers of all sectors to include gender dimensions of climate risk in research, and investments and programme decision-making.

[4] GED4ALL: https://www.gfdrr.org/sites/default/files/publication/Exposure%20data%20schema_final%20report.pdf

7. Risk education and communication:

The risk message doesn't resonate with an authority or community unless it is understood and there's some ownership. Recommendations include:

a. **Knowledge transfer has to go both ways: Climate experts and risk practitioners need to understand the aptitude and appetite in each country and to learn how to better convey their message.** This can be addressed by fostering exchanges between national stakeholders, the private sector and international and bilateral organisations.

b. Gaps in education can be addressed by online courses – best delivered with real-world application of the concepts – but must be embedded within a project or longer dialogue.

c. It takes more than a technical solution to address climate risk. Capacity building in risk education and communication are key to long term risk reduction and resilience.

7.4 Common concerns relating to the recommendations

As with any major change, counter-arguments can, and should, be raised to test logic and feasibility.

Some of the issues discussed in the development of this paper are highlighted here, for transparency and further debate:

Market disruption

"Open-source data and models provide opportunities to build ownership and trust of the data inputs, while automatically increasing the return on investments of generating the data.[5]*"*

The recommendations suggest partnership between public and private sectors that would involve commitment of public funds for public good purposes. Procurement rules quite rightly proscribe spending that would distort functioning private sector markets.

As the above quote implies, the authors believe that the recommendations would have the opposite effect. The world is inexorably moving to open, interoperable data, enabling choice and access while still enabling providers to realise the value of their intellectual property.

Digital markets are becoming more efficient in every sector from banking and communications to entertainment – imagine what it would be like if it were necessary to buy a different television to watch each entertainment channel. Risk analytics should move in the same direction, while maintaining forms of licensing that protect and realise the value of investment in research.

A more open digital ecosystem for risk analytics and data would be additive. It would create greater choice and access for users, and greater market reach for a wide range of providers including vendor modellers, brokers, science institutions and academia. The market will continue to grow for proprietary ecosystems, which provide a distinct offering. However, it is also notable that some commercial modellers are seeing further opportunity for growth by aligning their data with open source platforms.

The working assumption is that this leads to a far more level playing field. For development agencies and international NGOs, often purchasing risk insight, it becomes far more possible to compare like with like and to validate research. It also encourages non-commercial providers such as academics to deliver material in a translated, compatible form that works for applied project use.

An economic study to test and quantify these assumptions would be worthwhile.

Simplicity versus Complexity

'Just tell me where I can find a flood map!' is not an unusual comment in discussions with country partners and their agencies. There's an understandable desire for simple answers, and the point is often raised that countries don't have the capacity to take on complex analysis.

There is no intention in the recommendations to impose unwanted or overly complex solutions, nor a naive ambition to create disaster modelling experts overnight.

As we have seen in Chapter 3, for some applications the requirement may be for the data building blocks rather than the full risk analysis. Adoption has to be demand driven and therefore providers can only match the appetite. However it is essential to become risk aware and develop risk judgment, and for that the risk owner needs knowledgeable internal specialists and advocates.

We have seen evidence in earlier chapters that there is a desire in many countries for greater ownership of the analysis, to drive national planning commitments and inform conversations with international markets. It is assumed that a gender-diverse raw talent pool exists in countries that could be developed to create a risk discipline; however the current supply chain doesn't provide the tools or the training.

Every country's interests and needs will be different. There will be barriers to overcome – for example, the World Bank and others have reported instances of low confidence in models, particularly after negative experiences of basis risk. However if the open modelling infrastructure and a usable interface are made available, the solution can be co-defined and co-developed realistically to match foreseeable capacity. Involvement of the risk owner in the process is the important factor.

Additionally, in the proposed open modelling ecosystem, which serves as a community and marketplace, those flood maps would be much easier to find.

[5] InsuResilience 'Analysing Stakeholder Needs for Climate and Disaster Risk Finance Data', Feb 2020.

Sustainability

Public investment in stimulating such a market would most likely be time limited, perhaps for 3-5 years. Any entity set up to drive change during that period would either have achieved its aims and folded, or more likely would be sustained through continued project work on public goods, and realisation of intellectual property value through licensing to commercial organisations, operating within state-aid rules.

Sustainability of country capacity would again be different in each case. There are undoubted challenges related to political change, staff turnover and cross-departmental alignment, but the case studies in this paper show that where there is a desire to plan for risk, the means can be found, and the international community is willing to partner over time to make that happen.

Vision versus reality

The recommendations point to significant change. Following a set of principles is desirable, but day to day considerations of current regulations, competing interests, deadlines and financial prudence all create a counter-narrative in the short term. The authors suggest that investment and insurance regulators could have a particularly important role to play in effecting these changes, by setting expectations and rules that promote market development. Regulation has been outside the scope of this paper but the authors recommend further work on the application of these principles in the regulatory environment.

Timing

The view of this paper has been developed by 'standing on the shoulders of giants[6]'. The recommendations are distilled from the experience and work of many and some of the themes should be familiar. **However, acting on these recommendations now is more important than ever.** Reasons include:

c. The time to galvanise political will is during and after a crisis. Global public and political attention to risk has not been this high for a very long time and there is a genuine desire to avoid such shocks in the future. The time to lock risk awareness and understanding into national processes is now.

d. The next Conference of the Parties (CoP26) is on the horizon (November 2021) and the link is increasingly being made between climate risk and other risks, including pandemic, both in terms of causal links and the compounding of impacts. The build-up to CoP26 offers the necessary mechanism to bring the proposed change to the attention of donors, foundations and development partners.

[6] Letter from Isaac Newton to Robert Hooke, February 1675, suggesting that he was only able to look further in science because he was building on the great work of others.

Annexes

Annexes

Glossary

Basis risk: In parametric or index-based risk transfer instruments, basis risk refers to the difference between the payout and the actual loss. It can be positive or negative. For example a payment for crop failure may not occur if model assumptions fail to simulate drought conditions and planting practices. Equally an index may trigger a payment unnecessarily.

Catastrophe bond: A high yielding insurance-linked security providing for payment of interest - and/or principal to be suspended or cancelled - in the event of a catastrophe described by severity and location.

Catastrophe risk models: A disaster risk modelling approach widely used to inform financial risk transfer. Models simulate the magnitude, intensity and location of a large number of possible events to determine the probable amount of damage and estimate the potential loss in financial terms.

Disaster: A serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts.

Disaster Risk Finance: Financial instruments used in development and humanitarian programmes to reduce vulnerability to the impacts of disasters, with the expectation of rapid and dependable payout as a preferable alternative to emergency aid. Categories commonly deployed at sovereign or provincial level include insurance or insurance-like mechanisms and contingent credit.

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

Disaster Risk Reduction: The policy objective of disaster risk management, disaster risk reduction is aimed at preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and therefore to the achievement of sustainable development.

Economic loss: Total economic impact, being the sum of:

- Direct economic loss: the monetary value of total or partial destruction of physical assets existing in the affected area. Direct economic loss is nearly equivalent to physical damage.
- Indirect economic loss: a decline in economic value added as a consequence of direct economic loss and/or human and environmental impacts.

Ex ante risk financing: Risk financing instruments requiring advance planning. Examples include reserves, contingency budgets, contingent debt, and risk transfer mechanisms such as insurance, catastrophe bonds and anticipatory finance.

Ex post risk financing: Reactive finance measures including emergency budget reallocation, domestic or external credit, tax increases or emergency aid.

Expected loss: The modelled average loss relating to a particular risk transfer contract. The expected loss is related to the return period; for example expectation of a 1 in 200 year event would give rise to a 0.5% expected loss.

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

Gender: Refers to relations between men and women, which are based on socially constructed behaviours and norms, and can change over time and from place to place.

Gender responsive: A term to describe approaches (for example to risk analytics) designed to overcome historic gender biases to reduce inequalities. Gender responsive risk analysis and actions recognise that women and men face different risks on the basis of their gender, as well as different vulnerabilities to shared risks.

Hazard: The UN Hazards Definition and Classification Review (2020) defines hazard as a process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation. Hazards may be Hydrometeorological, Geological/ geophysical, Environmental, Biological, Technological or Societal.

Indemnity insurance: Traditional insurance mechanisms that pay out after an assessment of the loss, harm or damage suffered by the insured.

National Adaptation Plans: A process established by the United Nations Framework Convention on Climate Change (UNFCCC) to facilitate adaptation planning. NAPs identify and address medium to long term adaptation needs in a continuous and iterative process.

Parametric (or index-based) mechanisms: Insurance or insurance-like instruments that pay out on an index or parameter established in a contract. A threshold of severity or intensity of an event is agreed based on risk analysis and payments are triggered automatically when the threshold is exceeded. The advantages are simplicity and speed of response, as no loss assessment is required, but the disadvantage may be the realisation of basis risk.

Resilience: The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.

Risk layering: Governments, insurers and other risk owners or carriers can manage their expected loss by separating those categories of risk they wish to cover from within their own resources (for example high frequency, low impact events) and those residual risks they wish to transfer (for example extreme 'tail' events.)

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

Further definitions may be found at:

InsuResilience Global Partnership website:
www.insuresilience.org/glossary

UNDRR website:
www.UNDRR.org/Terminology

IDF Library: For example:
https://www.insdevforum.org/idf-paper-how-technology-can-help-bridge-protection-gap

Centre for Disaster Protection:
https://disasterprotection.squarespace.com/glossary

Annex A: Case Studies supporting Chapter 4

The case for building country capacity in risk analysis →

Case study 1

Building Disaster Resilience to Natural Hazards in Sub-Saharan African Regions, Countries and Communities

Authors: Roberto Rudari (CIMA Foundation), Adrien Gignac-Eddy (CIMA Foundation), Isabel Gomes (CIMA Foundation)

Introduction

Over the last four decades, sub-Saharan Africa has experienced more than 1000 disasters, affecting approximately 320 million people (World Bank, 2017; PreventionWeb 2019). The majority of disasters in Africa are hydro-meteorological in origin, with droughts affecting the largest number of people and floods occurring frequently along important river systems and in many urban areas.

Cyclones, geological events, sea level increase, coastal erosion and storm surges also deeply affect the continent. These disasters disproportionately affect societies' most vulnerable groups, exacerbating existing inequalities. Women for example, have higher rates of mortality, morbidity and economic damage to their livelihoods following a disaster, due to pre-disaster inequalities, social vulnerabilities, and gender norms (Care, 2018).

Furthermore, at the national level, existing exposure and vulnerabilities are exacerbated by countries' limited coping capacities and resources for investing in disaster risk reduction and recovery measures. In this context, post-disaster rehabilitation often implies the intervention of international aid or the diversion of national funds originally planned for development interventions, resulting in tremendous setbacks for societal development as a whole.

In 2013, the European Union (EU) and the African, Caribbean and Pacific Group of States (ACP) signed an agreement to support disaster risk management in Sub-Saharan Africa. Under this agreement, the 'Building Disaster Resilience to Natural Hazards in sub-Saharan African Regions, Countries and Communities Programme' was launched in July 2015 to provide effective implementation of an African comprehensive disaster risk reduction (DRR) and disaster risk management (DRM) framework.

As part of the programme, UNDRR, one of the main implementing partners, fostered comprehensive risk assessment activities and contracted CIMA Research Foundation, VU Amsterdam, and the University of Wageningen to develop probabilistic flood and drought risk assessments in the present and in a future climate scenario.

This exercise was done in close partnership with sixteen sub-Saharan African countries and their institutions: Angola, Botswana, Cameroon, Côte D'Ivoire, Equatorial Guinea, Gabon, Gambia (Republic of The), Ghana, Guinea Bissau, Kenya, Eswatini (the Kingdom of), Namibia, Rwanda, São Tomé and Principe, United Republic of Tanzania and Zambia.

The development of probabilistic risk assessments was chosen to obtain the most accurate, quantifiable and applicable risk knowledge. The probabilistic risk assessments provided these sub-Saharan countries with a comprehensive view of hazard, vulnerability, exposure, risk and uncertainties for floods and drought, considering both the present and a projected future climate, as well as socio-economic projections for each country.

The study also included the analysis of regional and global risk patterns and trends. Ultimately, it aimed to support government's risk informed decision-making and investments as well as to increment institutional strengthening and existing DRR/DRM capacities in the countries involved.

In 2019, an extension of the project allowed for a more collaborative approach between researchers, institutions, and DRR/DRM practitioners in Angola, United Republic of Tanzania and Zambia. The risk assessments were refined by incorporating local data to the global and regional datasets used in the first phase.

While the short timeframe of this initiative put limits on the possible extent of the collaborative approach adopted by the working group, the efforts made over the course of this year greatly improved the mainstreaming of the risk profile results when compared to the first phase of the project. The approach led, for example, to important policy outputs in the form of national endorsements and subsequent policy initiatives at the national level. We will argue, therefore, that the project offers essential insight into how a bottom-up approach to modelling risk, one that includes the at-risk community in its process, can produce benefits for implementation even under such time constraints. This collaboration took place in two distinct spheres of the project:

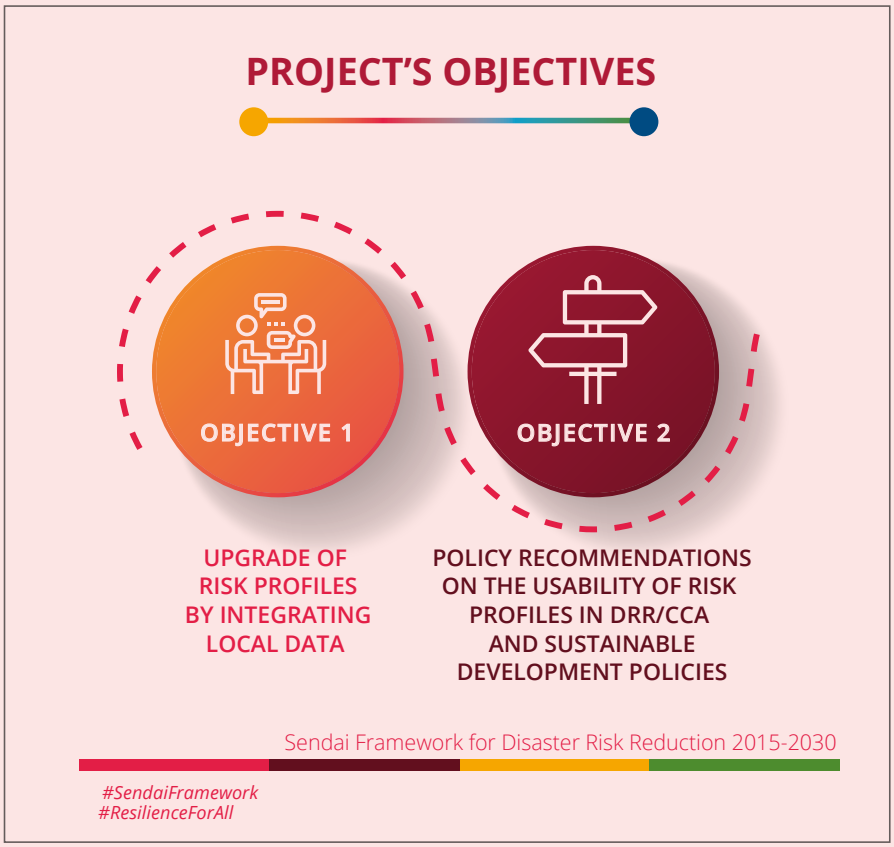
i) Sphere 1 – integration of local data to the risk profiles;

ii) Sphere 2 – the elaboration of participatory policy recommendations based on the risk assessment results.

initiative put limits on the possible extent of the collaborative approach adopted by the working group, the efforts made over the course of this year greatly improved the mainstreaming of the risk profile results when compared to the first phase of the project. The approach led, for example, to important policy outputs in the form of national endorsements and subsequent policy initiatives at the national level. We will argue, therefore, that the project offers essential insight into how a bottom-up approach to modelling risk, one that includes the at-risk community in its process, can produce benefits for implementation even under such time constraints. This collaboration took place in two distinct spheres of the project:

i) Sphere 1 – integration of local data to the risk profiles;

ii) Sphere 2 – the elaboration of participatory policy recommendations based on the risk assessment results.



Sphere 1: Integrating Local Data

The one-year extension in Angola, UR of Tanzania and Zambia, allowed for extensive collaboration at the local level that was not possible in the first phase of the project. From the beginning of the risk assessment process, the team of researchers emphasised the need for collaboration with local institutions as a cornerstone of its methodology in order to ensure that the project would be fully embraced by the national institutions. Collaboration was considered to be crucial for several reasons, but mainly to:

i) improve the accuracy of the profile risk evaluations;

ii) validate the risk profile results with national stakeholders;

iii) increase the ownership and the application of risk information into national policies and strategies;

At the start of the study, for each of the considered exposed elements, a series of available global datasets were used as a standard set for each country. These datasets had a global coverage, ensuring the background exposure knowledge necessary to perform acceptable risk analyses, even in data-poor regions like Sub-Saharan Africa.

Nevertheless, these datasets offered a global coverage at the expense of resolution, both in terms of spatial scale and of the detail of the associated information. In order to improve the accuracy of the final risk assessment, a series of input data and knowledge from local stakeholders were therefore added.

THE IMPORTANCE OF NATIONAL DATA

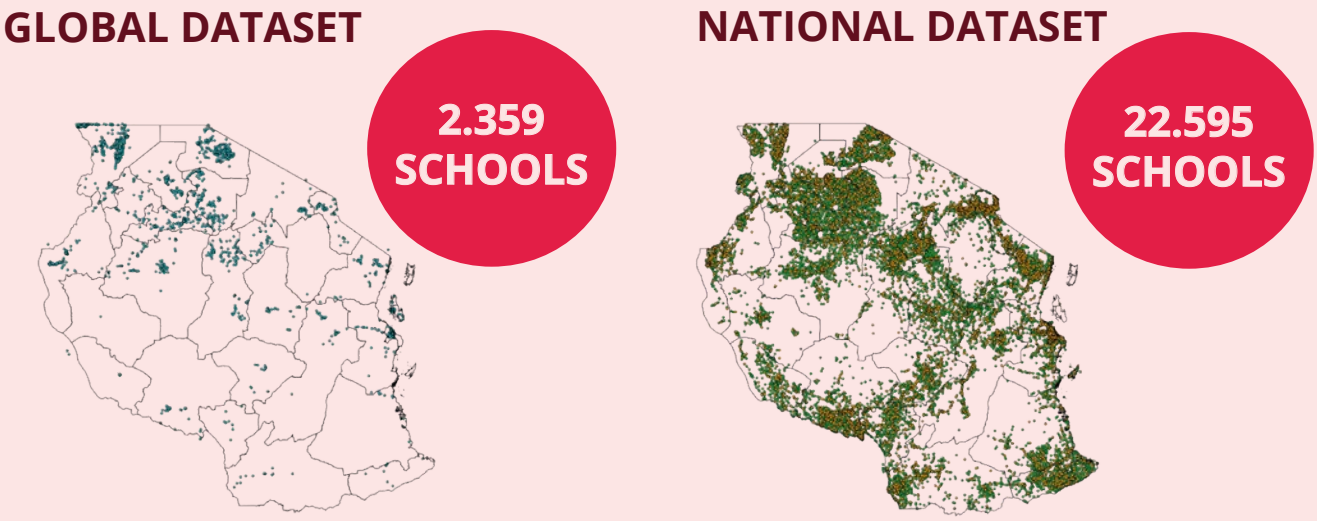


Fig. 2-3 : *Education Facilities Distribution, Tanzania*

Fig. 4-5 : *Education Facilities Distribution, Angola*

The gathering and processing of local data was made possible thanks to the help of each of the national disaster risk management agencies. Visits were held in all the countries, and a study visit took place at CIMA Research Foundation's headquarters.

These visits gathered policymakers and technical staff from civil protection and hydrometeorological services, fostering the integration of data from hydrological, meteorological, and statistical agencies into decision-making. For technical staff, this was also an important opportunity to learn from other countries, as well as to express their needs regarding the continued development of their own capacities. Collectively, the visits allowed the team to make common decisions on data inclusion/exclusion for the risk assessment process.

Sphere 2: Policy Recommendations

Collaboration on the mainstreaming of the results into disaster risk reduction policies began with the communication of the risk profile results to a non-technical audience. The profiles were co-designed by the consortium's communication team and the national DRR/Sendai focal points, who decided on several elements to better represent risk results in their countries. The focal points provided key inputs on the use of maps, graphs and images, and helped validate the general content and information. Further communication materials that weren't originally planned in the project were also suggested by national focal points to mainstream risk results throughout the countries (ex. posters with key results were requested to be distributed among provincial civil protection units). This local support helped build trust with higher level authorities, paving the way for the subsequent national endorsements of the risk profiles.

These efforts did not limit themselves to the effective communication and presentation of the results. Steps were taken to highlight the nexus between disasters and development, encompassing the main messages from the post-2015 development agendas on risk reduction and resilience building. The risk profiles offered an opportunity to begin illustrating and discussing important issues related to integrated, risk-informed development and the team began efforts to secure the political engagement required for these aims.

The elaboration of policy recommendations based on the risk profile results continued this development of political engagement. These collaborations took place during three-day national workshops in each country in December 2019.

Participants included technical national DRR/DRM staff, policymakers and civil servants from relevant ministries and the consortium/ UNDRR staff. To facilitate the discussions, CIMA Research Foundation created a guideline document on the use of risk profiles for understanding risk, risk-informed development and strengthening disaster risk governance, which was presented during the workshops.

Subsequently, the difficulties and advantages of implementation of the risk results were extensively discussed, and inputs from all of the participants formed the basis of the policy recommendations. These were then integrated in the final risk profile reports in a chapter entitled *Policy Recommendations*, targeted at upper level policymakers.

Outcomes/indicators of success

In spite of the project's short timeframe, the risk profiles have successfully followed various implementation paths in each country. The risk profiles were endorsed by the office of the Vice-President in Zambia, the office of the Prime Minister in Tanzania and the Ministry of the Interior in Angola. In Zambia, plans were made to present the results to parliament so that they could be mainstreamed into the national development strategies. Evaluations were also made on how to use the risk profile figures in helping the country negotiate risk transfer options with the Africa Risk Capacity, whose activities are at their onset in Zambia.

Tanzania has moved to quickly integrate the risk profile results into their DRR strategic plan, reviewing the initiatives that had already been laid out and aligning them to the risk profile results. As the Tanzania risk profile was endorsed as an official document from the government, other related governmental initiatives (e.g. the Climate Change adaptation plan) will be updated with the results from the profile, but this process is ongoing.

Finally, Angola used the profiles to launch a risk awareness campaign targeting civil protection practitioners throughout the country. The country is also launching other DRR initiatives as a result of the project, such as the development and implementation of an Early Warning System at the national level.

While improving the implementation of the risk profiles into national policies and initiatives, it is clear that the collaborative approach also empowered local partners and institutions. The act of gathering and organising local data served as an important institutional capacity development exercise, both by clarifying how the data would be used in the modelling and by promoting the advantages of contributing local data for more accurate risk results.

This resulted in an increased ownership of the risk profiles, especially when compared with the first phase of the project, when local engagement for data collection could not take place.

For policymakers in Angola, Zambia, and Tanzania, a non-negligible change in risk awareness and in the understanding of risk was observed. Understanding risk is the first step

for DRR, resilience building and sustainable development as those are only different stages of a common path towards all-inclusive and improved life conditions.

Although it is not possible to measure the project's outcomes in terms of development impacts in such a short timeframe, the consortium followed the indications provided by the Sendai Framework for Disaster Risk Reduction (SFDRR) and the Sustainable Development Goals (SDGs) of the 2030 Agenda.

The disaster-related impacts were projected using socio-economic indicators, which referred to the number of men and women affected, the direct economic losses by sector and the damages to critical infrastructure. Having evidence-based information on those indicators, which are key assets for societal prosperity, represents an entry-point for national development strategies, especially if considering future risk trends. Being able to anticipate risk is crucial to plan adequately, encompassing a multi-sector, multi-stakeholder and a multidisciplinary approach.

Lessons learned

This project offers a clear insight into the advantages of collaborative risk assessment work in the context of risk awareness and policy implementation. While the long term benefits of its second phase will require more time to assess, the short term impacts in terms of momentum for real change in disaster risk reduction policy are encouraging, and far more meaningful than the outputs of the first phase where collaboration was not made the main focus.

Going into the second phase, much of this need for collaboration was based on an opportunity to improve the accuracy and detail of the risk assessments, yet while this hypothesis revealed itself to be true, it was not the most important lesson.

Above all, this project has shown that a collaborative approach to modelling risk that includes the at-risk community in its process increases local ownership, which necessarily leads to a better implementation of the results and policy outcomes.

Indeed, engaging with all stakeholders in the different phases of implementation, respecting their knowledge and responsibilities in the process of DRR within the countries were crucial to the successful outcomes of the project's second phase.

GEM Foundation capacity building in South America

Authors: Ana Beatriz Acevedo (Universidad EAFIT) and John Schneider (GEM Foundation)

Abstract

Earthquake risk in South America is greatest in the seven Andean countries, where more than 3000 deaths and US$30 billion in direct losses from earthquakes have occurred over the past two decades. Although expert capabilities exist in these countries to assess earthquake risk, the information, infrastructure, tools, and collaboration networks necessary to develop comprehensive knowledge among scientists and engineers and to move this knowledge into the mainstream of disaster risk reduction activities has been lacking.

GEM Foundation began a series of collaborative projects in 2013 focussed on developing local capacities across sectors (academic, public and private), across technical disciplines (e.g., hazard, risk, IT), and including organisations responsible for the implementation of disaster risk reduction policies and programs. GEM provided its OpenQuake earthquake hazard and risk analysis software suite[1] (Figure 1) to facilitate the development of databases, models and analysis results.

Through the development of a wide range of partnerships, the program has promoted principles for collaboration, protocols for open sharing of information, and developed common tools and protocols for analysis (e.g., Creative Commons licensing), resulting in DRR activities across public and private sectors that is synergistic and self-sustaining at a regional scale. Resulting data, models and tools are being used for input to seismic building regulation, catastrophe insurance, local planning and national risk assessment applications.

Introduction

South America incorporates some of the most seismically active regions on Earth, where the South American subduction zone generates the forces to create the Andes Mountains and drives the occurrence of destructive earthquakes across Chile, western Argentina, Bolivia, Ecuador, Peru, Colombia and Venezuela.

In turn, the high vulnerability of many structures and the high population density of the main cities are factors that contribute to the region's high seismic risk. In the last two decades alone, over 3,000 fatalities have been reported, and the economic losses have exceeded US$30 billion (EM-DAT, www.emdat.be).

While expert capabilities exist in these countries to assess earthquake risk, the information, infrastructure, tools, and collaboration networks necessary to develop comprehensive knowledge among scientists and engineers and to move this knowledge into the mainstream of disaster risk reduction activities has been lacking.

Methodology

The South America Risk Assessment (SARA) Project, funded by Swiss Re Foundation from 2013-2015 and led by GEM Foundation, brought experts, institutions, and stakeholders from the seven Andean countries to develop a regional assessment of earthquake hazard and risk. The approach was to leverage international best practice tools and methodologies developed by GEM with local expertise and knowledge needed to establish local ownership and define risk assessment objectives and priorities.

GEM focussed on developing local capacities across sectors (academic, public and private), across technical disciplines (e.g., hazard, risk, IT), and through to the implementation of disaster risk reduction policies and programs. GEM provided its OpenQuake earthquake hazard and risk analysis software suite[1] (Figure 1) to facilitate the development of databases, models and analysis results.

More than 50 of the region's experts across 17 institutions collaborated to produce critical data sets, develop common approaches, and develop open-source tools for both data collection and interpretation.

[1] Pagani, M., D. Monelli, G. Weatherill, L. Danciu, H. Crowley, V. Silva, P. Henshaw, L. Butler M,. Nastasi, L. Panzeri, M. Simionato, D. Vigano. Seismological Research Letters (2014). OpenQuake Engine: An Open Hazard (and Risk) Software for the Global Earthquake Model, Seismological Research Letters, 85 (3): 692–702. (https://doi.org/10.1785/0220130087)

Figure 1: OpenQuake is a suite of open-source software that allows users to collaboratively access and use data, build earthquake hazard and risk models, perform analyses and share the results with the community of users worldwide.

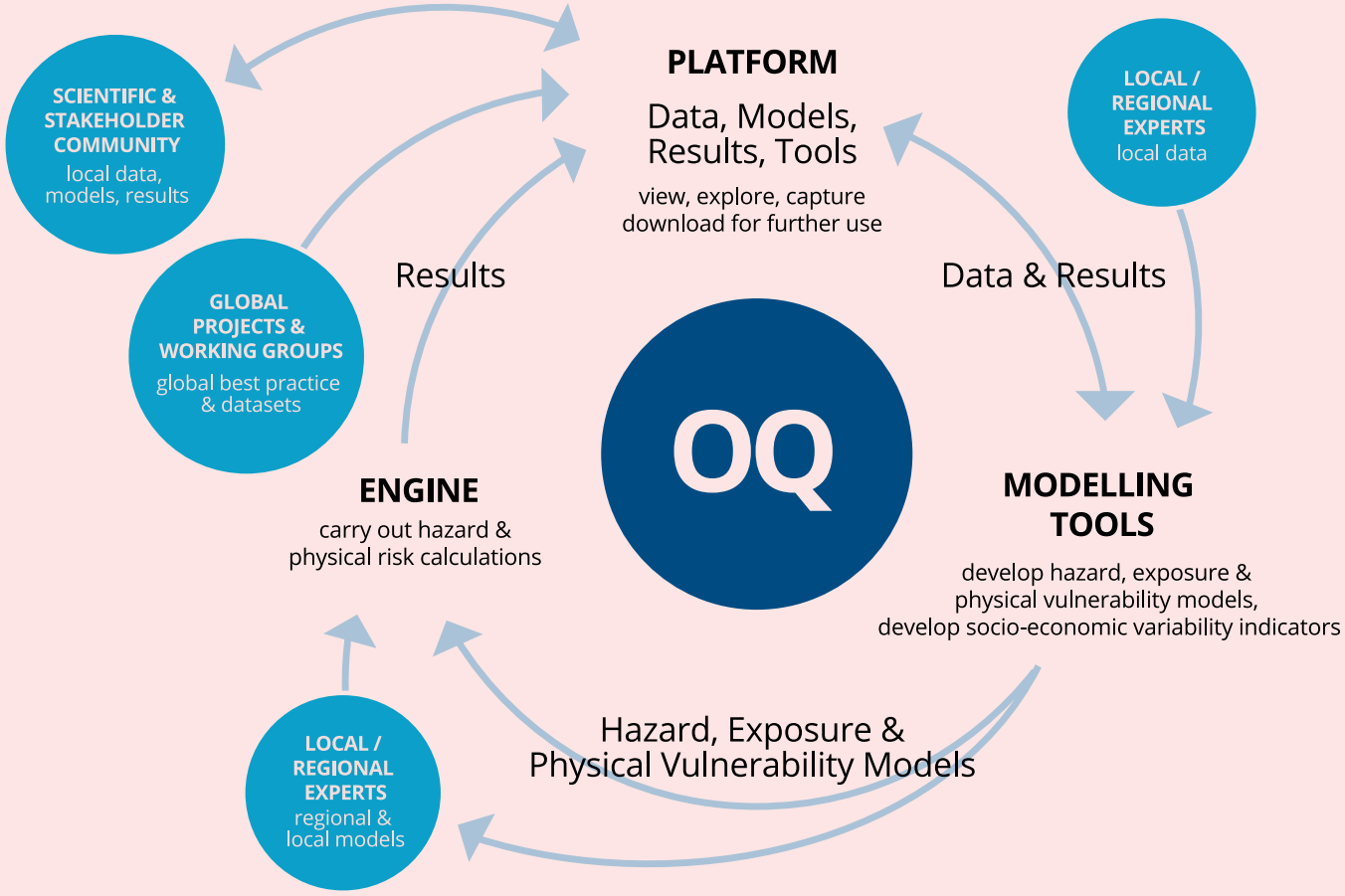


Figure 2: OpenQuake training session in Medellin Colombia in May 2017.

Results/solutions

Key products from the SARA Project are:

- a regional probabilistic earthquake hazard model;
- an exposure database and vulnerability models for residential building stock;
- exposure database and social vulnerability model of human population;
- earthquake risk profiles at national to subnational level;
- the Integrated Risk Management Tool (IRMT) software for integrated risk indicators; and
- a methodology for assessing community earthquake resilience called the Resilience Performance Scorecard.

The SARA Project also provided the foundation for formal and informal collaborations at many levels and for many purposes. GEM subsequently developed formal partnerships across public and private sectors (e.g., Suramerica Insurance, the Geological Survey of Colombia), academic partnerships (e.g., Universidad EAFIT and Universidad del Norte, Universidad Catolica de Chile), non-profits (e.g., OSSO).

In 2019, funded by the US Agency for International Development, GEM initiated Project TREQ (Training & Communication for Earthquake Risk Assessment). At present, TREQ is being implemented with the broader DRR community in South America and the Caribbean, including universities, private companies, and local governments in Cali (Colombia), Quito (Ecuador), and Santiago de los Caballeros (Dominican Republic), where results will be used for local planning purposes and university courses.

Beyond the direct results of SARA and other GEM collaborations, we are now witness to indigenous collaborations and outcomes, such as the following:

- research projects at many universities;
- OpenQuake incorporated into academic curricula (e.g., Universidad EAFIT);
- collaboration across public, private and academic sectors (e.g., Medellin);
- coordination and sharing of information involving local, provincial and national government organisations (e.g., Medellin, Antioquia and Colombia national);
- multi-national collaboration for urban risk assessment (Colombia, Ecuador and Dominican Republic);
- national hazard modelling informing building code/ regulation;
- development banks and (re) insurance companies using GEM data and models to develop risk financing mechanisms.

Outcomes/indicators of success

The GEM collaboration in South America that started with the SARA Project succeeded in embedding the principles for collaboration, protocols for open sharing of information, and common tools and protocols for analysis (e.g., Creative Commons licensing), resulting in an environment for collaboration on DRR activities that is synergistic and self-sustaining at a regional scale.

Indicators of Success

- Several hundred individuals participated in: technical training to build hazard and risk models (scientists & engineers); applications training in the use of results (disaster risk management community); and risk communication to raise awareness (e.g., other stakeholders). Figure 2 shows one such training event.
- More than 200 collaborators from geological groups & associations, universities, scientists, engineers, international agencies, municipalities and government agencies.
- Operational use of models, data and tools for risk assessment across sectors (e.g., research projects, training activities, risk communication).
- Applications of results to building regulation, risk financing, disaster response, disaster planning.

Lessons learned

The most important lessons learned from the SARA project and subsequent interactions in Colombia and the region are the focus on local participation and engagement; institutional collaboration; and the challenges of data sharing. Specific lessons learned are:

- Active participation of local experts is essential in incorporating local knowledge and the sense of ownership of the results among local stakeholders.
- Governance arrangements for the institutional, legal and financial frameworks are essential for the uptake of risk assessments into disaster risk reduction activities.
- Provision of open tools and training using a common methodology can expedite capacity building and bridge communication barriers across sectors.
- Formal agreements with institutions are necessary to bring commitment, reliability, sustainability and credibility to the project.
- Early engagement of stakeholders is key to ensuring local ownership, proper consideration of local priorities, and utilisation of the results.
- Concepts of open-source, licensing, and information sharing are not commonly accepted or understood, and therefore require dedicated training modules to facilitate proper handling of data and to promote active information sharing and access.

The Economics of Climate Adaptation (ECA) in San Salvador

Authors: Maxime Souvignet (UN University)

Abstract/Images

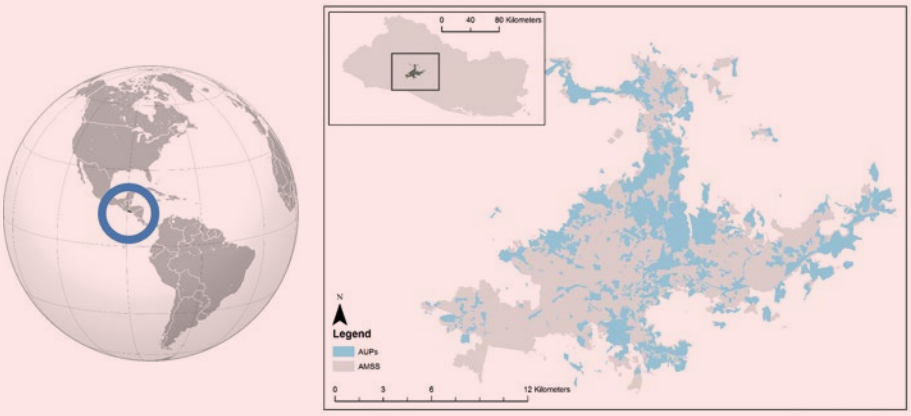
The Economics of Climate Adaptation (ECA) Study in San Salvador aimed at identifying the adaptation measures targeting especially people and their dwellings in vulnerable zones as well as people in general and key infrastructure such as schools, hospitals and road networks. This case study offers a rare example of how risk modelling, via capacity building and stakeholder engagement, help to unlock climate finance.

ECA offers a systematic and transparent approach that fosters trust and initiates in-depth inter-sectoral stakeholder discussions. The methodology can be flexibly applied from the national down to local level to different sectors and different hazards.

It provides key information for programme-based approaches, insurance approaches and has potential to support National Adaptation Plans' (NAPs) development. Recently, KfW decided to implement two pilot studies in Bangladesh and El Salvador using the ECA methodology.

The main objectives were to support decision makers in developing their adaptation strategy and to develop a CCA measures investment portfolio. This case study presents the main finding, reflects on stakeholder capacity development and on lessons learned.

Figure 1: San Salvador Metropolitan area location. Clusters of urban poor and vulnerable populations are indicated in blue.



Introduction

El Salvador and its capital city, San Salvador experience a high rate of urbanisation putting increasing pressure on its ecological and environmental systems. It has also a limiting effect on potential areas to grow for the community. Climate change is increasing this pressure by raising the economic and environmental impacts of river floods, tropical storms and landslides in the country.

KfW identified the ECA framework as a valuable approach to (1) provide local decision makers with the fact base to develop their own adaptation strategy, (2) foster the development of KfW's CCA portfolio to include more loan and program based finance as well as climate risk insurance approaches, not least in the context of (3) the future challenge of National Adaptation Plans (NAPs), and to (4) learn for its climate screening procedure.

The main challenges facing the implementation of the study included that the ECA Framework principles, developed by the reinsurance sector, had never been applied to poor and vulnerable people.

Could a monetisation of climate risk grasp the impact on those most vulnerable, but whose assets are worth the least? How to quantify assets with a very marginal value? Can the ECA framework possibly unlock climate finance by quantifying impacts of a various range of assets for different hazards? How to raise ownership for a method requiring advanced skills in modelling and climatology?

Case study 3

Figure 2: How could poor and vulnerable populations be included? Mapping at the household levels in a highly clustered urban area in San Salvador (UNU-EHS & KfW, 2016)

This case study will present how the study was developed, as well as the main objectives followed. It will present the main results achieved by the study, and discuss the outcomes for stakeholders in El Salvador. Lessons learnt and follow-up activities are highlighted in conclusion.

How was study developed?

In 2015 KfW started to implement two pilot studies in Bangladesh (Barisal) and El Salvador (San Salvador) testing the feasibility of ECA approach to prepare climate change adaptation (CCA) measures in urban areas. KfW identified the ECA framework as a valuable approach to foster the development of KfW's CCA portfolio to include more loan and program based finance as well as climate risk insurance (CRI) approaches.

The Economics of Climate Adaptation (ECA) approach offers a unique contribution, which combines risk assessment, adaptation measures and risk transfer. Its results allow a flexible identification of cost-effective climate adaptation measures for a variety of projects and sectors.

The ECA is powered by a unique open source software CLIMADA and it evaluates current and potential costs of climate change and how to prevent them by determining a location's total climate risk –calculated by combining existing climate risks, climate change and the value of future economic development.

The Economics of Climate Adaptation (ECA) addresses in particular the following questions:

1) What is the potential climate-related damage over the coming decades?
2) How much of that damage can be averted, using what type of CCA measures?
3) What investments will be required to fund those measures - and will the benefits of these investments outweigh the costs?

The ECA Studies in San Salvador concentrated on three types of Climate hazards: Flood risk, landslides and tropical winds. The choice of these hazards, as well as numerous decisions regarding exposure, definition of study areas were the results of an extensive stakeholder consultation with the main partners of the project.

KfW contracted GFA consulting Group, a consultancy and SwissRe a Reinsurance company with the implementation of the first large scale ECA Studies in San Salvador. Local partners were the Ministry of Environment, the Ministry of Public Infrastructure, the Municipality of San Salvador and the University Centroamericana (UCA). The role of the UCA was central in organising capacity building efforts between KfW and local partners.

Results/solutions

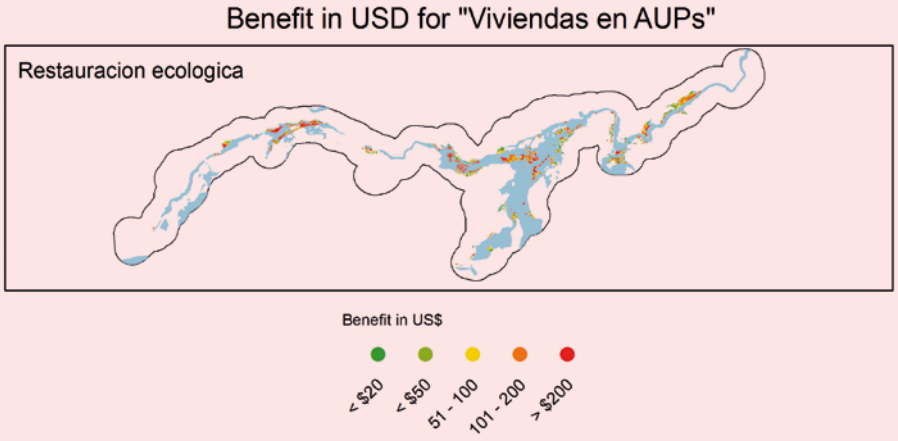
The ECA Study in San Salvador offers a large range of results. First, a ranking of the best investments in terms of adaptation measures was discussed between KfW and possible stakeholders. These measures included infrastructural projects but also Ecosystem Based Adaptation (EbA) measures such as reforestation. The benefits of more than 28 measures were evaluated.

Second, the ECA Studies in San Salvador showed that the ECA framework and CLIMADA can be used to evaluate and quantify climate risk, as well as adaptation measures for poor and vulnerable populations.

Third, strong limitations due to the complexity of the approach, the set of skills necessary to its implementation, forced the stakeholders to put a particular emphasis on capacity building. Partners such as the UCA in San Salvador, but also UNU-EHS in Bonn developed several lectures, manuals and guidebooks to disseminate the method.

At the COP23 (Bonn, 2017), the Minister of Environment of El Salvador, Mrs Pohl presented the ECA framework and further projects in planning for the country. UCA, ETH Zürich and UNU-EHS are still cooperating with the implementation of ECA studies in Central America and other countries.

Figure 3: Spatial distribution of benefits for ecosystem based adaptation. A good entrypoint for stakeholder engagement.



A further step: connecting to the Oasis ecosystem

In 2019 the InsuResilience Solutions Fund facilitated a further development of the San Salvador project, using CLIMADA to analyse the costs and benefits of risk prevention projects and risk transfer mechanisms alongside each other in a risk layered strategy. In particular it demonstrated the 'triple-dividend' of climate risk insurance:

- The risk analysis for insurance helps to assess the main hazards as well as the sectors and assets most at risk.
- Climate risk insurance puts a price on risk, which in turn incentivises investment in physical adaptation measures.
- Delivery of insurance based metrics enables payouts that reduce the long term impact of climate change and extreme natural events.

Lessons learned

The studies showed both strengths and limitations of the ECA methodology as well as the need for capacity development and stakeholder engagement for quantitative risk analytics, especially for bridging between analysis and investment.

It showed the crucial role that academia can play in developing countries. The existing set of skills often available in universities, allow countries to embed the ECA approach in their own structures, and therefore foster a more sustainable approach.

Disaggregation of households data showed that large families, where women share a heavier workload, were most affected by climate risks. Nevertheless, no direct gender related measures were implemented as such. More efforts in this direction are planned for future studies.

Climate risk analytics need to be embedded in local structures. A systematic and transparent approach, based on open modelling methodologies, builds trust. It also enables an open cross-sector stakeholder discussion based on a shared language and understanding.

Case study 4

Armenia Seismic Hazard Assessment

Authors: Daniel Raizman (AIR Worldwide), Roger Grenier (AIR Worldwide), and Marco Pagani (GEM Foundation)

Abstract

Beginning in 2016, a consortium made up of AIR Worldwide Corporation (AIR), the Global Earthquake Model Foundation (GEM), and the GEORISK Scientific Research Corporation (GEORISK) teamed to conduct a Probabilistic Seismic Hazard Assessment (PSHA) for the Republic of Armenia.

The project, sponsored by the World Bank Group on behalf of the Armenian National Survey for Seismic Protection (NSSP), resulted in the development of digital and printed hazard maps (see Figure 1 below) and hazard curves which were leveraged in the establishment of a revised national building code in 2019.

Engagement between local experts at GEORISK and international partners (AIR and GEM) enabled the creation of robust tools which considered the local seismicity of the Republic of Armenia and international seismologic and modelling expertise.

Figure 1: New seismic zonation map for the Republic of Armenia. Seismic zones indicated by PGA 0.1g contour levels. Note that the capital, Yerevan, is fully contained within the 0.4g PGA zone (not explicitly shown on this map).

Problem Statement:

The Republic of Armenia and the surrounding region is an area of known elevated seismic hazard. On December 7, 1988, a magnitude 6.9 event, known as the Spitak Earthquake, caused widespread destruction in northern Armenia and took the lives of an estimated 25,000 to 50,000 Armenians.

In response to this shock, the government of Armenia established the National Survey for Seismic Protection (NSSP) as its leading institution in seismic risk reduction and disaster prevention. In 1998, the NSSP released a new peak ground acceleration (PGA)-based seismic zonation map for the Republic.

From 2016 to 2018, a consortium made up of AIR, GEM, and GEORISK sought to develop an updated seismic zonation map, the first since the NSSP's release, which could be used to inform building code updates and provide analytics to underpin the Republic's risk financing strategy.

Methodology:

The consortium, comprised of local experts (GEORISK) and international seismologists (GEM and AIR), framed the project around seven project components outlined by the World Bank Group, including:

1. Collection, creation and quality assurance/quality control of input datasets
2. Construction of the ground-motion model (GMM)
3. Construction of the earthquake source model (ESM)
4. PSHA software selection, hazard calculation during model development stages and the final hazard calculation
5. Zonation maps preparation and map explanatory notes
6. Reporting
7. Collaborative development, training and technology transfer activities

The outputs of the first five components yielded seismic hazard and zonation maps while the final two project components consisted of reporting on the findings and building capacity locally with the NSSP. These components served to ensure careful consideration and review of existing data and techniques to appropriately guide the model development efforts. Furthermore, paramount to the project's success was both effective collaboration by the consortium and a focus on assuring that the tools and outputs developed would be transferable and usable by the NSSP.

At the launch of the initiative in early June 2016, the consortium held a kickoff meeting in Armenia. The meeting served to introduce the three organisations making up the consortium to the NSSP, inter-ministerial working group, and the World Bank Group teams.

Presentations were given by members of the respective organisations overviewing the goals of the initiative in addition to introducing the scientists' backgrounds and expertise. Following the inception event, the consortium held a 2-day workshop midway through the project and video conferences throughout to engage, communicate, and transfer findings to the NSSP.

In addition to suggesting a project framework, the World Bank Group worked with the Ministry of Emergency Situations (MOES) to establish an inter-ministerial working group comprised of key stakeholders from other government ministries, academia, and the private sector.

This working group was tasked with reviewing and commenting on all outputs from the assignment. The close collaboration between the consortium and local stakeholders encouraged ownership of results by the NSSP and also ensured the viability of the tools to inform decision-making.

Case study 4

Results/solutions/outcomes/ indicators of success

The consortium conducted a Probabilistic Seismic Hazard Assessment (PHSA) for the Republic of Armenia encompassing a wide range of exceedance probabilities (i.e., 5% and 10% in 75 years; 0.5%, 1%, 2%, 5%, 10% and 20% in 50 years; and 10% in 10 years) using three intensity measures (i.e., PGA, Sa(0.2s) and Sa(1.0s)). The assessment culminated in the development of an updated seismic zonation map (as shown in Figure 1), the first substantial update since the NSSP's 1998 zonation map release.

In addition to the use of the PHSA for the ongoing update to seismic building codes, the project outputs can also be leveraged in a variety of infrastructural settings as well as disaster risk financing. The Government of Armenia is working to establish a seismic risk reduction program to identify a strategic approach for addressing risks across key sectors to guide future risk reduction investments, including the possibility of targeting an investment in earthquake insurance.

Lessons learned

While the development of tools informed by seismological experts was key to the success of the initiative, of equal importance was ensuring that the outcomes were accepted and understood by key stakeholders that could benefit from their creation. GEORISK's local expertise was essential in encouraging acceptance of the results and orienting the consortium with available datasets and national insights.

Furthermore, the consortium's continued engagement through workshops and presentations allowed ample time to discuss the methodologies employed and to build comfort and confidence in the tools that were being developed. Local capacity building encouraged ownership and enabled increased benefit to the Republic of Armenia.

The success of the project was not solely the result of the efforts taken by the organisations forming the consortium. The Government of Armenia had critically formed an agency fully responsible for seismic risk mitigation, i.e. the National Survey for Seismic Protection (NSSP) under the Ministry of Emergency Situations (MOES).

This ensured there was a clear institutional/governance system in place enabling the new hazard maps to be both approved by government and adopted by the Committee of Urban Development for inclusion into the seismic building code. Both of these actions came to fruition following the project closeout. The confluence of government appetite for improvement of seismic risk understanding and an understanding of the importance of a data-driven approach to risk quantification enabled informed decision-making and promoted a successful outcome.

Conclusions:

A consortium of organisations including AIR, GEM, and GEORISK was engaged from 2016 to 2018 to conduct a Probabilistic Seismic Hazard Assessment for the Republic of Armenia. The initiative successfully engaged local and international partners to build a modern and robust view of the seismic hazard across Armenia.

The capacity building efforts both in person and virtually encouraged ownership of the new products. This, coupled with the Government of Armenia's interest in gaining a better understanding of the region's seismic risk, proved effective in increasing the value of the multi-year effort.

The new seismic zonation map prepared by the consortium for the NSSP helped to enable the Government of Armenia to draft an update to its national seismic building code. Once enacted, the new code should lead to improved seismic standards for all infrastructural settings in the Republic. In addition to the proposed updates to the seismic building codes, the project outputs are key metrics often leveraged in the development of disaster risk finance products and insurance mechanisms.

Following the completion of the Project

"With assistance from the World Bank and other development partners, the Government of Armenia adopted a National Disaster Risk Management System and Strategy in 2017, both of which are aligned with the Sendai Framework for Disaster Risk Reduction – the global framework to strengthen disaster resilience – and with the Sustainable Development Goals. Together, these frameworks provide the government with new, forward-looking targets for social, physical, and economic resilience by 2030" (https://www.preventionweb.net/news/view/69464)

Annex B: Case studies supporting Chapter 5: Gender considerations

Unconscious bias training for insurance agents

The IFC piloted a program in Nigeria with insurer AXA Mansard to train female and male insurance agents and staff to better understand the women's insurance market and tailor products for female customers. It revealed significant levels of unconscious bias, which were in turn addressed. The results of the programme led to AXA Mansard increasing its portfolio of women clients by 52%, and the company reported a 56% increase in gross written premiums from its women's portfolio.[1]

A gender plan to support national disaster management in Mozambique

UN Women and UNDP have worked in Mozambique on a Strategic Gender Plan of the National Institute for Disaster Management 2016-2020. The plan addresses topics such as the prevention of and response to gender-based violence in emergency situations to complement its national disaster management plan. A gender unit has been established to lead in the implementation, monitoring, evaluation and accountability of this plan.[2] A subsequent World Bank Mozambique Disaster Risk Management and Resilience Program is seeking to in turn strengthening the participation of women in local DRM committees, aiming to achieve a female participation rate of 50%.[3]

Lloyd's of London – Addressing Gender Workforce Diversity Challenges

Lloyd's of London is charter signatory of the Women in Finance Charter and has created a target to achieve at least 40% male and at least 40% female representation in its senior management population by 2021. Notably, the company links its performance against these goals into the objectives of its executive team and senior management as part of its performance management and reward system. Other steps taken include to conduct unconscious bias awareness learning for its senior executives, and mandatory inclusive hiring workshops.[4] In order to encourage and increase the number of senior female leaders in the insurance industry, it has established a female development programme called Advance for 15 mid-level female leaders from across the market and the Lloyd's Corporation.[5,6]

1 https://www.ifc.org/wps/wcm/connect/news_ext_content/ifc_external_corporate_site/news+and+events/news/women-insurance
2 UNDRR, 2019.
3 World Bank, 2019.
4 https://www.lloyds.com/about-lloyds/diversity-and-inclusion-at-lloyds/women-in-finance-charter
5 https://www.lloyds.com/news-and-risk-insight/news/lloyds-news/2019/09/request-for-nominations-developing-future-female-leaders-in-the-lloyds-insurance-market
6 https://www.lloyds.com/~/media/files/about/advance--developing-our-future-female-leaders-cohort-3-jan-2020.pdf?la=en

Gender diversity and sex-disaggregated data among FSPs in Myanmar

The United Nations Capital Development Fund (UNCDF) with financing from the Australian government, has supported Myanmar-based financial service providers to apply a gender-based self-assessment tool in order to promote their workforce gender diversity in management and leadership, and increase targeted outreach to women clients through gender-sensitive products and services.[7]

Women's Leadership within Financial and Insurance Regulators

Women's World Banking has established a nine-month Leadership and Diversity Programme for Regulators to build the women's leadership pipeline in regulatory organisations and support financial regulators to develop policies that close the gender gap in financial inclusion.[8] The programme is being run in collaboration with various international organisations.

For example, the Alliance for Financial Inclusion (AFI), funded by the Visa Foundation, is supporting Deputy Governors and high potential women leaders of AFI member institutions through the programme. Participating AFI members include representatives from the National Bank of Rwanda, the Bank of Tanzania and the Central Bank of The Bahamas.[9] This initiative is part of its members' commitments to the Denarau Action Plan, which aims to increase the number of women with access to quality and affordable financial services globally by 2021. While all members have committed to the DAP, AFI member institutions in 32 countries have articulated national policy commitments on gender and women's financial inclusion.[10]

Additionally, the Access to Insurance Initiative (A2ii), the InsuResilience Global Partnership and Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ), are separately funding scholarships for senior insurance supervisors and high potential women from their authorities, to participate.[11] To date, insurance sector representatives have been supported from Burundi, Bolivia, Madagascar, the Philippines, and Ghana.

Women's participation as risk mappers

Humanitarian OpenStreetMap Team (HOT) is an international team dedicated to humanitarian action and community development through open mapping. It works to provide map data to support disaster management, reduces risks, and contributes to achievement of the Sustainable Development Goals. Specifically, it works to empowering female mappers, supporting projects which promote equal rights, and providing local communities with the resources and training to encourage equal participation in their mapping initiatives.1[2] In 2019 as part of the US AID funded WomenConnect Challenge, HOT supported three communities in Peru, Tanzania and Zambia to contribute data about gendered issues that affect them. This involved creating a space for men and women to use map data to identify and challenge gender norms and barriers, share and implement solutions, and change community structures.[13] Separately, following the 2017 Mexico earthquakes, the GeoChicas team have started a pilot project researching informal shelters and their relation to women's security after a disaster. The project is based in the Oaxaca region which suffered two major earthquakes in 2017. Collaborating with disaster response experts, the aim is to create a database of informal provisional shelters and designated shelters to overlay with the geographical locations of reports of sexual harassment and gender violence. The maps produced will help inform and improve women's safety in the area and during future disaster management.[14]

7 UNCDF, 2019.

8 https://www.womensworldbanking.org/womens-leadership-programs/leadership-and-diversity-program-for-regulators/

9 https://www.afi-global.org/news/2019/04/wwb-afi-gather-central-bankers-senior-policymakers-kick-inaugural-leadership-and

10 https://www.afi-global.org/news/2019/04/wwb-afi-gather-central-bankers-senior-policymakers-kick-inaugural-leadership-and

11 https://www.insuresilience.org/apply-now-leadership-and-diversity-program-for-regulators-scholarship-opportunity-by-a2ii-and-insuresilience-global-partnership/

12 https://www.hotosm.org/projects/women_and_girls_in_mapping

13 https://www.hotosm.org/projects/women-connect-number-letgirlsmap-growing-female-open-data-leaders-across-5-continents/

14 https://www.hotosm.org/projects/geochicas

Women's participation and gender criteria in climate change financing decisions

Since 2016, the Global Green Growth Institute (GGGI) has been supporting the government of Vanuatu in the development of a National Green Energy Fund (NGEF) that aims to enable women and men to access credit to invest in green technologies. In doing so it assisted the government to align the fund to the Sustainable Development Plan and National Gender Policy and to integrate gender and inclusion into the funding criteria. In addition to managing the gender impact of the fund, it sought to ensure the women's participation in the process of developing the fund by requiring women on the board, including the Department for Women's Affairs. This is in a context of a donor supported Vanuatu Climate Change Finance Review published in 2018, which incorporates a gender and social inclusion analysis.[15]

A gender strategy for an association of actuaries

In the UK, the Institute and Faculty of Actuaries (IFoA) has conducted regular diversity and inclusion surveys of its members,[16] developed a diversity and inclusion strategy and an accompanying plan,[17,18] and created an IFoA Diversity Advisory Group.[19]

Canada-Caribbean Resilience Facility

Supported by the Canadian government, the World Bank and the Global Facility for Disaster Reduction and Recovery (GFDRR) have established the Canada-Caribbean Resilience Facility (CRF), a single-donor trust fund for the period 2019-2023, aimed at achieving more effective and coordinated gender-informed climate-resilient preparedness, recovery, and public financial management practices in targeted Caribbean countries.[20]

15 DCED, 2019.
16 IFoA, 2019.
17 IFoA, 2016.
18 IFoA, 2019b.
19 https://www.actuaries.org.uk/news-and-insights/news/international-womens-day-time-act
20 Canada, GFRDD and the World Bank, 2019.

Annex C: Theory of change for risk analytics in development

Introduction

'Theory of Change' is a description and illustration of why and how a desired change is expected to happen, commonly used to assess and monitor investment in development and humanitarian programmes[1]. Here the desired change is a significant increase in use of – and confidence in – risk information across governments, sectors and geographies. The theory is that this will lead to a greater sense of ownership of risk, and better decision-making at policy and operational levels for the protection of all populations and encouragement of growth. The long-term results should be positive outcomes against SDG targets.

The task of accelerating risk understanding across all activities under the 2030 Global Agenda is enormous and requires breaking up to be manageable. Theories of change have been proposed and developed by the authors for the three areas of 'Risk prevention', 'Risk transfer' and 'Anticipatory action'. For the purpose of illustration this annex shows the theory of change for 'Risk transfer'. It describes the behaviours and mechanics of how the spread of risk insight may be achieved, and is applicable whether the risk assessment is at a national strategic level or at the level of operational instruments.

We have already seen in Chapter 3 that these principles are not yet widely applied. A lot of development dollars are being spent on 'black box' metrics purchased for single transactions with no visibility of the assumptions behind them. There is a market for this approach which can and should continue, but these metrics only offer a single view of risk, usually for a single hazard, and offer only a snapshot of a single point in time. The risk owner is often left none the wiser.

The proposed change offers a route to scale and to empower risk owners with sustained risk understanding over time. And the good news is that the components already exist.

[1] www.theoryofchange.org

Theory of Change: Making better risk transfer decisions through open modelling and cross-sector collaborations.

Context

Risk transfer is increasingly used by sovereign governments and municipalities as a means to reduce aid dependency, reduce post-disaster borrowing and encourage investment. It includes a range of options through which risk owners can pass on risk that they can ill-afford to carry locally, usually to an international risk bearer or risk pool, in return for payment of a premium. The principle works when a risk-owning nation or city chooses to transfer risk for infrequent, higher severity events. The principle of insurance does not work for high frequency lower impact events. Options include direct mechanisms (micro-insurance for households, SMEs or farmers, or macro-schemes such as sovereign insurance with international re/insurers) or indirect mechanisms (multi-national risk pools or catastrophe-linked securities on capital markets.)

What problem is being addressed?

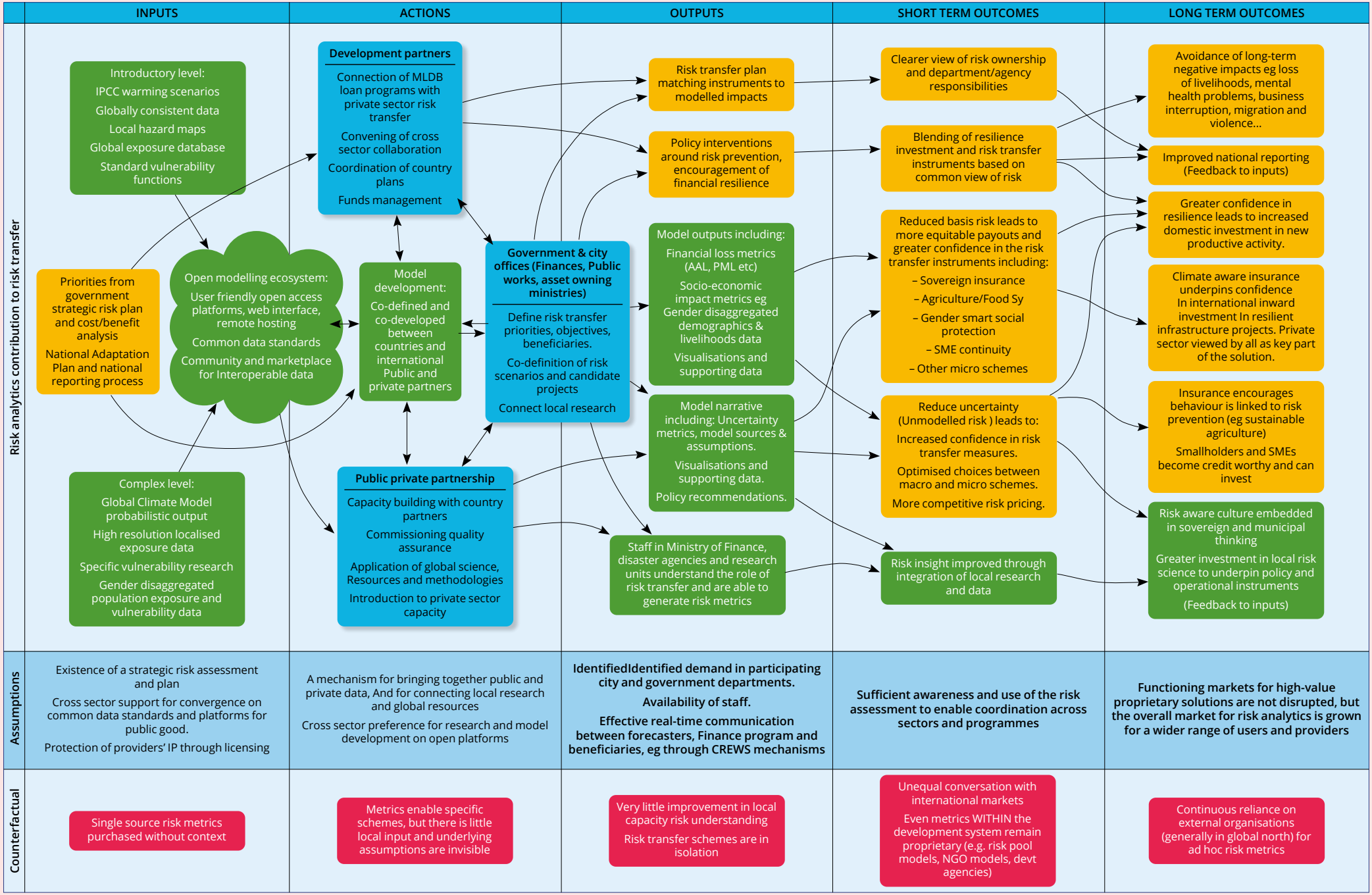
Primary challenges are:

- How to ensure that risk transfer instruments are relevant and targeted to SDG outcomes[2], including gender smart solutions (see Chapters 1 and 5).
- How to move to a multi-hazard view (Chapter 1). Governments and municipalities cannot justify risk transfer for a single hazard, when citizens may experience flood, drought, wildfire and epidemic/pandemic in the same year.
- How to move the centre of effort to a strategic *ex ante* view of risk, when the current supply chain is based on remotely generated, single model metrics purchased for single transactions (Chapter 1).
- How to enlist private sector risk expertise and resources in the development effort (Chapter 1).
- How to build the most useful and usable level of insight for the decisions being made (Chapters 3, 5 and 6).
- Specifically, how to reduce the problems caused by basis risk (Chapter 2).
- How to promote risk-aware behaviours, when concepts such as insurance may be viewed as alien or unaffordable (Chapter 3).
- How to connect the benefits of risk transfer to increased investment in resilience.[3]
- How to convert this opportunity to greater risk awareness in communities. (Chapter 6).

[2] 'Publicly funded insurance schemes should actively seek to realise wider public goods and sustainable development benefits beyond financial risk transfer alone.' (Equitable, effective and pro-poor climate risk insurance,' BOND, 2016)

[3] Warner et al 2016

THEORY OF CHANGE: OPEN ANALYTICS FOR RISK TRANSFER IN VULNERABLE ECONOMIES



Recommendations

Development of sustainable capacity in risk analytics for operational risk transfer, as well as education in the context.

Use of a risk layered approach (eg retained risk, reserve funds, re/insurance, weather index securities, international risk pooling) based on risk assessment and within a national risk framework consistent with SDGs.

Base capacity development on use of an open modelling ecosystem to encourage cross-agency understanding and open up markets for risk models and data.

Models should be designed and data translated for operational use, delivering financial metrics meaningful to all contracting parties.

Procurement conditions for operational risk transfer programmes should specify:

- Co-definition and co-development of risk analysis projects from the outset, working with staff from sovereign and municipal departments.
- Transparency of assumptions
- Interoperability of risk data sources to enable an ensemble approach, providing more than a single model snapshot view.
- Inclusion of disaggregated metrics for risk-diverse vulnerable groups, and gender considerations mandated by SDG 5 and the UN FCCC gender action plan.
- Licensing terms that realise the value of IP with non-public goods users.

Diversity principles applied throughout selection of personnel engaged in risk assessment.

Development of risk education programmes for the understanding of risk concepts, the communication of risk model outputs and the framing of decisions.

Creation of a public-private partnership mechanism specifically for the purpose of promoting and implementing these recommendations on a demand-driven basis.

Benefits

Governments:

A well thought through, comprehensive risk transfer programme reduces aid dependency and unplanned diversion of funds to emergency response.

Confidence in a country's financial ability to recover is an incentive to inward investment and market growth.

Access to multiple views of risk and reduction in unmodelled risk reduces uncertainty.

Citizens:

Reduced loss of life, livelihoods and wider negative effects on wellbeing (mental and physical health, displacement, domestic and other violence.)

Confidence in ability to recover from crisis leads to longer term thinking and investment (eg in smallholder agriculture and SMEs)

Inclusive, disaggregated exposure and vulnerability metrics enable more targeted instruments supporting women and girls, and those at greatest risk.

International partners:

Clarity of national policy and assignment of risk ownership. Private sector understands who to work with, and the framework to work within.

Increased confidence that allocated funds will reach the beneficiaries the solution is designed for.

Risk transfer mechanisms reduce the risk premium on investment in resilience measures.

Supporting examples

Programme	Context	Outcomes and learning
Malawi 2016[4] African Risk Capacity	African Risk Capacity (ARC) is an international risk pool owned by the African Union. It currently has 34 member states, and has access to resources including the ARC Capacity Building Programme, ARC Limited's risk transfer services and the Africa RiskView (ARV) modelling software. The government of Malawi took out an index driven parametric insurance policy with African Risk Capacity which included cover against drought. In the 2015/16 season the country suffered a severe drought but the ARV model suggested a much lower number of people affected than was really the case. As no payout was triggered in spite of obvious need, an internal technical review took place as well as a study by the Centre for Agricultural and Rural Development (CARD) of Lilongwe University of Agriculture and Natural Resources. The findings identified a shortcoming in model input assumptions regarding agricultural practices. For example, in reality farmers were planting a shorter-cycle variety of maize than was assumed by the model; with a 90 day cycle compared to the assumed cycle of 120-140 days. The result was the model did not identify how pronounced the actual crop failure really was.	This was a clear illustration of the problem of basis risk – the difference between an index's estimation and actual losses. When ARC researched and entered new data into the model, based on updated local knowledge, actual conditions were created more accurately and a payout was possible. To their credit, ARC invested a lot of time investigating the causes of the failure. Lessons learned included: › The value of a sensitivity analysis on input parameters to identify areas where uncertainty can be understood and controlled. › The importance of building in quality assurance processes during the model build. › The value of in-country technical working groups to collect stakeholder knowledge › Technical adjustments in the model to provide more accurate estimates of how the drought conditions translate into impact (for example more reference crops, multiple sowing criteria, batch processing.)
Sierra Leone 2017-18 Urban flood/landslide risk assessment (Arup/JBA/ BGS/INTEGEMS)	Between 1980 and 2010, over 220,000 people in Sierra Leone were affected by floods (EM-DAT, 2009). Records of flooding in Sierra Leone suggest that floods are a regular occurrence (7 times in 17 years; EM-DAT, 2016). Kroo Bay in Freetown, one of the largest coastal slums, for example, has flooded almost every year since 2008 due to heavy rains. This is exacerbated by the expansion onto floodplains (Africa Research Institute, 2015). The most common consequences of flooding are loss of life and livestock, disease outbreak, and damage to infrastructure, housing and crops, especially where flood water stands for prolonged periods over newly planted rice crops. This occurs both along the valley bottoms and up-slope nurseries. Under ACP-EU funding (development cooperation between the European Union and the countries of the African, Caribbean and Pacific Group of States), the World Bank Global Facility for Disaster Reduction and Recovery aimed to support development of new hazard and risk information in Sierra Leone. This targeted cities as well as identified priorities for disaster risk management investments for the Sierra Leone Urban Resilience project.	The international team of Arup, JBA Risk Management, British Geological Survey and local consultant INTEGEMS delivered a wide range of technical and management expertise and data across hazard, exposure, vulnerability, geo-spatial information, terrain and landslide susceptibility. The use of JBA's probabilistic catastrophe modelling enabled the quantification of expected loss/impact from each event to portfolios of assets (buildings), numbers of fatalities and people affected and characterisation of loss uncertainty. The guidance on risk delivered by the project is being used to enhance urban resilience in Sierra Leone and ultimately to save lives. Tragically, while the research was still underway heavy rain fell on Freetown, the capital, resulting in a landslide which claimed over 1,000 lives. Subsequent analysis of early results from the modelling showed alignment between risk areas and the site of the disaster. This information was helpful in assessing the ongoing risk of secondary events and planning recovery and mitigation work. Learning from the project includes: › The value of bringing private sector expertise into the public sector project. It dispels the impression sometimes held that the private sector is only capable of modelling the value of physical assets. › The value of joint work on the analysis with local agencies.

[4] ?

Programme	Context	Outcomes and learning
Oasis Platform for Climate and Catastrophe Risk Assessment in Asia (July 2018 - December 2020) (Souch and Whitaker)	Flood accounted for 15% of the total economic losses around the world in 2019 but only 6% of insured losses. Insurance uptake in Asia (9% of economic losses for all perils) lags behind uptake in developed markets like the US. In Bangladesh, insurance penetration is less than 1%. Catastrophe risk models are lacking for uninsured perils and countries, and are not affordable for in-country usage. This project is co-developing risk assessment tools with national scientific agencies and academics to reflect local data and risk levels. The partners will have the ability to run the models and update them with new data self-sufficiently. It is creating capacity in governments and the private sector to create new risk transfer products and take ownership of risk assessment and management in the long term. The majority of disaster loss in the Philippines and Bangladesh is beyond the capacity of national disaster risk budgets and overseas development assistance, and has to be borne by government spending e.g. through budget realignments, deficit spending, and by affected businesses and households. In 2019 the Honourable Prime Minister of Bangladesh Sheikh Hasina declared 1st March National Insurance Day, stating that: *"There is a need for insurance to play a more effective role in protecting the economic development of Bangladesh... its contribution is currently less than one percent".*	The Oasis Platform for Climate and Catastrophe Risk Assessment in Asia project (2018-2020) supported by the German Federal Ministry for the Environment (BMU) International Climate Initiative (IK) is co-developing an open models (flood for the Philippines and Cyclone for Bangladesh) with local scientists and creating capacity across the public and private sector in the development, understanding and usage of the models. It will support government agencies in decision-making aspects e.g. determining contingent liabilities, developing risk transfer products, hazard awareness, adaptation and disaster resilience. The project will also support innovation by insurance companies of new products for flood, creation of risk pools and microinsurance. As noted by Allan Santos, CEO of the National Reinsurance Corporation of Philippines (Nat Re): *"It is an honour to be a part of this pioneering project as it is the first of its kind for developing nations. We are pooling together the expertise of key influencers of disaster risk management and disaster risk financing and insurance from the government, the academe, and the insurance sector, all of whom have a shared vision of more disaster resilient communities"* In Bangladesh, there is significant interest in creating new Cyclone insurance products by local insurance companies from the project which is underway at the time of writing this report.
Caribbean Catastrophe Risk Insurance Facility (CCRIF)	Formed after Hurricane Ivan devastated Grenada and damaged Jamaica and the Caymans. Risk analysis started using a global model vendor's products but over time a requirement was identified for more local granularity and understanding of the risks faced. There was also a desire to include the work of local research centres such as the Caribbean Institute of Hydrology and Meteorology.	Outcome: In 2010 modelling was brought closer to user requirements using a different provider, improving: › Local resolution and understanding. › Transparency of historical loss results, real-time track forecast results, hazard maps, details of risk profiles and selected scenario event footprints. The learning in this project so far is: › Appetite at sovereign level for better risk understanding. › The desire (and value) of including local science agencies and data in the risk analysis process. › The utility of an open source platform in giving shared access to the analysis across project participants.

Plausibility, feasibility and evidence

Donor governments and other funders protect taxpayers' money by testing proposals for plausibility, feasibility, evidence – and honesty about where the evidence is thin or assumptions require further research[5]. Regarding evidence, the message of this theory of change is not based on newly commissioned primary research, but rather on the experience of the authors. Primary research on the demand side is a logical next step. The theory is also necessarily pitched at an international level, and it is fully acknowledged that the needs and practicalities of implementation in every country will be different. In the scoping phase of capacity building projects, further evidence should be acquired through direct conversations with country risk owners and their agencies.

Regarding plausibility and feasibility, the recommendations only work if:

- There is cross-sector agreement on the desirability of the vision. This can only be achieved through significant work in cross-sector forums such as InsuResilience, the Coalition for Climate Resilient Investment, the Insurance Development Forum, NGO forums and others.
- There is country demand for building national and municipal risk understanding, and sufficient support to create a sustainable core of risk expertise, allowing for staff turnover in relevant departments.
- There are programmes through which such change can be executed. This cannot be a standalone initiative but should work side by side (or within) other initiatives – for example:
  - The rollout of the UN's Global Risk Assessment Framework (GRAF), which starts with a number of country pilots.
  - UN and development agency programmes supporting, for example, National Adaptation Plans, national risk financing frameworks and disaster risk management capabilities.
  - Operational programmes such as the Tripartite Agreement between the German government, UNDP and the Insurance Development Forum.

A number of practical considerations in implementation are discussed after the summary of recommendations in Chapter 7.

[5] See, for example DfID's UK Aid Connect Guidance Note: 'Developing a Theory of Change.'

References:

Chapter 2

Challinor AJ, Watson J, Lobell DB, Howden SM, Smith DR, Chhetri N. A meta-analysis of crop yield under climate change and adaptation. Nature Climate Change 4: 287 – 291 (2014)

CIF, 2016. Private Sector Investment in Climate Adaptation in Developing Countries: Landscape, Lessons Learned and Future Opportunities. Climate Investment Funds c/o The World Bank Group. https://www.preventionweb.net/files/52887_7544wbcifppcrreportv5.pdf. Accessed April 10 2020

Clarke, Daniel and Dercon, Stefan. 2016. Dull disasters? How planning ahead will make a difference. Washington, D.C. : World Bank

DRK/RCCC, 2017. Manual for Forecast-based Financing. Deutsches Rotes Kreuz and Red Cross / Red Crescent Climate Centre. https://www.preventionweb.net/educational/view/58309. Accessed April 10 2020.

ECA, 2019. Shaping Climate-resilient Development – a framework for decision-making. A report of the Economics of Climate Adaptation Working Group. https://www.swissre.com/our-business/public-sector-solutions/thought-leadership/economics-of-climate-adaptation.html Accessed April 8 2020.

Emanuel, K. Assessing the present and future probability of Hurricane Harvey's rainfall. Proceedings of the National Academy of Sciences (2017)

Emily Wilkinson, Lena Weingärtner, Richard Choularton, Meghan Bailey, Martin Todd, Dominic Kniveton and Courtenay Cabot Venton, 2018. Forecasting hazards, averting disasters: Implementing forecast-based early action at scale. Overseas Development Institute. https://www.odi.org/sites/odi.org.uk/files/resource-documents/12104.pdf. Accessed April 10 2020.

European Commission (EC) (2007) Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks. http://data.europa.eu/eli/dir/2007/60/oj. Accessed April 10 2020

GFDRR, 2014. Understanding Risk in an Evolving World. Emerging Best Practices in Natural Disaster Risk Assessment. https://www.gfdrr.org/sites/gfdrr/files/publication/Understanding_Risk-Web_Version-rev_1.8.0.pdf

GIZ, 2015. Assessing Financial Literacy in Rural Laos. https://www.giz.de/en/downloads/giz2015-en-assessing-financial-literacy-rural-areas-laos.pdf. Accessed April 8 2020.

Gunasekera, R., 2017, Catastrophe Models and Applications in the Public Sector, in Mitchell-Wallace et al., 2017, Natural Catastrophe Risk Management and Modelling A Practitioner's Guide, Wiley-Blackwell, pp506.

Hallegatte, Stephane; Bangalore, Mook; Bonzanigo, Laura; Fay, Marianne; Kane, Tamaro; Narloch, Ulf; Rozenberg, Julie; Treguer, David; Vogt-Schilb, Adrien. 2016. Shock Waves : Managing the Impacts of Climate Change on Poverty. Climate Change and Development;. Washington, DC: World Bank. © World Bank. https://openknowledge.worldbank.org/handle/10986/22787 License: CC BY 3.0 IGO

Hallegatte, Stephane; Vogt-Schilb, Adrien; Bangalore, Mook; Rozenberg, Julie. 2017. Unbreakable : Building the Resilience of the Poor in the Face of Natural Disasters. Climate Change and Development;. Washington, DC: World Bank. © World Bank. https://openknowledge.worldbank.org/handle/10986/25335 License: CC BY 3.0 IGO.

Harris, Clare and Cardenes, Iliana. 2020. Basis risk in disaster risk financing for humanitarian action potential approaches to measuring, monitoring, and managing it. Centre for Disaster Protection Insight paper, Centre for Disaster Protection, London.

Insurance Development Forum, 2017, Understanding risk to create resilient platforms for sustainable growth and human dignity, 32 p. https://www.preventionweb.net/publications/view/54432 Accessed March 26 2020.

Insurance Development Forum, 2019, IDF Practical Guide to Insuring Public Assets, 137 p. https://www.insdevforum.org/sites/default/files/2019_09_IDF%20Practical%20Guide%20to%20Insuring%20Public%20Assets%20-LR.pdf Accessed March 23 2020.

InsuResilience Global Partnership, 2019, InsuResilience Global Partnership Vision 2025, 9 p. https://www.insuresilience.org/wp-content/uploads/2019/09/InsuResilience-Global-Partnership_Vision-2025-with-Workplan1.pdf Accessed April 3 2020.

Kulp, S.A., Strauss, B.H. New elevation data triple estimates of global vulnerability to sea-level rise and coastal flooding. Nat Commun 10, 4844 (2019)

Matthew Hughes, Mark Quigley, and Sjoerd van Ballegooy (2015) The sinking city: Earthquakes increase flood hazard in Christchurch, New Zealand. GSA Today 25(3):3-4. DOI: 10.1130/GSATG221A.1

Munich Climate Risk Initiative (MCII), 2017. Climate risk insurance for the poor and vulnerable: how to effectively implement the pro-poor focus of insuresilience. Bonn, November 2017 207 pp. https://climate-insurance.org/wp-content/uploads/2020/05/MCII_2016_CRI_for_the_Poor_and_Vulnerable_full_study_lo-res-2.pdf. Accessed 17 June 2020

Michel, A. How risk models are helping Madagascar after Enawo. AIR Worldwide blog. https://www.air-worldwide.com/blog/posts/2017/4/how-risk-models-are-helping-madagascar-after-enawo. Accessed April 10 2020.

Miles, Katherine S. and Wiedmaier-Pfister, Martina. 2019. Integrating Gender Considerations into Different Models of Climate Risk Insurance (CRI). InsuResilience Global Partnership. https://www.insuresilience.org/wp-content/uploads/2019/12/IntegratingGenderConsiderations.pdf

Mitchell-Wallace, K., 2017, Applications of Catastrophe Models, in Mitchell-Wallace et al., 2017, Natural Catastrophe Risk Management and Modelling A Practitioner's Guide, Wiley-Blackwell, pp506.

Mitchell-Wallace, K., Jones, M., Hillier, J., and Foote, M. (Eds.). 2017. Natural Catastrophe Risk Management and Modelling – A Practitioner's Guide. Wiley Blackwell.

Rajput, S; Wilkinson, E; Reid, R Curle J; Rentschler, JE; Tanner, T; Surminski, S.2018. The triple dividend of resilience: realizing development goals through the multiple benefits of disaster risk management (English). Washington, D.C. : World Bank Group. http://documents.worldbank.org/curated/en/993161515193991394/The-triple-dividend-of-resilience-realizing-development-goals-through-the-multiple-benefits-of-disaster-risk-management

Gunasekera R., Daniell J., Pomonis A., Donoso Arias RA., Ishizawa O., Stone H. Methodology Note on the Global RApid post-disaster Damage Estimation (GRADE) approach. https://www.gfdrr.org/sites/default/files/publication/DRAS_web_04172018.pdf. Accessed April 10 2020.

START Network (2017). Drought Financing Facility. https://start-network.app.box.com/s/p75bh32dy1abeov845rcd9zfq8v517m2. Accessed April 10 2020.

UNDRR, 2015, Sendai Framework for Disaster Risk Reduction 2015-2030. United Nations Office for Disaster Risk Reduction (UNDRR). 32p. https://www.preventionweb.net/go/43291 Accessed April 10 2020.

UNDRR, 2018. The Global Risk Assessment Framework Concept Note, September 2018. https://www.preventionweb.net/files/globalplatform/5cd89ca4c27b3GRAF_Concept_Note_2018_FINAL.pdf

UNDRR. 2019. Words into Action: Developing National Disaster Risk Reduction Strategies. United Nations Office for Disaster Risk Reduction. https://www.preventionweb.net/files/65095_wianationaldrrstrategies10052019.pdf Accessed April 8 2020

UNECE, 2017. Guidance on Land-Use Planning, the Siting of Hazardous Activities and related Safety Aspects. UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE http://www.unece.org/fileadmin/DAM/env/teia/images/1735403E_Final_ENG_web.pdf Accessed April 10 2020.

World Bank. 2017. SIERRA LEONE RAPID DAMAGE AND LOSS ASSESSMENT OF AUGUST 14TH, 2017 LANDSLIDES AND FLOODS IN THE WESTERN AREA. http://documents1.worldbank.org/curated/en/523671510297364577/pdf/Sierra-Leone-Rapid-damage-and-loss-assessment-of-August-14th-2017-landslides-and-floods-in-the-western-area.pdf

World Bank, 2019, World Bank Catastrophe Bond Transaction Insures the Republic of Philippines against Natural Disaster-related Losses Up to US$225 million, press release November 25 2019. https://www.worldbank.org/en/news/press-release/2019/11/25/world-bank-catastrophe-bond-transaction-insures-the-republic-of-philippines-against-natural-disaster-related-losses-up-to-usd225-million. Accessed March 26 2020.

Young, Simon, 2015 Protecting Development Gains: The Power of Risk Pooling and the G7's InsuResilience Initiative, p41-43, in Understanding Risk and Finance Conference – Proceedings of the 2015 URf Conference, https://understandrisk.org/wp-content/uploads/URf-Proceedings_FINAL_web.pdf

Chapter 3

Aznar-Siguan, Gabriela and Bresch, David N. 2019. CLIMADA v1: a global weather and climate risk assessment platform. Geoscientific Model Development 2, 3085–3097, http://doi.org/10.5194/gmd-12-3085-2019

Fakhruddin B., Murray V., and Gouvea-Reis F. 2019. DISASTER LOSS DATA IN MONITORING THE IMPLEMENTATION OF THE SENDAI FRAMEWORK. International Science Council. https://council.science/publications/disaster-loss-data-in-monitoring-the-implementation-of-the-sendai-framework/

Fraser, Stuart and Nkoka, Francis. 2015, What Risks? A Sample Set of Risk Assessments from across Africa and How to Use Them, p9-11, in Understanding Risk and Finance Conference – Proceedings of the 2015 URf Conference, https://understandrisk.org/wp-content/uploads/URf-Proceedings_FINAL_web.pdf

Grown, Caren and Otano, Cristina. 2019. The gender gap in the disaster risk management sector: why it matters. World Bank Sustainable Cities Blog. https://blogs.worldbank.org/sustainablecities/gender-gap-disaster-risk-management-sector-why-it-matters. Accessed 25 June 2020.

Harris, Clare and Jaime, Catalina. 2019. People-centred and Transparent Risk Analytics. Impact Before Instruments Series, Paper 2. Start Network https://blogs.worldbank.org/sustainablecities/gender-gap-disaster-risk-management-sector-why-it-matters. Accessed 25 June 2020.

InsuResilience Global Partnership, 2020. Analysing Stakeholder Needs for Enhancing Climate and Disaster Risk Data. International Climate Initiative (IKI). 2020. Oasis Platform for Climate and Catastrophe Risk Assessment – Asia – project data. https://www.international-climate-initiative.com/en/details/project/oasis-platform-for-climate-and-catastrophe-risk-assessment-asia-18_II_165-3018. Accessed 2 July 2020.

MIDIMAR. 2015. The National Risk Atlas of Rwanda. Ministry of Disaster Management and Refugee Affairs, Government of Rwanda. https://www.gfdrr.org/en/publication/rwanda-national-risk-atlas. Accessed 1 June 2020

Murnane, R. et al. 2019. Extensible data schemas for multiple hazards, exposure and vulnerability data. Contributing Paper to GAR 2019. 20p. https://www.undrr.org/publication/extensible-data-schemas-multiple-hazards-exposure-and-vulnerability-data Accessed on April 10 2020.

Roussos, J., R. Bradley and R. Frigg, 2020: Making confident decisions with model ensembles. Making confident decisions with model ensembles. [Preprint] Philosophy of Science.

Souvignet, Maxime, Wieneke, Florian, Mueller, Lea and Bresch, David N. 2016. Economics of Climate Adaptation (ECA) – Guidebook for Practitioners. A Climate Risk Assessment Approach Supporting Climate Adaptation Investments. KfW Materials in Development No. 6, December 2016. https://collections.unu.edu/eserv/UNU:6181/Guidebook_Economics-of-Climate-Adaptation_EN__002_.pdf Accessed June 17 2020

Wieneke, Florian and Bresch, David N. 2016. Economics of Climate Adaptation (ECA) in Development Cooperation: A Climate Risk Assessment Approach – Supporting decision making on climate change adaptation measures. KfW Materials in Development No. 5, September 2016. https://www.kfw-entwicklungsbank.de/PDF/Download-Center/Materialien/2016_No5_Economics-of-Adaptation_EN.pdf Accessed April 8 2020.

Chapter 5

IFC, AXA and Accenture. 2015. She for Shield: Insure Women to Better Protect All.

A2ii. 2017. The role of insurance regulation and supervision in promoting inclusive insurance for women.

Alliance for Financial Inclusion (AFI). 2017. Leveraging Sex-disaggregated Data to Accelerate Progress towards Women's Financial Inclusion.

Araujo A. and Quesada-Aguilar A, with Aguilar L. and Pearl R. 2007. Gender Equality and Adaptation. Women's Environment and Development Organisation (WEDO) and the International Union for Conservation of Nature (IUCN), USA.

APWLD. 2005. Why are women more vulnerable during disasters? Asia Pacific Forum on Women, Law and Development, NGO in consultative status at UN ECOSOC.

Baez, de la Fuente & Santos. 2010. Do Natural Disasters Affect Human Capital? An Assessment Based on Existing Empirical Evidence.

BMZ, GIZ, International Finance Corporation, Women's World Banking (2017) Mainstreaming Gender and Targeting Women in Inclusive Insurance: Perspectives and Emerging Lessons A Compendium of Technical Notes and Case Studies

BMZ et al, 2019. Press Release: UN Development Programme, Germany, UK and Insurance Development Forum announce commitments to increase insurance protection in climate-exposed countries in line with the InsuResilience Vision 2025 goals

Canada, GFRDD and the World Bank, 2019. Canada Caribbean Resilience Facility.

Care, 2020. Gender Implications of COVID-19 Outbreaks in Development and Humanitarian Settings.

Cropper, M. and Sahin, S. 2009. Valuing Mortality and Morbidity in the Context of Disaster Risks World Bank Policy Research Working Paper 4832

Data2X. 2019. State of Gender Data Financing Early Findings

Davies, S. and Bennet, B. 2016. A gendered human rights analysis of Ebola and Zika: locating gender in global health emergencies. In International Affairs, Volume 92, Issue 5, September 2016, Pages 1041–1060.

Dazé, A. and Church, C. 2019. Toolkit for a Gender-Responsive Process to Formulate and Implement National Adaptation Plans (NAPs) Supplement to the UNFCCC Technical Guidelines for the NAP Process

Dazé, A. and Dekens, J. 2018. Towards Gender-Responsive National Adaptation Plan (NAP) Processes: Progress and Recommendations for the Way Forward

DCED. 2019. Gender-Responsive Green Growth: Green Finance

Demirguc-Kunt, Asli; Klapper, Leora; Singer, Dorothe; Ansar, Saniya; Hess, Jake. 2018. Global Findex Database 2017: Measuring Financial Inclusion and the Fintech Revolution. Washington, DC: World Bank

ECLAC. 2003. Handbook for estimating the socio-economic and environmental effects of disasters.

FAO. 2013. Good practice policies to eliminate gender inequalities in fish value chains

GESI Working Group. 2017. A Common Framework for Gender Equality and Social Inclusion.

GFDRR et al. 2018 Gender Equality and Women's Empowerment in Disaster Recovery

GFDRR. 2017. Post-Disaster Needs Assessment (PDNA) Guidelines Volume B

GIZ. 2019. An Analysis of Women Entrepreneurship in India Current Profile, Future Landscape and Recommendations for Policymakers and Implementing Partners

GRAF, 2019. Global Risk Assessment Framework Concept Note.

Government of Kiribati, 2019. Kiribati Joint Implementation Plan for Climate Change and Disaster Risk Management (KJIP)

Government of Nepal, 2014. Gender Equality and Social Inclusion Toolbox.

GSMA. 2020. The Mobile Gender Gap Report 2020.

Hallegatte, Stephane; Vogt-Schilb, Adrien; Bangalore, Mook; Rozenberg, Julie. 2017. Unbreakable : Building the Resilience of the Poor in the Face of Natural Disasters. Climate Change and Development

Halvorson, Sarah J. 2010. Gender and Environmental Hazards in Encyclopaedia of Geography

IAIS and A2ii, 2019. Bridging the Gender Gap: The role of the Insurance Supervisor.

IAIS, SSN and A2ii. 2019. Roundtable on Insurance for Women: Specific Needs and Inclusion For insurance supervisory authorities, insurance practitioners and policymakers Buenos Aires, Argentina, June 12, 2019

IFAD. 2020. Insured. Insurance for rural resilience and economic development.

IFoA, 2019. 400 Club, Diversity and Inclusion Survey.

IFoA, 2019b. Diversity Action Plan 2018/2019

Ikeda, K. 1995. Gender Differences in Human Loss and Vulnerability in Natural Disasters: A case Study from Bangladesh.

ILO. 2017. World Social Protection Report 2017–19: Universal social protection to achieve the Sustainable Development Goal

ILO. 2018. Weaving Gender. Challenges and Opportunities for the Myanmar Garment Industry.

IFoA, 2016. Diversity Makes Us Stronger – Our Diversity Strategy

IMF, 2017. IMF Working Paper Banking on Women Leaders: A Case for More?

IMF, 2018. Women in Finance. A Case For Closing the Gaps.

InsuResilience. 2020. Analysing Stakeholder Needs for Enhancing Climate and Disaster Risk Data

InsuResilience. 2019. Integrating Gender Considerations into Different Models of Climate Risk Insurance (CRI)

InsuResilience. 2019b. InsuResilience Global Partnership Vision 2025.

InsuResilience. 2018. Applying a Gender-lens to Climate Risk Finance and Insurance

IPCC. 2012. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of the Intergovernmental Panel on Climate Change. See Chapter Two.

IPCC. 2014. Climate change 2014. Impacts, Adaptation and Vulnerability. Chapter 11: Human Health: Impacts, Adaptation and Co-benefits.

IUCN, 2012. The Art of Implementation Gender Strategies Transforming National and Regional Climate Change Decision Making

Lewis, H. 2020. Don't Build Roads, Open Schools. The idea of child care as women's (unpaid) work holds the issue back in political discussions.

Oxfam International. 2020. Time to Care. Unpaid and underpaid care work and the global equality crisis.

Parkinson, D. and Zara, C. 2013. The Hidden Disaster: Domestic violence in the aftermath of natural disaster. In Australian Journal of Emergency Management Vol 28 issue 2 (Apr 2013).

Portas, J. and Chartered Institute of Insurers (CII), 2020. Living a Financially Resilient Life in the UK – The Moments that Matter in improving Women's and all of our financial futures.

Portas, J and Chartered Institute of Insurers (CII), 2019. Risk, exposure and resilience to risk in Britain today. Women's Risk in Life – an interim report.

Rushton, A. Gray, L., Canty, J., and Blanchard, K. 2019. Beyond Binary: (Re)Defining "Gender" for 21st Century Disaster Risk Reduction Research, Policy, and Practice

Save the Children, UNICEF, Plan, World Vision, undated. Children's Ebola Recovery Assessment: Sierra Leone

Smith, J. 2019. Overcoming the 'tyranny of the urgent': integrating gender into disease outbreak preparedness and response

Soroptimist International of the Americas 2008. Soroptimist International of the Americas. 2008. Reaching Out to Women When Disaster Strikes. White Paper: Disaster Relief. Philadelphia, PA: Soroptimist International of the Americas.

United Kingdom HM Treasury. Undated. Women in Finance Charter.

UN. 2019 Global Assessment Report on Disaster Risk Reduction

UN. 2015. Transforming our world: the 2030 Agenda for Sustainable Development

UN. 2015b. Gender Responsive Disaster Risk Reduction. A contribution by the United Nations to the consultation leading to the Third UN World Conference on Disaster Risk Reduction.

UN. 2014. Gender Responsive Disaster Risk Reduction A contribution by the United Nations to the consultation leading to the Third UN World Conference on Disaster Risk Reduction Version 2

UN Women, 2015. Making National Social Protection Floors Work for Women.

UN Women. 2020. Policy Brief. The Impact of COVID 19 on Women.

UN Women, undated. Climate Change, Disasters and Violence Against Women in the Pacific.

UNCDF. 2019. Gender Self-Assessment Toolkit for Financial Service Providers.

UNDP. 2019. Human Development Report 2019 Beyond income, beyond averages, beyond today: Inequalities in human development in the 21st century

UNDRR. 2019. Developing National Disaster Risk Reduction Strategies

UNISDR. 2019. 2018 Annual Report

UNISDR. 2015. Sendai Framework for Disaster Risk Reduction – 2015-2030

United Republic of Tanzania, 2013. National Strategy on Gender and Climate Change.

UNFCCC. 2019 b. Gender and climate change Proposal by the President Draft decision -/CP.25 Enhanced Lima work programme on gender and its gender action plan

UNFCCC. 2019. Differentiated impacts of climate change on women and men; the integration of gender considerations in climate policies, plans and actions; and progress in enhancing gender balance in national climate delegations – Synthesis report by the secretariat

WEIGO and ILO, 2019. (Bonnet, Florence, Joann Vanek, and Martha Alter Chen) Women and Men in the Informal Economy: A Statistical Brief.

Wenham, C., Smith, J., Morgan, R. 2020. COVID-19: the gendered impacts of the Outbreak. Published in the Lancet, 6 March, 2020.

World Health Organization (WHO). 2020. 2019 Novel Coronavirus (20190nCoV): Strategic Preparedness and Response Plan.

World Health Organization (WHO). 2011. Gender, Climate Change and Health.

World Bank. 2016. More and Better Gender Data: A Powerful Tool for Improving Lives

World Bank, 2019. Mozambique Disaster Risk Management and Resilience Program Technical Assessment Report

World Bank. 2020. Women Business and the Law 2020.

Weblinks

https://www.girlsnotbrides.org/child-marriage/sierra-leone/

https://www.cgdev.org/blog/how-will-covid-19-affect-women-and-girls-low-and-middle-income-countries

https://www.hotosm.org/projects/women-connect-number-letgirlsmap-growing-female-open-data-leaders-across-5-continents/

https://genderandenvironment.org/2015/08/stop-being-so-sensitive-the-shift-from-gender-sensitive-to-gender-responsive-action/

https://www.insuresilience.org/apply-now-leadership-and-diversity-program-for-regulators-scholarship-opportunity-by-a2ii-and-insuresilience-global-partnership/

https://www.lloyds.com/about-lloyds/diversity-and-inclusion-at-lloyds/women-in-finance-charter

https://www.lloyds.com/news-and-risk-insight/news/lloyds-news/2019/09/request-for-nominations-developing-future-female-leaders-in-the-lloyds-insurance-market

https://www.lloyds.com/~/media/files/about/advance--developing-our-future-female-leaders-cohort-3-jan-2020.pdf?la=en

https://www.womensworldbanking.org/womens-leadership-programs/leadership-and-diversity-program-for-regulators/

https://www.afi-global.org/news/2019/04/wwb-afi-gather-central-bankers-senior-policymakers-kick-inaugural-leadership-and

https://www4.unfccc.int/sites/nwpstaging/Pages/soe.aspx

http://napglobalnetwork.org/resource/pour-un-processus-de-plan-national-dadaptation-pna-qui-reponde-aux-questions-de-genre-au-benin/

http://napglobalnetwork.org/resource/orientations-pour-la-prise-en-compte-du-genre-dans-le-processus-de-pna-du-togo/

http://napglobalnetwork.org/2020/01/naps-and-the-gap-five-ways-national-adaptation-plan-processes-can-support-implementation-of-the-enhanced-gender-action-plan/

https://genderandenvironment.org/works/ccgaps/

https://genderandenvironment.org/resource/zambia-climate-change-gender-action-plan-ccgap-report/

https://a2ii.org/en/knowledge-center/the-role-of-insurance-regulation-in-promoting-inclusive-insurance-for-women

Chapter 6

Antos, Sarah and Triveno Luis, Resilient housing joins the machine learning revolution. World Bank Sustainable Cities blog. November 16 2018. https://blogs.worldbank.org/sustainablecities/resilient-housing-joins-machine-learning-revolution

CREWS. 2020. Using 3D technology to bring early warnings to rural communities in Afghanistan CREWS Impact Feature, March 2020, https://spark.adobe.com/page/E5GFcvbSq3GRD/

GFDRR, 2014. Understanding Risk in an Evolving World. Emerging Best Practices in Natural Disaster Risk Assessment. https://www.gfdrr.org/sites/gfdrr/files/publication/Understanding_Risk-Web_Version-rev_1.8.0.pdf

GFDRR, 2016. Solving the Puzzle – Innovating to reduce risk. Global Facility for Disaster Reduction and Recovery. https://www.gfdrr.org/sites/default/files/solving-the-puzzle-report.pdf

GFDRR. 2018, Machine Learning for Disaster Risk Management. https://www.gfdrr.org/en/publication/machine-learning-disaster-risk-management

Hallegatte, Stephane, Adrien Vogt-Schilb, Mook Bangalore, and Julie Rozenberg. 2017. Unbreakable: Building the Resilience of the Poor in the Face of Natural Disasters. Climate Change and Development Series. Washington, DC: World Bank.

Harris, Clare and Jaime, Catalina. 2019. People-centred and Transparent Risk Analytics. Impact Before Instruments Series, Paper 2. Start Network.

Hostache, R., Chini, M., Giustarini, L., Neal, J., Kavetski, D., Wood, M., et al.(2018). Near-real-time assimilation of SAR-derived flood maps for improving flood forecasts.WaterResources Research,54, 5516–5535.https://doi.org/10.1029/2017WR022205

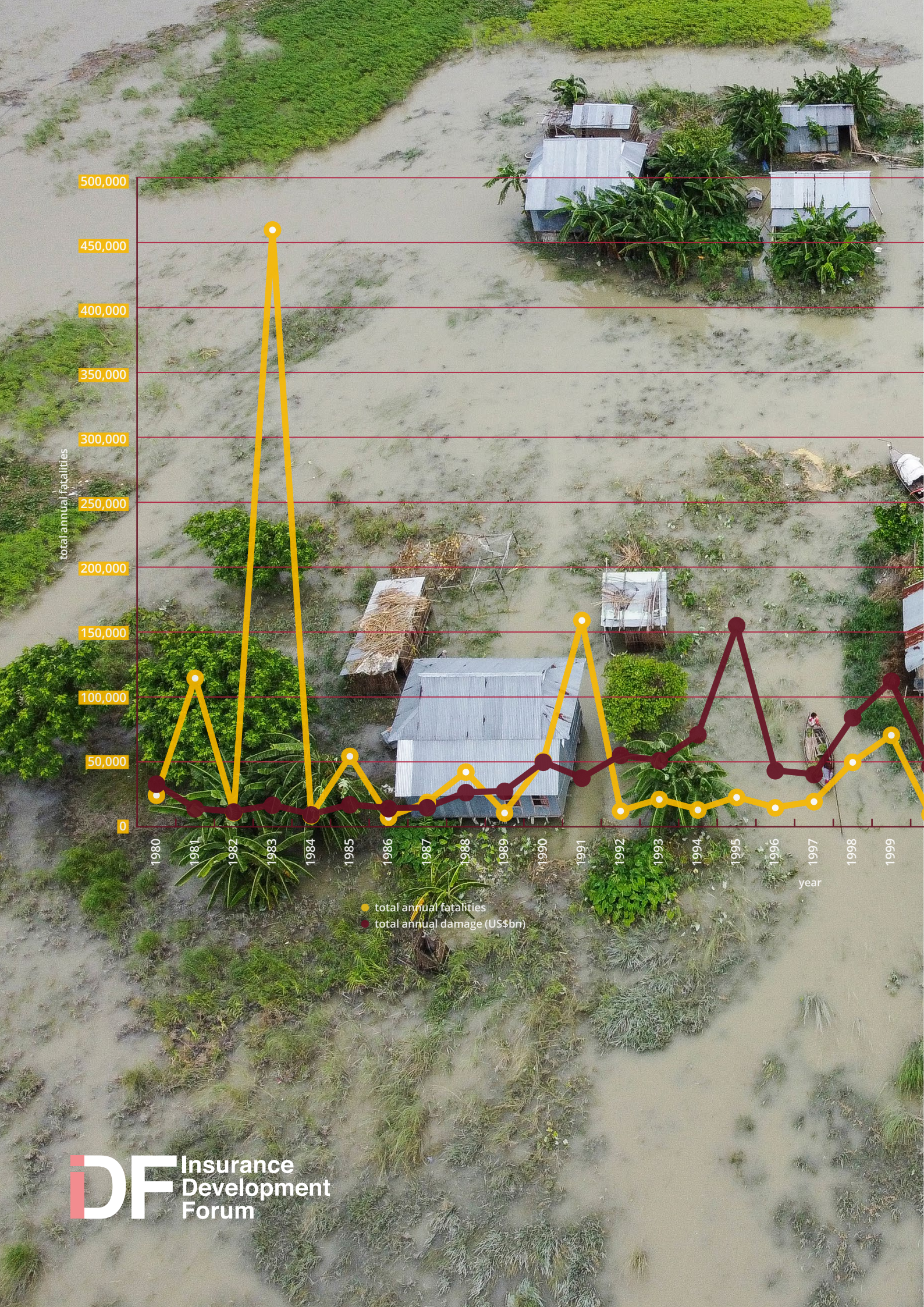
InsuResilience Global Partnership, 2019, InsuResilience Global Partnership Vision 2025, 9 p. https://www.insuresilience.org/wp-content/uploads/2019/09/InsuResilience-Global-Partnership_Vision-2025-with-Workplan1.pdf Accessed April 3 2020.

Jarzabkowski, P., K. Chalkias, D. Clarke, E. Iyahen, D. Stadtmueller & A. Zwick. Insurance for climate adaptation: Opportunities and limitations, Cass Business School, August 2019

UN Sustainable Development Solutions Network. 2019. Counting on the World to Act - A Roadmap for Governments to Achieve Modern Data Systems for Sustainable Development. https://www.unsdsn.org/counting-on-the-world-to-act-2019

Munich Climate Risk Initiative (MCII), 2017. Climate risk insurance for the poor and vulnerable: how to effectively implment the pro-poor focus of insuresilience. Bonn, November 2017 207 pp. https://climate-insurance.org/wp-content/uploads/2020/05/MCII_2016_CRI_for_the_Poor_and_Vulnerable_full_study_lo-res-2.pdf. Accessed 17 June 2020

GIZ, 2015. Assessing Financial Literacy in Rural Laos. https://www.giz.de/en/downloads/giz2015-en-assessing-financial-literacy-rural-areas-laos.pdf. Accessed April 8 2020.



Insurance Development Forum