2014

Understanding Risk

Producing Actionable Information

Proceedings from the 2014 UR Forum

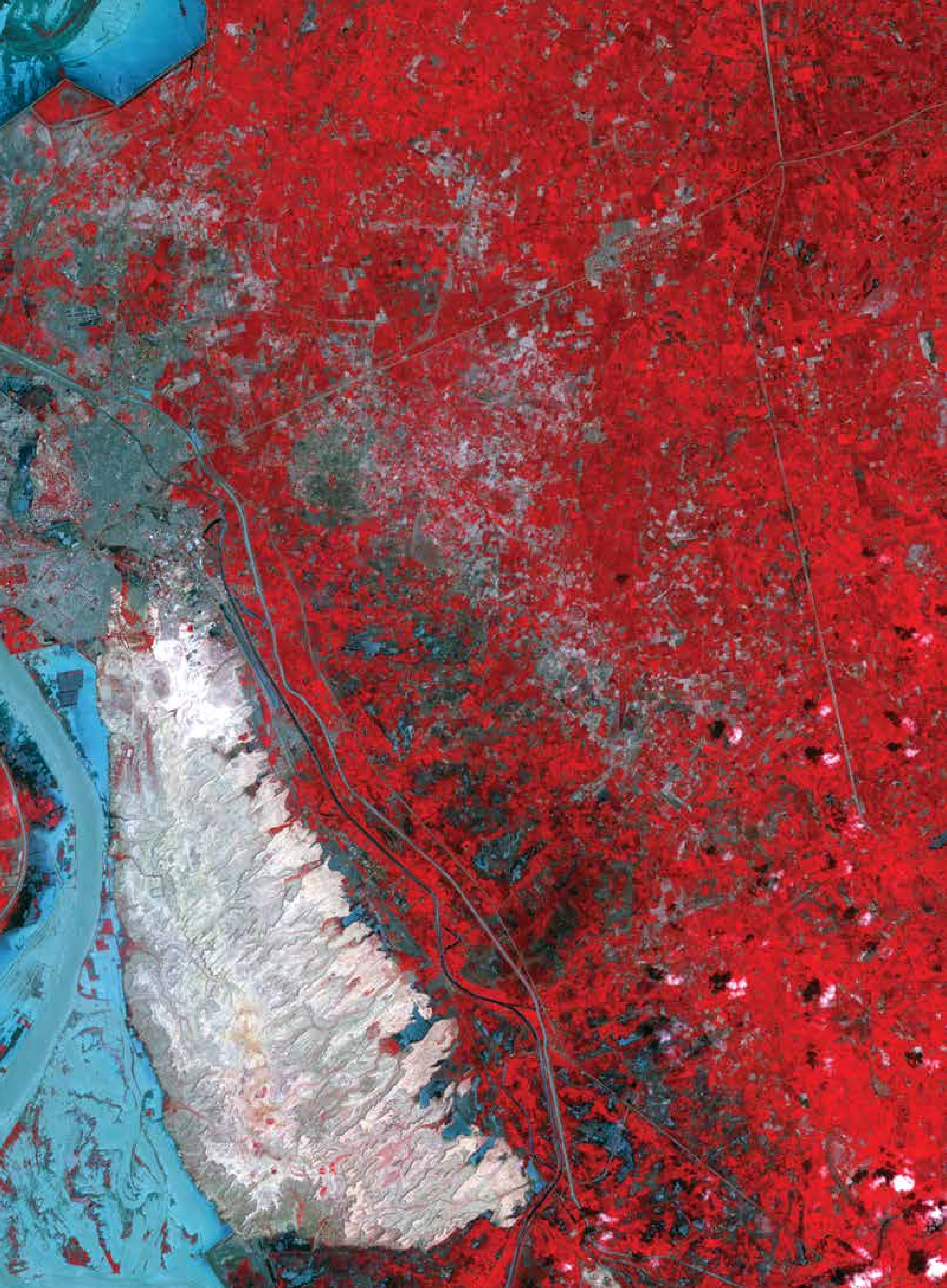
Understanding Risk (UR)

Washington, D.C. November 2014
Editors: Anne Himmelfarb, Emma Phillips, and Angela Wyan
Designed by Miki Fernández (miki@ultradesigns.com), Washington, D.C.

Manufactured in the United States of America
First printing November 2014

Join the Global UR Community
www.understandrisk.org

Photo: The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument on NASA's Terra spacecraft captured this image strip over the Indus River, Pakistan. The city of Hyderabad is near the middle of the image. In this false-color image, vegetation appears red, water is medium to dark blue and non-vegetated hills are light.
Credit: NASA/GSFC/METI/ERSDAC/JAROS, and U.S./Japan ASTER Science Team



Contents

Psychology of Risk

Building Resilience

Partnerships

OF INTEREST

Acknowledgements

Thank you for the enthusiasm and energy devoted to the 2014 UR Forum in London. While we cannot mention all the organizations and individuals who contributed their time and ideas, we would like to highlight some of our key contributors.

First off, we would like to thank the 2014UR partners: University College London, the Africa Caribbean Pacific – European Union Natural Disaster Risk Reduction Program financed by the EU, Willis, the World Bank Group, the Global Facility for Disaster Reduction and Recovery (GFDRR), Esri, RMS, Google, and Siemens.

A special thank you to all the organizations that were involved in the UR Forum by leading a technical session, running a workshop, or participating in the UR exhibit: ARUP, AIR Worldwide, the American Red Cross, the British Red Cross, CARLtd, ClimateWise, Center for Research on the Epidemiology of Disasters (CRED), Deltares, eartH2Observe, European Commission – Joint Research Centre, FM Global, Global Earthquake Model (GEM) Foundation, GFZ Potsdam, ImageCat, Inc., the International Federation of Red Cross and Red Crescent Societies (IFRC), the Institute for Environmental Studies (IVM), the London School of Economics (LSE), Mitsui Sumitomo Insurance, The Nature Conservancy (TNC), Oasis, Overseas Development Institute (ODI), Red Cross/ Red Crescent Climate Centre, Renaissance Re, Research Councils UK (RCUK), Secondmuse, Swiss Re, UK Agency for International Development (UK AID), UK Foreign and Commonwealth Office (UK FCO), UK Department for International Development (DFID), UNESCO, United Nations Development Programme (UNDP), United Nations Office for Disaster Risk Reduction (UNISDR), VU University Amsterdam, Willis Research Network, the Wharton School of the University of Pennsylvania, the World Bank Institute, World Meteorological Organization (WMO), and Zurich Insurance Group.

We would also like to extend our gratitude to our keynote, opening, and closing speakers: Professor Michael Arthur, Rowan Douglas, Ed Parsons, Robbie Schingler, and Professor David Spiegelhalter. Thank you to those who contributed to our inaugural plenary: Dr. Aris Alip, Honorable Mayor Lianne Dalziel, Honorable Mayor Patricia de Lille, Dr. Roman Frigg, Sir Edward Lister, and Matt Frei. We are grateful for the support of our Champions for Disaster Resilience: Helen Clark, Kristalina Ivanova Georgieva, Secretary Justin Greening, Rachel Kyte, Secretary Cesar V. Purisima, and our moderator Professor Ngaire Woods. Thank you to the distinguished speakers who joined us at Guildhall: the Right Honorable Lord Mayor of London, Alderman Fiona Woolf, CBE; Dr. Jeffrey Sachs;

Stéphane Jacobzone; Sebastian von Dahlen; Michel Lies; and Rebecca Moore. Thank you to the inspiring speakers at the 5x15 event who provided a different perspective on risk: Giles Duley, Professor Ian Goldin, Dr. Henry Thomas Marsh, Heather McGregor, and Ed Smith.

Thank you to our session leads for putting extensive time and effort into organizing their sessions, and for writing the summaries for this publication: Abigail Baca, Michael Bonte, Daniel Clarke, Adam Cooper, Jo da Silva, Tiguist Fisseha, Matt Foote, Linda Freiner, Maryam Golnaraghi, Lou Gritzo, Debarati Guha, Akshay Gupta, Niels Holm-Nielsen, Alex Kaplan, Nicole Keller, Kamal Kishore, Howard Kunreuther, Neil Morisetti, Robert Muir-Wood, David Nash, Massimiliano Pittore, John Rees, Vica Rosario Bogaerts, Sahar Safaie, Peter Salamon, Simon Sharpe, Benedikt Signer, Robert Soden, Pablo Suarez, Philip Ward, Emily Wilkinson, and Hessel Winsemius. A special thanks to all of their panelists and coauthors too.

We would like to acknowledge the teams that were involved and the following individuals: Bianca Adam, Sajid Anwar, Yewondwossen Assefa, Christophe Aubrecht, Trish Barrett, Sofia Bettencourt, Jack Campbell, Keren Charles, Manuela Chiapparino, Christophe Chung, John Crowley, James Daniell, Vivien Deparday, Eric Dickson, Laura Dorling, Edouard Ereno Blanchet, Ruben Graml, Tiguist Fisseha, Marc Forni, Oscar Ishizawa, Yohannes Kesete, David Lallemant, Rick Murnane, Marc Neilson, James Newman, Ariel Nunez, Shaela Rahman, Robert Reid, Keiko Saito, Prashant Singh, Samanmalee Sirimanne, Annegien Tijssen, Luis Tineo, Vladimir Tsirkunov, Jon Walton, and Steven Wong.

Thanks to the different teams and individuals who through the planning process helped us coordinate the forum, in London: Olivia Gray, Daisy Leitch, Michael Stevns, and the TFI Group (Valerie Bassigny, Barbara Blow, Alice Crocker, Rui Cruz Alves, Laura Drake, Rob Eveleigh, Lynda Judge, Sean McGrath, Ben Stanley, and Caroline Windsor); and in Washington, DC: Desy Adiati, Regianne Bertolassi, Miki Fernández, Anne Himmelfarb, and Katie Moss.

And last, but not least, the UR2014 volunteers: Mirianna Budimir, Evie Kerman Fiore, Alexandra Popescu, and Sabina Sadigova. Thank you for your time, dedication, and creativity in making this event a success!

The UR core team—Francis Ghesquiere, Dr. Alanna Simpson, Emma Phillips,
Joaquin Toro, Angela Wyan, Simone Balog, and Clio Heslop

Foreword

How can we communicate risk information in a way that leads decision makers to take concrete actions to reduce risk from adverse natural events? In June 2014, almost a thousand risk assessment experts and practitioners from around the world gathered in London to answer this question at the third biennial Understanding Risk (UR) Forum. Over a five-day period, the UR community— scientists, modellers, economists, psychologists, disaster risk management practitioners, and policy makers—explored better ways of "Producing Actionable Information."

Since UR2010, we have seen new applications and techniques proliferate and a growing community take on the challenge of understanding disaster risk. These proceedings try to capture the rich discussions that took place during the Forum. The articles are organized into seven categories that reflect the range of topics covered during the event. All of the articles explore how to improve the way we provide decision makers with robust, credible, and trusted information that will be used to build a more resilient future.

Changing risk /uncertainty

The changing drivers of disaster risk—mainly demographics, urbanization, and climate change—increase our uncertainty about risk, further complicating efforts to assess and communicate it. Discussions were centered on these changing landscapes and highlighted the need to work together to develop new ways of understanding the evolution of risk and the potential impacts of climate change.

Data

In the last decade we have seen an explosion in access to and availability of data. Forum participants discussed actionable use of data and explored the role of technological advances, such as drone technology and data management systems, in helping us better understand risk, even as risk continues to evolve.

Risk modelling

Modelling disaster risk is central to producing actionable information: modelling can help policy makers quantify and value the future impact of decisions made today. New multi-hazard risk modelling platforms for open and inclusive collaboration and ongoing efforts to explore the potential interoperability of existing tools were among the most striking developments presented at the Forum.

Risk finance and insurance

We learned how Small Island States—among the world's most vulnerable communities—have used risk assessments to establish innovative financial protection mechanisms to pool and transfer their risk. Globally, more and more countries are using risk information to leverage innovative risk financing solutions to protect their fiscal space against disasters and climate extremes.

Psychology of risk

We took a closer look at games and gameplay as a means of helping decision makers understand the complexities of probabilities and uncertainty. The Forum explored how understanding the process of decision making can help us communicate risk information more effectively and develop incentives to modify behavior and promote resilience.

Building resilience

Applying risk information to build community resilience was a core topic of the Forum. Participants discussed exciting new work to measure resilience, technological innovation to support community participation, and other actions on the ground.

Partnerships

UR's main objective is to encourage the creation of atypical partnerships. As in previous years, the Forum provided a platform for all sorts of communities to interact, discuss issues, and challenge current thinking. I am always impressed by the number of new partnerships that emerge from the Forum and their ability to promote entirely new ideas on how we can address disaster risk.

Many activities that took place during the Forum (though not presented in these proceedings) pushed our intellectual boundaries and inspired us to think about risk in new ways. Among them was our collaboration with 5x15, a cultural events company that hosted a conversation on risk between a neuroscientist, a former national cricketer, a war photographer, an Oxford professor, and a Financial Times columnist—challenging the audience to think more creatively about risk. We encourage you to explore this event and others at www.understandrisk.org.

It goes without saying that an event as rich as UR2014 would not have been possible without the collaboration and contribution of many individuals and organizations, nor the generous support of our sponsors who enabled us to bring practitioners from around the globe.

Thank you to everyone for your support. We hope you enjoy the proceedings, and look forward to working with you all again. See you in 2016!

Francis Ghesquiere
GFDRR Secretariat

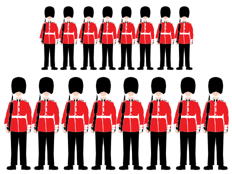
Abbreviations

AAL	average annual loss
ACP-EU	Africa, Caribbean and Pacific-European Union
AFAD	Disaster and Emergency Management Presidency (Turkey)
CAPRA	Comprehensive Approach to Probabilistic Risk Assessment
CBA	cost-benefit analysis
CCRIF	Caribbean Catastrophe Risk Insurance Facility
CDKN	Climate and Development Knowledge Network
CDRP	country disaster risk profile
CEDIM	Center for Disaster Management and Risk Reduction Technology
CNT	conviction narrative theory
DEM	digital elevation model
DFID	Department for International Development (United Kingdom)
DRFI	disaster risk financing and insurance
DRM	disaster risk management
DRRM	disaster risk reduction and management
EAP	expected annual probability
EO	Earth Observation
FONDEN	National Fund for Natural Disasters (Mexico)
FP7	Seventh Framework Programme
GAR	Global Assessment Report on Disaster Risk Reduction
GDP	gross domestic product
GEM	Global Earthquake Model
GFDRR	Global Facility for Disaster Reduction and Recovery
GFP	Global Flood Partnership
GIS	geographic information system
GLOFRIS	GLObal Flood Risk with IMAGE Scenarios
G-Safety	Global Safety
HFA	Hyogo Framework for Action
IA	Impact Appraisal
IDCT	Inventory Data Capture Tool

IFRC	International Federation of Red Cross and Red Crescent Societies
IIASA	International Institute for Applied Systems Analysis
InfoRM	Index for Risk Management
IPCC	Intergovernmental Panel on Climate Change
IRIDeS	International Research Institute for Disaster Science
ISMEP	Istanbul Seismic Risk Mitigation and Emergency Preparedness Project
MCEER	Multidisciplinary Center for Earthquake Engineering Research
NOAH	Nationwide Operational Assessment of Hazards
NSET	Nepal Society of Earthquake Technology
OGC	Open Geospatial Consortium
OpenDRI	Open Data for Resilience Initiative
OSM	OpenStreetMap
PAGER	Prompt Assessment of Global Earthquakes for Response
PCRAFI	Pacific Catastrophe Risk Assessment and Financing Initiative
PML	probable maximum loss
RCP	Representative Concentration Pathway
RRVS	rapid remote visual screening
SENSUM	Framework for integrating Space-based and in-situ sENSing for dynamic vUlnerability and recovery Monitoring
SIDS	Small Island Developing States
TRGS	technical risk grading standard
UAV	unmanned aerial vehicle
UNDP	United Nations Development Programme
UNISDR	United Nations Office for Disaster Risk Reduction
UN OCHA	United Nations Office for the Coordination of Humanitarian Affairs
UR	Understanding Risk
USAID	United States Agency for International Development
VGI	volunteered geographic information
WMO	World Meteorological Organization

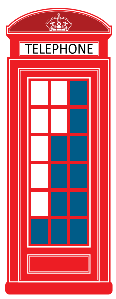
60

countries represented



840

attendees



9
PLENARIES

24
TECHNICAL SESSIONS

24
SIDE WORKSHOPS AND TRAININGS, AND

2
ON-SITE EXHIBITS

institutions represented

including civil society, private sector, academia, research institutions , and government agencies.

Overview

Understanding Risk (UR) is a global community of almost 3,500 experts and practitioners in the field of disaster risk assessment. Every two years, the Global Facility for Disaster Reduction and Recovery (GFDRR) convenes the UR Forum—a five-day event to showcase best practices and the latest technical know-how in disaster risk assessment. The Forum provides organizations with the opportunity to highlight new activities and initiatives, build new partnerships, and foster advances in the field.

UR2014, the third biennial Forum, was held in London, UK, from June 30 to July 4, 2014. Under the theme "Producing Actionable Information," participants explored the creation of risk information for decision making. Since our first UR Forum in 2010, the UR community has grown exponentially. Attendance at UR2014 was twice that of the previous UR Forum, held in South Africa. We are confident that future forums will continue to engage the disaster risk community, fostering the growth of partnerships to spur the advances in risk assessment needed for achieving sustainable development and building resilience.

Organized by

GFDRR
Global Facility for Disaster Reduction and Recovery

In partnership with

ACP-EU Natural Disaster Risk Reduction Program
An initiative of the African, Caribbean and Pacific Group, funded by the European Union and managed by GFDRR

UCL

Willis

WORLD BANK GROUP

With financial support from

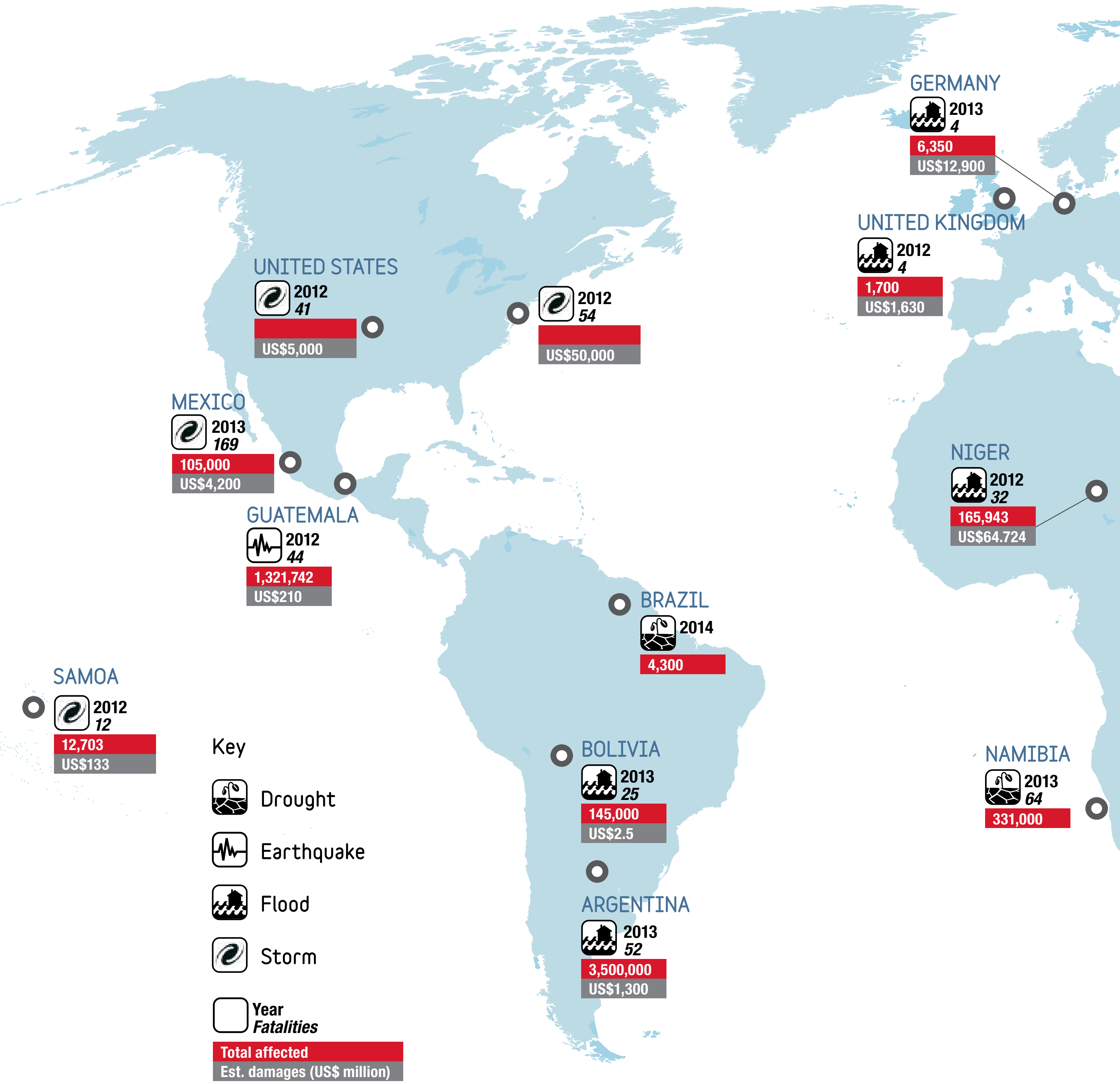
esri

RMS

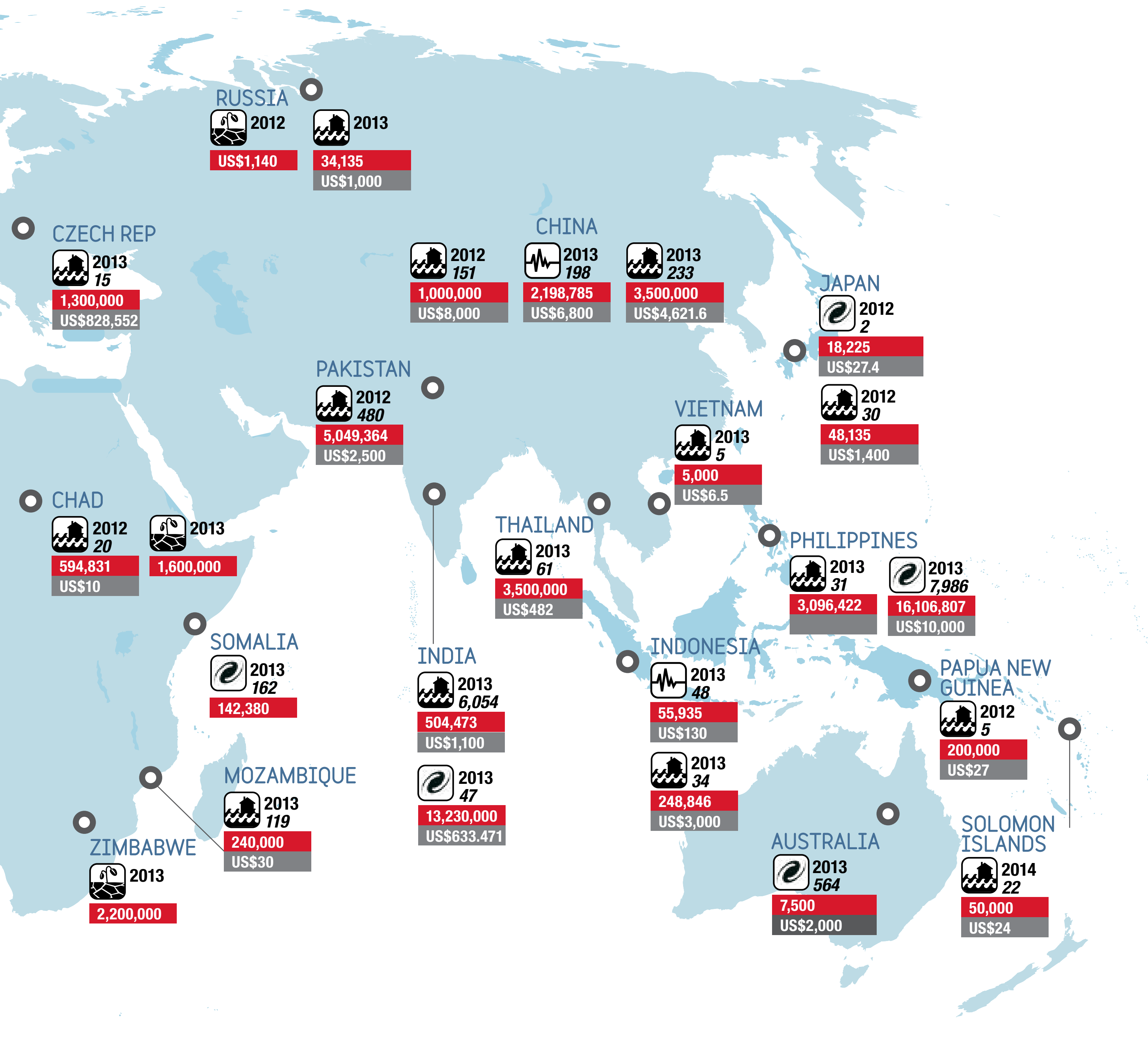
Google

SIEMENS

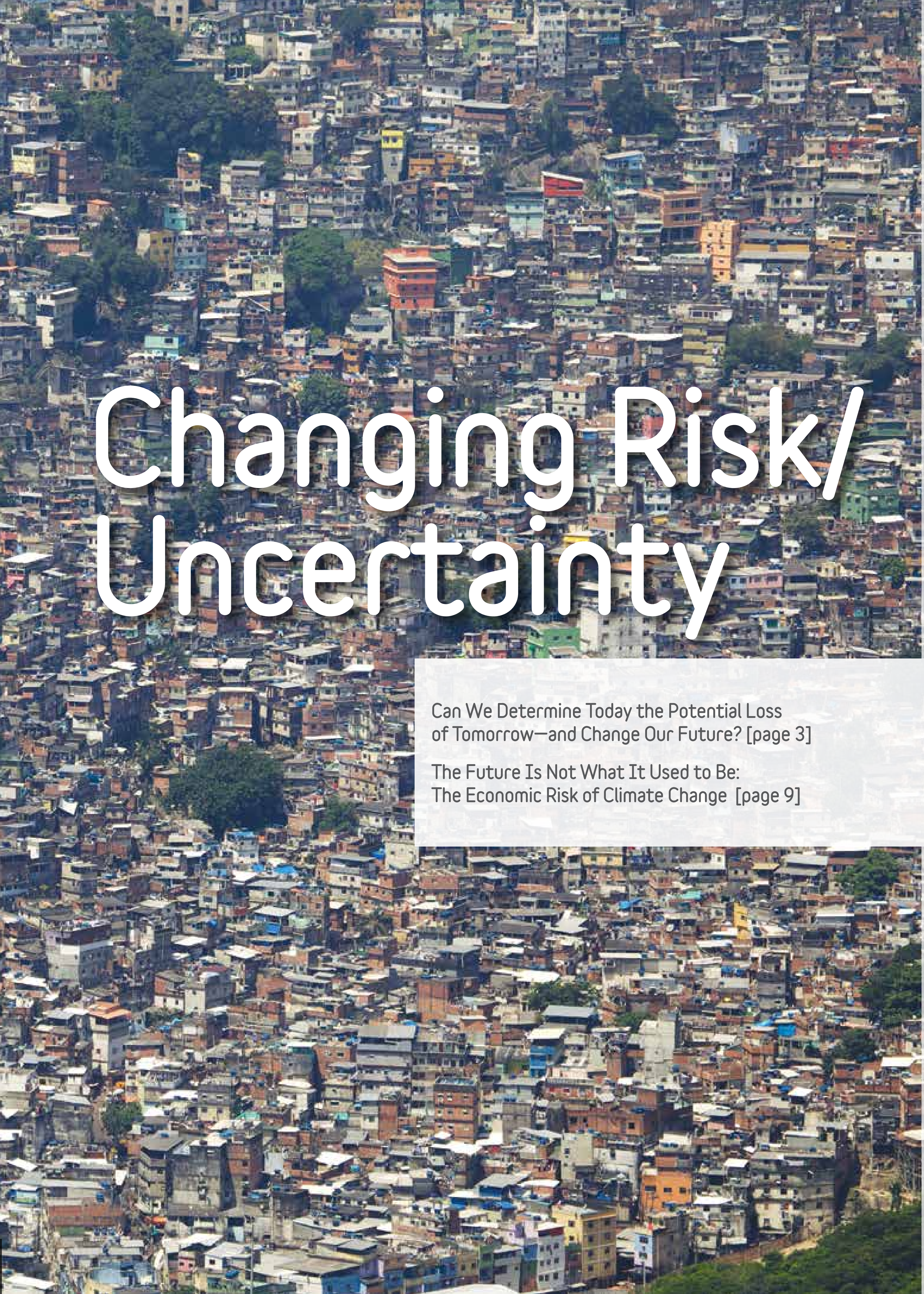
Major Disasters since UR2012



Since the second meeting of the Understanding Risk (UR) Community in Cape Town, South Africa, in July 2012, the world has seen hundreds of natural disasters that have caused more than US$1 trillion in losses, the vast majority of them uninsured, and affected thousands of lives. Below are some of the largest disasters in terms of economic losses and human impact.



Rocinha is the largest favela in Brazil, and is located in Rio de Janeiro's South Zone between the districts of São Conrado and Gávea.
Photo: dislentev/Thinkstock.com



Changing Risk/ Uncertainty

What does best-practice risk information look like? The word cloud is based on responses to a survey of the Understanding Risk community and on submissions to the Global Facility for Disaster Reduction and Recovery report *Understanding Risk in an Evolving World: Emerging Best Practices in Natural Disaster Risk Assessment* (Washington, DC: World Bank, 2014).

Can We Determine Today the Potential Loss of Tomorrow—and Change Our Future?

Dr. Alanna Simpson, Senior Disaster Risk Management Specialist, GFDRR

Kamal Kishore, Program Adviser, Disaster Risk Reduction and Recovery Team, United Nations Development Programme, Bureau for Crisis Prevention and Recovery

A range of new approaches to understanding risk—from collection of new data to new methods for modelling and communicating risk information—has facilitated evidence-based decision making across the globe. Our progress in understanding risk has gaps, however, including our failure to adequately model and communicate future risk, and a failure to communicate risk information so that it triggers action.

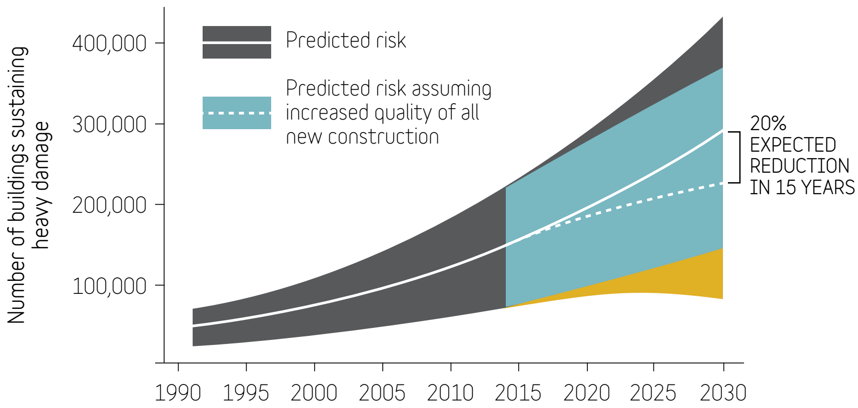
The experiences and innovations in understanding and managing risk described in this session—from Peru, Morocco, Jordan, Turkey, Nepal, the Philippines, and Papua New Guinea—highlight the urgent need for risk information that is targeted, authoritative, trusted, robust, open, and understandable, and that ultimately can be used to create a safer and more resilient future. The case studies featured in this session are also captured in the new publication *Understanding Risk in an Evolving World: Emerging Best Practices in Natural Disaster Risk Assessment*.[1]

How Well Can Growing Risk Be Modelled?

Risk assessments need to account for temporal and spatial changes in hazard, exposure, and vulnerability, particularly in rapidly urbanizing areas or where climate change impacts will be felt the most. A risk assessment that provides an estimation of evolving or future risk is a way to engage stakeholders in carrying out actions now in order to avoid or mitigate the risk that is accumulating in their city or country. For example, analysis can now be undertaken to show the decrease in future risk that arises from better enforcement of building codes, and hence demonstrates the benefit of spending additional funds on building inspectors.

Recent analysis in Kathmandu used a single earthquake scenario, a reproduction of the 1934 magnitude 8.1 Bihar earthquake, to capture the seismic risk trajectory of this highly vulnerable city. Simulating changes in exposure and building vulnerability through time, the analysis shows the rapid increase in the number of heavily damaged or collapsed buildings. The results show the current and potential future (or predicted) seismic risk for Kathmandu based on the building practices common today and the rapidly changing exposure. Critically, however, this analysis also shows that this predicted risk is not yet realized risk; that is, we still have a chance to ensure an outcome different from the one projected. For example, increasing the quality of all new construction in Kathmandu could result in a 20 percent decrease in risk in 15 years (figure 1), vastly reducing the number of people killed, homes destroyed, and lives and livelihoods disrupted.

Figure 1. Changing seismic risk in Kathmandu, Nepal. The figure shows the result of ensuring that all new construction is better designed for earthquakes.



Source: David Lallemant.

Risk Information Should Have a Clear Purpose and End-User

The importance of ensuring that risk information has a clearly defined purpose and end-user can be seen in the experiences of Morocco, where targeting disaster risk information was part of an integrated approach to risk management. This approach, which also considered commodity and agricultural risk, enhanced the vertical and horizontal engagement within the government of Morocco; enabled the consistent identification and prioritization of key risks; improved an understanding of key risk interdependencies; enhanced communication and coordination; and helped the government to make informed and cost-effective decisions.

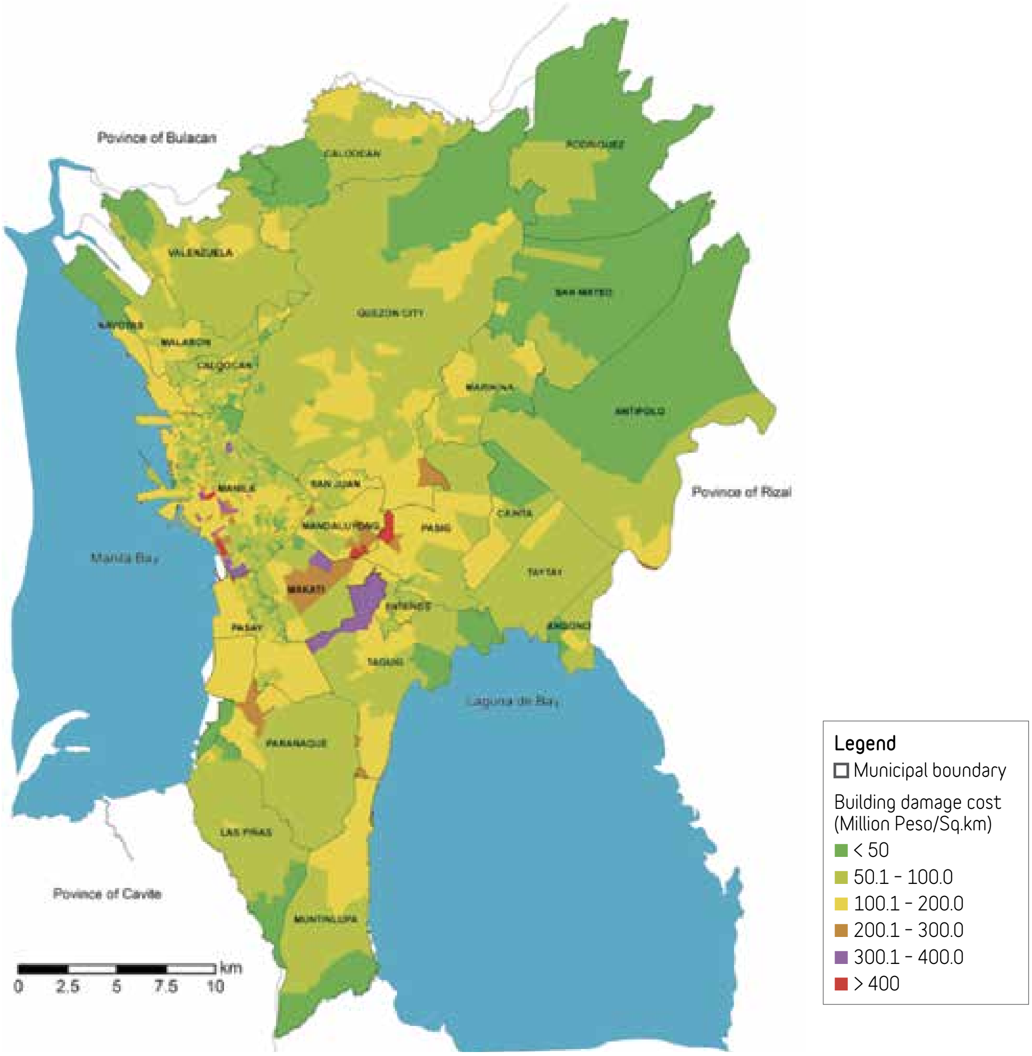
Targeted seismic risk information is also proving valuable in Peru, where Ministry of Education officials have used it to inform a retrofitting program aimed at 1,500 schools comprising more than 5,000 individual buildings. This successful use of risk information to reduce risk was founded on a three-part strategy that (1) used the results of the seismic risk assessment to inform a US$200 million retrofitting program in Lima; (2) enabled the risk assessment to be scaled to the whole country while soliciting local experts to improve vulnerability functions; and (3) ensured that decision makers in the Ministry of Education trusted the risk modellers producing the information.

Risk Information Should Be Credible, Trusted, and Transparent

The credibility of risk information is critical to its uptake and use by decision makers at all levels. This understanding has successfully guided a long-term Australian-Philippine partnership, which was established to support national government authorities in the Philippines in locally developing credible, transparent, and trusted risk information. Under the Greater Metro Manila Area Risk Assessment Project, which was undertaken as part of this partnership, more than 10 Philippine government agencies and Local Government Units worked with Geoscience Australia to develop and deliver a quantitative, multi-hazard risk assessment, using open source modelling tools. This highly technical analysis was then communicated to local government officials and

The experiences and innovations in understanding and managing risk described in this session—from Peru, Morocco, Jordan, Turkey, Nepal, the Philippines, and Papua New Guinea—highlight the urgent need for risk information that is targeted, authoritative, trusted, robust, open, and understandable, and that ultimately can be used to create a safer and more resilient future.

Figure 2. Severe wind risk map for Manila highlighting modelled building damage for a hazard with a 1-in-500-year return period, or 0.2 percent expected annual probability (EAP).



Source: Philippine Atmospheric, Geophysical and Astronomical Services Administration.

communities through animations (http://www.youtube.com/watch?v=1W0QCfFQB3w). Figure 2 shows a map developed under the project.

Credible seismic risk information was part of what made development in the city of Aqaba, Jordan, possible, and was also a key part of its transition into a Special Economic Zone (a move that has the potential to promote substantial economic growth and investment in the city). The seismic risk analysis was carried out in Aqaba from 2009 to 2010 by the Royal Scientific Society in partnership with the Civil Defense authorities, Jordanian National Building Council, and Jordanian Engineers Association.[2] Strong partnerships made up of local institutions were able to produce a credible analysis that is informing building codes, urban zoning and construction, and enforcement monitoring. Communicating the seismic results to various public and private groups to raise awareness will remain an ongoing focus.

Risk Information Should Be Well Communicated to Different Audiences

Communicating new information on volcanic, tsunami, and earthquake risks to local communities was a priority of a partnership between the governments of Australia and Papua New Guinea. Educational materials were produced in English

Figure 3. Educational materials on volcano risk produced under a partnership of the Papua New Guinea and Australian governments.

Source: Geoscience Australia.

and local languages after extensive consultation with local authorities and members of the community (see figure 3 for an example).

Another example of effective communication of risk information is offered by Turkey, whose Disaster and Emergency Management Presidency (AFAD) has made significant progress in using risk information to reduce seismic risks. Under the Istanbul Seismic Risk Mitigation and Emergency Preparedness Project (ISMEP) project,[3] more than a thousand buildings have been retrofitted or reconstructed in Istanbul, including schools serving more than 1.1 million students and teachers and hospitals serving about 8.7 million patients annually. Less well known but also very important is AFAD's effort to communicate risk information through many different channels and approaches, including earthquake museums to help residents remember past disasters; mobile disaster training centers that teach citizens what to do during an earthquake or other disaster; and various mobile applications and teleconference systems to ensure that needed information reaches as many citizens as possible.

How Can We Avoid Future Losses?

While the risk in rapidly urbanizing cities is changing dramatically and mostly for the worse, there is an important opportunity today to reduce future risk by avoiding the risks that are yet to be realized. Risk modelling can help policy makers avoid future risk by quantifying and valuing the future impact of the decisions made today.

Christchurch, New Zealand, offers an example of such avoided losses. When a magnitude 7.9 earthquake struck Napier, New Zealand, in 1931, it destroyed most of the city of 28,000 residents and resulted in 256 fatalities. Eighty years later, a shallow magnitude 6.3 earthquake occurred directly below Christchurch—but this far more populous city (375,000 residents) experienced fewer (185) fatalities. As powerful and devastating as this earthquake was, the impacts would have been much worse had not the New Zealand government acted over the decades to reduce risk. Its ban on unreinforced masonry construction in the aftermath of the Napier event meant that the building stock in Christchurch was inherently more earthquake resilient than if this decision had not been taken. Elaboration of these cases of avoided loss could provide a powerful narrative to decision makers, who have the authority to make decisions today that affect the generations of tomorrow.

Contributors to the session

Dr. Andrew Jones, Regional Development Section Lead, Geoscience Australia

David Lallemant, Graduate Fellow, Stanford University

Fernando Ramirez, Senior Disaster Risk Management Specialist, World Bank Group

Axel Baeumler, Senior Urban Specialist, World Bank Group

Abu Aisha, Director Architecture, Planning, and Disaster Risk Management, Aqaba Special Economic Zone Authority (ASEZA), Jordan

Ozlem Velioglu, Disaster and Emergency Management Presidency, Turkey

Endnotes

1 Global Facility for Disaster Reduction and Recovery, *Understanding Disaster Risk in an Evolving World: Emerging Best Practices in Natural Disaster Risk Assessment* (Washington, DC: World Bank, 2014), https://www.gfdrr.org/RAReferenceGuide.

2 The assessment received funding from the Swiss Agency for Development and Cooperation (SDC) and the United Nations Development Programme.

3 For more about ISMEP, see http://www.worldbank.org/en/results/2014/08/05/enhancing-seismic-preparedness-in-istanbul.

Further resources

- GFDRR, *Understanding Disaster Risk in an Evolving World: Emerging Best Practices in Natural Disaster Risk Assessment* (Washington, DC: World Bank, 2014), https://www.gfdrr.org/RAReferenceGuide.

  This report highlights the contributions disaster risk assessments have made over the last 10 years and examines case studies spanning 43 countries.
- GFDRR, *Understanding Disaster Risk in an Evolving World: A Policy Note* (Washington, DC: World Bank, 2014), https://www.gfdrr.org/RAPolicyNote.

  This policy note demonstrates the need to continue investment in accurate risk information and suggests recommendations for future disaster risk assessments.
- GFDRR, *Review of Open Source and Open Access Software Packages Available to Quantify Risk from Natural Hazards* (Washington, DC: World Bank, 2014), https://www.gfdrr.org/RASoftwareReview.

  This systematic review of freely available hazard and risk modelling software is designed to facilitate selection of appropriate tools for various disaster risk management (DRM) activities.
- M. Haklay, V. Antoniou, S. Basiouka, R. Soden, and P. Mooney, "Crowdsourced Geographic Information Use in Government," Report to GFDRR (World Bank), London, 2014, https://gfdrr.org/crowdsourced-geographic-information-use-government.

  This report focuses on government use of information produced through "crowdsourcing," the process of obtaining information from many contributors among the general public.
- GFDRR, *Open Data for Resilience Initiative Field Guide* (Washington, DC: World Bank, 2014), https://gfdrr.org/ODRIFG.

  This guide, which highlights the experience and approaches of Open Data for Resilience (OpenDRI), including the use of tools such as GeoNode and crowdsourcing, is aimed at practitioners considering how open data may support a DRM project.

Photo: abluecup/Thinkstock.com

The Future Is Not What It Used to Be

The Economic Risk of Climate Change

Dr. Louis Gritzo, Vice President, Head of Research, FM Global

Introduction

Changes in the climate have the potential to produce significant changes in the risk posed by natural hazards around the world. As highlighted in the latest Intergovernmental Panel on Climate Change report,[1] the current state of knowledge on climate science, and hence the risk posed by climate change, is clouded with uncertainty. Given the potentially devastating economic effects on cities and regions, and on the businesses and people located there, it is vital for disaster risk managers to have a current factual understanding of climate change and its impact on natural hazards. Gaining this knowledge requires that experts in climate science, economic trends, and business resilience work together with a common goal of ensuring public well-being.

Background/Concepts

As the world economy grows and changes, the risk to businesses, governments, and public well-being will be dominated by the combined dynamic effects of changes in hazards, and the increasingly fast evolution of economic vulnerability to extreme events.

Current trends show overall annual losses from natural catastrophes have exceeded US$250 billion twice in the last 10 years and have averaged near US$100 billion in the prior 30 years.[2] Global data from Munich Re show that the number of extreme events (those exceeding US$1 billion in economic impact) tends to fluctuate on the time scale of every 6 to 10 years, but has slowly increased overall during the last 30 years. In addition to rising total losses and numbers of extreme events, recent years have also seen an increase in the scale and scope of individual catastrophes. For example, the 2011 floods in Thailand exceeded US$46.5 billion in damage and direct losses,[3] not including the cascading losses arising from affected supply chains of global businesses.

These impacts not only affect business shareholder value. They can also have a devastating effect on small- to medium-size businesses that rely heavily on a small number of products or components to sustain jobs that support local economies. According to the World Bank assessment of the Thailand floods, the most severely impacted populations from that event were from poor and marginalized households who could least afford the lost income; they suffered more than US$3.4 billion in lost wages.

Preventing the escalation of the economic consequences of natural hazards requires assessing increases in vulnerability along with changes in climate. Factors driving increases in vulnerability—including the total assets exposed to these hazards and the consequences of those assets being impacted—continue to expand at a steady rate. Interconnected economic growth is increasingly concentrated in emerging economies and coastal urban areas, which increases the density of economic value in regions that are disproportionately exposed to hazards from wind and water—the two hazards most impacted by changes in the climate. In a scenario in which the number of extreme weather events did not change but emerging regions had at risk the same economic value as that found in developed regions, worldwide natural hazard losses would increase by a factor of three.

Disaster risk managers face several challenges. They need to monitor trends; they need to understand potential changes in the climate and the evolution in vulnerability; and they need to take measures to prevent, mitigate, and/or recover from the consequences. The word that best describes this goal is "resilience." Achieving resilience requires public policy makers, business leaders, and researchers to translate the current science into action and collaborate to accelerate the understanding of the evolving risk.

Achieving resilience requires public policy makers, business leaders, and researchers to translate the current science into action and collaborate to accelerate the understanding of the evolving risk.

Recommendations

Recommended efforts are both local and global in scale, and must be based on the following lessons learned:

1. **Climate science is not a long-term weather forecast.** The goal of a climate projection is to understand the trends present in the changing statistics of weather. These trends are subject to an evolving bias in the change of the overall climate and hence have to be expressed in probabilistic terms due to the high degree of variability in what we observe as weather.
2. **The specific hazards and the time frame of change are important.** Although short-term increases have been predicted in the past, they have proven not to be credible. The disconnect between short-term trends and long-term observations is reflected in the discrepancies between climate science and the portrayal of events by some media. Despite media coverage that attributed specific storms to climate change, U.S. hurricanes have not increased in frequency or intensity since 1900. Continual and highly geographically variable increases in sea level, however, are well established.
3. **Risk is currently driven by economic factors.** Although losses continue to increase, when adjusted for increase in value, there is no upward trend in loss from natural hazards. This observation does not mean changes won't occur in the future, only (as per above) that the trends

will evolve over long periods of time.

4. **The need for energy is the driving factor of economic growth.** Population growth and urbanization will continue to increase demand for energy in the most available and cost-effective forms. Energy is the key challenge in terms of efficiency and overall business value stability.

5. **There is a space full of opportunity for improved economic growth and reduced risk.** Sustainable modes of energy efficiency are already making a huge difference. The right technologies will continue to expand, and—with economic growth—the potential for investing in more resilient and lower-emitting energy sources should improve in step. Investing in these systems, and making others more resilient, is good economics. Innovation (of all types) that is firmly in this space is yet another economic opportunity.

Conclusions

With the world changing faster every year, it's more important than ever for disaster risk managers to be informed and avoid the trap of inaction produced by the cloud of uncertainty. Taking a factual view of the economics of climate risk is the basis for a proactive approach to reducing risk. This approach must involve climate change mitigation (from reduced environmental impact) and climate adaptation (through improved resilience). Even in an environment where hazards are not increasing, the current acceptance of risk will lead to unacceptable outcomes in the long term. The potential long-term climate change trends, however, underscore the urgency of taking actions that are both good for the economy and good to reduce risk. In summary, measures to reduce risk should have a "trigger point" for implementation where cost-effective measures of resilience are reasonable and actionable.

Contributors to the session

Professor Tim Palmer, Royal Society Research Professor in Climate Physics, Oxford University, Co-director of the Oxford Martin Programme on Modelling and Predicting Climate

Professor Roger Pielke Jr., Professor and Director of Center for Science and Technology Policy Research at University of Colorado

Mr. Jeremy Oppenheim, Director of McKinsey's Global Sustainability and Resource Productivity Practice and Leader of New Climate Economy Project

Endnotes

1 IPCC, "Summary for Policymakers," in *Climate Change 2013: The Physical Science Basis*. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, ed. T. F. Stocker et al. (Cambridge and New York: Cambridge University Press, 2013), http://www.climatechange2013.org/images/uploads/WGIAR5-SPM_Approved27Sep2013.pdf.

2 *2013 Natural Catastrophe Year in Review*, Munich Re NatCat Service, January 7, 2014.

3 Global Facility for Disaster Reduction and Recovery, "Thai Flood 2011: Rapid Assessment for Resilient Recovery and Reconstruction Planning," World Bank, 2012.

Further resources

- R. J. Pielke, *The Climate Fix* (New York: Basic Books, 2011).
- McKinsey Global Institute, "Resource Revolution: Meeting the World's Needs for Energy, Food, Water and Materials," 2011.

Photo: agsandrew/Thinkstock.com

Data

Photo: hkeita/Thinkstock.com

What if Rome had Been Built in a Day? The Rapid Changes in Urban Exposure

Toward Capturing and Fusing Dynamic Information with Exposure Models through New Technology

Dr. Keiko Saito, Disaster Risk Management Specialist, GFDRR

In the context of disaster risk modelling, exposure data are an expression of the "population, assets, and values at risk" from natural hazards. They are meant to quantify the number and value of both stocks and flows at risk. To estimate the likely risk (e.g., in terms of expected social or monetary loss) from natural hazards, the exposure data and the vulnerability of the exposed assets are considered in relation to the severity and spatial extent of the hazard in question.

Most exposure modelling methodologies capture the values at risk in a static manner—i.e., the data represent the value at risk at a certain point in time. However, the values at risk change over time, sometimes rapidly, and their capacity to change introduces a further element of uncertainty in the exposure model. By exploiting the wealth of information that is now becoming available through Earth Observation (EO) and other continuous data-capturing frameworks, it is possible to move toward a more dynamic approach. The challenge is to find innovative, efficient methodologies for collecting, organizing, storing, and communicating exposure data on a local or even global scale, while also accounting for the inherent spatiotemporal dynamics.[1]

Case Studies

There are typically two approaches to developing exposure models, the so-called top-down approach (based on the disaggregation of country-level, large-scale geo-data sets) and the bottom-up approach (based on the integration of *in situ* field data collection). Many developing countries exposed to natural hazards do not uniformly collect consistent and detailed data sets applicable for exposure modelling, such as cadastral data. To compensate for this lack of data and the computational limitations of modelling, aggregated exposure data sets are commonly used in disaster risk models.

An example of a top-down exposure modelling approach is the one pursued by the *World Bank's Global Practice for Social, Urban, Rural, and Resilience* disaster risk management team in creating probabilistic country disaster risk profiles (CDRPs) for the Caribbean. This novel approach to exposure modelling integrates three different exposure databases (disaggregated gross domestic product, infrastructure, and building stock inventory databases) at a $1km^2$ spatial grid resolution to represent economic/asset values at risk to natural hazards. It also uses innovative techniques in exposure disaggregation, building typology distribution, and asset value determination. The resultant gridded exposure database can be convolved with hazard and vulnerability components to create CDRPs for multiple hazards. This approach also highlights use of global data sets such as MODIS 500m (2010), BuREF (2012), GUF (2013), and Landscan (2012), which are compared to assess issues of spatial accuracy, sensitivities of the disaggregation results, and the implications of these results for disaster risk modelling. The sensitivity of the output is especially important for risk analysis of Small Island Developing States, where a small systematic shift in the identification of inhabited areas could create a large difference in the estimated physical stock value.[2]

Approaches that include bottom-up data collection components are particularly useful when global data sets do not provide a realistic picture of the exposed assets, and when the exposure rapidly changes with time. In the Kyrgyz Republic, for instance, where a rapid increase in the values at risk in recent years has been observed, the *Earthquake Model Central Asia project* is building an exposure model that can take advantage of data efficiently collected on the ground. A rapid visual assessment approach has been implemented based on the use of mobile mapping, omnidirectional imaging, and geographic information system (GIS) technologies (figure 1). The approach is being developed in order to prioritize and speed up the collection, storage, and integration of building-by-building exposure data in Central Asia.

Similarly developed exposure models are being tested in operations by the *Turkish Catastrophe Insurance Pool (TCIP)*, which was established after the 1999 Kocaeli earthquake caused extensive damage and loss of life in Istanbul. Istanbul has a population exceeding 14 million and a building stock of more than 800,000 buildings, and it is considered Turkey's economic center. Because of its proximity to several well-known fault systems, Istanbul's concentration of social and economic assets is permanently threatened by potentially devastating earthquakes. Currently, insurance offered by TCIP covers more than 40 percent of the total residential housing in Istanbul. In the event of a large earthquake, TCIP will face the daunting task of managing hundreds of thousands of claims from customers.

Introducing technologies that can assist in this task is the key to improving TCIP´s operational capacity in a post-event situation. Claims management requires detailed building-level data, and geospatial modelling of exposure is therefore being implemented, including the use of mobile mapping systems to scan the exposed assets. Improving claims management would increase the resilience of the

Figure 1. Snapshot of the omnidirectional camera and the buildings captured in the footage as part of the Earthquake Central Asia project.

Source: Earthquake Model Central Asia project (top) and Google Maps (bottom).

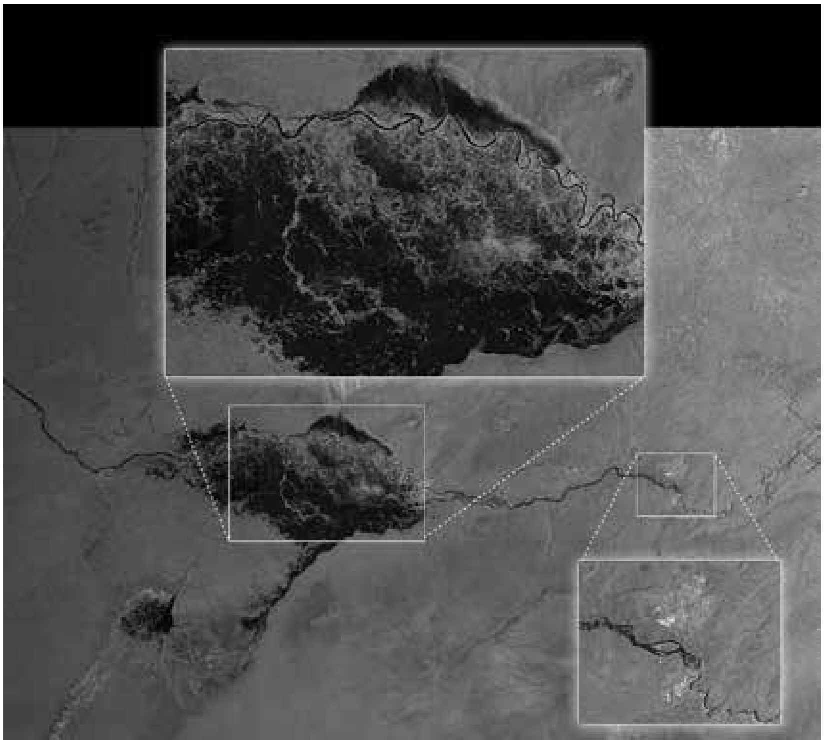
impacted communities in Istanbul, ensuring a faster recovery of the society as a whole.[3]

Data from satellites are now making an important contribution to exposure modelling. Each year, public and private organizations launch new satellites that increase our ability to monitor and analyze activities on the Earth's surface in more detail and with greater frequency. With the launch of Sentinel-1 (S-1A) in April 2014, Europe has entered a new era of using global, open, and sustained EO data from space for both science and risk applications. A sample image from S-1A is in figure 2.

S-1 is part of a series of operational Sentinel satellites developed by the European Space Agency within the framework of the European Copernicus initiative to provide sustained observations in support of a portfolio of Copernicus services. The family of missions includes a high-resolution land-monitoring mission (S-2) and a medium-resolution ocean- and land-monitoring mission (S-3) due to be launched over the next few years to ensure continuity with previous missions such as Envisat, SPOT, and Landsat.

Over the next decades, the Sentinels will routinely deliver sustained EO data streams, which will provide unique insight into the state of our environment, its evolution, and the extreme events and natural disasters that affect it. Creating a streamlined work flow that incorporates the use of these data sets will be important to fully leverage the power that the Sentinels bring.

Figure 2. First radar vision for Copernicus Sentinel-1A in support of flood management in Namibia.

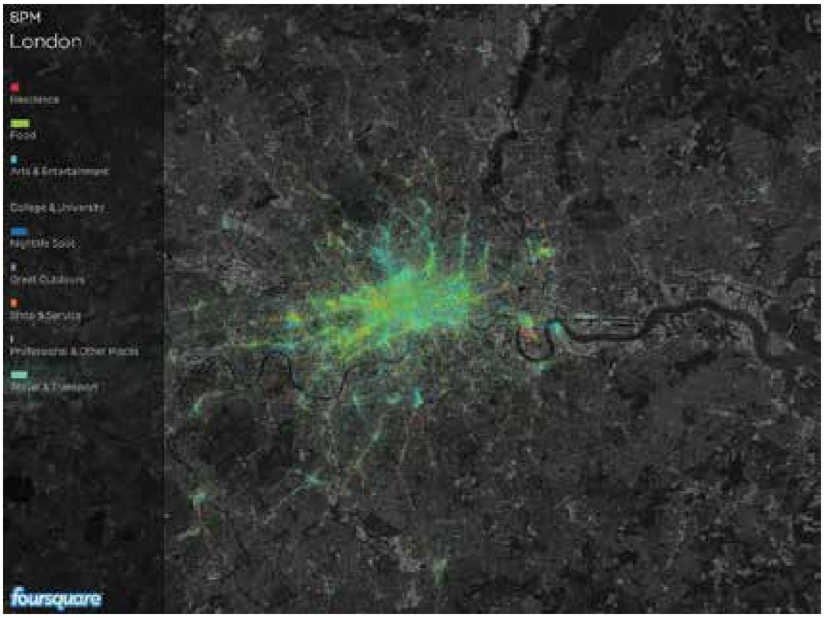


Source: European Space Agency.

As **social media** infiltrates our daily lives, the data it generates contain a wealth of information about our society. Social media gives us new ways to understand our daily activities, and our exposure to a multitude of natural and other hazards. Given that exposure modelling is concerned with quantifying economic activities, we can imagine how data gleaned from use of social media might be incorporated into the modelling process. For example, information about a population's income level could be captured by analyzing use of iPhones, Androids, or Blackberries, each of which is associated with a certain income range. Or an area's social composition and underlying social activity could be understood by analyzing the languages used in social media; clustering of social media messaging in multiple foreign languages in a large urban area could make it possible to identify economic and temporal zones associated with tourism. In general, an awareness of language is important for mining social networks and getting the most out of the data. In the OpenStreetMap data for Thailand, for example, more local information is shown in the Thai version than in the English version.

Social media also has the potential to be used to identify workplaces, residential buildings, entertainment venues, etc., by creating and capturing a dynamic baseline of people's movements over time (figure 3). Such an experiment is already starting in Bangladesh, where the information will be used by a Japanese team to design a flood early warning system. Finally, wearable devices are producing an explosion of shared data that are being used to create "emotional maps"—of London, San Francisco, and other cities—that offer insight into hazards, lifestyles, traffic conditions, and attitudes about city services.

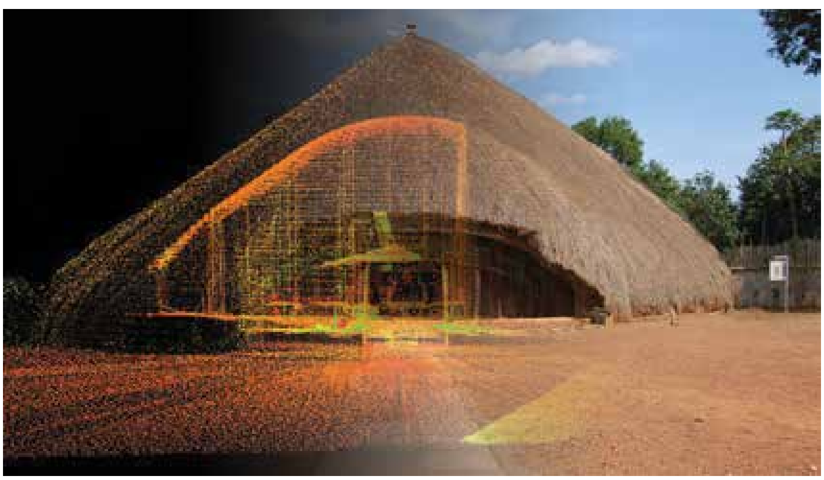
Figure 3. Image showing people's movement at 8 p.m. in London, captured on social media platform Foursquare.



Source: Foursquare Labs. Used with permission; further permission required for reuse.

Cultural heritages are irreplaceable but also vulnerable to the impacts of natural disasters. While the values that inhere in them are not addressed in exposure modelling methodologies, **terrestrial laser scanning of cultural heritage sites** now offers a promising approach to protecting them: with a 3-D point cloud, the original form can be restored if damage occurs. An initiative called CyArk 500 is collaborating with various organizations to survey 500 heritage sites globally using terrestrial laser scanning. Until recently, terrestrial laser scanners were not easy to use. The bottleneck was the post-processing, which could be handled only by specialists. In recent years the post-processing software has evolved and is much easier to use, so much so that in some areas, high school students are embarking on capturing their local cultural heritage. Scans taken of the Kasubi Tombs in Uganda before they burned down in 2010 will aid in the site's reconstruction (figure 4).

Figure 4. Photograph of the Kasubi Tombs before the fire, merged with the 3-D point cloud captured using terrestrial laser scanning.



Source: © CyArk. Used with permission; further permission required for reuse.

Challenges

While dynamic exposure modelling is still in its very early stages, the data and technologies it requires appear to be plentiful and growing. A plethora of global geo-data sets and EO sources is already available, and will be further stocked by upcoming space missions. At local scale, simple and efficient mobile mapping systems are increasingly capable of providing relevant data. The combination of this expanding observing capability with rapid advances in information and communication technologies (e.g., big data technologies, cloud computing, machine learning) will

The most important challenge will be to convert raw data into actionable information that can be used—a process we can liken to the refining of crude oil into usable products.

provide decision makers with a very powerful analytical tool to help them better quantify, model, predict, and manage environmental risks at a variety of scales in space (from local to global) and time (from minutes to decades).

Making the most of these new capabilities and technologies involves new challenges, specifically in how we access, discover, distribute, integrate, mine, and exploit available data. The most important challenge will be to convert raw data into actionable information that can be used—a process we can liken to the refining of crude oil into usable products.

Addressing this challenge will require a mix of new skills, approaches, and international partnerships (involving for example space agencies, international conventions, scientific programs, funding bodies, and the private sector) as well as closer collaboration between data providers and data users. In this way, it will be possible to deliver the true value of these data sets and accelerate the process of building resilient societies.

Conclusions

Dynamic exposure modelling depends on shifting the paradigm toward a continuous, incremental assessment of risk. This type of assessment will be able to keep up with the change in the exposed assets (people, building stock, infrastructure) instead of leaning on static estimates that—especially in economically developing countries—promptly become obsolete. Exploiting global and freely accessible data sources is a challenge that calls for a closer interaction between risk practitioners and scientists on the one hand, and civil protection authorities and policy makers on the other.

Contributors to the session

Session leads

Dr. Massimiliano Pittore, Senior Scientist, Helmholtz Centre Potsdam, German Research Centre for Geosciences (GFZ)

Dr. Keiko Saito, Disaster Risk Management Specialist, GFDRR

Panelists

Dr. Rashmin Gunasekera, Senior Disaster Risk Assessment and Financing Specialist, the World Bank Group; CDRP team

Marc Wieland, Researcher, Helmholtz Centre Potsdam, German Research Centre for Geosciences (GFZ)

Ismet Gangor, Chief Executive Officer, Turkish Catastrophe Insurance Pool (TCIP)

Pierre-Philippe Mathieu, Earth Observation Applications Engineer, European Space Agency

Mark Polyak, Vice President, Analytics, Courage Services Inc.

Elizabeth Lee, Vice President, CyArk

Endnotes

1 For an engineering perspective on the challenge of addressing evolving urban risk, see "Back to the Drawing Board" in this publication. For use of new technologies in fostering urban resilience to risk, see "How Might Emerging Technology Strengthen Urban Resilience?" in this publication.

2 For a discussion of the vulnerability of Small Island Developing States, and of the strategies they use to "become big," see "Big Numbers, Small Islands, and Risk Pooling for Insurance" in this publication.

3 For more on risk pooling, see "Big Numbers, Small States, and Risk Pooling for Insurance" in this publication.


Photo: © Alexander Kolomietz | Dreamstime.com

Game of Drones

Vica Rosario Bogaerts, Disaster Risk Management Specialist, GFDRR

Drone technology can add significant value to efforts to make communities, cities, and countries more resilient. At low cost, drones can be used for mapping, surveying, 3-D modelling, and enhancing search-and-rescue operations in the aftermath of a disaster. But drones will be able to fulfill their potential only if challenges related to legislation, safety, and privacy are sufficiently addressed.

The Rise of Civilian Drones

Unmanned aerial vehicles (UAVs, also commonly known as drones) are often associated with controversial military operations. Over the last several years, however, a new generation of drones has emerged. The market for civilian drones appears to be growing rapidly as a range of industries sees the potential of drones and as drones themselves become more versatile and sophisticated.

Agriculture is one of the sectors that have embraced drone technology. In Japan, for example, 90 percent of crop dusting is currently done by drones. In the oil and gas industry, drones with infrared cameras are being used to monitor thousands of miles of pipelines for leaks. The number of private companies using drone technology is growing, and drones will soon be used by retail companies—notably the Australian textbook rental service Zookal, which will start its first deliveries by drones next year, and Amazon, which is also pursuing drone technology for deliveries.

The public sector, particularly humanitarian and development practitioners, is also starting to experiment with the use of drones. Most recently, events in the Philippines (Typhoon Haiyan in 2013) and Bosnia and Herzegovina (floods in 2014) provided the opportunity to use drone technology to map the impact on the ground.

Drone Technology Today

The latest generation of civilian drones builds on developments in smartphone technology, not military technology. As technology giants such as Apple and Google compete for market share, they invest great resources to improve sensors, processors, and batteries of smartphones—exactly the core components required to build an autopilot for a drone. In other words, without support from

Table 1. Civilian vs. military drones

	Flight time	Distance	Size
Civilian	15-50 minutes	1-15km	100g-15kg
Military	Hours-days	100s-1,000s of km	Full-size aircrafts

Table 2. Rotary vs. fixed-wing drones

	Pros	Cons
Rotary 	▶ Takes off/lands in tight locations ▶ Hovers	▶ Limited to slower, shorter flights, lower coverage: up to $1km^2$ ▶ Less safe (heavier)
Fixed-wing 	▶ Capable of quicker, longer flights, greater coverage: up to $12km^2$ per flight ▶ Safer (light weight) ▶ Handles stronger winds	▶ Larger take-off/landing area ▶ Cannot hover

the military, civilians have been able to push drone technology (see table 1 for a comparison of civilian and military drones). As a result, drones today are smarter, smaller, easier to use and, above all, a lot more affordable than they would otherwise be. Civilians can now choose between fixed-wing drones and rotary drones, such as quadcopters or other multi-bladed small helicopters (see table 2 for a comparison of the two types).

In addition, drone makers have started to invest in the development of innovative software that allows users to create high-resolution georeferenced orthmosaics and digital elevation models based on the data collected by drones. Advances in digital image processing and development of increasingly sophisticated algorithms have allowed drone makers such as senseFly to overcome the problem of putting oblique images together in a mosaic. Today, within a couple of hours after a flight, it is possible to develop a georeferenced 3-D model of the physical environment.

Challenges

The costs of acquiring drones have gone down, and the potential benefits of using drones are significant. At the same time, civilian use of drones poses a number of unique challenges. One challenge involves safety: a drone almost collided with a US Airways plane near Tallahassee, Florida, in 2014. While this incident was a near miss, the absence of formalized safety programs means a real accident may happen in the future. Another concern relates to the issue of privacy. As the size of drones continues to decrease, they are more likely to be used to monitor and track movements of individuals without their consent. A final challenge is the current lack of any mechanism for easily sharing data collected by drones.

Moving Forward

While civilian drones show great potential to add value to our ability to understand and manage disaster risk, they also pose great challenges that cannot be ignored. Moving forward with drone technology in the service of managing disaster risk will require significant improvements in various areas, including development of policies and regulations related to drone equipment (fail-safe policies), operator certification, emergency flight permit applications, and insurance for drones. Other areas that should be prioritized include the establishment of infrastructure required to share data collected by drones and the short-listing of organizations allowed to fly civilian drones.

Contributors to the session

Hendrik Bendixen, CEO and Managing Director, Anthea Technologies

Matthew Wade, Marcomms Manager, senseFly

Manuel B. Fiol, Fellow Research Associate, United Nations Institute for Training and Research; Imagery Analyst, UNOSAT

Harry Wood, Board Member, Humanitarian OpenStreetMap

UR Interview

Patricia de Lille
Mayor of Cape Town,
South Africa

Q: You participated in the 2012 Understanding Risk Forum when it was held in Cape Town. This year you've joined the Forum again, flying all the way to London. Why is it important for you to be part of this Forum?

A: We are living in a global village, and certainly natural disasters know no borders. It's important to share information about how to respond to natural disasters and how to rebuild communities afterward. I've come here today to share the Cape Town story. I hope to describe what we are doing, and in particular how we're catering for a city that has been urbanized at a very rapid pace. We are the fastest-growing city in South Africa, and we have had to shift our planning to deal with natural disasters.

Q: What's your overriding impression of the Forum?

A: I think we've got a good combination of the partners that we need in dealing with natural disasters: government, business, NGOs, universities. It's a good platform for sharing information. As we face new challenges, effective collaboration is key to minimizing the global impact of DRM problems.

Q: What do you make of all the representation from other countries?

A: The many dozen countries represented show that problems are the same around the world, wherever you have to deal with disasters. The only difference might be the impact or the severity of the disaster. But we all agree about the need to understand risk better.

Photo: Sudipto Das

The Power of the Crowd

Harnessing Communities and Opening Data

Robert Soden, Disaster Risk Management Specialist, GFDRR*

Introduction

In the four years since the first Understanding Risk Forum took place in Washington, DC, our community has both witnessed and fostered significant changes in the conduct of risk assessments. Among these changes are the shift toward open data practices and the growth of crowdsourcing and community mapping projects. Together, these trends facilitate a far more dynamic and engaged understanding of risk than has been possible in the past. While these approaches are becoming more widespread, there is still a need to document and learn from successful examples and further institutionalize their adoption before they can be considered mature.

Background and Key Concepts

Open data is not a new idea. Obtaining risk information—that is, data about underlying exposure, hazard, and historical loss—enables better disaster risk management decisions by policy makers, particularly decisions related to core development planning. Citing the high cost of creating data, the burden this cost places on the governments that fund data creation, and the importance of peer review, scientific communities have championed sharing of raw data for decades. Since the 1990s the Open Government movement has advocated open government data policies in order to encourage transparent governance and promote citizen engagement.

The World Bank launched its Open Data Initiative in 2010 with these values in mind. While there is some variation in how open data projects are designed and implemented, for data to be considered "open" they should be both technically open and legally open. Technically open means that the data set is structured such that it can be opened and analyzed in a variety of software tools, while legally open means that the data are released under a license that permits reuse and redistribution for both commercial and noncommercial purposes.

*This session was organized in partnership with Google.

In recent years, projects have incorporated a number of strategies to make the process of risk assessment more inclusive. One strategy, embodied in the OpenStreetMap (OSM) project, is to involve new actors and nontraditional participants in the process of collecting data needed for the risk assessment. Frequently called the "Wikipedia of maps," OSM was founded in the United Kingdom in 2004 by software developers who were frustrated with restrictive licensing schemes applied to much of the spatial data they were seeking to use in their applications. OSM is now a global project with over 1.5 million registered users and active local chapters in 80 countries. It was first used in a large-scale fashion for disaster risk management (DRM) following the 2010 Haiti earthquake. Since then it has been incorporated into DRM projects all over the world to support disaster risk assessment, preparedness, and contingency planning activities.

Case Studies

Dominica. With the support of donors and development agencies, the government of Dominica has been working with geographic information system (GIS) technology since 1995. Over the years, high priority has been given to the creation of fundamental geospatial data sets to support transportation and land-use planning, DRM, and other development goals. In 2012, over 40 representatives from ministries and local nongovernmental organizations gathered to discuss improving spatial data management in the country. Open data was identified as a key strategy for improving access to information. A subset of participants in the workshop has since collaborated to launch an open spatial data–sharing platform where much of Dominica's geospatial information can be accessed. The platform is based on the open source GeoNode tool and is online at http://dominode.net/.

Project NOAH. The Philippines faces significant annual hydrometeorological hazards and has developed a number of sophisticated approaches for soliciting actionable information from citizens and releasing government data and analysis to the public. The Nationwide Operational Assessment of Hazards (NOAH) was created by the Philippine Department of Science and Technology to provide communities with high-quality data and information to inform planning and early warning systems. Project NOAH recently launched WebSafe, a disaster impact analysis tool, adapted from the open source InaSafe software that was developed in partnership between GFDRR, AusAID, and the Indonesian government. More information about Project NOAH can be found at http://noah.dost.gov.ph/.

Open Cities. The World Bank's Open Cities Project supports community mapping activities that provide high-resolution and up-to-date information for disaster risk assessment and urban planning. Open Cities has completed projects in Dhaka, Kathmandu, and Batticaloa, and is currently planning the next phase of activities. Each project leveraged the OpenStreetMap platform to facilitate participation in mapping schools, hospitals, and other critical facilities. More information about the project can be found at http://opencitiesproject.com.

The OpenDRI Field Guide In 2011 the Global Facility for Disaster Reduction and Recovery (GFDRR) launched the Open Data for Resilience Initiative (OpenDRI) to bring the philosophies and practices of the global open data movement to bear on the challenges of reducing vulnerability to natural hazards and the impacts of climate change. In the three years since, OpenDRI has partnered with governments, civil society organizations, and the private sector in over 25 countries to implement these ideas. In March of 2014, GFDRR, along with partners from the U.S. Agency for International Development (USAID), United Nations Office for the Coordination of Humanitarian Affairs (UN OCHA), American Red Cross, and United Nations Office for Disaster Risk Reduction (UNISDR), released the OpenDRI Field Guide, a practical guide that assists those seeking to implement their own open data projects related to disaster and climate risk management. More information is available at https://www.gfdrr.org/ODRIFG.

Crowdsourcing in Government As part of the session, Dr. Muki Haklay launched a new report, "Crowdsourced Geographic Information Use in Government." This publication is the result of a six-month study conducted by University College London and GFDRR's OpenDRI. To gain insight into patterns of adoption, successful approaches, and other key issues, the research team assessed nearly 30 cases of government usage of crowdsourced data. Among the findings of the report are these:

- There are some established cases of close collaboration between government and the public, which range from land management and biodiversity monitoring to disaster response. These examples demonstrate that successful interaction is possible under certain conditions.
- Many of the lessons from the early implementation of GIS technology in government hold true for volunteered geographical information (VGI) projects and can be used to ensure their successful implementation.
- Where governmental data are lacking, the need for suitable data sets can lead to the initiation of VGI projects.
- Technical issues are not insurmountable, so these are not the limiting factor in VGI adoption by government.
- Organizational practices, regulations, and legal issues such as license conditions are much more likely to restrict VGI projects than technical issues.
- The acceptance and use of VGI will be influenced by individual, organizational, business model, technical, and conceptual factors.

More information about the report can be found at http://crowdgov.wordpress.com/; a downloadable version is at https://gfdrr.org/crowdsourced-geographic-information-use-government.

Recommendations

A number of steps should be taken to ensure that open data and crowdsourcing continue to thrive:

1. Develop partnerships for open data. As some of the case studies show, open data and community engagement in risk assessment require the involvement of a wide variety of experts and local actors. Data used in risk assessment, such as building footprints, street networks, land use, or population density, are frequently useful for other purposes. There is therefore an opportunity to build strong cross-sector alliances to advocate for and implement open data efforts. Ensuring that a broad network of participants is engaged in these processes is critical to their success and long-term sustainability.

2. Involve participants in community mapping projects early. Too often, projects that aim to incorporate crowdsourcing or other forms of public engagement reach out to intended participants only after the data collection process is ready to begin. To increase local ownership of the project, to ensure that the data collected are most useful to those involved, and to increase the chances that participants will continue to contribute and use the data once the formal project period has ended, key stakeholders should be involved as early as possible during the planning phases.

3. Clearly document case studies. With a now-significant number of projects incorporating open data approaches, there is an opportunity to evaluate the impacts of these initiatives and generate valuable lessons about successful project design. Rich documentation of successful examples and the benefits they have generated also helps to communicate the value of open data and community involvement in risk assessment and to encourage wider adoption of these practices.

Contributors to the session

Lyn Baron, GIS Technician, Physical Planning Division, Dominica

Dr. Alfredo Mahar Francisco Lagmay, Executive Director, Project NOAH, Philippines

Marc Forni, Senior Disaster Risk Management Specialist, World Bank Group

Rebecca Moore, Engineering Manager, Google Earth Outreach and Earth Engine

Dr. Muki Haklay, Professor of Geographical Information Science, University College London

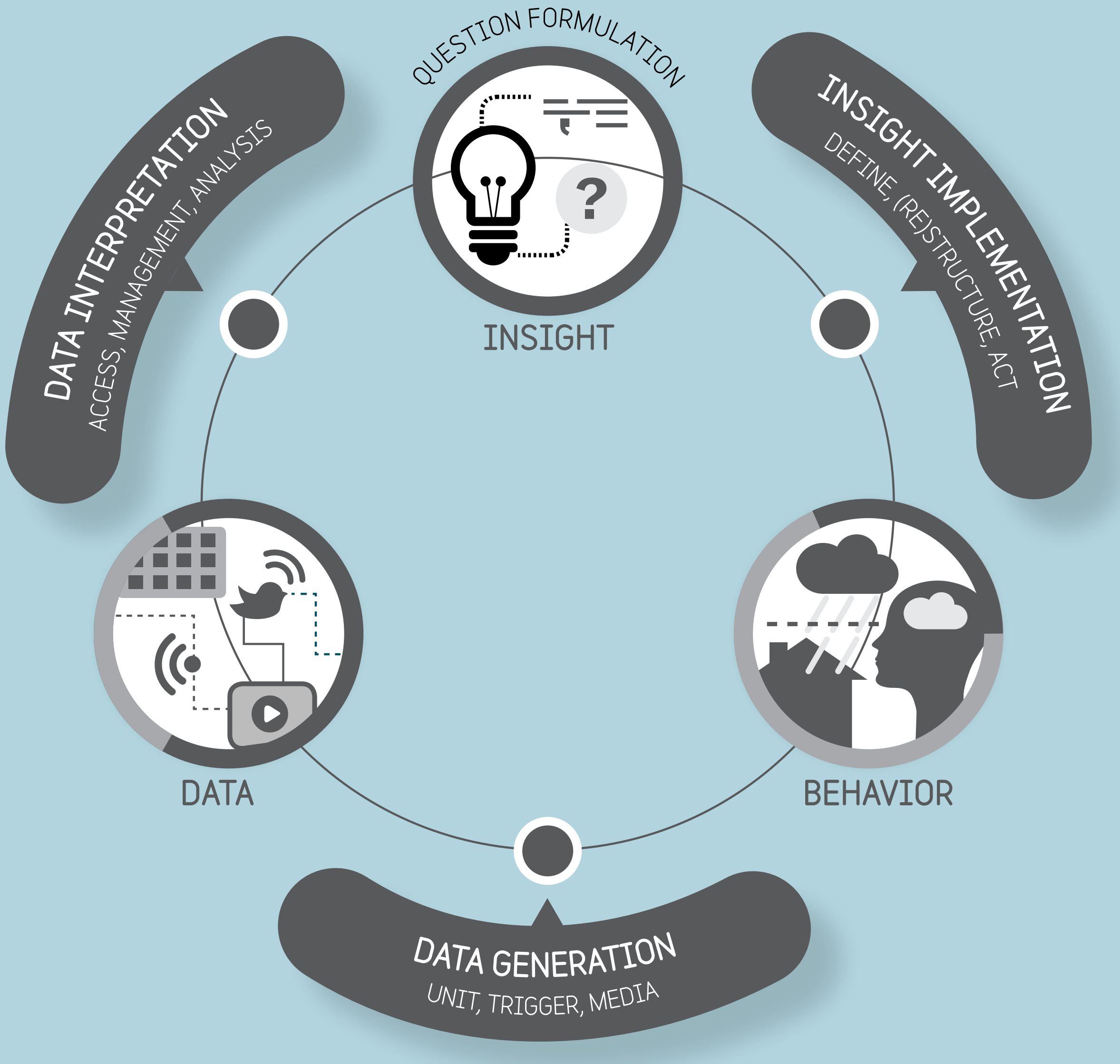


Figure 1. OpenDRI framework.

Source: World Bank.

Open Data for Resilience Initiative: Key Challenges

GFDRR Innovation Lab
Google
SecondMuse

How can the global community use open data to meet the big challenges in building climate and disaster resilience?

This was the question explored at a UR Forum workshop by experts in the fields of disaster risk, climate, and open data. Working in groups, the workshop participants identified key challenges to the use of open data. To facilitate this exploration, a lightweight framework (shown in figure 1) was used.

This framework reflects the cycle of data to action in a real-world context. Data generated from human behavior and world conditions are collected and interpreted. Insights gained from the interpretation are implemented, and new behaviors encouraged. These, in turn, create new data, which form the basis for further analysis, monitoring, and evaluation.

Challenges

Workshop participants identified the following challenges associated with the use of open data:

1. Open data alone does not equal impact.

In thinking about how to ensure that data have a positive impact, we need to keep in mind all phases of the data cycle (figure 1). Stated differently, open data does not equal impact. A positive impact arises from a considered process that broadly understands how the data will influence decisions and thus behavior.

2. Behavior is the blind spot.

While workshop participants covered a wide portion of the framework, their experience and expertise was heavily skewed toward the technical sections of data generation and interpretation. Yet as many of the workshop discussions acknowledged, the real challenges for the community have become less technical and more human-centered. Needs finding and definition are critical but underdeveloped skills, and greater insight into behavior change would also be helpful. The tools and data that technical experts create will be more useful if they fit into existing decision-making work flows.

3. Effective communication is a key in changing behavior.

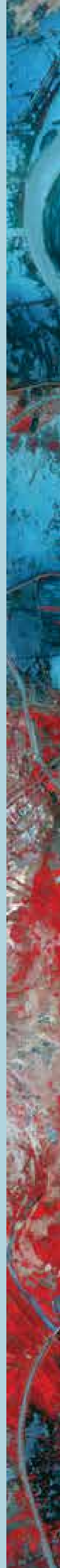
Participants agreed that a lot of work goes into "doing things," while less goes into effectively communicating. This failure to invest and build capacity in effective communication is a significant limiting factor in changing behavior. Better communication would be especially beneficial to local communities that could benefit from open data.

4. The case for open data still needs to be made.

One of the central communication challenges is the case for open data. The thought of using open data for a new or unanticipated purpose for some still inspires anxiety. This is in contrast to the central value proposition of open data, which is the unexpected value from usage. To be sure, there are a variety of reasons, good and bad, why people resist open data, including effective business models to support the quality of data, the perception that information is power, and even embarrassment over the quality of data. These objections need to be better understood and addressed in order to encourage data sharing.

5. Access to data is a significant challenge, but not so much a technical challenge anymore.

Over the last several years, tools for sharing data have significantly increased. What continues to limit data sharing is the remaining



social and regulatory challenges, which range from issues involved in sharing data between agencies (within governments, between governments, and between multilateral agencies), to the challenge of getting the data to communities, to the legal and regulatory frameworks that may complicate or hinder sharing.

6. Sometimes things are too easy. The proliferation of data platforms and tools.

As building and deploying digital tools has grown easier, tools (of various quality) and data portals have proliferated. In most cases this growth works to fragment effort and decrease the benefits of collaboration and scale. It also takes energy away from creating higher-value products.

7. Sometimes things are too hard. The complexity of critical disaster outputs.

While building tools has grown easier, using tools is often not straightforward. The complexity of certain disaster products is a critical challenge facing the community. Complexity might be intrinsic—for example, poor handling of uncertainty in data products, or the propagation of that uncertainty in the calculations. Or it might be a function of poor communication about fitness for use.

8. There are key data still missing.

Models are very sensitive to data quality. If the wrong data or data of insufficient resolution are used, the model outputs will be unreliable and form a poor basis for decision making; users of the data will wrongly believe that they understand a situation when in fact they do not. Some of the most critical data include the following:

- Fundamental data sets, such as high-resolution imagery and elevation data with license to create derivative works that may be shared
- Global databases for assets (human, ecosystem, infrastructure, etc.) that can be used to understand, quantify, and manage climate and disaster risks
- Past disaster damage data to com-municate impact and validate models

9. We may be collecting the wrong data.

The challenge of collecting all useful data is overwhelming. There is still little consensus on which data sets are most useful in supporting actual decision making. We need to understand users and their needs in order to identify high-value data sets and inform the design of tools that use that data.

10. Data are not enough!

Metadata—the descriptive data about the data of interest—greatly increase data's usability and accessibility. A risk map, for example, has little use by itself; but once the critical descriptive metadata (such as return period) are available, the map becomes much more valuable. Even linking a descriptive report (if one exists) to data has important value.

11. Data beyond the sensor are important, too.

While physically sensed and modelled data such as risk maps and elevation are critical, there is a whole class of data that is currently undervalued and not often integrated into decision making. This is the experience of local communities. There is a need to better understand, systematically collect, and integrate these data to create deeper insights. Open does not just mean accessible.

12. There is more to being open than just being open.

Open does not just mean accessible. Openness enables participation. If we are to truly benefit from open data, we need to embrace collaboration and increase participation by involving key stakeholders at every step of the process. This approach increases stakeholders' sense of ownership and promotes understanding between participants, which leads to better outcomes.

13. It is insufficient to simply invest in data; we need to invest in people.

To ensure that data have a positive impact, expertise and experience must exist at all points within the data cycle at the local level. Said another way, in addition to investing in data, we need to invest in people to collect, design, analyze, communicate, and interpret that data. Without these key competencies we will never fully benefit from the promise of open data.

14. How do we know when we get there?

To make a positive impact, the ability to measure that impact is crucial. Thus clear objectives and meaningful measures of achievement are critical for the success of this community and its work. Participants stressed that part of measuring impact has to do with managing expectations, since success moves at different paces around the cycle. Creating data and providing access to it are relatively quick processes, while developing insight takes more time, and behavior change even longer. These differences need to be kept in mind when impact is measured.

15. Resources are available for well-defined problems.

Several different resources—both human and technical—were available among participants and were ready to deploy. Holding them back was the lack of clear direction and understanding of how or where to contribute. Ideally, as the community develops a shared vision of its role and the challenges it faces, situations of this sort will become less common.

Conclusions

Clearly articulated challenges provide a practical rallying point for members of the community. There remains room to refine, validate, and better understand them, but we have made a good start. The bigger task is to begin to meet these challenges. Ideally partnerships like the Understanding Risk community will help us—and inspire us—to advance..

Contributors to the session

Session organizers

Christiaan Adams, Developer Advocate, Google

Steph Bannister, Associate, SecondMuse

Stuart Gill, Partner, SecondMuse

Dr. Alanna Simpson, Senior Disaster Risk Management Specialist, GFDRR

Robert Soden, Disaster Risk Management Specialist, GFDRR

Dave Thau, Senior Developer Advocate, Google

Presentations

Rebecca Moore, Engineering Manager, Google Earth Outreach and Earth Engine

Paolo Gamba, Associate Professor of Telecommunications, University of Pavia

David Lallemant, Graduate Fellow, Stanford University

Dr. Alfredo Mahar Francisco Lagmay, Executive Director, Project NOAH, Philippines

Phil Tickle, Business Development and Research Manager, Cooperative Research Centre for Spatial Information, Australia

Jo Mummery, Special Adviser, Climate Science, Department of the Environment, Australia

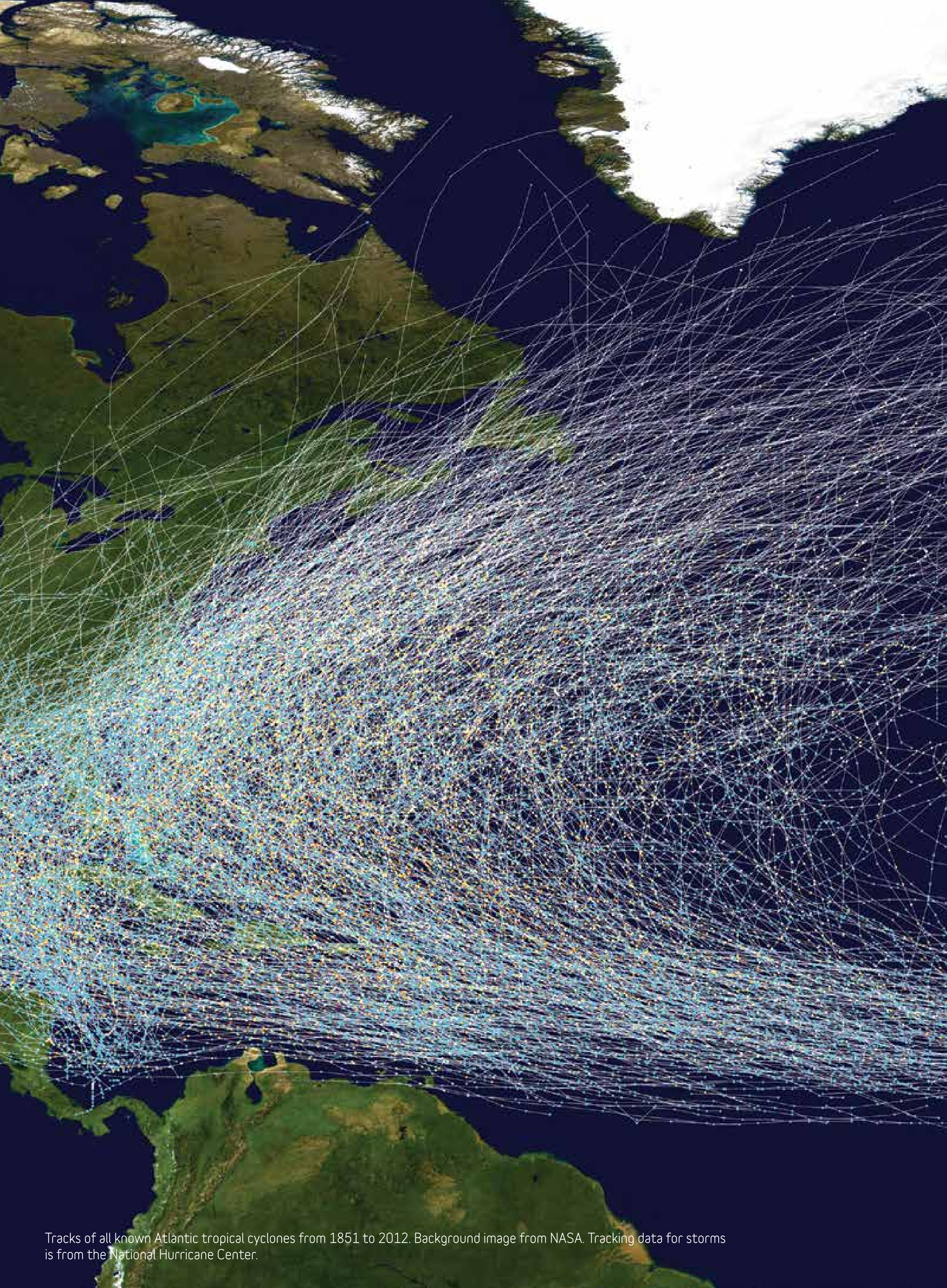
Marc Forni, Senior Disaster Risk Management Specialist, World Bank Group

Guy Schumann, Researcher, NASA Jet Propulsion Laboratory

Liz Hughes, Chief Executive, Map Action

Further resources

- OpenDRI email list, http://opendri.email.
- M. Haklay, V. Antoniou, S. Basiouka, R. Soden, and P. Mooney, “Crowdsourced Geographic Information Use in Government,” Report to GFDRR (World Bank), London, 2014, https://gfdrr.org/crowdsourced-geographic-information-use-government.
- Open Cities website at http://opencitiesproject.com/.
- InaSafe website at http://inasafe.org/.



Tracks of all known Atlantic tropical cyclones from 1851 to 2012. Background image from NASA. Tracking data for storms is from the National Hurricane Center.

Risk Modelling

Photo: Robert Churchill

Mission Impossible?

Using Global Flood Risk Assessments for Local Decision Making

Dr. Peter Salamon, Scientific Project Officer, Joint Research Centre, European Commission

Dr. Philip J. Ward, Senior Researcher, Institute for Environmental Studies and Amsterdam Global Change Institute, VU University Amsterdam

Dr. Hessel C. Winsemius, Senior Hydrologist, Deltares

The Challenge of Improving Flood Risk Management Worldwide

In terms of human impact, frequency, and economic loss, floods are among the biggest natural disasters worldwide. Climate change, population increase, urbanization, and land-use changes continue to contribute to flood risks globally, especially in coastal cities.

Minimizing the impact of floods requires (1) awareness about the existing risk of flooding; (2) expert knowledge to quantify the risk and plan prevention/preparedness measures; (3) appropriate legal and administrative frameworks to establish risk management plans; and (4) economic investments. Unfortunately, some or all of those requirements are missing in many parts of the world.

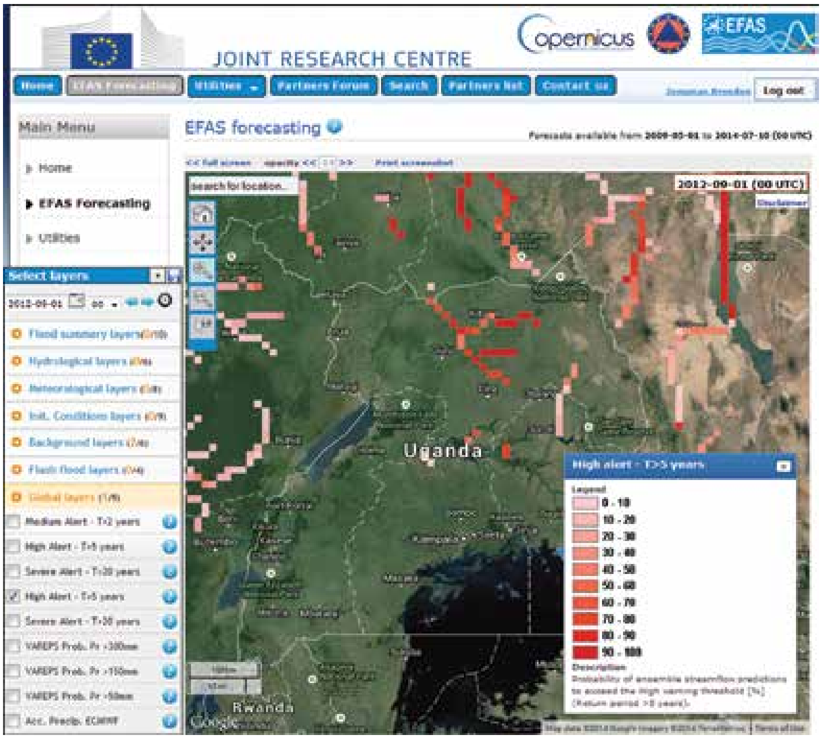
The Benefits of Global Flood Risk Management Tools

Several scientific organizations have recently started to develop comprehensive global flood risk management tools, ranging from satellite monitoring[1] and forecasting systems[2] to flood hazard and risk assessment models.[3] Those tools can provide valuable information to international aid organizations (e.g., International Red Cross/Red Crescent Movement, World Food Programme), global financing and development institutions (e.g., World Bank), or global (re)insurers, allowing them to plan and to allocate resources more efficiently. In addition, in regions where local flood risk information is either incomplete or absent, global flood risk management tools can fill the gap, or at least be complementary. Finally, global flood risk management tools can foster awareness raising, knowledge exchange, and data sharing, thus strengthening efforts to reduce local disaster risk.

The floods affecting southeast Europe in 2014 offer a very recent example of how a large-scale flood risk tool can improve local decision making. Between May 14 and 18, the heaviest rain in 120 years of recordkeeping caused severe floods in Serbia and in Bosnia and Herzegovina, forcing hundreds of thousands from their homes. In this case, the European Flood Awareness System,[4] a continental-scale flood early warning system, provided warnings with lead times of more than three to four days to national authorities and to the Copernicus Emergency Management Service (EMS).[5] The Copernicus EMS, which covers a wide range of natural and man-made emergency situations around the world, tasked satellites to acquire high-resolution images of the areas in those countries that would potentially be most affected by flooding. These data were used to generate detailed flood extent maps as early as May 18, and the maps were then used by local rescue teams and emergency managers.

The benefits of global-scale flood risk management tools can also be seen in the forecast-based financing of humanitarian actions. Researchers from the Red Cross/Red Crescent Climate Centre, German Red Cross, Royal

Figure 1. Sample hindcast derived from the GloFAS online platform for September 1, 2012. The red gradient indicates the estimated probability of a flood with a return period greater than five years occurring within 10 days after the forecast. A flood hit the area between Kitgum and Lira (dark red on the map) a few days later and led to the displacement of 15,000 people.



Source: GloFAS, www.globalfloods.eu.

Netherlands Meteorological Institute, and VU University Amsterdam are assessing the possibility of automatically triggering emergency finance based on forecast warnings of weather extremes.[6] With the goal of improving and increasing the impact of humanitarian action, such a forecast-based financing system would match certain thresholds of forecast probability of disaster with appropriate actions; standard operating procedures would be in place that embodied a clear mandate to act when these thresholds were crossed but before disaster struck. The system is currently being piloted in Togo and Uganda (see figure 1) with funding from the German Federal Ministry for Economic Cooperation and Development, using a global flood early warning system. Eventually it could be scaled up in disaster-prone areas worldwide to make disaster risk reduction efforts more effective.

Examples of Global Flood Risk Management Tools

The benefits of global flood risk management tools, the growing availability of high-quality global data sets, and the increase in computer power have led to improvements in tools' spatial resolution and model output

The goal of GLOFRIS is to establish flood hazard and impact estimates at a high enough resolution to allow for their combination into a risk estimate, which can be used for strategic global flood risk assessments.

quality. The following examples do not provide a comprehensive list of all available tools, but they illustrate the variety currently being developed.

A Global 1km Resolution Hydrodynamic Model

Currently available global flood hazard maps consider the hydrological processes leading to the flooding only in a limited way and make the implicit assumption that the approach is transferable across hydrologically and hydraulically diverse areas. However, tools and more importantly data now exist to develop a truly global hydrodynamic model for an improved assessment of flood hazard. Scientists at the University of Bristol, UK, and SSBN Ltd. have employed highly efficient wave-routing and flood-spreading algorithms with global terrain data,[7] which were specifically post-processed for hydrodynamic modelling,[8] along with other global data sets (river network, river geometry,[9] global flow return periods, flood defenses) to produce a global 1km flood hazard model that is then downscaled to 90m resolution (see figure 2). In collaboration with the Google Earth Engine team and NASA's Jet Propulsion Laboratory, the University of Bristol-SSBN team is working to integrate global flood hazard data into cloud-based platforms such as Google Earth.

Figure 2. Part of a 90m resolution flood hazard map produced by the University of Bristol, UK, and SSBN Ltd. by downscaling from a 1km resolution global hydrodynamic model. The map shows the area at risk from fluvial and pluvial flooding with an annual probability of 0.01 (1-in-100-year return period) for Phnom Penh, Cambodia.

Source: © University of Bristol and SSBN Ltd. Used with permission; further permission required for reuse.

GLObal Flood Risk with IMAGE Scenarios (GLOFRIS)

GLOFRIS is a framework for global river flood risk assessment that can be applied in either current or future conditions.[10] The goal is to establish flood hazard and impact estimates at a high enough resolution to allow for their combination into a risk estimate, which can be used for strategic global flood risk assessments. The framework estimates hazard at a resolution of $1km^2$ using global forcing data sets of the current or future climate, a global hydrological model, a global flood-routing model, and an inundation downscaling routine. The risk component of the framework combines hazard with flood impact models at the same resolution (e.g., damage, affected GDP, and affected population) to establish indicators for flood risk (e.g., annual expected damage, affected GDP, and affected population). GLOFRIS's usefulness for decision makers has been shown in several studies, including World Bank studies that rapidly assessed and mapped current and/or future flood risk in Nigeria, Eastern Europe, and Central Asia.

In its test phase, GloFAS was able to predict floods up to two weeks in advance. Currently, further research and development are ongoing to create an operational tool for a wide variety of decision makers.

The Global Flood Awareness System (GloFAS)

GloFAS is a global flood forecasting system developed by the Joint Research Centre of the European Commission and the European Centre for Medium-Range Weather Forecasts.[11] It couples state-of-the art ensemble weather predictions with a distributed hydrological model. With its global-scale setup, it provides downstream countries with information on upstream river conditions and produces continental and global overviews. It has produced daily flood forecasts in a pre-operational manner since June 2011, and has shown its potential during the floods in Pakistan in August 2013 and Sudan in September 2013.

In its test phase, this global forecasting system was able to predict floods up to two weeks in advance. Currently, further research and development are ongoing to create an operational tool for a wide variety of decision makers.

Challenges[12]

Several challenges remain in global flood risk modelling. Global flood risk assessment models are coarse by their nature, and necessarily represent both physical and socioeconomic processes in simplified ways. This simplification need not be a problem, as long as the limitations are recognized and communicated, and the models are used to answer appropriate questions.

One major issue is that current global digital elevation models (DEMs) cannot resolve the detail of terrain features that control flooding.[13] More effective flood hazard maps could be created by obtaining high-resolution stereo images from satellites for inclusion in flood modelling using supercomputers. First efforts are ongoing and show promising results,[14] but further work to adapt the high-resolution DEMs to hydrodynamic modelling is needed.

Moreover, many global-scale river flood risk models have assessed flood risk under the assumption that no flood protection measures (dikes, reservoir control dams, retention areas) are in place. In reality many regions, especially those prone to flooding, are protected by infrastructural measures up to certain design standards. Efforts are now under way to develop global data sets of protection measures, and indeed simulations with GLOFRIS have already been completed in which preliminary estimates of flood protection measures are included. These results will be made available shortly to both the research and policy-making communities.

Another challenge for global or large-scale flood risk assessments is the validation of the results, for example the economic impacts or the number of affected people or fatalities. While a few databases of reported flood impacts do exist (EM-DAT, for example[15]), they generally contain little information on the location of flooding, except for the country. Efforts to strengthen such databases are clearly needed.

Partnering for Better Management of Flood Impacts Globally

In order to fully exploit the potential of the global flood forecasting, monitoring, and impact assessment systems currently being developed and to tackle remaining challenges, the Global Flood Partnership (GFP) was established in 2014.[15] The GFP is an informal network of scientists and practitioners from public, private, and international organizations interested in global flood monitoring, modelling, and forecasting. It seeks to provide operational, globally applicable flood forecasting and monitoring tools and services, complementary to national capabilities, by linking all the different models together to cover the entire disaster risk management cycle. The GFP also serves as a forum to bridge the gap between science and operations, thus bringing together the scientific community, service providers (satellite and weather), national flood and emergency management authorities, humanitarian organizations, and donors.

Currently, the GFP is in a two-year pilot phase, which is allowing the partners to align their activities in a coordinated manner and to develop specifications and terms of reference for the GFP's different components. The pilot phase will be used to assess the value that the GFP adds to flood preparedness and response activities as well as to estimate the feasibility and cost of a full implementation.

Contributors to the session

Professor Paul Bates, Professor of Hydrology and Head of School in Geographical Sciences, University of Bristol

Dr. Tom de Groeve, Senior Scientist, Joint Research Centre, European Commission

Brenden Jongman, PhD researcher, Institute for Environmental Studies, VU University Amsterdam

Dr. Maarten van Aalst, Director, Red Cross/Red Crescent Climate Centre

Dr. Alanna Simpson, Senior Disaster Risk Management Specialist, GFDRR

Endnotes

1 See the website for the Global Disaster Alert and Coordination System at http://www.gdacs.org/flooddetection/; or see the University of Maryland's Global Flood Monitoring System at http://flood.umd.edu/.

2 See the Global Flood Awareness System (GloFAS) website at www.globalfloods.eu.

3 See P. J. Ward, B. Jongman, F. Sperna Weiland, A. Bouwman, R. Van Beek, M. F. P. Bierkens, W. Ligtvoet, and H. C. Winsemius, "Assessing Flood Risk at the Global Scale: Model Setup, Results, and Sensitivity," *Environmental Research Letters* 8: 044019 (2013), doi:10.1088/1748-9326/8/4/044019; and H. C. Winsemius, L. P. H. Van Beek, B. Jongman, P. J. Ward, and A. Bouwman, "A Framework for Global River Flood Risk Assessments," *Hydrology and Earth System Sciences* 17 (2013): 1871–92, http://www.hydrol-earth-syst-sci.net/17/1871/2013/hess-17-1871-2013.html.

4 See the European Flood Awareness System website at www.efas.eu.

5 See the Copernicus EMS website at http://emergency.copernicus.eu/.

6 See E. Coughlan de Perez, B. van den Hurk, M. van Aalst, B. Jongman, T. Klose, and P. Suarez, "Forecast-Based Financing: An Approach for Catalyzing Humanitarian Action Based on Extreme Weather and Climate Forecasts," Discussion Paper, *Natural Hazards and Earth System Sciences* 2 (2014): 3193–3218, www.nat-hazards-earth-syst-sci-discuss.net/2/3193/2014/.

7 For the algorithms, see J. Neal, G. Schumann, and P. Bates, "A Subgrid Channel Model for Simulating River Hydraulics and Floodplain Inundation over Large and Data Sparse Areas," *Water Resources Research* 48 (2012), DOI: 10.1029/2012WR012514.

8 See C. A. Baugh, P. D. Bates, G. Schumann, and M. A. Trigg, "SRTM Vegetation Removal and Hydrodynamic Modeling Accuracy," *Water Resources Research* 49 (2013): 5276–89, doi:10.1002/wrcr.20412.

9 See D. Yamazaki, F. O'Loughlin, M. A. Trigg, Z. F. Miller, T. M. Pavelsky, and P. D. Bates, "Development of the Global Width Database for Large Rivers," *Water Resources Research* 50 (2014): 3467–80, doi:10.1002/2013WR014664.

10 GLOFRIS is described in Ward et al., "Assessing Flood Risk at the Global Scale."

11 See the Global Flood Awareness System (GloFAS) website at www.globalfloods.eu.

12 For discussions of the challenges of flood resilience, see "Can Flood Resilience Be Measured?" and "The Role of Ecosystems in Reducing Risk" in this publication.

12 See G. J.-P. Schumann, P. Bates, J. Neal, and K. Andreadis, "Fight Floods on a Global Scale," *Nature* 507 (2014): 169, doi: 10.1038/507169e.

13 Maps currently available using this approach are shown at http://www.astrium-geo.com/worlddem/.

14 EM-DAT is available at http://www.emdat.be/.

15 See the GFP website at http://portal.gdacs.org/Global-Flood-Partnership.

Further resources

- Global Flood Awareness System (GloFAS) website at www.globalfloods.eu.
- P. J. Ward, B. Jongman, F. Sperna Weiland, A. Bouwman, R. Van Beek, M. F. P. Bierkens, W. Ligtvoet, and H. C. Winsemius, "Assessing Flood Risk at the Global Scale: Model Setup, Results, and Sensitivity," *Environmental Research Letters* 8: 044019 (2013), doi:10.1088/1748-9326/8/4/044019.
- Global Flood Partnership website at http://portal.gdacs.org/Global-Flood-Partnership.
- E. Coughlan de Perez, B. van den Hurk, M. van Aalst, B. Jongman, T. Klose, and P. Suarez, "Forecast-Based Financing: An Approach for Catalyzing Humanitarian Action Based on Extreme Weather and Climate Forecasts," Discussion Paper, *Natural Hazards and Earth System Sciences* 2 (2014): 3193–3218, www.nat-hazards-earth-syst-sci-discuss.net/2/3193/2014/.
- G. J.-P. Schumann, P. Bates, J. Neal, and K. Andreadis, "Fight Floods on a Global Scale," *Nature* 507 (2014): 169, doi: 10.1038/507169e.


Photo: David McNew/Thinkstock.com

Plug and Play

What Will It Take to Connect the Modelling Tools?

Ian Branagan, Chief Risk Officer and Senior Vice President, RenaissanceRe Holdings Ltd.

Dr. James Daniell, Research Scientist, Center for Disaster Management and Risk Reduction Technology, Karlsruhe Institute of Technology

Matthew Foote, Head of Exposure and Catastrophe Management, Mitsui Sumitomo Insurance

Dr. Rashmin Gunasekera, Senior Disaster Risk Assessment and Financing Specialist, World Bank Group

Dr. Richard Murnane, Senior Disaster Risk Management Specialist, GFDRR

Professor John Rees, Risk Research Coordinator, Research Councils UK

Introduction

As population and wealth increase, so does the risk to property and lives from perils such as earthquakes, tropical cyclones, and floods. The overlap between areas where these hazards are frequent and severe and where the largest increases in population and wealth are expected—near coasts, along rivers, and in mountainous regions—exacerbates risk further. Anthropogenically driven changes in climate are also likely to alter the risk landscape by changing the distribution of risk from certain hazards (such as storm surge, which will extend farther inland due to rising sea levels) and by leading to more intense precipitation and stronger winds.

Because extreme events have serious ramifications, there is avid interest across a variety of sectors in quantifying current and future risk. Currently, the best way to quantify catastrophe risk is with a catastrophe risk model (cat model). Cat models integrate scientific, engineering, and socioeconomic knowledge into a unified package that helps users understand risk. As illustrated in figure 1 and described further in the box, cat models typically have four main components: hazard, exposure, vulnerability, and loss. The origin of cat models in the global insurance and reinsurance industry—and their continuing use by this industry—has influenced not only the design and calibration of models, but also the community of knowledgeable users and the focus

Cat Models

Catastrophe risk models can be divided into four components: hazard, exposure, vulnerability, and loss. The **hazard** component is used to characterize the frequency, intensity, and spatial distribution of a peril. In some cases the hazard component can include secondary perils associated with the primary peril (such as liquefaction and fire following from earthquakes or storm surge produced by tropical cyclones). A hazard catalog comprises a suite of synthetic events representing plausible scenarios for a peril. Empirical observations from historical events are combined with theory and expert judgment to form the foundation for simulating the range of feasible peril events that are collected in the hazard catalog.

Depending on the purpose of a risk analysis, the **exposure** component may account for people, property, services, livelihoods, and the environment exposed to a hazard. Typical exposure-related information includes the location and replacement costs of the exposed assets. More complex risk analyses may require information such as date of construction and structural characteristics of a building, or socioeconomic data such as age, gender, and income of a population.

The **vulnerability** component accounts for the response of the exposure to the hazards generated by an event. Vulnerability functions are used to estimate a variety of phenomena, including damage to structures and their contents, injuries and fatalities, reductions in a region's gross domestic product, impacts on agricultural production, and the amount of time required for rebuilding.

The **loss** component is used to estimate the monetary impacts and/or loss of life produced by a peril event as well as statistics such as average annual loss and exceedance probabilities. Models used by the insurance industry also account for insurance-related factors such as deductibles, limits, quota shares, and layers.

for ongoing investment in model developments. Nonetheless, these models offer robust frameworks and approaches that provide a starting point for a community-wide open modelling approach.

Part of truly understanding one's risk is quantifying the uncertainty in the output generated by cat models. A range of factors (efficient pricing of reinsurance, Solvency II regulations, the cost of mitigation projects, as well as others) makes better assessment of this uncertainty desirable. An intriguing approach to assessing uncertainty in cat models involves developing the ability to "plug and play"—that is, to exchange components among models to assess how various views of hazard and vulnerability affect model results.

The effort to make plug and play a reality will entail at a minimum the development of standards for interoperability and the acceptance of these standards by the modelling community. Given the diversity of that community (spanning disciplines, developers, and users) and of the models themselves (which can be proprietary or public, open source or closed), the effort will likely be a complex one that requires careful planning. If the effort is successful, model users will have access to an array of model components, data libraries, and visualization tools in a fully interoperable plug-and-play environment, in which risk information can be shared effectively and confidence in model application and output is high.

Making Progress on Plug and Play: Some Preliminaries

To make progress on the development of plug and play, the risk modelling community will need to reach consensus on a number of issues, beginning with the definition of "plug and play." Does the term have a relatively restricted connotation? Does plug and play merely imply, for example, that a model can accept exposure data in a specific format and produce output in a standard format? Or is the term understood to involve more sophisticated capabilities, such as having a single vulnerability component that can easily be used with multiple, perhaps independently developed, hazard components for a single peril?

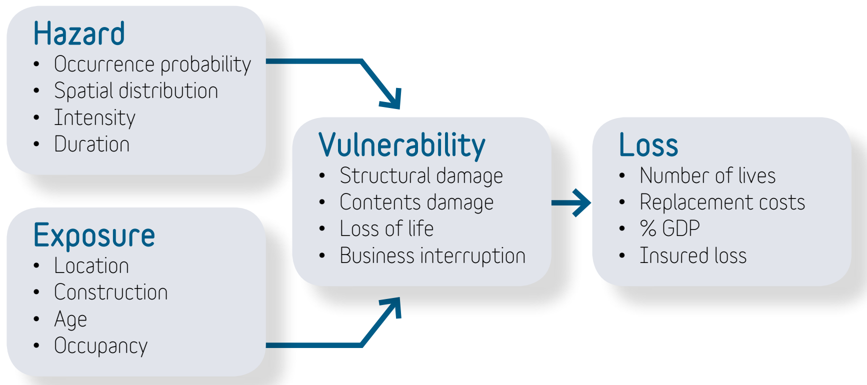


Figure 1. Schematic depicting the four major components of a catastrophe risk model (hazard, exposure, vulnerability, and loss) along with some features associated with each component. For exposure, the features are generally provided by users or derived from public or proprietary data sets. The hazard examples are features that characterize a hazard event that may cause damage to the exposure. The vulnerability examples illustrate different types of impacts that can be caused by a hazard event. The loss examples illustrate the types of loss associated with a hazard event.

Another seemingly simple issue that on reflection is more complex is the definition of the risk modelling community itself. Does the community include local people, homeowners, administrators, and corporate risk managers? Or is it limited to regulators, emergency managers, international agencies, insurers, and reinsurers? The more inclusive the community, the broader the spectrum of its requirements—and the harder it will be for a single standard/approach to adequately meet these requirements.

Other fundamental issues that require consideration, if not resolution, are related to the purpose and benefits of plug-and-play capability in risk models. We need to think about the questions plug and play is meant to answer, and why the questions are being asked in the first place. There is a case to be made for developing a widely agreed-upon methodology for better understanding uncertainty using an ensemble of model results—just as there is a case for letting the interpretation of the results from multiple models remain an ad-hoc exercise. We also need to think through some of the pitfalls of the capability. Will multiple hazard and/or vulnerability components allow users to better quantify uncertainty and perhaps price risk—or will it instead confuse them with too much information? Such considerations raise yet more fundamental questions of how to develop, maintain, and assess the competencies of cat model users and providers to ensure successful interoperability and correct decision making. Clearly, successful interoperability, and the adoption of standards across communities, will be achieved only if there is an incentive to work collectively. This is as much a hearts and minds exercise as a technological challenge.

Other preliminary considerations include whether the plug-and-play standard would apply to detailed models capable of site-specific analyses, to aggregate models dealing with spatially aggregated exposure and spatially averaged perils, or to both. While a suite of sophisticated detailed models is available for many perils and regions, the global risk-financing problem being faced by the disaster risk management community will require this aggregate view to be effective across perils and at a global geographic level.

Ideally, plug-and-play model components would offer decision makers a powerful tool. But not all users will understand the different model components such that they will be able to create a customized view of their risk. It is not unusual for users to rely on current model results as "truth" or to overestimate the results' precision and reliability. This problem will not be alleviated by using open source models.

The effort to make plug and play a reality will entail at a minimum the development of standards for interoperability and the acceptance of these standards by the modelling community.

Tools and Platforms Available for Risk Modelling

A fundamental step toward developing plug and play is an awareness of existing tools and platforms as well as innovations that are expected to become available in the future. A presentation during the session that summarized existing, nonproprietary models offered important information about tools and platforms. In addition, a detailed analysis of existing open source and open access models can be found on the Global Facility for Disaster Reduction and Recovery website (see "Further resources" below).

Rate-Limiting Factors That Inhibit Interoperability

There is no real technical problem with making plug-and-play model components. The interaction of components from different models can be seen for example in OpenMI, an open protocol that facilitates two-way exchange of data between models. OpenMI gives a model free range to play in a "sandbox" and run as developed. The standards define how a model accepts input data and provides output data. OpenMI is now an OGC (Open Geospatial Consortium) standard. Another possible approach for using multiple components within a single platform is to define a standard computational framework, such as is done by OASIS. OASIS standards impose rules that models must follow if they are to play in the sandbox.

Perhaps the rate-limiting step in a move toward interoperability will be reaching agreement on what standards risk model developers should adopt to promote interoperability. For example, what wind speed averaging time should be used for sustained winds? Should all winds be provided as gusts in open terrain? What frequencies should be used to specify spectral acceleration due to an earthquake? Without agreement on such technical details, a simple combination of model components will produce spurious results.

Building the Community That Will Build Plug-and-Play

How can we build the community that will successfully develop plug-and-play standards?

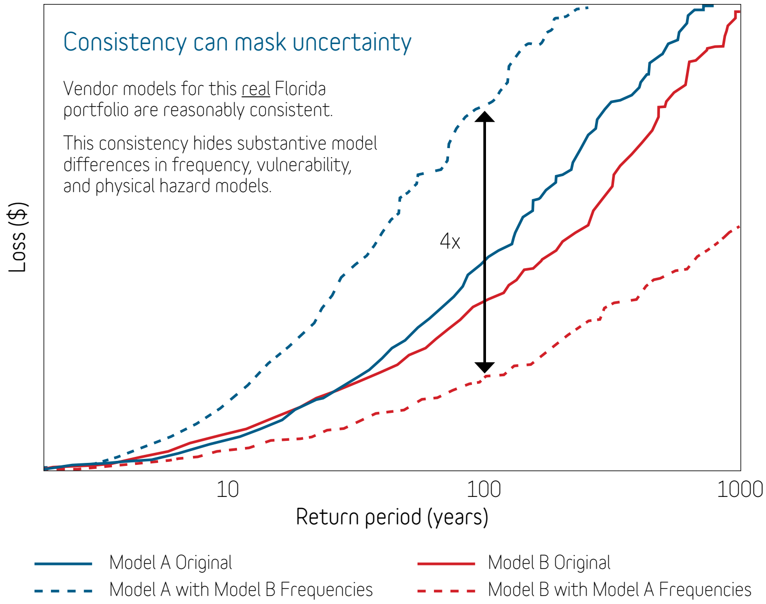
While we can't yet answer this question, we do know several issues that must be considered for this effort to go forward. One issue is managing the desires, expectations, and capacities of a spectrum of agents—ranging from the private sector, which develops proprietary models, to model users in developing countries, who are limited to freely available models. Another issue concerns adopting or extending existing standards, which are diverse and do not serve all users equally well: some standards, such as UNICEDE, are widely used by the insurance industry and are open, while others are de facto standards exemplified by the (closed) exposure formats for proprietary models. The diverse interests of model users and developers of proprietary models, open access models, and open source models make unanimity unlikely. It's not clear whether something akin to majority rule will be sufficient for a successful implementation of plug and play. In all likelihood, though, the various factors motivating a common desire to better quantify and understand risk will be strong enough to drive a successful effort to implement a plug-and-play capability.

The Value of Assessing Uncertainty: The Example of Storm Frequency's Role

An example of the potential value that could be derived through plug and play is the response of modelled losses to an insurer's portfolio of residential homes in Florida (figure 2). The losses produced by each model are relatively similar and might suggest that both hurricane hazard and the vulnerability of homes in Florida are quite well understood. However, as shown in the figure, a relatively simple change—switching the storm frequencies between

Figure 2. An example of results generated when the storm frequencies of two cat models are switched with one another. The solid lines depict loss exceedance curves produced by two hurricane cat models that analyzed a portfolio of residential homes in an insurer's portfolio. The occurrence of storms contained in the hazard catalog is assigned a frequency that varies as a function of intensity. The dotted lines show the changes in loss exceedance curves when the frequencies are switched but all other model components remain the same.

Source: © RenaissanceRe. Used with permission; further permission required for reuse.



model A and model B— can create a large shift in model results. The storm frequencies are a function of intensity, with the frequency falling as intensity increases. Importantly, the storm frequencies will be derived from a common set of data, the historical record of tropical cyclones in the Atlantic Ocean. One explanation for the difference is that the expert judgment used to develop the storm catalog and other model components can result in "overtuning" when calibrating the model to the historical loss record. This overtuning can hide the true uncertainty by inducing consistency in model results.

Conclusion

The number of open access, open source, and proprietary hazard and risk modelling tools and software packages has grown rapidly in response to a pressing need to understand risk. A possible new avenue for growth is the development of the ability to mix and match model components across models. This plug-and-play approach will provide new insights into the uncertainty in model results. Agreeing on which standards to adopt as part of plug-and-play capability will require support from the community of risk model developers and users as well as from decision makers.

Contributors to the session

Rowan Douglas, Chair, Willis Research Network, Willis Group

Denise McKenzie, Executive Director, Communications and Outreach, Open Geospatial Consortium

Dr. Hessel Winsemius, Senior Hydrologist, Deltares

Dr. Scott Steedman, Director of Standards, BSI

Dr. Nicola Ranger, Climate Science Adviser, UK Department for International Development

Dr. Greg Holland, Director, NCAR Earth System Laboratory, National Center for Atmospheric Research

Dr. Alanna Simpson, Senior Disaster Risk Management Specialist, GFDRR

Further resources

- GFDRR, *Understanding Risk: Review of Open Source and Open Access Software Packages Available to Quantify Risk from Natural Hazards* (Washington, DC: World Bank, 2014), https://www.gfdrr.org/RASoftwareReview.
- GFDRR, *Understanding Risk in an Evolving World: Emerging Best Practices in Natural Disaster Risk Assessment* (Washington, DC: World Bank, 2014), https://www.gfdrr.org/RAReferenceGuide.
- OpenMI website at http://www.openmi.org/.
- OASIS website at http://www.oasislmf.org/.

Photo: Songquan Deng

Risk Finance and Insurance

Photo: RomoloTavani

Worth Your Money?

What Risk Models and Economic Models Tell Us about the Development Impact of Insurance and Financial Protection

Dr. Daniel J. Clarke, Senior Disaster Risk Finance and Insurance Specialist, World Bank Group

Introduction

Financial protection mechanisms can support timely, well-targeted government action in the aftermath of a disaster, helping the government finance recovery and reconstruction without taking resources away from development programs.

Following in the footsteps of a handful of pioneering countries, more and more governments (and donor agencies) are looking to invest in financial protection to safeguard development gains. Yet the evidence about the impact, effectiveness, and efficiency of such programs remains limited. Very few evaluations of financial protection programs exist, and those that do exist typically do not provide insights into the impacts of programs on the poor, or model these impacts in a probabilistic setting.

To fully understand and capture the poverty and development benefits of financial protection, it is crucial to understand risk, exposure, and vulnerability; the information produced by probabilistic risk models likewise must be complemented with economic data. In an effort to develop a methodology for evaluating the true benefits of financial protection, risk modellers, insurance experts, and economists are beginning to explore how probabilistic risk models and economic models can be reconciled.

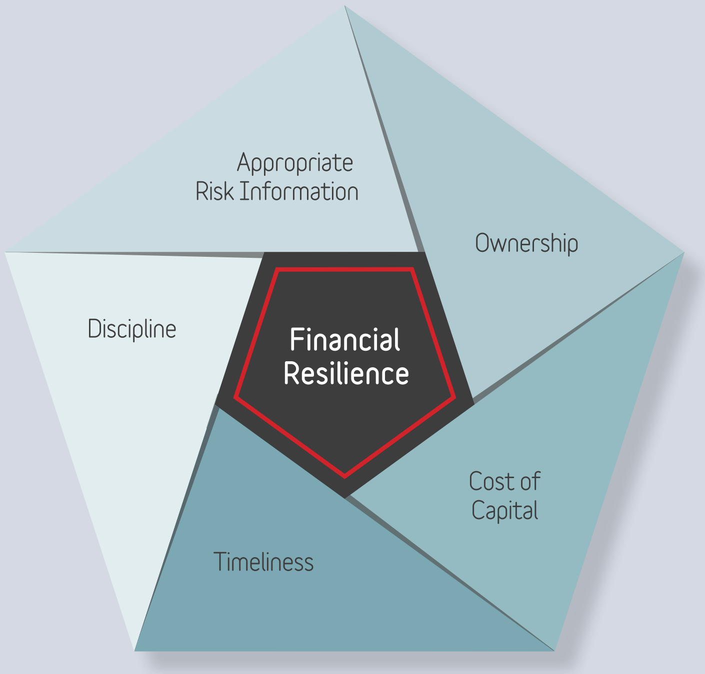
Disaster risk financing and insurance (DRFI) can contribute to improving five characteristics that together build financial resilience across society: appropriate risk information, ownership of risk, cost of capital, timeliness of post-disaster financing, and discipline (see figure 1 and text box). These characteristics are not outcomes of one specific project or intervention but an integrated set of features that can support each other to strengthen financial resilience.

In developing countries these characteristics are usually underdeveloped, and DRFI interventions across policy areas act upon and improve them. Only by comprehensively working across priority areas can a government build financial resilience throughout society. For example, improving the take-up of agricultural insurance can strengthen one or two of these characteristics for farmers and herders, but such an intervention would have to be integrated with sovereign DRFI in order to advance all characteristics needed for financial resilience. Similarly, DRFI projects rarely tackle just one of these building blocks. Insurance of public assets, for example, seeks to provide the required capital, but it will also improve the speed at which this money is available, put a price on risk, and push the government toward more transparency and discipline in public financial management.

Background and Concepts

The increasing frequency and severity of hazard events

Figure 1. How DRFI can contribute to financial resilience.



Source: World Bank-GFDRR Disaster Risk Financing and Insurance Program, 2014.

Five Characteristics that Build Financial Resilience across Society

Appropriate risk information. Appropriate risk information allows decision makers to assess the underlying price of risk, and clarify costs and benefits of investing in risk reduction or risk financing.

Ownership of risk. Clarifying who is responsible for risk—that is, clearly establishing the contingent liability of the national and subnational government, donors, the private sector, and households—overcomes challenges such as the Samaritan's Dilemma.

Cost of capital. Sufficient access to capital is necessary for effective emergency response and reconstruction as well as for investment in risk reduction and prevention. Different sources of money come with different costs.

Timeliness of post-disaster financing. Post-disaster funds need to be available at the appropriate time following a disaster. In the aftermath of a major disaster, the government will not require the money for the entire reconstruction program at once. Rapid response is crucial in the aftermath of a disaster to limit humanitarian costs.

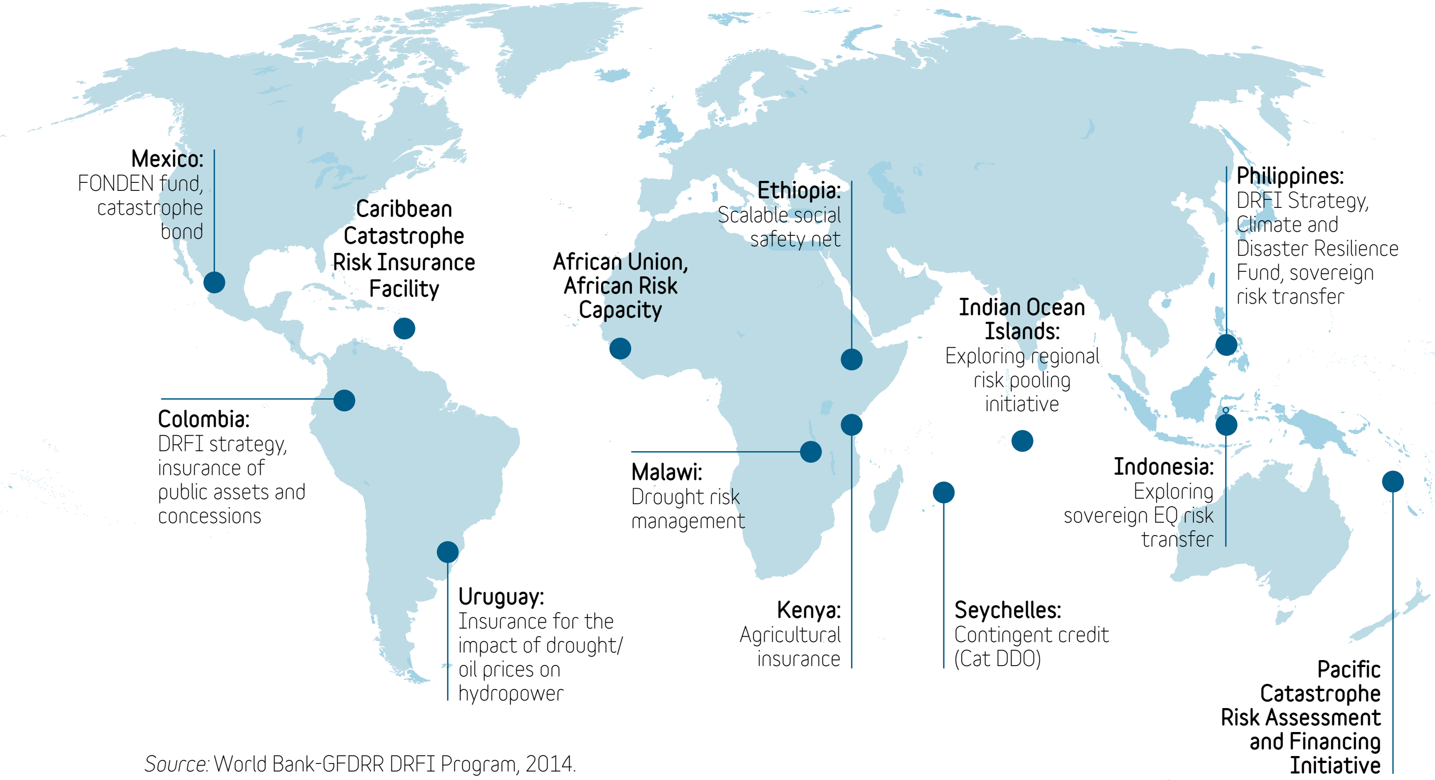
Discipline. Disaster risk financing helps governments and stakeholders plan in advance of a disaster and agree ex ante on rules and processes for budget mobilization and execution. This approach creates greater discipline, transparency, and accountability in post-disaster spending.

has forced governments to consider new ways of meeting the financial consequences of natural disasters. This growing interest in implementing sovereign DRFI programs has resulted in tremendous growth across the world in the number and type of financial and budgetary instruments available (figure 2), ranging from disaster reserve funds and lines of contingent credit to insurance instruments. However, evidence as to which sovereign DRFI strategies are most cost-effective relative to their impact on development and disaster-affected individuals remains limited. To meet the need for evidence on this question, the UK Department for International Development, the World Bank, and the Global Facility for Disaster Reduction and Recovery have partnered to improve evaluation and evidence for sovereign DRFI programs. The project, which began in 2013 and is expected to run to 2016, will design, test, and finalize a framework for quantitative ex ante appraisal of sovereign DRFI programs, both to assess the likely effectiveness, efficiency, and impact of current and potential programs, and to generate new evidence in this area.

DRFI Impact Appraisal Project

Extreme disaster events are by nature rare, and any backward-looking evaluation methodology relying solely on recent historical disaster experience is unlikely to reflect future disaster risk accurately. The project therefore

Figure 2. Sovereign DRFI around the world.



Source: World Bank-GFDRR DRFI Program, 2014.

takes a forward-looking impact appraisal (IA) approach (figure 3), evaluating selected sovereign DRFI programs based on a large number of simulated scenarios. Probabilistic disaster risk models will be used to present the relative likelihood and developmental consequences of different events. These will be estimated drawing on theory and evidence from public finance, financial economics, actuarial science, development economics, and post-disaster needs assessment.

The project seeks to understand whether forward-looking IAs can help effectively target support for disaster risk activities. It aims to understand whether it is possible to develop a conceptually sound, quantitative IA tool that does the following:

- Takes into account the probabilistic nature of the impact of sovereign DRFI programs and avoids being too heavily influenced by recent disaster events
- Quantifies trade-offs between many of the key dimensions of sovereign DRFI programs
- Generates results that are sufficiently robust to model and parameter uncertainty but are still able to guide evidence-based decision making
- Complements more qualitative measures of impact
- Results in headline figures on the impact of sovereign DRFI programs on development and poverty that are meaningful for decision makers

Project outputs have been designed to enable decision makers to understand when sovereign DRFI programs are (and when they are not) effective components of a comprehensive approach to managing the financial risk associated with disasters.

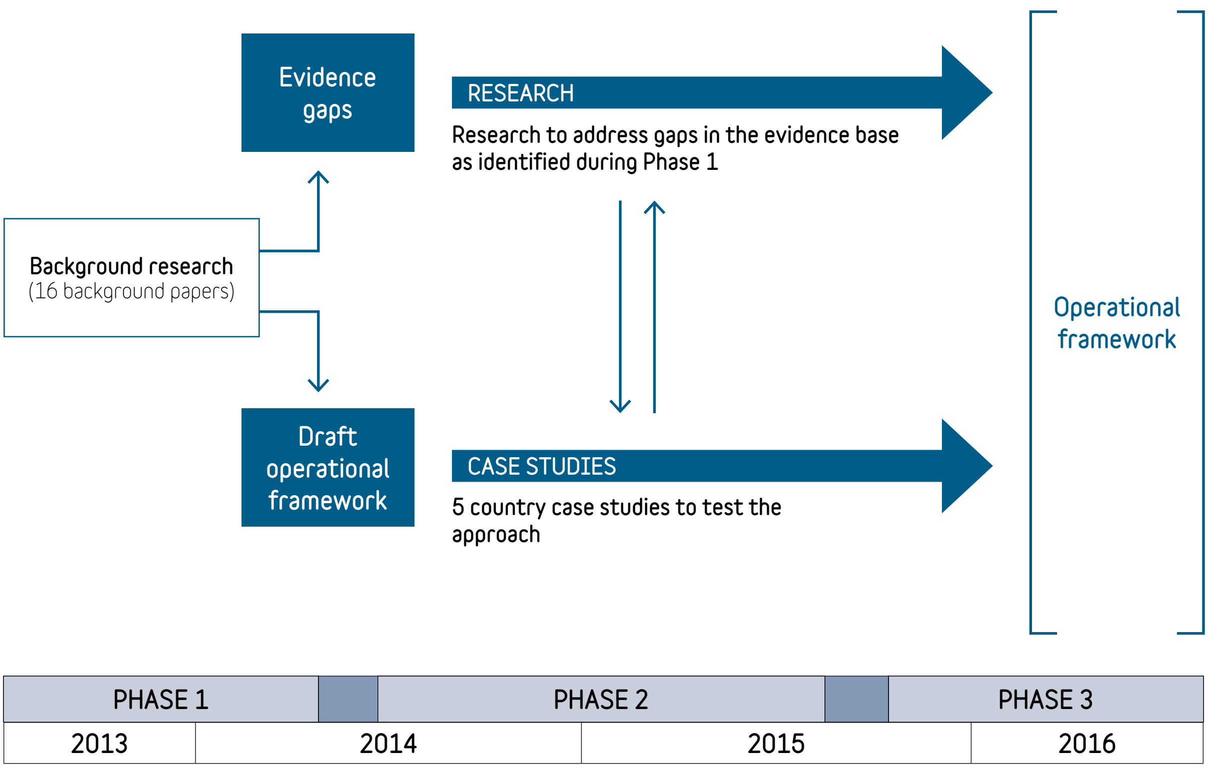
This project will include conceptual work, development of an operational framework, and five case studies. The initial phase of the project focused on developing a draft operational framework and identifying gaps in the evidence base through extensive research into risk modelling; into microeconomics, macroeconomics, and public economics; and into costing of sovereign DRFI instruments. Building on the outputs of phase 1, the second phase of the project will carry out an extensive research agenda to address identified evidence gaps, and test the draft operational framework in a series of five country case studies. The research themes have been chosen to address the specific gaps in the generic evidence base identified during phase 1 and to complement the country case studies.

Alongside the research track, a parallel work stream will carry out the case studies in Bangladesh, Ethiopia, Jamaica, Niger, and the Philippines. The five countries were selected by the Project Steering Committee based on a series of preestablished selection criteria. Among these criteria were strong government interest in/ commitment to sovereign DRFI, income level of the country, vulnerability of the country's economy to disaster shocks, and the quality and capacity of institutions. In each of these countries, the IA project will aim to expand the generic evidence base on the impact of sovereign DRFI and to gather further evidence to develop an IA methodology. Depending on the specific country context, the IA project team will focus on building evidence on sovereign DRFI through a combination of risk modelling, actuarial and economic analysis, and/or public finance research.

Challenges

While the model itself, as the first of a kind of research being conducted, represents a challenge for the team, coordination of inputs from multiple disciplines represents an additional challenge. The vision for sovereign DRFI IA proposed in this project centers on probabilistic risk models complemented by other types of insight and information. Any evaluation methodology that relies solely on historical DRFI experience will suffer from the fallacy of hasty generalization; with less than 100 years of experience, the past is unlikely to offer a reasonable guide to future disaster risk, and decision making based solely on average historical experience is unlikely to be sound.

Figure 3. Sovereign DRFI Impact Appraisal Project.



Source: World Bank-GFDRR Disaster Risk Financing and Insurance Program, 2014.

A probabilistic risk model, developed to generate an objective assessment of risk faced, can overcome this challenge. Such models are widely used by the private sector whenever disaster risk decision making is sufficiently important (e.g., in disaster insurance or reinsurance markets). However, while a modelled approach can accurately account for the relative likelihood of different physical events, it must be integrated within a broader framework that draws on theory and evidence in public finance, financial economics, actuarial science, development economics, and post-disaster needs assessment to be useful for IA decision making for DRFI.

Conclusions

The aim of the project is to help national governments and international donors do a better job of targeting and prioritizing future investments in sovereign DRFI programs. In order to reach the desired outcome the IA team has selected the best possible academics in the relative disciplines. The expected outcome of this work is to show that conceptually sound, ex ante, objective, quantitative appraisal for sovereign DRFI programs is operationally feasible, and that it can result in headline figures that are meaningful to decision makers.

Contributors to the session

Juan Miguel Adaya Valle, Director of Risk Analysis, Ministry of Finance and Public Credit, Mexico

Charlotte Benson, Senior Disaster Risk Management Specialist, Asian Development Bank

Julie Dana, Lead Financial Officer, World Bank Treasury

Emmanuel Dooc, Insurance Commissioner, Philippines

Robert Muir-Wood, Chief Research Officer, RMS

Further resources

- DRFI at the World Bank, http://go.worldbank.org/J7Q2X62090.
- DRFI Impact Appraisal Project introduction, http://www.gfdrr.org/sites/gfdrr.org/files/Sovereign_DRFI_Impact_Appraisal_Project.pdf.
- DRFI Impact Appraisal Project website at http://go.worldbank.org/OIYHJGV280.
- DRFI Impact Appraisal Project blog at http://blogs.worldbank.org/psd/evidence-wanted-effectiveness-sovereign-disaster-risk-financing-and-insurance.
- Kate Galbraith, "How to Save for a Disaster," New York Times, November 27, 2013.

Photo: bestdesigns

Models Make Markets

How Catastrophe Risk Models Facilitate New Systems of Risk Transfer, Risk Pooling, and Risk Reduction

Robert Muir-Wood, Chief Research Officer, RMS

History of the Role of Models

Catastrophe modelling, first developed at the end of the 1980s, has proved vital to how catastrophe insurers and reinsurers conduct their business. Recent historical experience is insufficient to reveal the full potential of catastrophic loss. Catastrophes form part of a highly skewed distribution of losses, for which a short time sample tends to give a misleading idea of the underlying mean behavior, or what is the potential for suffering an extreme loss.

The purpose of the model is to provide a synthetic catalog of extreme events, representing 10,000 or 100,000 years of activity, as well as the means to link the hazard at a location to the loss that would be generated according to the nature of the exposure. In particular the model can provide answers to the two key questions that underlie catastrophe insurance: (1) what is the technical price to charge for the risk, representing the annualized cost of all potential damages (the "burn cost") plus appropriate loadings; and (2) how much capital should the insurer hold against the potential for extreme losses that recur infrequently—for example, on average only once every 200 years?

The model will have to satisfy a range of calibration tests to be accepted, in particular demonstrating that results match the actual losses of recent events for which the hazard footprint, and underlying exposure, are known. The loss exceedance probability distribution from the model at shorter return periods should also show consistency with the past few decades of loss experience.

How Models Bring Order to Markets

Twelve insurers went bankrupt after Hurricane Andrew in 1992, because they had not anticipated a loss of this magnitude. This outcome helped usher in the era of catastrophe modelling.

Once a catastrophe model becomes trusted it can help bring order to a risk market. The technical price of the risk in the model can provide a floor below which prices will not fall, even during a period of low losses. The results of the model can also discourage wild upward swings of prices in the aftermath of an extreme catastrophe. In principle, the level of risk remains the same irrespective of whether there have just been two big losses or no losses at all for 10 years.

After major loss events, a significant process of learning will need to follow, in particular using data collected through the insurance claims process to refine how vulnerabilities are defined. There may also be new scientific findings on the population of extremes. The problems and uncertainties of catastrophe estimation can never be fully solved, however. The model is always work in progress.

Examples of Models Making Markets

While in many areas models have helped bring order to preexisting insurance systems, catastrophe models have also facilitated the creation of new markets. Some examples of these markets include index-based risk transfer systems and catastrophe risk securitization.

There are now many examples of index-based solutions for risk transfer, in particular around crop micro-insurance. One prominent index-based scheme is the Caribbean Catastrophe Risk Insurance Facility (www.ccrif.org). In the Caribbean as in many lower-income countries, public assets are often poorly known, and there may be no values or even locations for government properties. The costs for disaster management that fall to a government in the immediate aftermath of a catastrophe will be very hard to predict. The speed with which funds arrive can be more important than precisely matching what costs have been incurred, especially when no alternative funding arrangement exists. In such situations, it makes sense to have payouts determined by some rapidly calculated index of the hazard based on available parametric data. For governments, "basis risk" may be theoretical, because they never know their full costs. However, there remains a challenge for the public officials charged with paying the premium for such a scheme, in that they may lose their jobs if their country suffers a loss and there is no index-based payout.

Claims management is the most challenging part of the insurance process. In India claims adjustment can cost more than the value of the property. One approach to this challenge might be to expand the use of index payouts, or band losses into a small number of categories, as in Japan and Taiwan, which allows very rapid payouts.

The risk securitization market came into existence only as a result of the confidence gained in catastrophe risk modelling. It remains impossible to arrange a transaction, calculate an expected loss, and develop a price for a bond without a trusted model. While based on its own significant experience the conventional reinsurance market can function even where there are no models, investors are prepared to trust the risk analysis only if it is undertaken to a level of detail, and with suitable calibrations from a reputable modelling agent. Figure 1 illustrates the influx of investors' money into nontraditional risk transfer markets since 2000 as a result of the increased trust in catastrophe models.

Where Models Help Create New Markets

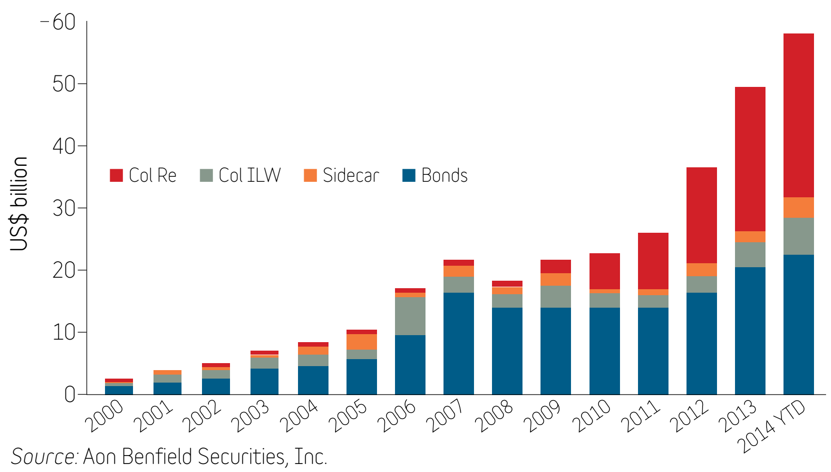
What are the frontiers of the modelled world, and how might they be expanded? Potential routes for expansion include an increase in coverage of perils and secondary consequences of loss in countries where there is already a thriving insurance industry, or the expansion of risk modelling to low-income and lower-middle-income countries.

For commercial modellers, the potential for a thriving catastrophe risk (re)insurance market becomes the inducement to invest in the development of a new model. The existence of a market will imply a number of agents willing to license the model. There will inevitably be less commercial interest and ultimately less investment in the quality of a model if only a single public monopoly catastrophe insurer is to be established in a territory.

Where Models Do Not Facilitate Market-Based Solutions

Better knowledge of risk is perhaps most contentious around flood. Models reveal very strong variations in flood risk pricing for identical and even neighboring properties situated at elevations that differ by only a few feet. (Consider two identical houses, one flooded four times a century to 3 feet, causing a 20 percent loss, and once a century to 6 feet, causing a 40 percent loss), alongside its three-foot-higher neighbor, for which the technical cost of flood insurance will be one-sixth the price.) For a property that can

Figure 1. Bond and collateralized market development.



Source: Aon Benfield Securities, Inc.

Note: Col Re, or collateralized reinsurance, is a reinsurance contract or program that is fully funded in advance by investors or third-party capital providers to cover in full the potential claims that could arise from the reinsurance contract. Col ILW, or collateralized industry loss warranty, is the funding put in place to cover a contract whose payout is determined by the size of the total insurance industry loss for that peril and territory. A sidecar is a financial structure created to allow investors to assume the risk and return of a group of insurance policies written by a (re)insurer and so earn the risk and return that arises from that business.

expect to suffer a major flood more often than once in every 50 years, or a house affected by wave action more often than once in every 100 years (as in the U.S. coastal "V zone"), the annual risk cost may be in excess of 1 percent of the property's value. Even before these levels, insurance rates become politically unpalatable—blamed by real estate organizations as causing blight, and lambasted by politicians as "intolerable."

In other words, when people are unprepared to accept the risk differentials, improved knowledge does not necessarily facilitate market solutions. This is not just a problem with flood risk. In Mexico City the same high-rise building can have risk costs that differ by a factor of 30 depending on an apartment's location relative to the underlying soils.

Models' Role in Market-Based Solutions for Disaster Risk Reduction

In Mexico, a country that helped pioneer the idea of probabilistic modelling, catastrophe models have been developed beyond the use of the insurance sector to explore risk to the National Fund for Natural Disasters (FONDEN) system. FONDEN was established by the Mexican government in the late 1990s to support the rehabilitation and reconstruction of public infrastructure, low-income housing, and certain elements of the natural habitat that were affected by natural catastrophes. The FONDEN scheme purchases reinsurance, and in 2007, with the involvement of Swiss Re, for the first time issued a catastrophe bond to the risk securitization market.

However, the principal output of models for the FONDEN scheme concerns economic impacts. The question then remains: can we create market-based mechanisms that also consider loss of life in disasters? In thinking about how to incentivize actions that have the biggest impact on reducing casualties, we might consider a scenario in which developers bid for a project in a city that has to provide accommodation for 1,000 families and also has to achieve the greatest reduction in expected casualties for the cost. The catastrophe model outputting expected casualties could help tell them how to achieve this.

The Effect of New Technology on the Distribution and Use of Risk Information

Catastrophe models are becoming more complex, with ever larger stochastic event sets, while at the same time becoming more granular, and working at higher resolution, in particular for flood. Models are becoming more demanding for hardware—even beyond the capacity of what a single insurance organization can run—especially for those weeks of the year around the renewal of reinsurance programs, when the full power of modelling has to be harnessed. It then makes efficient economic sense to employ cloud- based computing capacity. Cloud technology also opens up the potential of hosting multiple models on the same platform, and brings many other advantages as well, such as simultaneous and instant updates of the model to all users, or the possibility of one model user offering selected counterparties access to his or her results.

Conclusions

At the start of the 1990s, most insurance and reinsurance organizations consumed models only by receiving a report on their results. They soon moved to license models in house, thereby empowering themselves to take ownership of models—adjusting and stress-testing them to make them their own. This ability to run models under their own terms is the same evolution that we can now see for all other users of modelled outputs.

Contributors to the session

Mario Gustavo Ordaz Schroeder, Professor, Institute of Engineering, Universidad Nacional Autónoma de México; President of Evaluación de Riesgos Naturales, Mexico

Simon Young, Consultant, Caribbean Catastrophe Risk Insurance Facility and Africa Risk Facility

Paul VanderMarck, Chief Products Officer, RMS

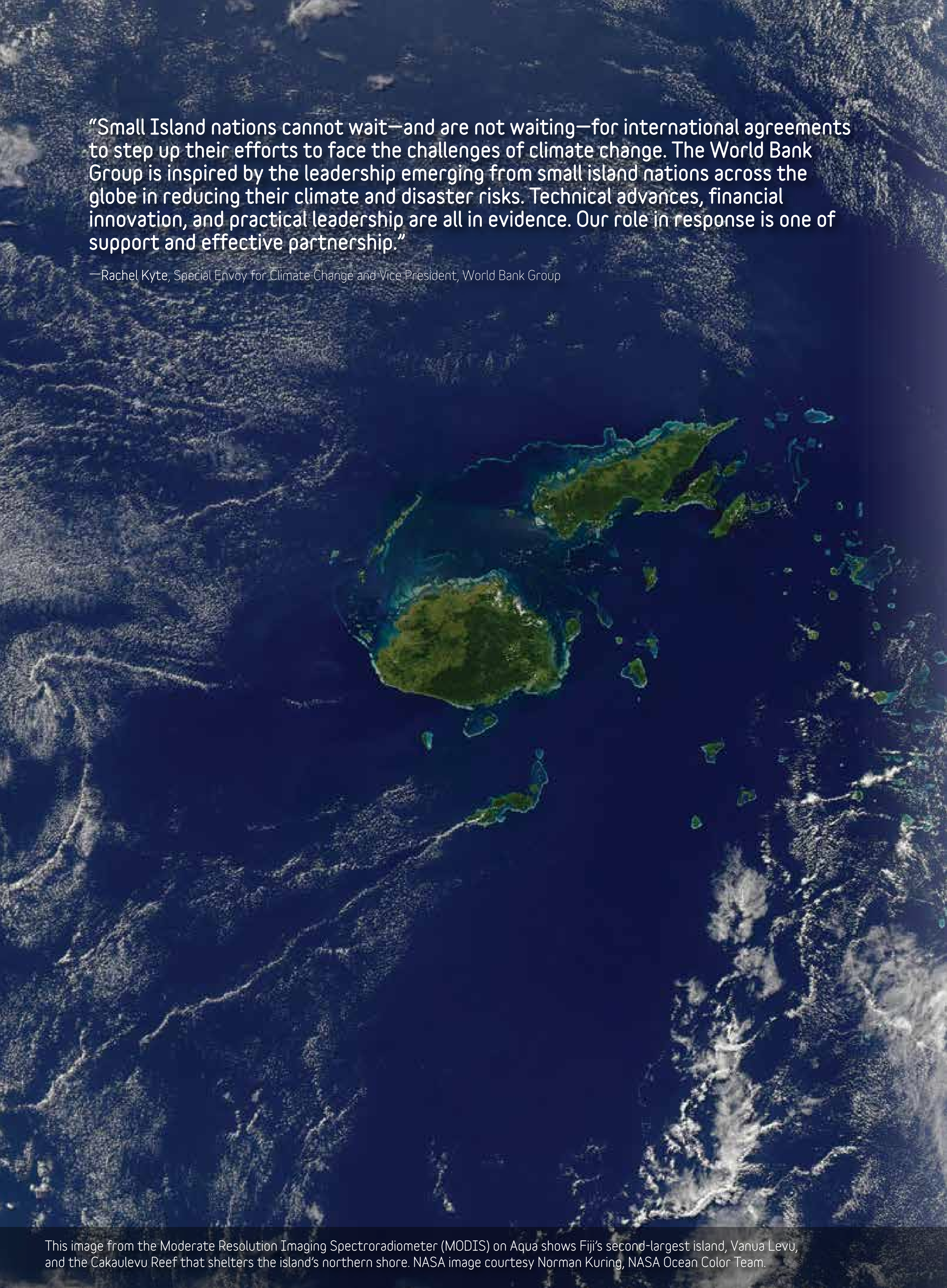
Martine Woolf, Director of Climate Hazard and Risk Section, Environmental Geoscience Division, Geoscience Australia

Rashmin Gunasekera, Senior Disaster Risk Assessment and Financing Specialist, World Bank Group

Alexander Allmann, Head of Geo Risks, Munich Re

"Small Island nations cannot wait—and are not waiting—for international agreements to step up their efforts to face the challenges of climate change. The World Bank Group is inspired by the leadership emerging from small island nations across the globe in reducing their climate and disaster risks. Technical advances, financial innovation, and practical leadership are all in evidence. Our role in response is one of support and effective partnership."

—Rachel Kyte, Special Envoy for Climate Change and Vice President, World Bank Group



This image from the Moderate Resolution Imaging Spectroradiometer (MODIS) on Aqua shows Fiji's second-largest island, Vanua Levu, and the Cakaulevu Reef that shelters the island's northern shore. NASA image courtesy Norman Kuring, NASA Ocean Color Team.

Big Numbers, Small States, and Risk Pooling for Insurance

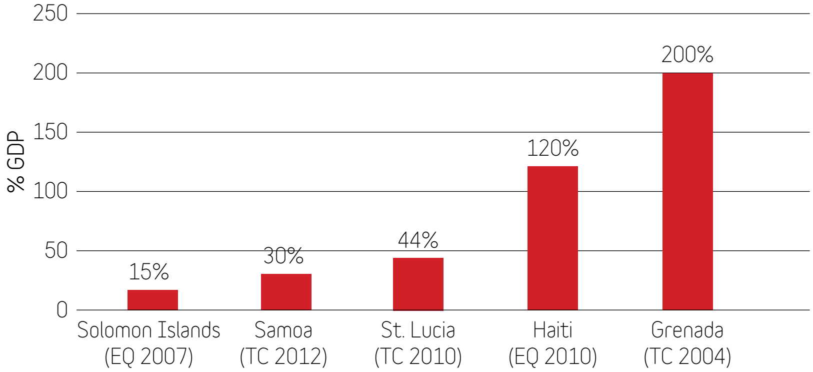
Olivier Mahul, Program Manager, Disaster Risk Financing and Insurance Program, World Bank Group
Abigail Baca, Disaster Risk Management Specialist, World Bank Group
Benedikt Signer, Disaster Risk Financing and Insurance Specialist, World Bank Group

When small island nations suffer disaster losses, the impact on their economies can be significant. These countries are indeed small: Grenada, for example, is 133 square miles, Maldives is 115 square miles, the Marshall Islands is 70 square miles, and Tuvalu is just 10 square miles. Taken together, these four countries would cover just over 50 percent of the city of London. The concentration of assets and people on these small islands is like the proverbial placement of all your eggs in one basket: it creates a high degree of vulnerability that cannot be ignored.

This level of vulnerability leads to big impacts. In 2004, Hurricane Ivan, a Category 3 storm, devastated Grenada's main productive crop, nutmeg, and left two-thirds of the population without sufficient housing. Total damages were estimated around US$900 million, equivalent to 200 percent of national gross domestic product (GDP) at the time. Imagine if the United Kingdom suffered a comparable event: 200 percent of its GDP would be US$5.6 trillion. While Grenada's experience with Hurricane Ivan is extreme, Small Island Developing States (SIDS) across the world continue to suffer significant disaster losses. Figure 1 shows the economic impacts of disasters in SIDS as a share of GDP.

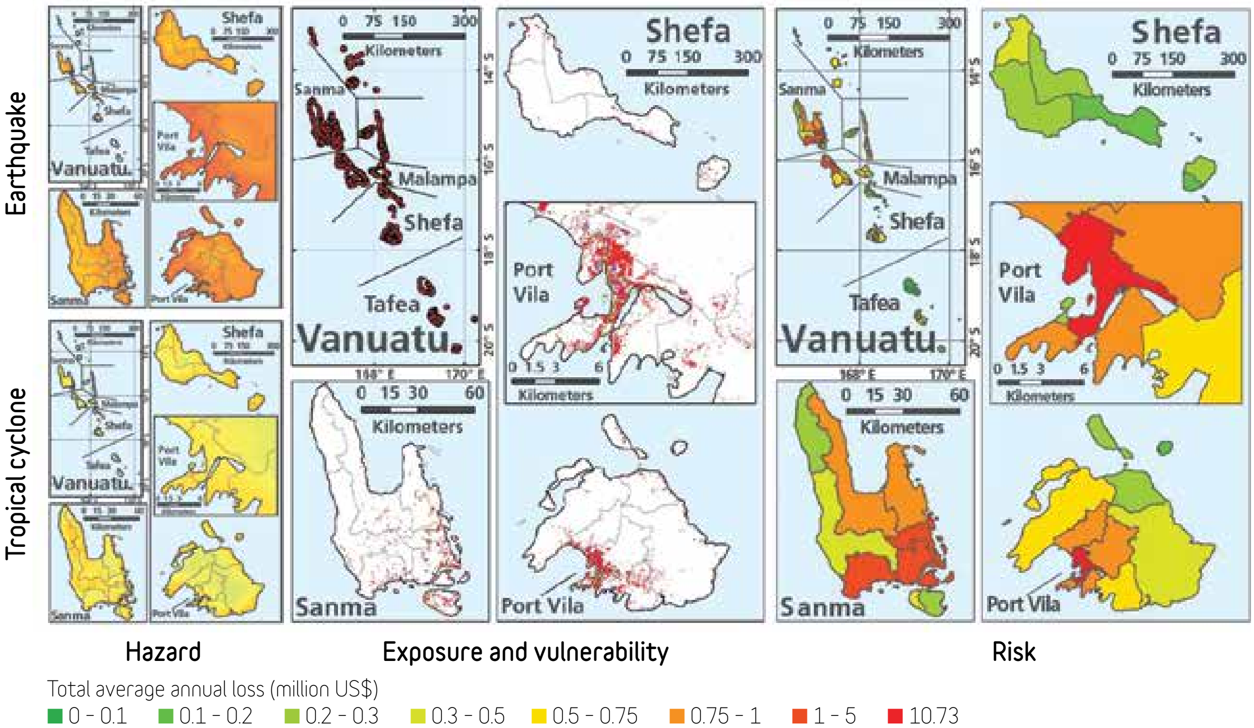
This summary draws on discussions with practitioners from the Caribbean, Indian Ocean Islands, and the Pacific Islands in a technical session as well as a full-day workshop on the experience of small island states. Generous support by the Africa, Caribbean and Pacific-European Union (ACP-EU) National Disaster Risk Reduction Programme enabling the participation of SIDS representatives at UR2014 is gratefully acknowledged.

Figure 1. Economic impacts of recent disasters in SIDS (percentage of GDP).



Source: Prepared by World Bank with data from EM-DAT.
Note: EQ = earthquake; TC = tropical cyclone.

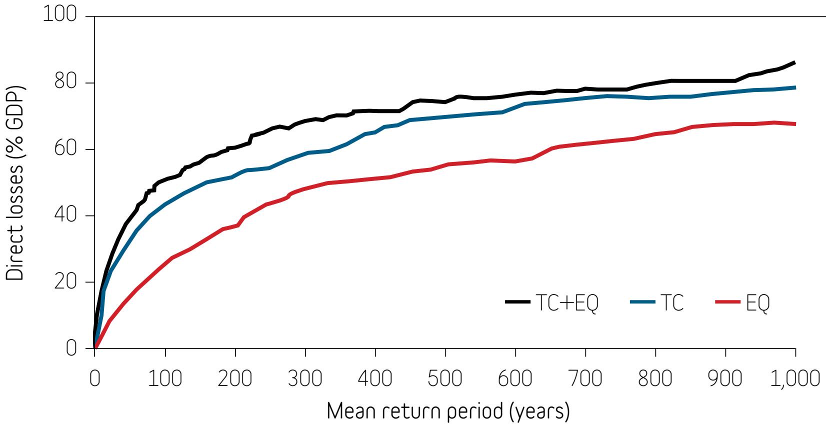
Figure 2. Data on hazard, exposure, and vulnerability used as the basis for risk maps in Vanuatu.



Source: Pacific Catastrophe Risk and Financing Initiative, "Country Risk Profile: Vanuatu," http://pcrafi.sopac.org/.

To understand not just what has happened in the past, but what could happen in the future, countries can leverage available models and data through risk assessments. But building a robust understanding of natural disaster risks—particularly in terms of economic losses—is not always easy. It requires good data on hazards, exposure, and vulnerability. Maps combining these three components offer a simple and powerful way of showing the spatial dimensions of risk, as well as the underlying factors often hidden from policy makers when data about exposure and hazard are not available. For example, the maps representing the risk profile for the South Pacific nation of Vanuatu show the tropical cyclone and earthquake hazards, distribution and value of public and private infrastructure, and the average annual loss in each administration unit (figure 2).

Figure 3. Risk profile for Vanuatu.



Annual probability	Loss (US$ million)	Loss (% GDP)
Average annual	48	6.6
1/50	285	40
1/100	370	51
1/250	480 M	66

Source: Pacific Catastrophe Risk and Financing Initiative, "Country Risk Profile: Vanuatu," http://pcrafi.sopac.org/.

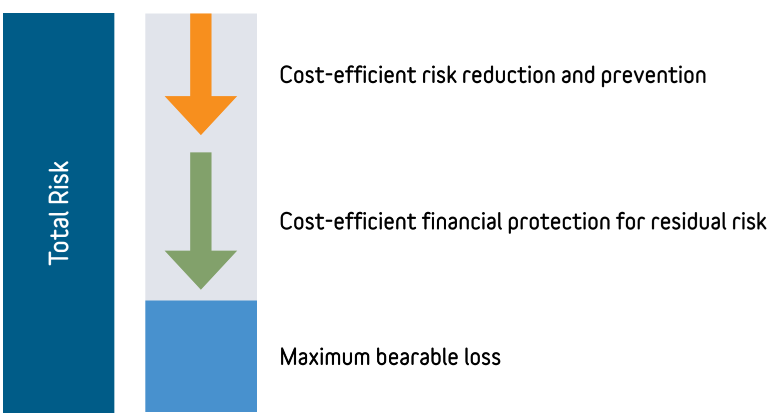
Note: TC = tropical cyclone; EQ = earthquake.

These types of risk assessments provide metrics indicating both the average annual loss and the annual probability of experiencing higher losses associated with less frequent but more severe disasters. The risk profile for Vanuatu presented in figure 3 shows that while the country's average annual loss is US$48 million (or 6.6 percent of GDP), losses of US$285 million (40 percent of GDP) or greater have a 50-year return period, or 2 percent annual probability.

Faced with the possibility of losses on this scale, the governments of SIDS have a seemingly intractable problem. How can they pursue long-term development objectives so they are not completely derailed when such a disaster strikes? What instruments and strategies are available to protect the fiscal space of the governments operating in such conditions? How can small states work together to become "big" and address these challenges at the required scale?

The risk information that highlights the scale of the challenge also informs two crucial steps in addressing these impacts: (1) reducing the underlying drivers of risk through risk reduction and prevention, and (2) putting in place financial protection strategies to address residual risk, which is either not feasible or not cost-effective to mitigate (figure 4).

Figure 4. Risk reduction and financial protection as complementary strategies to help governments manage the total risk they face.



SIDS have taken leadership, in the political arena as well as in technical work, in finding innovative ways to work together to "become big." In the Caribbean and the Pacific, designing policies for financial protection with finance ministries has motivated investments in reliable and appropriate data to quantify the economic and fiscal impacts of disasters. Such information can support the development of sovereign disaster risk financing tools, such as disaster funds, sovereign risk transfer mechanisms, or risk pooling schemes. Financial instruments such as catastrophe bonds and parametric reinsurance contracts are particularly effective at providing rapid liquidity for emergency response costs. These can be combined with other sources of funds (budget reallocations, reconstruction loans, donor funds) for long-term

Figure 5. Risk layering, or use of various financial instruments to address increasing levels of loss.

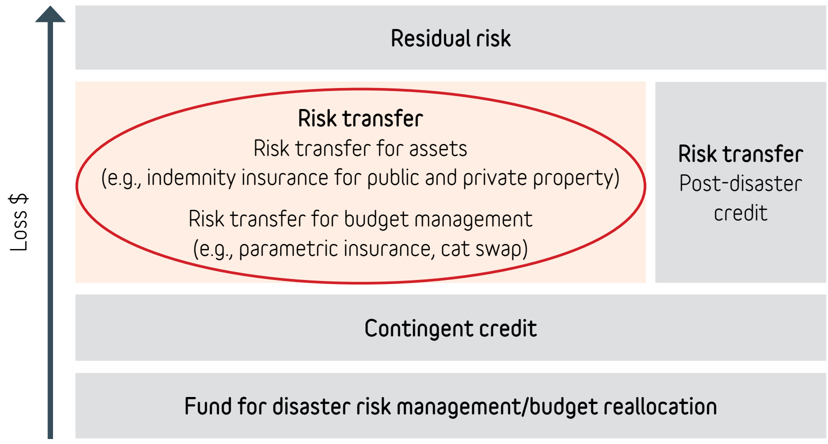


Figure 6. Reduction in insurance premium through pooling.

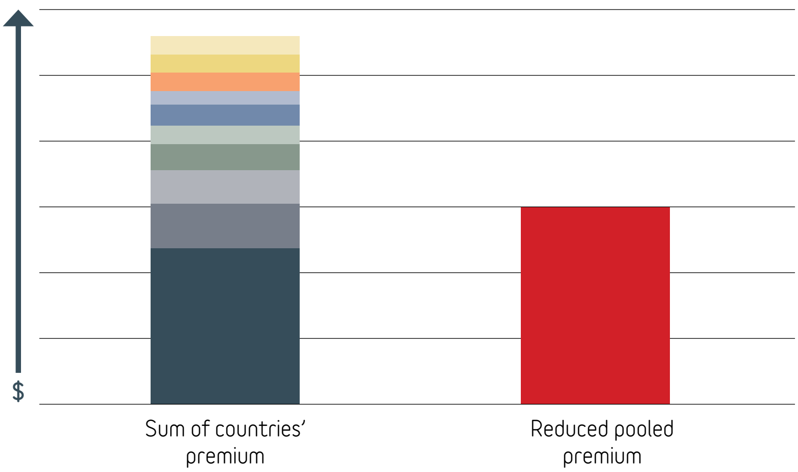
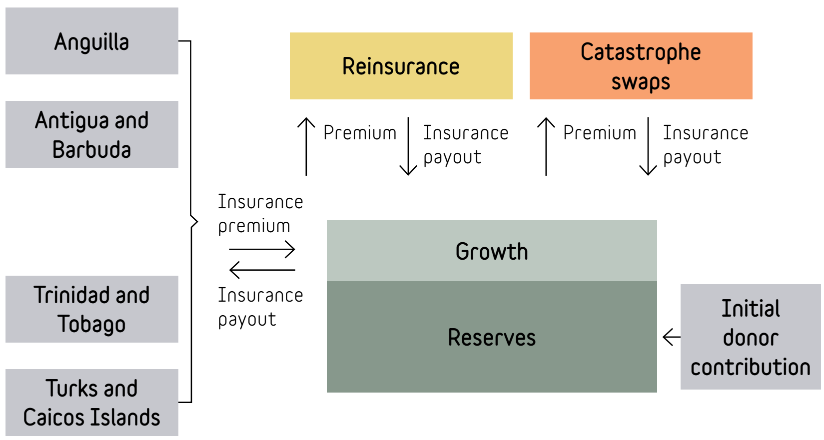


Figure 7. Setup of the Caribbean Catastrophe Risk Insurance Facility.



Note: Not all member countries are shown.

recovery and reconstruction. The resulting risk-layering strategy ensures that more cost-effective financial tools, such as dedicated reserves for disaster, are used first, and that the more expensive risk transfer instruments, such as parametric insurance, are used only in exceptional circumstances (figure 5).

Investing in detailed risk data yields payoffs far beyond risk financing. The same information can help governments, the private sector, communities, and individuals make informed decisions in reducing their risk.

For SIDS, accessing market-based risk transfer products (see red circle in figure 5) has historically been very difficult. Approaching the market individually, SIDS would face higher costs for risk transfer because the reinsurer would pass on to them the higher transaction costs for these small markets. Working together to diversify the risk portfolio presented to the market has resulted in significantly lower costs to SIDS. It has also required significant investment in risk information and innovative structures such as risk pools. Figure 6 shows a real example of countries achieving lower premium costs by pooling their risk into a single instrument with higher volumes and greater risk diversification.

In 2007, the Caribbean Catastrophe Risk Insurance Facility (CCRIF) launched the first-ever multi-country risk pool; today, it operates with 16 countries participating (Anguilla, Antigua and

Barbuda, the Bahamas, Barbados, Belize, Bermuda, Cayman Islands, Dominica, Grenada, Haiti, Jamaica, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Trinidad and Tobago, and Turks and Caicos Islands). As a parametric sovereign risk transfer facility, the CCRIF provides member countries with immediate liquidity following disasters. Since inception it has made eight payments totalling US$32 million, always within two weeks of the triggering disaster. The structure of the CCRIF is shown in figure 7.

The CCRIF and more recently the insurance pilot under the Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI) have demonstrated the financial benefits of risk pooling for insurance; the countries involved have received as much as a 50 percent reduction in the cost

"For Vanuatu and other SIDS, our future depends on being smarter about investing in resilience and leveraging innovative risk financing solutions, like the PCRAFI, to protect our fiscal space against disasters and climate extremes."

—Honorable Ralph John Regenvanu, Minister for Lands and Natural Resources, Vanuatu

Key Priorities for SIDS

1. **Obtaining risk information to enable better disaster risk management decisions.** This priority includes investing in the following: underlying exposure, hazard, and historical loss data to inform risk assessments; risk information systems to make these data available; and risk analytics so that data can inform decisions by policy makers, particularly those concerning core development planning.

2. **Enhancing the resilience of vulnerable communities and SIDS through both soft and hard measures**. Strengthening resilience and sustainable financial protection requires hard measures, such as the integration of risk information in sectoral investments. But it also requires soft measures, such as the establishment of a risk management culture, greater awareness of the benefits of investing in prevention and long-term planning, and social safety nets between communities.

3. **Integrating disaster and climate risks in fiscal and development planning.** SIDS often struggle to gain the necessary fiscal space to respond to disasters and maintain development objectives at the same time. They need to accurately measure the fiscal impact of disasters and integrate this information in comprehensive fiscal risk management together with other contingent liabilities, such as debt and commodity price risk. Insurance of public assets and improved public financial management helps achieve fiscal stability. But only the integration of risk information in long-term development planning can address the underlying drivers of these risks.

4. **Continuing innovations to meet new challenges.** As can be seen in their efforts to develop regional sovereign risk pooling initiatives, SIDS have shown both political and technical leadership in addressing disaster and climate risks. Continued innovation is needed to face the challenges of the future, which include how to better communicate the fiscal impact of risk, how to measure and communicate the benefits of investing in risk reduction, and how to better quantify the poverty impacts of disasters and protect the most vulnerable, such as through disaster-linked social protection.

5. **Enabling solutions through regional programs.** SIDS face unique problems. Regional programs are already playing a crucial role in translating an improved understanding of disaster and climate risks into concrete solutions. For example, regional programs can help SIDS invest in better risk data. Regional approaches also facilitate the sharing of experiences across countries; this enables countries to improve their understanding of available instruments for building comprehensive financial protection strategies, instead of relying on individual instruments.

of premiums compared to the cost of approaching the market individually. The principles of pooling can equally be applied to other disaster risk reduction instruments and practices. For example, several SIDS have successfully enhanced early warning systems and basic risk information by sharing or pooling data and expertise.

In addition, insurance pools such as CCRIF or PCRAFI can be the first step in providing the incentives for longer-term investments in climate and disaster resilience. Investing in detailed risk data yields payoffs far beyond risk financing. The same information can help governments, the private sector, communities, and individuals make informed decisions in reducing their risk.

When SIDS representatives participating in the Understanding Risk Forum were asked to consider what it would take to reduce their country's disaster risk by 50 percent by 2030, all stressed the need to work together, to find regional solutions, and to become big by working in partnership; these are considered fundamental steps toward enabling the necessary investments for risk reduction and financial protection.

Contributors to the session

Rachel Kyte, Special Envoy for Climate Change and Vice President, World Bank Group

Honorable Ralph John Regenvanu, Minister for Lands and Natural Resources, Vanuatu

Mamy Razakanaivo, Executive Director, Prevention and Emergency Management Unit, Prime Minister's Office, Madagascar

Timothy Antoine, Permanent Secretary for Energy, Economic Development, Trade and Planning, Grenada

'Ana Fakaola 'I Fanga Lemani, Acting Deputy Secretary for Procurement, Ministry of Finance and National Planning, Tonga

Ms. Fathmath Thasneem, Deputy Minister of the National Disaster Management Center, Maldives

UR Interview

Lianne Dalziel
Mayor of Christchurch,
New Zealand

Q: What brought you to the 2014 Understanding Risk Forum in London?

A: I have come to share and learn from other perspectives and other countries' experiences. The Forum has been set up to bring together community leaders, people from the world of science and research, and people from the world of finance and reinsurance. And what you find here is a unique opportunity to join with others in truly understanding risk, which is key to building resilience and managing disaster risk.

Q: You mentioned the importance of learning from other countries' experience and the diversity of participation in the Forum. Why is diversity so important?

A: Challenges around disaster risk management vary from country to country, region to region, and city to city. Thus it is very important not only to cover a variety of subjects during the Forum, but also to have diversity among the participants. Participants bring their own experiences to share with others, and they represent different perspectives. Some of the talks today, for example, focused on how disaster has a far greater impact on the poor than on those with more resources. We heard about microfinance insurance, which is a fantastic concept that is more applicable to some environments than others, but in the end the important thing is that there is information and knowledge here applicable to any circumstance. That range of information becomes available when you bring different communities together to talk about risk.

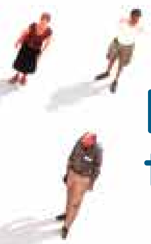
Q: Why have this event?

A: It is important for people with different perspectives to come together, share experiences, and learn about what others are doing—and about what they could be doing to better prepare their own cities and countries to manage disaster risk. Globally, we have got more people living in cities and coastal environments than ever before. That's why we need to understand the connection between disaster risk reduction, climate change adaptation, and sustainable community development. They all go together, and come together in the large cities on our coasts. And that's why we need this forum—to understand these connections as part of understanding risk.

Photo: adrian825/Thinkstock.com

Psychology of Risk

Illustration: DigtialStorm/Thinkstock.com



Game Over?

Exploring the Complexity of Actionable Information through Gaming

Pablo Suarez, Associate Director for Research and Innovation, Red Cross/Red Crescent Climate Centre

Imagine that your job consists of helping others understand risks: your task is to help them anticipate what can go wrong and inspire them to act to reduce avoidable losses. Imagine that the rapidly growing power of science and technology produces new, better information about hazards, vulnerabilities, and capacities to manage risks. Importantly, imagine that this information is *actionable*: as the probability of certain extreme events changes, specific decisions can be triggered that would save lives and livelihoods—and this applies whether you are talking about hurricanes, sea-level rise, or any other somewhat predictable natural hazard.

Now what do you think actually happens when you communicate that actionable information through conventional means such as PowerPoint presentations, journal articles, maps, and other unidirectional formats?

After a decade of working in the humanitarian sector trying to communicate science-based climate risks to extremely busy disaster managers in Africa and Latin America, I came to a concerning realization: my unidirectional approaches created a decidedly passive role for those who allegedly could take action based on that actionable information. That passivity was palpable in the audiences I addressed; their body language and facial expressions revealed that my effort to communicate was not only failing to engage them, it seemed to be temporarily shrinking their cognitive capabilities.

Under the circumstances, it was rather optimistic to assume that people would in fact act upon the allegedly actionable information they were exposed to. What was left after the presentation to passive audiences? Little more than a big question mark. Figure 1 shows what used to be my usual experience of communicating risk information.

A new communication approach was needed: one that captured the beautiful, elusive complexity of the systems we inhabit, in which *information* about changing risks and awareness of the likely *consequences* of action (or inaction) became the basis for actual *decisions* about whether to act. How to help people engage in the actual exploration of trade-offs, thresholds, feedbacks, delays, and other aspects of how information about likely future conditions can lead to better decisions today? The comfort zone of PowerPoint presentations and

Figure 1. A simplified representation of the usual experience of communicating risk.

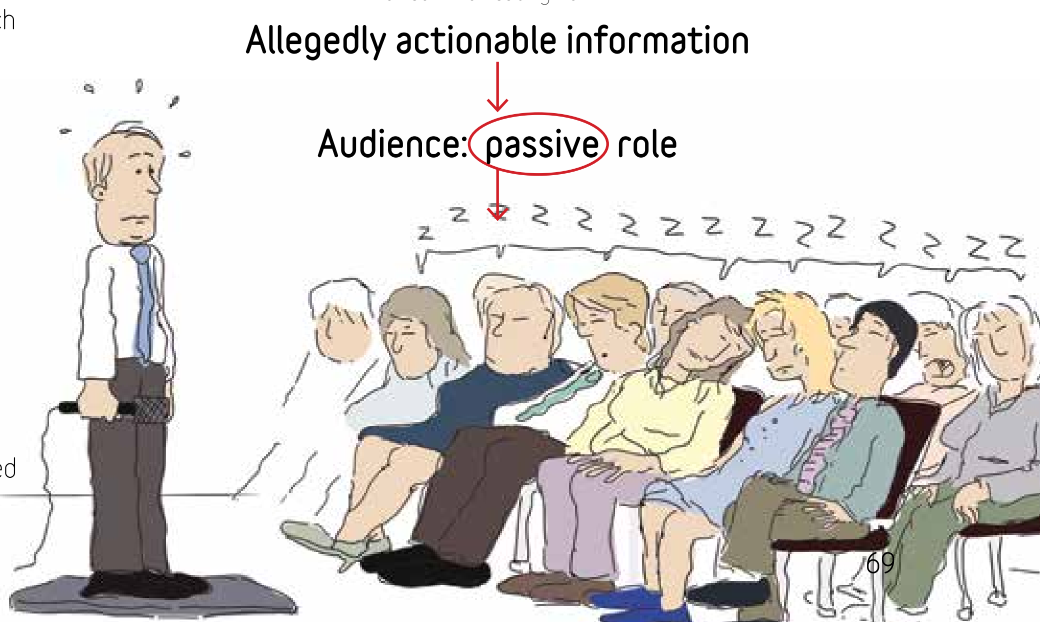


Illustration: PlanetFlem/Thinkstock.com

written documents was clearly not enough to inspire people to take actionable information and turn it into action. It was time to step outside of the comfort zone.

Participants in this intensely interactive, seriously fun UR Forum session discovered that *games can help us "inhabit" the complexity of climate risk management decisions, allowing us through system dynamics modelling to explore and test a range of plausible futures*. Well-designed games, like real-world risk management, link information to decisions with consequences. Unlike unidirectional communication approaches, games combine the analytic and questioning concentration of the scientific viewpoint with the intuitive freedom and rewards of imaginative, artistic acts.[1]

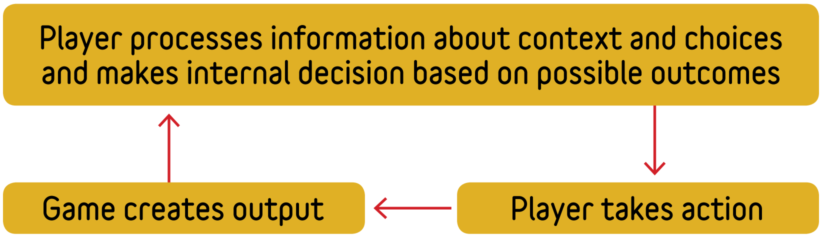
For the purposes of learning and of engaging in dialogue to improve climate risk management, useful games involve emergent systems: they generate, from a simple set of rules, patterns of complexity that are unpredictable or surprising. In games, the limited set of elements that constitutes the system can yield a vast array of plausible combinations and outcomes—what game designers call the *space of possibility*. Thus participants can start a gameplay experience with no awareness of specific causal relationships, and then, as the game unfolds and a range of outcomes is revealed, they can see a particular pattern of causality as exquisitely obvious. A model of the gameplay experience is shown in figure 2.

Game designers create large organic structures of designed interaction. These organic, playful structures successfully embody two of the most important trade-offs involved in climate risk: the "now versus later" trade-off (better outcomes for the longer-range future may require sacrifices in the short term), and the "me versus us" trade-off (on one hand, selfish decisions can more reliably lead to good outcomes, but the outcomes may be small; on the other hand, collective decisions can be riskier, but economies of scale make better outcomes possible). When both trade-offs are present, games offer a platform that is singularly conducive to learning and dialogue about disaster risk management and that allows for the exploration of plausible futures.

In the world of risk management, probabilities are everywhere. A disaster is, by definition, a rather improbable event. Yet in the words of Aristotle, "It is in the very nature of probability that improbable things will happen." The concept of probability implies knowledge of all possible outcomes, and an understanding of how many of those outcomes fulfill a certain condition. Thus in a roll of a six-sided die, there is clearly a 1/6 probability of rolling a one (which could represent about a 16 percent chance of drought in any given year). One of the games played at the UR Forum involved the roll of a giant die representing the probability distribution function of precipitation based on the historical record: a six represented a flood, and all other values represented good rains. Players stood up and took on the role of humanitarian workers. A row of players constituted a team. Before the roll of the die, each participant had to make an individual decision in preparation for the rainy season:

- Players who expected too much rain could choose an umbrella

Figure 2. A distillation of the experience of gameplay. When a player takes action, the game system creates output by applying rules. Such output becomes information about context and choices shaping subsequent decisions—or determines a win/loss state.



Note: The figure builds on the model proposed by Katie Salen and Eric Zimmerman, *Rules of Play: Game Design Fundamentals* (Cambridge, MA: MIT Press, 2003), 316.

(represented by placing one's arms above one's head in a protective shape).

- Players who expected good rains could invest in actions for the long term (represented by thumbs up).

By the end of the countdown, each player had to have chosen one of the two actions. Then the die was rolled to determine the rains. Players who hadn't chosen the "right" action had to sit down and were eliminated, whereas those who had chosen the "right" action remained standing and kept playing. The row with the most standing players after several rounds was the winning team.

What makes this apparently simple game challenging is that participants must collectively process the information about risk and allocate individual resources for a shared goal. Players must negotiate with teammates and anticipate how outcomes can be affected depending on what they do, what others do, and what the random rains deliver. As the game progresses, risks change: players no longer roll the large die but instead flip a giant coin that represents El Niño, which can enhance the probability of extreme rainfall from about 15 percent to 50 percent. Later in the game, climate change is introduced: the die is replaced by a large truncated cone with three possible outcomes—flood, drought, or good rains—that are very hard to estimate in terms of probabilities. When El Niño becomes a possibility, will teams adjust allocation of resources to flood preparedness? How will teams deal with the new, deep uncertainty surrounding climate change? Forced to consider questions of this kind, participants discover surprising, useful approaches to changing risks and are prompted to explore the implications of these changes. The game led to rich discussions about the role of forecasts, collaboration, incentives, and other key dimensions of humanitarian and development work.

In addition to offering an opportunity for serious gameplay, the session provided an overview of how games can be integrated into participatory processes, why they work well to engage people in envisioning and experiencing risk, and how humanitarian and development organizations (as well as some governments) have embraced the use of participatory games for real-world work. The Red Cross/Red Crescent Climate Centre, the World Bank, Oxfam, World Food Programme, United Nations Framework Convention on Climate Change, Tanzanian government, Zambian Red Cross, and many other entities have developed game-enabled initiatives to address a very wide range of issues, including hurricane preparedness, climate-resilient coastal development, gender dimensions of food insecurity, climate change attribution, crowdsourced early warning systems for floods, interinstitutional collaboration, and more. In the last five years, hundreds of game sessions on climate risks have engaged thousands of participants, ranging from residents of Nairobi shantytowns and Nicaraguan subsistence farming communities to negotiators at the UN Climate Conference and even to the White House. UR Forum participants got a flavor of the transformative potential of game-enabled processes for understanding risk, and many concrete ideas emerged for adding serious gameplay dimensions to ongoing initiatives around the world.

Endnotes

1 For another perspective on the role of games in risk assessment, see "Game Time: Monitoring Changing Riskscapes with GEM and SENSUM Tools" in this publication.

Further resources

- Climate Centre website at http://www.climatecentre.org.
- "Using Games to Experience Climate Risk: Empowering Africa's Decision-Makers," Final Report: CDKN Action Lab Innovation Grant, http://www.climatecentre.org/downloads/File/Games/CDKNGamesReport.pdf.
- Frederick S. Pardee Center for the Study of the Longer-Range Future, *Games for a New Climate: Experiencing the Complexity of Future Risks* (Boston: Boston University Pardee Center, 2012), http://www.bu.edu/pardee/publications-library/2012-archive-2/games-climate-task-force/.

Science and Emotion

Using Technical Information in Practice

Dr. Adam Cooper, Lecturer in Social Science and Public Policy, Department of Science, Technology, Engineering and Public Policy, University College London

The focus of much risk analysis across the worlds of finance, insurance, and disaster risk reduction tends to erase humans from the picture. There is a tendency to forget that the reason disasters are disasters or that risks are considered risks is because *someone* is affected or *someone* is thinking about the situation. This tendency might have a range of explanations: It could stem from a physical sciences view of disasters—that is, the view that disasters are about flooding or earthquakes that need to be predicted. Or it could stem from an engineering view of development, which sees new technology as a way to solve a long-standing problem. The absence of humanity—and whatever makes us human—at the heart of the global systems of finance and disaster risk management is something of an irony for the humanitarian sector. But it is a deep and enduring problem. The question is, how to understand this human-ness? How do we explore the role of humans and include social and societal factors when pursuing disaster risk reduction and management?

In the finance sector new disciplines have been emerging that try to foreground a deeper understanding of the role of people in analytic settings. We find in the reinsurance sector a firm reliance on modelling. But there can be a modelling culture that steamrollers the emotional response of those asked to do the modelling. As one respondent put it in a study of analysis in the reinsurance sector:

> "It's crazy that we've only [got data] for 40 years and talk about 1-in-500-year return periods. How the [hell] am I supposed to know [whether this model is accurate]?"[1]

The emotion in that response is palpable. Using approaches developed in the field of "strategy as practice," we can begin to understand the dynamics between the people caught in an analytic system that places numerical modelling outputs before human judgment. This preference for models is problematic on a number of levels, not least because it misses the opportunity to exploit a modelling system far more sophisticated than any Excel workbook: the human brain.

The role of people in making decisions about risk is something that is implicit within economic models, of course. There is no shortage of commentators willing to criticize the shortcomings of classical or neoclassical economic models of the human. Behavioral economics has moved the debate forward, but even behavioral economics misses critical factors about humans, including one that makes us most distinctly human: our emotional response to risk. We can turn to conviction narrative theory (CNT) (though it takes us a step beyond the normal analysis in this space) to affirm the need for a cross-disciplinary theory of economic action, based on how decisions are *actually* made. CNT recognizes that action is possible because actors create *narratives* of the future that allow them to feel confident about it. CNT draws on the human capacity to experience and solve the problem of action using situationally based imagination, emotion, narrative, and simulation; in other words, it goes beyond the mechanistic approach that characterizes deterministic computational economic modelling. It foregrounds "embodied narratives" that can be researched and understood by examining "relative sentiment shifts" in any unstructured database via text analysis. Such sentiment shifts can be used to predict emerging risks better than other methods. This approach represents one way in which understanding and examining emotional reactions can provide us with more information about what is happening in the world. This is exactly the information that analytic models of risk forget.

But emotions can be utilized and understood in a range of different ways. Especially in the fraught world of DRM, internalizing lessons about risks and trade-offs often requires a more instinctive understanding of the pressures and consequences of our choices than a purely "rational" or mathematical one. This fraught world is one where donor pressure on effective and efficient action forces the hand of local response teams to choose between investing in disaster risk reduction infrastructure now (before the risk materializes) or disaster response (after it's happened). The former carries the risk of wasted resources when the disaster fails to happen; the latter leaves itself open to accusations of failing to prepare and of acting expensively and too late. But how can we convey these trade-offs effectively to those not involved in such decision making? Using games to provide a structured experience that invokes the emotional lived experience of the sort felt *in vivo* is a key method. Crucially, such games can build on the use of nonlinear system dynamics models to present coherent scenarios that people can act out.[2] This is, in fact, another form of modelling, but one where the model is executed by people, and where one of the outputs is an emotional response, rather than a graph.

We need to develop a better understanding of risk analysis in practice, a better understanding of the way humans *think* or rather *emote* about risks, and better ways of articulating and training around the emotions associated with risks. But what about carrying out disaster risk response in practice? How can we embed the notion of the human, the social, and the emotional in the practice of DRM? Clearly there are no straightforward answers here, but experiences in Indonesia and Japan provide something of a template for future development.

The question is, how to understand this human-ness? How do we explore the role of humans and include social and societal factors when pursuing disaster risk reduction and management?

In Japan, programs like Global Safety (G-Safety), run by the recently established interdisciplinary International Research Institute for Disaster Science (IRIDeS), bring together a broad range of disciplines to understand disaster response better. IRIDeS used mixed methods in the aftermath of Fukushima to help local people articulate their anxiety about the future and their frustrations with the official response, including their irritation with the lack of information, their sense that authorities were not to be trusted, and their feeling that compensation for land was not equitable. G-Safety uses this information to generate simulations and record the history of the event, as well as to train disaster response teams for future operations.

In Indonesia, residents face the twin pressures of immediate disasters (such as the Mentawai tsunami in 2010 or the outer-rise earthquake and tsunami in 2012) and the more gradual sinking of their islands. The Indonesian Institute for Sciences has instituted the Public Education and Community Preparedness program to help citizens understand—and feel empowered to address—the risks arising out of these challenges. The program recognizes the challenge of mainstreaming messages to promote disaster risk response, and it has enlisted the cultural sector via Herbie Hancock to help spread these messages. This intelligent use of culture for disaster risk response recognizes the way people engage with narratives that are potentially difficult to entertain or deal with.

It is clear that there would be enormous benefits to developing a deeper and broader understanding of what it means to be human throughout the range of disaster risk response efforts, including the world of finance and reinsurance. Developing a method for understanding the human and social elements of disaster risk response is critical if we are to make sense of the human capacity for resilience. The social sciences are a core part of that effort, but new interdisciplinary or transdisciplinary methods and approaches are likely at the heart of making it a success.

Contributors to the session

Paula Jarzabkowski, Professor of Strategic Management at CASS Business School, City University

David Tuckett, Professor in Psychoanalysis and Director of the Centre for the Study of Decision-Making Uncertainty, University College London

Pablo Suarez, Associate Director for Research and Innovation, Red Cross/ Red Crescent Climate Centre

Yasuhito Jibiki, Assistant Professor, International Research Institute of Disaster Science, Tohoku University

Irina Rafliana, Public Policy, Education and Science Communication, Indonesian Institute of Sciences

Endnotes

1 P. Jarzabkowski, R. Bednarek, and A. P. Spee, *Making a Market for Acts of God: The Practice of Risk-Trading in the Global Reinsurance Industry* (Oxford: Oxford University Press, forthcoming).

2 For more on the role of games and gameplay in understanding risk, see "GAME OVER: Exploring the Complexity of Actionable Information through Gaming" and "Game Time: Monitoring Changing Riskscapes with GEM and SENSUM Tools" in this publication.

Photo: George Doyle & Ciaran Griffin

Photo: Phil Ashley

Thinking Fast and Slow

Why Catastrophe Risks Lead Us to Behave Differently

Dr. Howard Kunreuther, Co-director, Wharton Risk Management and Decision Processes Center, the Wharton School, University of Pennsylvania

Thirty years ago, large-scale natural disasters were considered rare events. Between 1970 and the mid-1980s, annual insured losses from natural disasters worldwide (including forest fires) were only in the $3 billion to $4 billion range. In fact, Hurricane Hugo, which struck in 1989, was the first natural disaster in the United States to inflict more than $1 billion of insured losses.

Times have changed, and we now find ourselves managing risks in a new era of catastrophes. As shown in figure 1, economic and insured losses from earthquakes, hurricanes, and floods have increased significantly in recent years, primarily due to a higher degree of urbanization and an increase in the value of property at risk. In hazard-prone areas, these changes translate into greater concentration of exposed assets and hence a higher likelihood of catastrophic losses from future disasters.

Studies of behavior with respect to low probability-high consequence (LP-HC) events provide lessons for managing the risk of catastrophic occurrences, such as severe natural disasters, before these events take place. We cannot assume that the massive destructiveness of an event will lead us to appropriately respond to the risk. To the contrary, we know that individuals often deviate from expert assessments of risks that involve small probabilities and high degrees of uncertainty. There was considerable discussion of this tendency at the Understanding Risk Forum.[1]

LP-HC events are subject to the availability bias, where the judged likelihood of an event depends on its salience.[2] There is thus a tendency for decision makers to perceive the risks of a disaster to be below their threshold level of concern, and as a result they

Figure 1. Natural catastrophes worldwide, 1980–2013: Overall and insured losses (US$ billion).

* Values adjusted for inflation using the Consumer Index (CPI) of each country.

Source: © Munich Re, Topics Geo: Natural Catastrophes 2013—Analyses, Assessments, Positions, 2014, http://www.munichre.com/site/corporate/get/documents_E1043212252/mr/assetpool.shared/Documents/5_Touch/_Publications/302-08121_en.pdf. Used with permission; further permission required for reuse.

do not pay attention to potential consequences so long as these disasters do not occur. More specifically, many homeowners in the United States buy flood insurance only after suffering a loss, and then cancel their policies several years later if they have not experienced any damage.[3] It is very hard to convince policyholders that *the best return on their insurance is no return at all*. One should celebrate *not* having had a serious loss rather than focusing on paying premiums that went for naught.

With all these challenges to decision making, consideration of ways to improve the choice process may be helpful, even as we recognize the obstacles to changing behavior. We must employ slow and careful thinking, coupled with short-term incentives, to create policies, procedures, laws, and institutions that will nudge or even require us to behave in ways that accord with our considered values for protecting human lives and property.

We must employ slow and careful thinking, coupled with short-term incentives, to create policies, procedures, laws, and institutions that will nudge or even require us to behave in ways that accord with our considered values for protecting human lives and property.

The tools for understanding risk build on the distinction between intuitive and deliberative thought processes described by Nobel laureate Daniel Kahneman in his thought-provoking book, *Thinking, Fast and Slow*.[4] Building on a large body of cognitive psychology and behavioral-decision research, Kahneman characterizes two modes of behavior: intuitive (*system 1*) thinking and deliberative (*system 2*) thinking.

System 1 thinking tends to be fast and effortless. System 2 thinking requires more time and attention. Intuitive thinking works well for routine decisions but can be problematic for LP-HC events, where there is limited opportunity to learn from personal experience. There are additional problems if the consequences are not likely to occur in the near term. For example, individuals may disregard the impact climate change will have on sea-level rise and future damage from floods and hurricanes because these consequences are seen as part of a distant future.

Households in hazard-prone areas may decide not to purchase insurance against LP-HC events because they have had limited or no experience with them. Trying to determine the likelihood and consequences of the risks they pose is also costly and time-consuming. Instead, residents often rely on feelings and intuition rather than careful thought in making decisions on whether to protect themselves against the financial consequences of suffering a loss from a natural disaster.

On the supply side, insurance companies face the risk of experiencing large claims payments, only part of which can be spread or diversified away through the law of large numbers if losses are highly correlated. Decision makers in the insurance industry and those involved in insurance regulation, legislation, and litigation are also likely to make mistakes for the same reasons that consumers do. With limited information from past experience on which to base their decisions, they often rely on their intuition rather than engaging in deliberative thinking. Prior to 9/11, for example, insurance losses from terrorism were viewed as so improbable that the risk was not explicitly mentioned or priced in any standard commercial policy. Following the terrorist attacks in the United States, most insurers and reinsurers refused to offer coverage against terrorism. There was a tendency to focus on the losses from a worst-case scenario without adequately reflecting on the likelihood of this event occurring in the future.

Recognizing the pitfalls of fast intuitive thinking in dealing with extreme events, we offer below two guiding principles for insurance and two strategies for encouraging long-term deliberative thinking. Adopting them should help us to protect ourselves against potentially catastrophic risks before it is too late.

The guiding principles for insurance are these:

- *Insurance premiums should reflect risk*. Risk-based

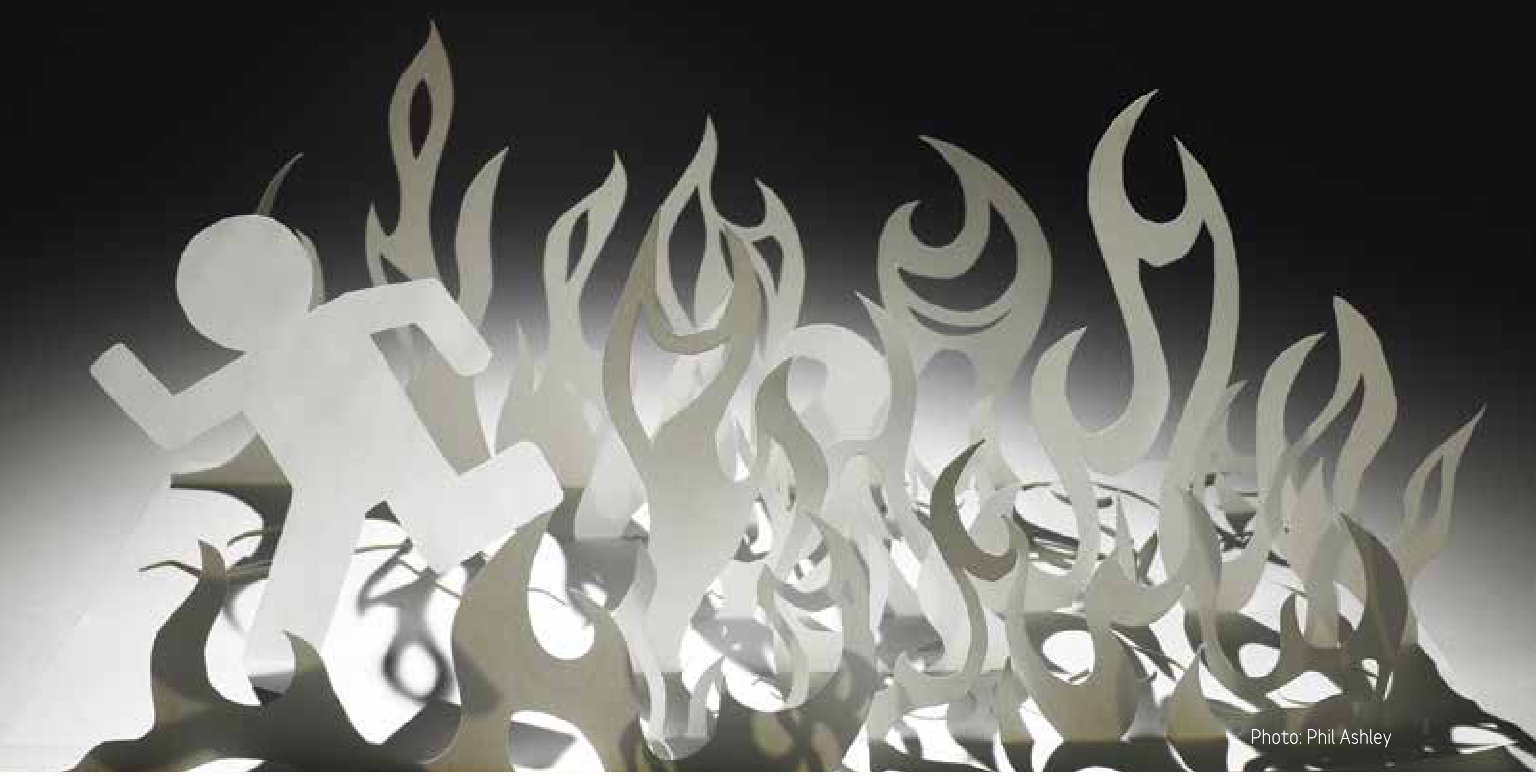


Photo: Phil Ashley

premiums signal the type and magnitude of hazards individuals face and encourage investment in cost-effective loss reduction measures through a reduction in insurance costs.

- *Equity and affordability issues should be addressed.* Any financial assistance given to individuals currently residing in hazard-prone areas (e.g., low-income homeowners) should come from general public funding and not through insurance premium subsidies.

The suggested strategies for deliberative thinking are these:

- *Stretch the time horizon for a particular risk.* Rather than telling homeowners that there is a 1-in-100 chance next year of damage from a severe hurricane, reframe the same probability and say that there is a greater than 1-in-5 chance of hurricane damage in the next 25 years. Empirical studies have shown that presenting data in this fashion leads individuals to take protective measures.
- *Provide short-term incentives to encourage protective behavior.* Require property insurance in hazard-prone areas and offer long-term loans for investing in protection to avoid the high upfront cost. The premium reduction from reducing the risk should be larger than the cost of the loan if the protective measure is a cost-effective one. From a financial point of view, everyone—even those who engage in short-term thinking—should want to adopt such measures.

Contributors to the session

Lead: Dr. Howard Kunreuther, Co-director, Wharton Risk Management and Decision Processes Center, the Wharton School, University of Pennsylvania

Panelists

Scott Belden, Senior Vice President, Travelers Companies

Margareta Drzeniek-Hanouz, Director and Lead Economist, World Economic Forum

Alex Wittenberg, Partner, Oliver Wyman/ Marsh & McLennan

Dr. Erwann Michel-Kerjan, Executive Director, Wharton Risk Management and Decision Processes Center, the Wharton School, University of Pennsylvania

Endnotes

1 On this point see also D. M. Cutler and R. Zeckhauser, "Extending the Theory to Meet the Practice of Insurance," in *Brookings-Wharton Papers on Financial Services*, ed. R. Herring and R. E. Litan, 1–53 (Washington, DC: Brookings Institution Press, 2004); and H. Kunreuther, M. V. Pauly, and S. McMorrow, *Insurance and Behavioral Economics: Improving Decisions in the Most Misunderstood Industry* (New York: Cambridge University Press, 2013).

2 A. Tversky and D. Kahneman, "Availability: A Heuristic for Judging Frequency and Probability," *Cognitive Psychology* 5, no. 1 (1973): 207–33.

3 E. Michel-Kerjan, S. Lemoyne de Forges, and H. Kunreuther, "Policy Tenure under the U.S. National Flood Insurance Program," *Risk Analysis* 32, no. 4 (2012): 644–58.

4 D. Kahneman, *Thinking, Fast and Slow* (New York: Farrar, Straus and Giroux, 2011).

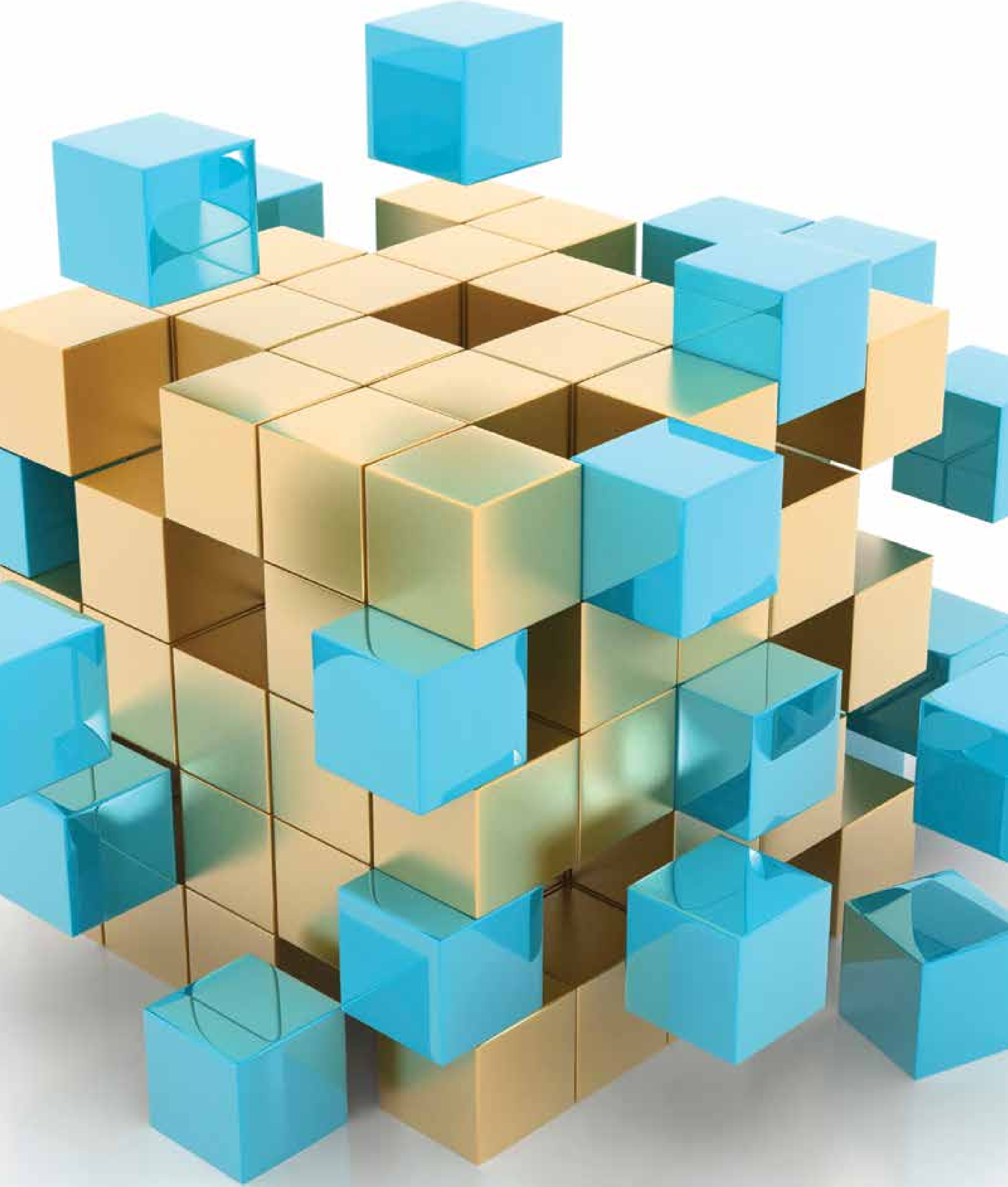


Photo: sarathsasidharan

Changing the Risk Paradigm

Reducing Losses and Exploiting Opportunities

Dr. Emily Wilkinson, Research Fellow, Overseas Development Institute

Introduction

Do risk assessments shape public investment decisions? Can they be used to leverage further development benefits? These are important questions for the Understanding Risk community and in particular for those interested in decision-making and public investment related to disaster risk management (DRM).

Background/Concepts

Whether disaster risk and climate change vulnerability assessments work in changing investment patterns is not entirely clear. Communities of donors, researchers, and practitioners are certainly wasting a lot of money if risk assessments are not actually informing decision making. According to Kamal Kishore of the United Nations Development Programme (UNDP), a significant percentage of internationally supported risk assessments undertaken as part of disaster risk reduction capacity development programs are not used for decision making. Critically, cost-benefit analysis, which is used elsewhere in public policy to inform investment decisions, and particularly capital investments, is not helping to promote ex ante risk management measures. The problem is that these studies often compare apples and oranges: $1 now in this investment period, during the current administration, versus $4 when a disaster occurs in an unknown future, when someone else will have to pay out. When budgets are stretched there is heavy competition for funds, and dollars saved on disaster recovery might not be your dollars.

Nonetheless, there are useful examples of where studies and disaster risk models have been influential. The key to effective uptake has a number of dimensions and is probably specific to the context and the scale at which risk is being studied; but generic characteristics of a good risk assessment include high levels of engagement with the end-users from the start. Process is as important as the final product.A related issue is how the loss-centered focus of DRM could be reformulated to consider the wider economic benefits and opportunities of DRM investments. If we figure out how the analysis of DRM costs and benefits can better capture these co-benefits, we can begin to shift the narrative away from focusing on losses toward promoting action.

Case Studies

Risk assessment is the foundation of good DRM, but according to Jolanta Kryspin-Watson, Senior DRM Specialist and Regional DRM Coordinator at the World Bank, often one needs more than a risk assessment to trigger action and investment decisions. In large cities like Istanbul and Metro Manila, the risk reduction needs may seem overwhelming, and governments have to take decisions on where to start. Methodologies therefore need to be developed for ranking and prioritizing investments with all parties involved: financiers, beneficiaries, and technical staff.

However, if a large event has not occurred for a long time, disaster risk is not part of the public psyche.

The question in this case centers on "if" an event will happen, not the magnitude of costs. Schools in Manila are vulnerable to earthquakes, and the moral aspects of protecting children catches the attention of governments and communities. According to the recently conducted study,[1] retrofitting just 5 percent of the most vulnerable schools (about 200) could result in saving 25 percent of the student population (about 7,000 children). If the seismic retrofitting expanded to 40 percent of most vulnerable schools (about 1,500 buildings), this could bring an estimated 80 percent reduction in potential fatalities (19,000 lives saved). This is a very compelling argument to prompt governments to take action. In Istanbul, 800 public buildings have been retrofitted through a World Bank–supported project, and this successful program increased retrofitting investments for public facilities by at least threefold. As observed in Turkey, retrofitting could also bring additional important benefits, such as a reduction in energy consumption, which would help the environment as well as reducing risks. All these opportunities and potential benefits need to be well presented to decision makers so that they look beyond simply the possibility of an earthquake occurring in the next 100 years.

In Mexico, CAT bonds and other financial tools have been developed to finance reconstruction, but this annual expenditure is not without its critics. Not everyone in government is convinced of the need to spend money on risk transfer when there may be nothing to show (no hazard event) during that fiscal year. This situation is more difficult when it comes to investment in infrastructure for mitigation and risk reduction, which implies larger expenditures. These attitudes are beginning to change thanks to a high-magnitude event and a federal government decision to invest in protective infrastructure. After the Tabasco floods in 2007, the Mexican government invested heavily in flood defense throughout the state to protect farmland, infrastructure, and housing from recurrent floods. Three years later a similar level of rainfall occurred, but these investments helped prevent damage. Loss reduction was three times larger than the cost of building flood defenses. The benefits in loss avoidance are not usually visible within the same political term, but studying cases like Tabasco is helping to make these benefits more visible and change views toward investments of this kind.

UNDP's experience working on DRM has gone through some major shifts, in part because 15 to 20 years ago, most governments were not basing their priorities for DRM on risk assessments. Since then governments themselves have realized that stronger evidence is needed for making decisions. Most disaster risk reduction programs now include a component on disaster risk assessments. However, risk assessments often remain only one of the several "components" of programming, rather than the foundation for all the other elements. As a result, underuse of risk assessments remains a problem.

> Some questions posed during the session: How do you create public demand for disaster risk reduction? Is the lack of investment in DRM just a communication problem? Is a new narrative needed for the development community to take risk seriously? Should risk assessments conform to some minimum standards or principles?

To have any impact, risk assessments undertaken (or commissioned) by UNDP need to respond to the development aspirations of the country. They need to address multiple hazards; in fact, an approach based on a single hazard will quickly run into problems. A careful balance also needs to be struck between building local capacity through the risk assessment (to undertake studies in the future and interpret the data) and a service delivery approach. Post-disaster recovery and particularly resettlement planning after major events provide a unique opportunity to promote the use of risk assessments for making critical decisions. In most cases, however, risk assessments take too long in the aftermath of a disaster, and affected communities often rebuild in high-risk areas in the meantime.

Research conducted by a group of Latin American academics for the Climate and Development Knowledge Network (CDKN) has also shed light on some common obstacles to the uptake of risk assessments in public investment decisions.[2] Risk assessments have had little impact on DRM practice when they are carried out as separate projects—that is, when they do not form part of a broader risk management process that involves decision makers at different scales. More attention needs to be paid to the way that assessments are presented to decision makers, and this may require "translation" of risk information into concrete recommendations for priorities and actions.

More generally, risk assessments and DRM should be seen as part of a broader process of reducing risk through development planning and investment, one that engages end-users by design, not as an afterthought. Scale is critical here; the complexity of data and scale of analysis should be consistent with the level at which decisions about development need to be taken. Researchers found that risk assessments tended to succeed in informing decisions on how to allocate funds when they were targeted at the specific sectors that are most affected by disaster and that are natural allies of DRM, such as water and agriculture. Reducing disaster risk should always be considered alongside other priorities and the need to invest and take risks in order to develop—which suggests once again that risk assessments need both to be more holistic in scope and to target critical sectors.

Conclusions

So how can we go beyond a loss-centric view of DRM and a negative discourse to an approach that captures the wider range of benefits associated with building resilience? In addition, from a political economy perspective, what is the best way to encourage decision makers to consider disaster and climate risks and incentivize greater investment in risk management? It seems clear that the co-benefits of particular DRM initiatives and investments need to be better understood. Reducing risk in one location may undermine the resilience of particular groups in another, so linking "types" of DRM investments to particular social and economic benefits is key. To develop more holistic risk assessments and methods for cost-benefit analysis, a deeper understanding of the potential co-benefits is needed, along with a better sense of how policy design and implementation shape these outcomes. This evidence can then be used to deliver a compelling logic to decision makers, so that investing in DRM is seen as beneficial regardless of whether a disaster occurs.

To develop more holistic risk assessments and methods for cost-benefit analysis, a deeper understanding of the potential co-benefits is needed, along with a better sense of how policy design and implementation shape these outcomes. This evidence can then be used to deliver a compelling logic to decision makers, so that investing in DRM is seen as beneficial regardless of whether a disaster occurs.

Contributors to the session

Lead: Tom Mitchell, Head of Climate Change, Overseas Development Institute

Panelists

Jolanta Kryspin-Watson, Senior Disaster Risk Management Specialist, World Bank Group, East Asia and the Pacific

Juan Miguel Adaya Valle, Director of Risk Analysis, Ministry of Finance and Public Credit, Mexico

Kamal Kishore, Program Adviser, United Nations Development Programme, Bureau for Crisis Prevention and Recovery

Emily Wilkinson, Research Fellow, Overseas Development Institute

Swenja Surminski, Senior Research Fellow, Grantham Research Institute, London School of Economics and Political Science

Endnotes

1 World Bank, *The Philippine Safe and Resilient Infrastructure Program: Development of Earthquake Strengthening Guidelines and Prioritization Methodology* (Washington, DC: World Bank, 2014).

2 E. Wilkinson and A. Brenes, "Risk-Informed Decision-Making: An Agenda for Improving Risk Assessments under HFA2," Climate and Development Knowledge Network, London, 2014, http://cdkn.org/2014/04/report-an-agenda-for-risk-informed-decision-making/.

Photo: Design Pics

Science, Politics, and What We Value

How Big Is the Risk of Climate Change?

Simon Sharpe, Head of Climate Risk Team at Science, Innovation and Climate Department, Foreign and Commonwealth Office

Decisions made about adapting to climate change increasingly make use of risk assessment as a matter of course. As the Intergovernmental Panel on Climate Change (IPCC) recently pointed out, risk assessment could be equally relevant to decisions about climate change mitigation.[1] But what would a mitigation-relevant climate risk assessment look like? This session suggested a possible framework.

According to Trevor Maynard, any risk assessment should follow these key principles:

1. Concentrate effort on the largest risks.

2. Base analysis on the best available information: where science is available, use it.

3. Avoid the dangers of averaging, which can understate or obscure extreme risks.

4. Carry out continual reassessment of the risk.

5. Cater for human factors by taking into account the possibility of human error and the risks arising from human behavior.

6. Take account of uncertainty by ensuring that the risks with the largest impacts are considered, even if their probability is very low or is itself uncertain.

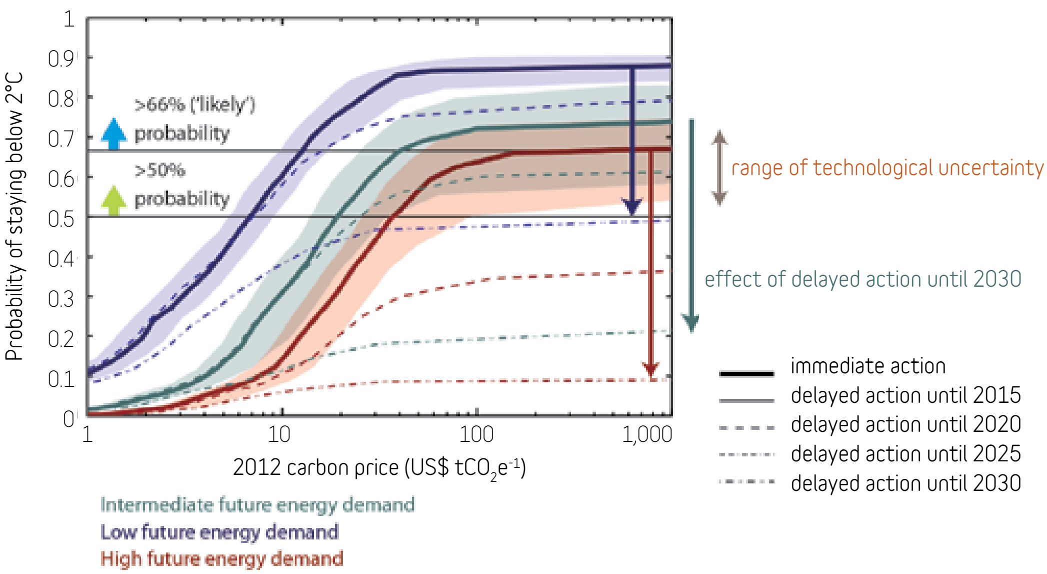
In a climate change risk assessment, the "best available information" includes political as well as scientific analysis, because the scale of the risk depends considerably on policy choices regarding carbon emissions. Analysis by Dr. Bill Hare shows that the aggregate effect of all countries' current policies is to keep the world on a pathway of high and rising carbon emissions. Projections indicate that, absent further and substantial policy action, emissions will continue to increase. One of the main drivers of increases in the future is the carbon intensity of the energy system: substantial decreases in carbon intensity, sustained over many decades, are needed for the world to get onto a 2°C pathway. Trends at present are in the wrong direction: whereas the carbon intensity of the global energy supply decreased from the 1970s until around 2000, in the last decade it has begun to increase again, driven by increases in coal use in a number of regions.

The analysis shows further that achieving a low-emissions pathway consistent with limiting climate change to below 2°C is still possible, but it will depend far more on the timing of political action to reduce emissions than on either the availability of technology or the economic costs (see figure 1). Current policies put the world on an emissions pathway where the middle estimate of temperature increase by the end of this century is around 3.7°C, with a 35–40 percent chance of exceeding 4°C.[2]

For any emissions pathway, the degree of temperature rise is highly uncertain. Professor Jason Lowe showed that according to a probability distribution of equilibrium climate sensitivity, which was estimated by combining information from observation and a range of complex climate models, the very low emissions pathway—Representative Concentration Pathway (RCP) 2.6—may have a 50 percent chance of limiting temperature rise to 2°C, but it also has a chance (perhaps 5 percent) of exceeding 3°C by 2100. Moreover, while the median estimate for the high emissions pathway RCP 8.5 in this study may be a temperature increase of around 5.5°C by 2100, this pathway also has a significant probability of exceeding 7°C (see figure 2).

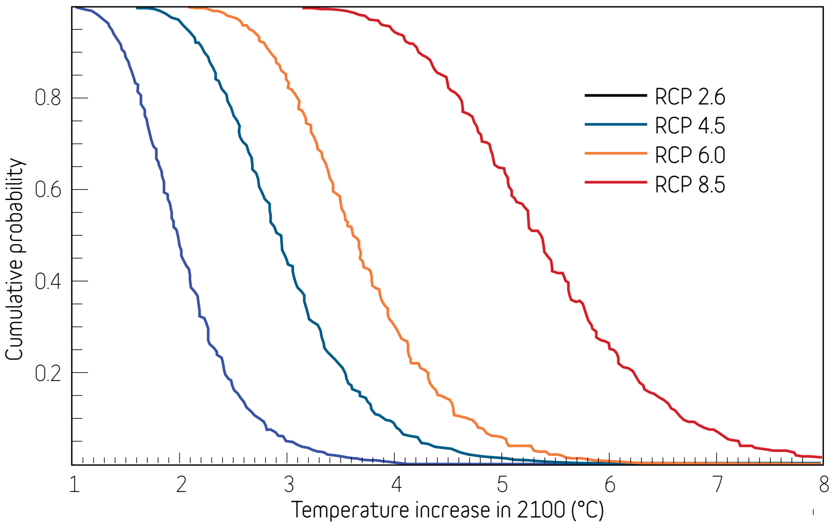
Jason Lowe explained that these estimates did not include the effect of many Earth system feedbacks (other than the carbon cycle-climate interactions), which could increase temperatures further. A first attempt to quantify this additional temperature increase for RCP2.6, the low emissions pathway, yielded a central estimate of around 0.5°C added to the median warming, within a wide range—from a very slight reduction in warming to additional warming of more than 1°C. Even these estimates do not take account of the potential

Figure 1. Probability of limiting temperature increase to 2°C as a function of carbon price, for high, medium, and low energy demand pathways. Shaded bands and the double-sided arrow show how this probability is affected by technological uncertainty; other arrows show how it is affected by delaying significant political action until 2030, in this model represented by imposing an equivalent global carbon price.



Source: J. Rogelj et al., "Probabilistic Cost Estimates for Climate Change Mitigation," *Nature* 493 (2013): 79–83. © J. Rogelj. Used with permission; further permission required for reuse.

Figure 2. Probability of temperature increase by 2100 for the emissions of the four Representative Concentration Pathways used by the IPCC, as estimated by a combination of complex climate models.



Source: Met Office Hadley Centre, AVOID program.

feedback effect of methane hydrates, which has not yet been quantified but which could increase warming even further.

Humans are uniquely able to adapt to changes in our environment. But as Professor Alistair Woodward explained, this capability is not unlimited. He gave three examples of where humans might bump up against these limits:

1. While sea level rises gradually, the risk of flooding can increase exponentially. For example, the Thames Barrier is designed to protect London from a 1-in-1,000-year storm surge. With 50cm of sea-level rise, the frequency of such a storm surge would increase to once in 120 years, and with 1m of sea-level rise, it would increase to about once every 12 years.[3] London has extensive plans in place to adapt its defenses to manage this risk, but depending on how high and how fast sea level rises, some less well-defended coastal cities may encounter limits to their ability to adapt.

2. As a consequence of plant biology, crops have upper limits to the temperatures they can tolerate. Breeding more heat-tolerant varieties of the major crops has so far proved difficult. As temperatures rise, these limits may be exceeded—causing crop failure—with increasing frequency. In the medium to long term, this situation could threaten the health and viability of many human settlements.

3. The human body has an upper limit to the degree of heat stress it can tolerate. Heat stress already limits outdoor labor productivity in hot parts of the world and can be fatal. However, in the present climate, no place on Earth ever experiences conditions that exceed wet-bulb temperatures of 35°C, when any prolonged exposure (even resting in the shade, while doused with water) would be fatal.[4] These conditions would be expected in some parts of the world with a temperature increase of 7°C, and across large regions with an increase of 10°C above present levels (see figure 3).

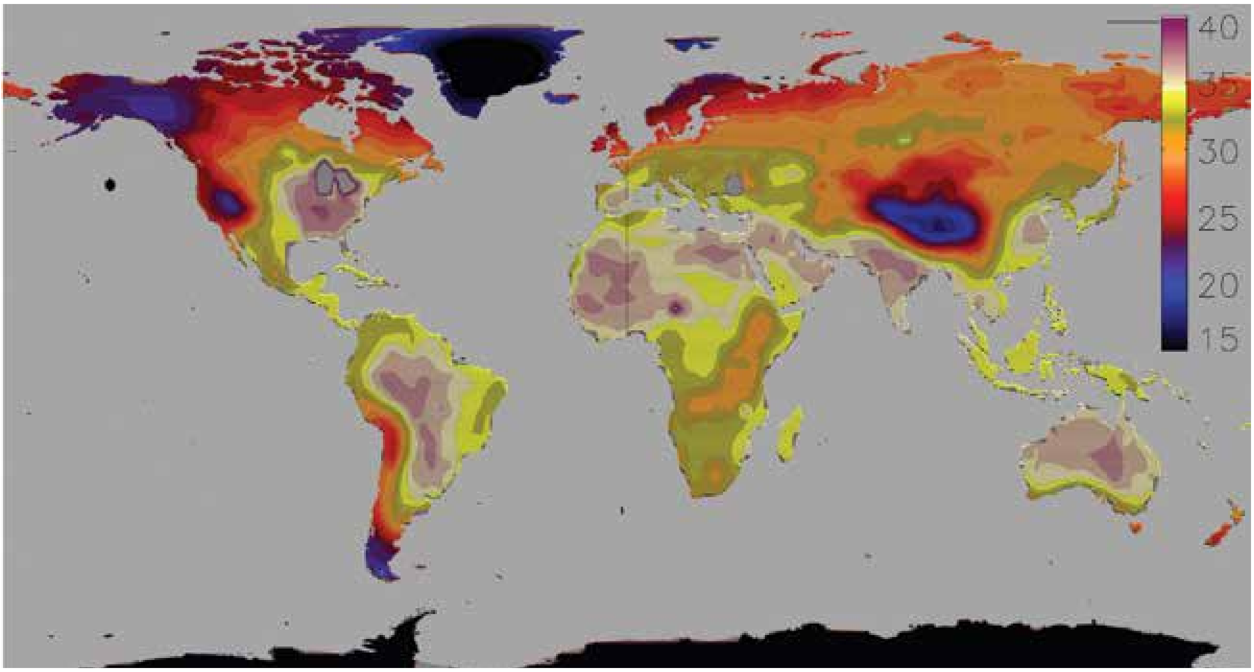
Rachel Kyte closed the session by observing that the time has come when critical choices affecting the human future must be made. In order to make these choices, both individually and collectively, we need to have a full understanding of the risks. Estimates of the economic costs of climate change are improving; but as Rachel Kyte explained, systemic risks such as the disruption of food markets, state failure, uncontrolled migration, and conflict are better understood in terms of human cost than in terms of economic cost. How to value human cost is inescapably an ethical and moral choice. Risk has been defined as "the effect of uncertainty on objectives."[5] The question remains: What *are* our objectives for the future of humanity?

Contributors to the session

Trevor Maynard, Head of Exposure Management and Reinsurance, Lloyds of London

Dr. Bill Hare, Director, Climate Analytics

Figure 3. Peak annual wet-bulb temperature in a climate where global average temperature is 10°C above the present temperature. The upper limit of human physiological tolerance for heat stress is reached at a wet-bulb temperature of about 35°C.



Source: S. C. Sherwood and M. Huber, "An Adaptability Limit to Climate Change due to Heat Stress," *PNAS* (2010): 9552–55. © S. C. Sherwood and M. Huber. Used with permission; further permission required for reuse.

Professor Alistair Woodward, Professor of Epidemiology and Biostatistics, University of Auckland

Professor Jason Lowe, Head of Knowledge Integration and Mitigation Advice, UK Met Office Hadley Centre

Rachel Kyte, Vice President and Special Envoy for Climate Change, World Bank Group

Endnotes

1 IPCC, "Summary for Policymakers," in *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects.* Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, ed. C. B. Field et al. (Cambridge and New York: Cambridge University Press, 2013).

2 These estimates do not take account of the Earth system feedbacks, which are discussed in the following section.

3 Data are from Proudman Oceanographic Laboratory, as cited in *From Ice to High Seas: Sea-Level Rise and European Coastlines*, ice2sea Consortium, Cambridge, UK, 2013, http://www.ice2sea.eu/2013/05/14/from-ice-to-high-seas/.

4 Wet-bulb temperature is "the lowest temperature that can be obtained by evaporating water into the air." NOAA's National Weather Service, "Glossary," http://w1.weather.gov/glossary/index.php?letter=w.

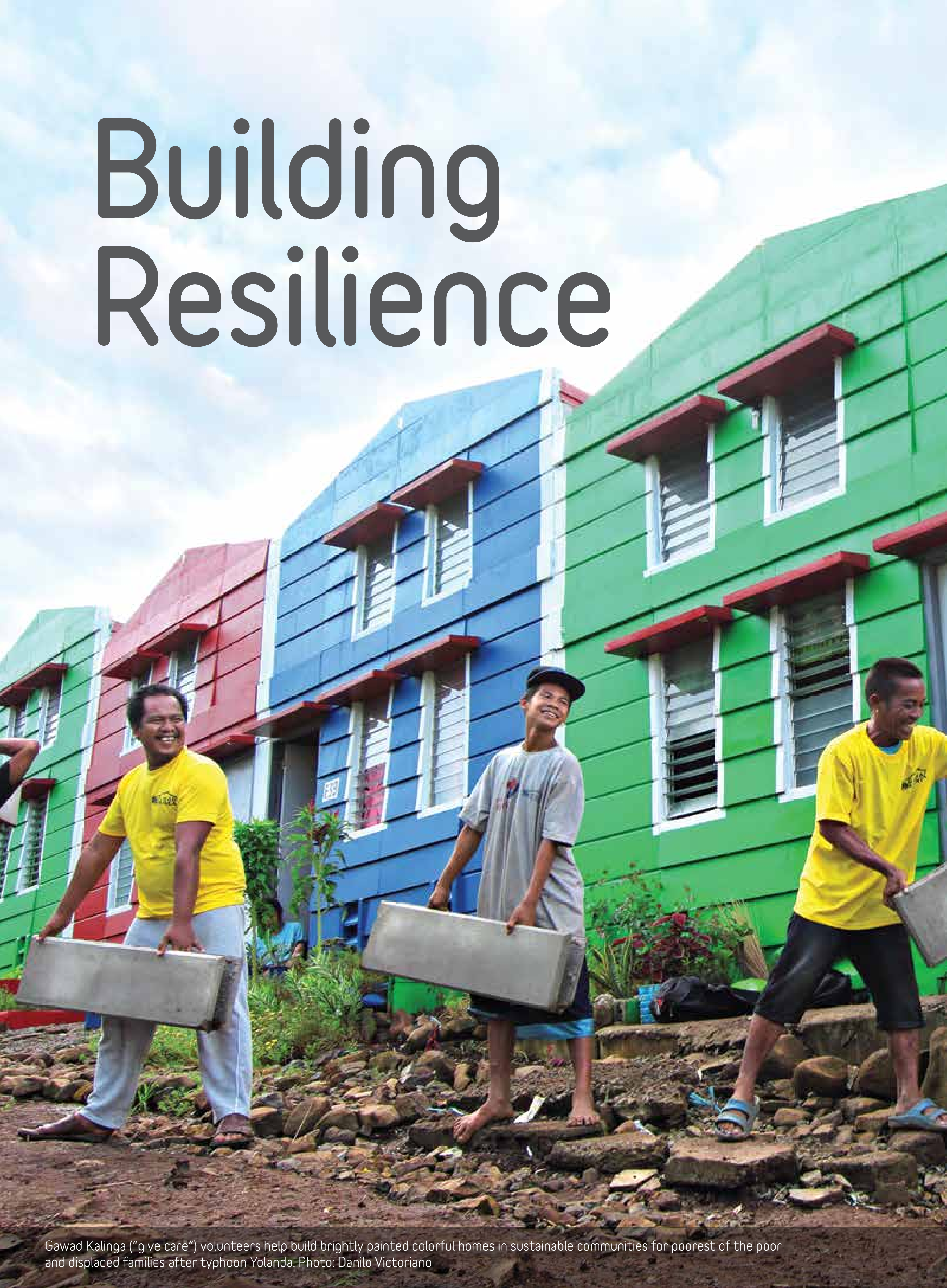
5 The definition is used by the International Organization for Standardization.

Further resources

- Glen P. Peters et al., "The Challenge to Keep Global Warming below 2 °C," *Nature Climate Change* 3 (2013).
- Berta Sánchez, Anton Rasmussen, and John R. Porter, "Temperatures and the Growth and Development of Maize and Rice: A Review," *Global Change Biology* 20, no. 2 (2014): 408–17.
- Tim Reeder, Jon Wicks, Luke Lovell, and Owen Tarrant, "Protecting London from Tidal Flooding: Limits to Engineering Adaptation," in *Adapting to Climate Change: Thresholds, Values, Governance,* ed. W. Neil Adger, Irene Lorenzoni, and Karen L. O'Brien, 54–63 (Cambridge: Cambridge University Press, 2009).
- Nick Stern, "The Structure of Economic Modeling of the Potential Impacts of Climate Change: Grafting Gross Underestimation of Risk onto Already Narrow Science Models," *Journal of Economic Literature* 51, no. 3 (2013): 838–59.
- Oliver Bettis, "Risk Management and Climate Change: Risk of Ruin," Grantham Research Institute on Climate Change and the Environment, London, 2014.

Antartic iceberg. Photo: goinyk

Building Resilience



Gawad Kalinga ("give care") volunteers help build brightly painted colorful homes in sustainable communities for poorest of the poor and displaced families after typhoon Yolanda. Photo: Danilo Victoriano

Photo: Michal Rozewski

Back to the Drawing Board

Hayley Gryc, Associate, Arup International Development
Dr. Damian Grant, Associate, Arup Advanced Technology
Professor Robin Spence, Director, Cambridge Architectural Research Ltd.
Dr. Matthew Free, Director, Arup Geohazard and Risk Management
Jo da Silva, Director, Arup International Development

Introduction

In delivering the ninth Brunel Lecture on behalf of the Institution of Civil Engineers in 2012, Jo da Silva, the director of Arup International Development, offered two key messages. First, much of the increase in risk now taking place is concentrated in urban settings, and we need to pay more attention to the role the built environment plays in enhancing or compromising the resilience of communities, particularly in rapidly growing towns and cities. Second, uncertainty is a reality, whether it is due to climate change or the complexity of our cities, and it is therefore harder to pursue traditional risk management practices that start with understanding (and quantifying) risk in order to prevent or mitigate its consequences.[1]

These messages remain relevant today as engineers and planners rethink how they communicate risk and how they design to mitigate risk.

Building Standards

Damage to buildings and infrastructure as a result of natural disasters often stems from the failure to adhere to an appropriate building code. In the 2010 Haiti earthquake, over 300,000 people were killed when buildings collapsed; but a month later, a much more powerful earthquake in Chile killed less than a thousand people and resulted in the collapse of far fewer buildings. This difference was due to Chile's rigorous enforcement of its building code since a series of earthquakes struck in the 1960s. In Haiti, where no significant earthquake had hit since 1942, building regulations were nonexistent and construction quality was very poor.

Building codes are recognized as important mechanisms for reducing disaster risk. But they are effective only if they are current, if they reflect local forms of construction and perceptions of risk, and if they are part of a wider culture of safety, education, and training, as well as legislation and enforcement. One recurring problem with building codes is that they are often overly complex, which hinders the ability and willingness of the construction industry, developers, and government to adopt them.

Even appropriately designed building codes alone, however, are not enough to prevent damage. Avoiding areas with high levels of exposure and preserving natural defenses are both critical to reducing the risk to natural hazards. Land-use plans and planning guidelines are therefore as important as, if not more important than, building codes for reducing exposure and vulnerability.

Building Performance

Modern building codes still do not focus on resilience, understood as the ability of an organization or community to recover quickly after an earthquake. In fact, the basic objective of these codes has not really changed in over 50 years, when the first modern seismic codes were introduced. Their main purpose is to safeguard against loss of life, not necessarily to limit damage or maintain functionality after a design-level earthquake. A design-level earthquake on the West Coast of the United States generally has around a 500-year return period, though this varies from location to location. Building codes allow structural damage as long as people can safely exit the building. In fact, to protect people, the building code relies on significant damage to dissipate energy and reduce the earthquake forces on the building.

"Life safety" therefore entails significant damage to both structural and nonstructural building elements. This damage may not be acceptable in all cases, and may not be what the client, public, or other stakeholders were expecting. Acceptable seismic performance is case-specific. For a critical manufacturing facility, significant building downtime may mean relocation of many people or inability to carry out business; damage to a historic church may result in the loss of irreplaceable works of art; damage to a space observatory in Chile may result in the failure to image a once-in-a-lifetime astronomical event. All of these will be considered unacceptable risks. Performance objectives should therefore be part of the initial conversation between client and engineer. Moreover, it must be remembered that seismic performance issues go beyond individual buildings to the related physical and social infrastructure; there is no use having an office or data center that is fully occupiable and ready for business if there is no water or electricity available, or if the employees are injured in their homes and cannot return to work.

Engineers are now developing tools to better compute and communicate expected seismic performance to stakeholders.[2] These tools will help owners, engineers, and architects achieve "beyond-code" resilience objectives by identifying limitations in the traditional code approach; they involve adopting some codified criteria for essential facilities, adopting non-codified best-practice approaches, or creating new approaches as needed.

Casualties

The last decade witnessed the highest annual death rate from earthquake-related disasters over the last 100 years. Allowing for population growth, the statistics show that in richer countries the death rate has been sharply reduced, but in poorer countries, there is no evidence of any sustained reduction in the death rate. Despite vast improvements in earthquake science and engineering knowledge, the number of casualties in earthquakes has continued to rise decade on decade; and given current patterns of uncontrolled urbanization, we face the prospect of a "million-death earthquake" in the not-too-distant future.

Though tsunamis have been responsible for most casualties in the last decade, in most other earthquake events, the vast majority of casualties were the result of building collapse. Factors affecting the mortality rate in any

Case Studies

In 2013 Arup undertook a project to reduce the risk and strengthen the resilience of Turks and Caicos Islands by improving the quality of the built environment. Hurricane Ike in 2008 had highlighted the critical influence of both the natural and manmade environment on the risks posed by natural hazards. According to a United Nations survey, a substantial reason for the damage sustained was that the building code was out of date. Big gaps also existed in the planning regulations. Both these issues characterize many small island developing nations globally, but they are capable of quite rapid improvement. In the case of Turks and Caicos Islands, the project to reduce risk and strengthen resilience sought both to update the building code and create a road map to address gaps relating to physical planning and environmental sustainability.

Using the International Building Code as a reference, the existing building code was updated. It now reflects local forms of construction and perceptions of risk, and hence is applicable, accessible, and relevant. The project identified key issues that could affect the extent to which the code would contribute to reducing risk, and offered simple, practical solutions to the government.

one event are the type of building and mode of collapse, the pattern and sequence of earthquake ground motion, the time of day of the event, occupants' behavior, and the effectiveness of search and rescue. With all these factors in play, predicting likely casualty rates in future events is difficult.

Reducing casualty rates in the future will depend on improving the quality of design and construction for the building stock in earthquake-prone areas. The principal target must be the poorly built multistory housing in rapidly urbanizing developing countries, such as Iran, Colombia, Nepal, and Turkey. To help achieve this goal, a five-point plan is proposed:

1. Improve codes of practice for design of new buildings.
2. Improve building control.
3. Implement safe building programs for non-engineered buildings.
4. Strengthen programs for high-risk buildings.
5. Guide future urban development.

Modelling

Several important elements connect many of the risk-contributing factors highlighted above, including their geographic dimension, the distribution of buildings of different types, the distribution of the population day and night, the distribution of businesses and other activities, the connectivity of the infrastructure that joins the elements of the built environment and society together, and the infrastructure that permits the emergency services to respond. Geographic information system (GIS) models of the built environment, the occupants, and other geographical context provide a useful tool for gaining an improved understanding of risk and for engineering effective risk management strategies.

Natural disasters (earthquakes, floods, wind storms) are uncommon, but they can be investigated by modelling events that impact different areas, occur over different ground conditions, follow population growth, or take place at different times of day or night. This approach offers lessons about hazards and risks, and permits appropriate risk management strategies to be engineered. These GIS models are most effective when built from the bottom up, with the individual buildings, infrastructure components, and their connectivity and dependencies defined using parameters based on the results of engineering analysis that begin back on the engineer's drawing board.

The performance of people in these analytical models is traditionally defined using empirical data (i.e., statistics of casualties observed as a result of an earthquake). However, engineers can now also effectively model avatars of people in the built environment to investigate the behavior of populations during defined events, an innovation that leads to improved understanding of risk and allows risk management strategies to be engineered.

Conclusion

Based on an increased understanding of risk, practitioners are pushing forward the frontiers of engineering practice to focus on reducing vulnerability and fostering resilient communities. Both environmental policy and building regulations play an important part in reducing risk.

As engineers come to better understand the performance of buildings, they are able to reduce damage and in this way promote business continuity and lower the cost of repairs. As they come to better understand human behaviors and capacity, moreover, they will be able to take timely and appropriate action to reduce risk and to communicate risk through spatial modelling of urban areas.

Contributors to the session

Jo da Silva, Director, Arup International Development

Dr. Damian Grant, Associate, Arup Advanced Technology

Professor Robin Spence, Director, Cambridge Architectural Research Ltd.

Dr. Matthew Free, Director, Arup Geohazard and Risk Management

Endnotes

1 For a discussion of the challenge of assessing risk in rapidly evolving urban settings, see "Rome May Not Have Been Built in a Day, but Urban Exposure Now Changes Daily" in this publication.

2 An example is Arup's REDi Rating System guidelines, available at http://publications.arup.com/Publications/R/REDi_Rating_System.aspx.

A man-made forest helps restore an ecosystem damaged by quarrying operations. Healthy forests lower soil erosion, decrease river sediment loads, and protect against flash floods. Photo: Danilo Victoriano

The Role of Ecosystems in Reducing Risk

Advances and Opportunities in Risk Assessment and Risk Management

Imen Meliane, Director, 7 Seas Foundation
Mark Spalding, Senior Marine Scientist, Nature Conservancy
Bregje van Wesenbeeck, Senior Adviser, Deltares
Borja G. Reguero, Postdoctoral Fellow, University of California–Santa Cruz and the Nature Conservancy
Zach Ferdaña, Senior Marine Conservation Planner, Nature Conservancy
Iñigo J. Losada, Research Director, Environmental Hydraulics Institute "IH Cantabria"

Introduction

Future coastal storms, flooding, and sea-level rise will affect millions of vulnerable people along with critical infrastructure, industry, tourism, and trade. The significant losses to economies that we see today will likely continue to increase over the coming decades, driven by coastal development and changing hazards. A study estimates that between 2005 and 2050, socioeconomic factors (such as population growth and urbanization) alone will increase average annual global flood losses ninefold, to US$52 billion a year. With no adaptation, risks from sea-level rise and land subsidence could bring total flood damage for large coastal cities up to US$1 trillion a year.[1] These low-lying coastal areas house some of the most socially vulnerable people—those with little ability to resist hazards or to recover from storm damage.

Investing in nature-based solutions—through conservation, enhancement, or restoration of ecosystems—is often a cost-effective option for increasing resilience. Ecosystems, particularly reefs and wetlands, prevent, mitigate, and regulate hazards (e.g., flooding, avalanches, heat waves) by acting as natural buffers and reducing people's exposure; they also reduce vulnerability to hazard impacts by supporting livelihoods and economies and provisioning key services (food, water, shelter)

Decision makers face various challenges and trade-offs in addressing the multiple management objectives of nature conservation, economic development, and risk management. Interactive, scenario-based tools help them consider and integrate social, ecological, and economic considerations in adaptation and risk reduction planning; they also help to engage stakeholders in finding suitable solutions.

before, during, and after impacts.[2] While many of these functions have been qualitatively described, there are fewer studies that assess them quantitatively.

As a result, risk reduction functions of ecosystems are often unaccounted for in projections of risk. Ecosystem loss and degradation can lead to increased vulnerability and economic and social losses.[3] As a risk driver, ecosystem services condition the resilience of communities and businesses, thereby influencing whether disaster loss cascades into a wider range of long-run socioeconomic impacts.[4] But the failure to account for this influence tends to hide the real cost of disasters[5] and may lead to ill-fitting resilience strategies with potential long-term impacts. Addressing underlying risk drivers like environmental degradation is the least-implemented priority within the Hyogo Framework for Action.[6]

Recently, momentum has grown for using nature-based solutions in resilience-building strategies, adaptation, and risk management portfolios. Interest from communities, donors, and decision makers is increasing, leading to more research and innovation in this arena.

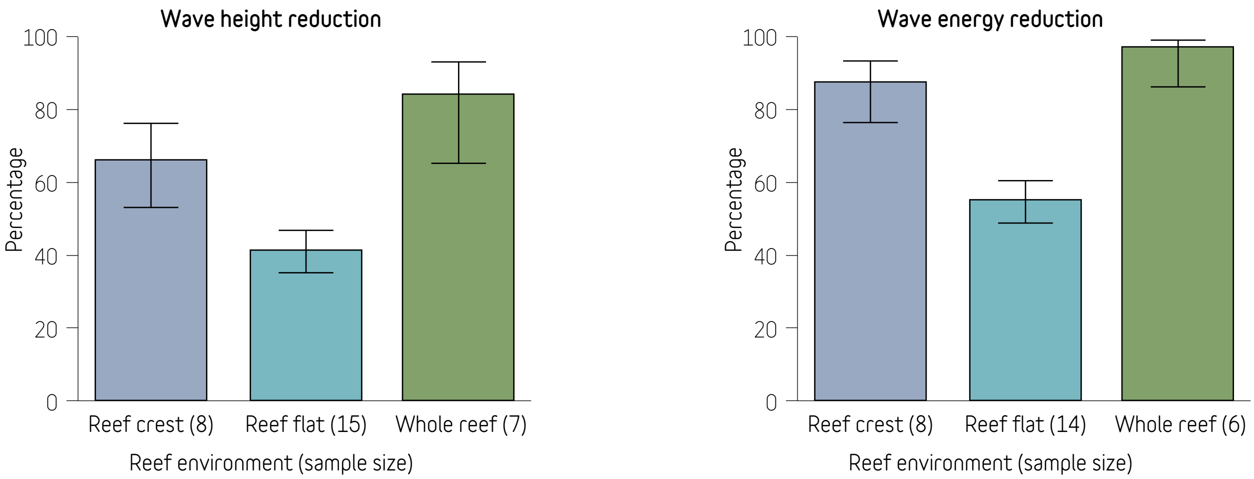
Experience has demonstrated that reef and wetland restoration can be effectively combined with other approaches to reduce risk and financial costs of adaptation, such as by combining ecosystems' natural infrastructure with hard infrastructure like dikes to reduce the latter's height.[7] The challenge is that there is still no consistent approach to estimating the role that nature plays in reducing risk and increasing resilience. Nor is there a clear way to account for the additional benefits that nature provides for development.

Case Studies

Advances in Quantifying Risk Reduction Ecosystem Services of Coastal Ecosystems

Coastal ecosystems, particularly marshes, mangroves, and coral reefs, play a critical role in reducing the vulnerability of communities to rising seas and

Figure 1. Coral reef and wave attenuation meta-analysis results. Values are the average percentage of wave height reduction and wave energy reduction in the three reef environments. Error bars represent a 95 percent confidence interval.



Source: F. Ferrario, M. W. Beck, C. D. Storlazzi, F. Micheli, C. C. Shepard, and L. Airoldi, "The Effectiveness of Coral Reefs for Coastal Hazard Risk Reduction and Adaptation," *Nature Communications* 5 (2014): 3794.

coastal hazards through their roles in wave attenuation, vertical accretion, erosion reduction, and the mitigation of storm surge and debris movement.[8] There is a growing understanding of the range of factors that affect the eficacy of these ecosystem services in different locations, as well as of the management interventions that may restore or enhance their values. Recent studies have quantified the risk reduction functions of mangroves,[9] salt marshes,[10] seagrasses,[11] oyster reefs,[12] and coral reefs.[13] Improved understanding and application of such information will form a critical part of coastal adaptation planning, likely reducing the need for expensive engineering options in some locations, and providing a complementary tool where engineered structures are needed.

Ferrario and coauthors analyzed the role and cost-effectiveness of coral reefs in risk reduction globally.[14] Their meta-analyses revealed that coral reefs provide substantial protection against natural hazards by reducing wave energy by an average of 97 percent, and wave height by 84 percent, with reef crests playing the biggest role. They estimate that some 100 million people living below 10m elevation may receive risk reduction benefits from reefs—or bear higher risks and adaptation costs if reefs are degraded. By dissipating wave energy and influencing hydrodynamics, reefs play a role in the morphodynamics of adjacent beaches and control erosion.[15]

Mangroves can reduce storm surge by slowing the flow of water and reducing surface waves. Mangroves are particularly effective at reducing surface wind waves, with reductions in wave height of 13–66 percent after 100m of passage through mangroves.[16] They can also reduce surge height by 5cm to 50cm per kilometer of mangrove width.[17] Numerical models for wind waves and storm surges have greatly increased our understanding of these processes and the factors that influence the effectiveness of mangroves in coastal protection in different settings.[18]

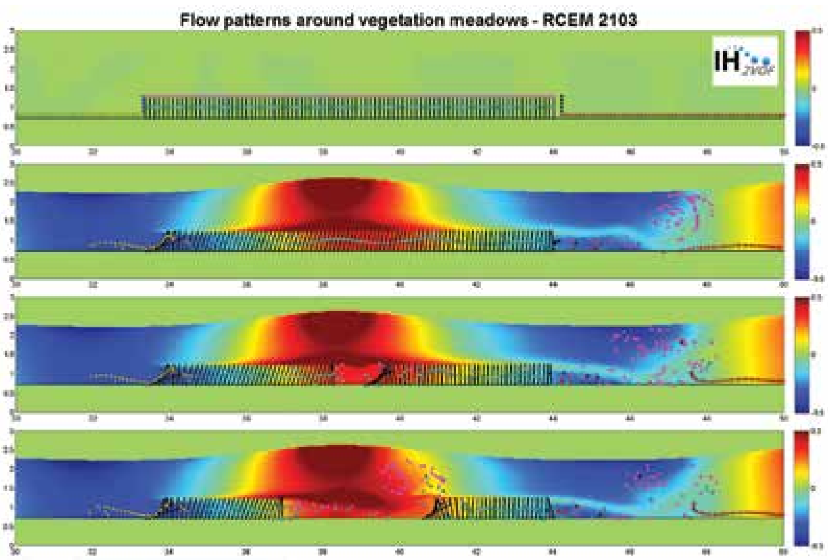
Similar advances have been made for seagrass and salt marsh communities, ranging from laboratory experiments, to the early parameterizations of wave attenuation for coastal vegetation,[19] to sophisticated models capable of modelling different processes of wave propagation and (as shown in figure 2) flow and vegetation interaction at very fine resolutions.[20]

Ecological Engineering of Mangrove Mud Coasts

Traditional protection from flooding—using structural measures such as seawalls and dams—has often resulted in adverse or unforeseen impacts on both local and surrounding ecosystems.[21] Often, hard-infrastructure solutions aggravate erosion problems and subsidence due to unanticipated interferences with sediment flows and soil conditions.[22] Moreover, they do not revive the many additional values and co-benefits of the lost coastal ecosystems.

Engineers have recently begun to experiment with "hybrid engineering" approaches in

Figure 2. Examples of high-resolution numerical models for the study of seagrasses in 2-D.



Source: © M. Maza, J. L. Lara, and I. J. Losada. Used with permission; further permission required for reuse.

an attempt to address delta and coastal vulnerability in an integrated manner and accommodate economic and social development needs. These approaches combine engineering techniques with natural ecosystems and processes, resulting in dynamic solutions that are more suitable to changing circumstances.[23] In a recent report, the U.S. Army Corps of Engineers highlighted an array of nature-based options for integrated risk management.[24]

Hybrid approaches are being used in northern Central Java and Vietnam, where mangrove belts have been promoted as a means to enhance coastal resilience. But mangroves can be successfully restored only if the shoreline morphology (sediment flows, bathymetry, etc.) and connection of the system to the river are rehabilitated as well. With this understanding, Deltares, Wetlands International, and the Indonesian government carried out a project in a location east of Semarang that combined permeable structures (to break the waves and capture more sediment) with engineering techniques such as agitation dredging (to increase the amount of sediment suspended in the water). This approach first stops the erosion process and then allows the shoreline to be accreted to sufficient elevation for mangroves to colonize naturally. The new mangrove belt can further break the waves and capture sediment in the long term.

Coastal Resilience: An Interactive Decision Support Tool

Decision makers face various challenges and trade-offs in addressing the multiple management objectives of nature conservation, economic development, and risk management. Interactive, scenario-based tools help them consider and integrate social, ecological, and economic considerations in adaptation and risk reduction planning; they also help to engage stakeholders in finding suitable solutions. Coastal Resilience is a web-based mapping decision support system backed by the best available science.[25] It lets planners, officials, managers, and communities evaluate various scenarios and cost implications in a specific context, so they can visually appreciate the magnitude of their risks and identify solutions that do not compromise the benefits that nature provides. The system has specific applications that help identify where natural solutions can be used as alternatives to infrastructure. The Risk Explorer app, for instance, combines information on coastal habitats and storm exposure with social vulnerability to assess where habitat loss may increase risks along U.S. coasts. The Coastal Defense app quantifies how natural habitats protect coastal areas by decreasing wave-induced erosion and inundation. It uses standard engineering techniques to calculate the reduction of wave height and wave energy in these habitats. Armed with this information, planners and decision makers are able to understand their risk and vulnerability, and identify appropriate nature-based solutions to increase community resilience.[26]

Coastal Risks, Nature-Based Defenses, and the Economics of Climate Adaptation

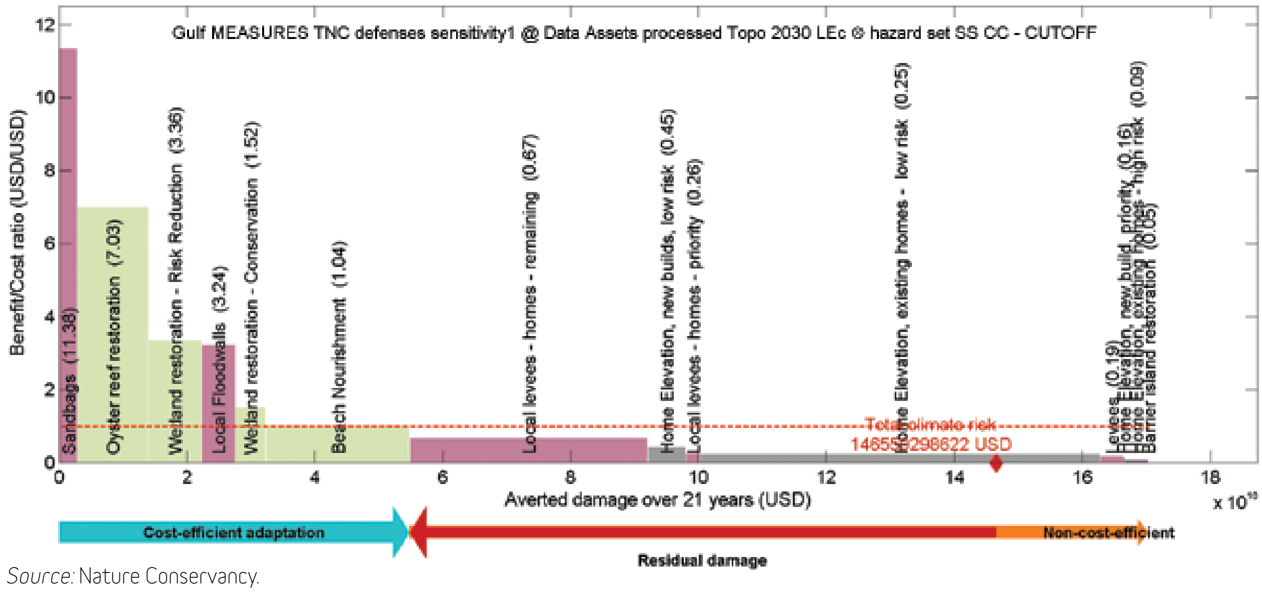
The Nature Conservancy, in collaboration with Swiss Re and ETH-Zurich, recently completed a probabilistic risk assessment in the Gulf Coast. The assessment, which followed the Economics for Climate Adaptation methodology,[27] examined the cost-effectiveness of adaptation options, including ecosystem-based solutions, in coastal areas.

Factoring in different scenarios and timelines for hazards and climate change, socioeconomic assets, adaptation options, and discounting policies, the study analyzed the most relevant factors affecting risk reduction and found that ecosystem-based solutions provide cost-efficient risk reduction across all scenarios (see figure 3). However, they do not provide the greatest risk reduction, particularly in high-intensity events, which points to the need for combining them with other risk reduction strategies in these cases.[28]

Challenges

Although recent years have seen impressive advances in the analysis, design, and implementation of nature-based solutions to climate and disaster risks, a few challenges and gaps remain. To enable the full integration of ecosystem

Figure 3. Benefit-cost curve for a scenario of coastal protection effectiveness and socioeconomic growth.



Source: Nature Conservancy.

services into climate and disaster risk modelling, more field science is needed to better quantify risk reduction functions, and estimate averted losses by ecosystem taking into account local settings. The design rules and testing protocols for ecosystems and their role in risk mitigation have yet to be standardized in applying hybrid engineering approaches. Currently most studies focus on coastal protection functions, but the contribution of ecosystems in reducing social vulnerability and increasing socioeconomic resilience also needs to be quantified. Moreover, as climate change increases vulnerability and even threatens the survival of certain ecosystems, constant management of ecosystem-based strategies will be required.

With the increase in testing and implementation of nature-based approaches, it will be even more important to model and monitor the biophysical interactions and socioeconomic performances in multiple locations. In this way it will be possible both to scale up successful interventions, and to avoid mistakes or unforeseen impacts.

Conclusions

Current and future scenarios for climate impacts and disaster risks have triggered a quest for sustainable adaptation strategies that protect against hazards and strengthen the resilience of the system overall. Ecosystem-based approaches can be used to remedy the limitations of conventional engineering, particularly in highly exposed coastal areas. Recent implementations of these strategies demonstrate that nature-based defenses can be more sustainable and cost-effective than conventional flood defenses, with additional socioeconomic benefits. This result should stimulate further research by engineers, managers, and economists, and motivate donors and governments to further invest in managing and restoring coastal ecosystems as an integral part of their adaptation and disaster risk management strategies.

Contributors to the session

Imen Meliane, Director, 7 Seas Foundation

Andrew Maskrey, Head of Risk Knowledge, UNISDR

Mark Spalding, Senior Marine Scientist, Nature Conservancy

Fernando Mendez, Head of Marine Climate and Climate Change Group, Environmental Hydraulics Institute "IH Cantabria"

Iñigo Losada, Research Director, Environmental Hydraulics Institute "IH Cantabria"

Bregje van Wesenbeeck, Senior Adviser, Deltares

Zach Ferdaña, Senior Marine Conservation Planner, Nature Conservancy

Borja Reguero, Postdoctoral Fellow, University of California-Santa Cruz, and the Nature Conservancy

Kalibo, Aklan, Philippines. The Bakhawan (mangrove) Eco-Park is a 75-hectare community based forest management project, a tourist attraction and the town's first line of defense against strong surges. Photo: Danilo Victoriano

Endnotes

For a further look at the challenges of flood resilience, see "Can Flood Resilience Be Measured?" in this publication. For a discussion of flood modelling, see "'Mission Impossible': Using Global Flood Risk Assessments for Local Decision Making" in this publication.

1 S. Hallegatte, C. Green, R. J. Nicholls, and J. Corfee-Morlot, "Future Flood Losses in Major Coastal Cities," *Nature Climate Change* 3 (2013): 802–6.

2 See W. N. Adger, T. P. Hughes, C. Folke, S. R. Carpenter, and J. Rockström, "Social-ecological Resilience to Coastal Disasters," Science 309 (2005): 1036–39; and F. Renaud, K. Sudmeier, and M. Estrella, eds., *The Role of Ecosystems in Disaster Risk Reduction* (Tokyo: United Nations University Press, 2013).

3 K. K. Arkema, G. Guannel, G. Verutes, S. A. Wood, A. Guerry, M. Ruckelshaus, P. Kareiva, M. Lacayo, and J. M. Silver, "Coastal Habitats Shield People and Property from Sea-Level Rise and Storms," *Nature Climate Change* 3 (2013): 913–18.

4 United Nations Office for Disaster Risk Reduction, *Suggested Elements for the Post-2015 Framework for Disaster Risk Reduction* (Geneva: UNISDR, 2014).

5 United Nations Office for Disaster Risk Reduction, *Global Assessment Report on Disaster Risk Reduction* (Geneva: UNISDR, 2011).

6 United Nations Office for Disaster Risk Reduction, *Suggested Elements for the Post-2015 Framework for Disaster Risk Reduction*, 2014.

7 W. B. Borsje, B. K. van Wesenbeeck, F. Dekker, P. Paalvast, T. J. Bouma, M. M. van Katwijk, and M. B. De Vries, "How Ecological Engineering Can Serve in Coastal Protection," *Ecological Engineering* 37 (2011): 113–22.

8 M. D. Spalding, S. Ruffo, C. Lacambra, I. Meliane, L. Z. Hale, C. C. Shepard, and M. W. Beck, "The Role of Ecosystems in Coastal Protection: Adapting to Climate Change and Coastal Hazards," *Ocean and Coastal Management* 90 (2013): 50–57.

9 A. L. McIvor, I. Möller, T. Spencer, and M. Spalding, "Reduction of Wind and Swell Waves by Mangroves," Natural Coastal Protection Series, Report 1, Nature Conservancy, University of Cambridge, and Wetlands International, 2012; A. L. McIvor, T. Spencer, I. Möller, and M. Spalding, "Storm Surge Reduction by Mangroves," Natural Coastal Protection Series, Report 2, Nature Conservancy, University of Cambridge, and Wetlands International, 2012; and A. L. McIvor, T. Spencer, I. Möller, and M. Spalding, "The Response of Mangrove Soil Surface Elevation to Sea Level Rise," Natural Coastal Protection Series, Report 3, Nature Conservancy, University of Cambridge, and Wetlands International, 2013.

10 C. Shepard, C. Crain, and M. W. Beck, "The Protective Role of Coastal Marshes: A Systematic Review and Meta-analysis," *PLoS ONE* 6, no. 11 (2011): e27374.

11 Barbara Ondiviela, Inigo J. Losada, Javier L. Lara, Maria Maza, Cristina Galván, Tjeerd J. Bouma, and Jim van Belzen, "The Role of Seagrasses in Coastal Protection in a Changing Climate, " *Coastal Engineering* 87 (2014): 158–68.

12 Nature Conservancy, "Re-engineering the Gulf of Mexico: Using Nearshore Wave Modeling to Abate Coastal Erosion by Prioritizing the Most Economically and Ecologically Valuable Sites for Restoration of Oyster Reefs, " Nature Conservancy, 2012, http://coastalresilience.org/geographies/gulf-mexico/coastal-protection.

13 F. Ferrario, M. W. Beck, C. D. Storlazzi, F. Micheli, C. C. Shepard, and L. Airoldi, "The Effectiveness of Coral Reefs for Coastal Hazard Risk Reduction and Adaptation," *Nature Communications* 5 (2014): 3794.

14 Ibid.

15 A. Ruiz de Alegria-Arzaburu, I. Mariño-Tapia, C. Enriquez, R. Silva, and M. Gonzalez-Leija, "The Role of Fringing Coral Reefs on Beach Morphodynamics," *Geomorphology* 198 (2013): 69–83.

16 McIvor et al., "Reduction of Wind and Swell Waves by Mangroves."

17 McIvor et al., "Storm Surge Reduction by Mangroves."

18 For wind wave models, see P. Vo-Luong and S. Massel, "Energy Dissipation in Non-uniform Mangrove Forests of Arbitrary Depth," *Journal of Marine Systems* 74, no. 1-2 (2008): 603–22; and T. Suzuki, M. Zijlema, B. Burger, M. C. Meijer, and S. Narayan, "Wave Dissipation by Vegetation with Layer Schematization in SWAN," *Coastal Engineering* 59, no. 1 (2011): 64–71. For storm surges models, see e.g. K. Zhang, H Liu, Y. Li, H. Xu, J. Shen, J. Rhome, and T. J. Smith III, "The Role of Mangroves in Attenuating Storm Surges," *Estuarine, Coastal and Shelf Science* 102 (2012): 11–23.

19 For laboratory experiments, see V. Stratigaki, E. Manca, P. Prinos, I. J. Losada, J. L. Lara, M. Sclavo, C. L. Amos, I. Caceres, and A. Sanchez-Arcilla, "Large Scale Experiments on Wave Propagation over Posidonia Oceanica, " *Journal of Hydraulic Research*, IAHR 49, Supplement 1 (2011): 31–43. For the early parameterizations, see F. J. Mendez and I. J. Losada, "An Empirical Model to Estimate the Propagation of Random Breaking and Non-breaking Waves over Vegetation Fields," *Coastal Engineering* 52 (2004): 103–18.

20 For modelling of processes of wave propagation, see Suzuki et al., "Wave Dissipation by Vegetation." For modelling of flow and vegetation interaction, see M. Maza, J. Lara, and I. J. Losada, "A Coupled Model of Submerged Vegetation under Oscillatory Flow Using Navier–Stokes Equations," *Coastal Engineering* 80 (October 2013): 16–34, DOI: 10.1016/j.coastaleng.2013.04.009.

21 B. K. Van Wesenbeeck, J. P. M. Mulder, D. J. Reed, M. B. de Vries, H. J. de Vriend, and P. M. J. Herman, "Damming Deltas: A Practice of the Past? Towards Nature-Based Flood Defences," *Estuarine, Coastal and Shelf Science* 140 (2014): 1–6.

22 J. C. Winterwerp, W. G. Borst, and M. B. de Vries, "Pilot Study on the Erosion and Rehabilitation of a Mangrove Mud Coast," *Journal of Coastal Research* 21, no. 2 (2005): 223–31.

23 Han Winterwerp, Bregje van Wesenbeeck, Jan van Dalfsen, Femke Tonneijck, Apri Astra, Stefan Verschure, and Pieter van Eijk, "A Sustainable Solution for Massive Coastal Erosion in Central Java: Towards Regional Scale Application of Hybrid Engineering," discussion paper, Deltares and Wetlands International, 2014.

24 U.S. Army Corps of Engineers, "Coastal Risk Reduction and Resilience," CWTS 2013-3, Directorate of Civil Works, U.S. Army Corps of Engineers, Washington, DC, 2013.

25 Z. A. Ferdaña, S. Newkirk, A. Whelchel, B. Gilmer, and M. W. Beck, "Adapting to Climate Change: Building Interactive Decision Support to Meet Management Objectives for Coastal Conservation and Hazard Mitigation on Long Island, New York, USA," in *Building Resilience to Climate Change: Ecosystem-Based Adaptation and Lessons from the Field*, ed. A. Andrade Pérez, B. Herrera Fernandez, and R. Cazzolla Gatti (Gland, Switzerland: IUCN, 2010).

26 For more information, see the Coastal Resilience website at www.coastalresilience.org.

27 Economics of Climate Adaptation, "Shaping Climate-Resilient Development: A Framework for Decision-Making," Report of the Economics of Climate Adaptation Working Group, 2009.

28 Nature Conservancy, "Coastal Risks and Economics of Climate Adaptation in the US Gulf Coast," forthcoming.

Photo: American Red Cross

How Might Emerging Technology Strengthen Urban Resilience?

American Red Cross
British Red Cross
International Federation of Red Cross and Red Crescent Societies

In an effort to explore how technology can help meet emerging humanitarian needs, the Red Cross/Red Crescent is looking beyond the question of how humanitarian organizations themselves can adopt and adapt new technologies for their work. Rather, with multi-sector partners, we are seeking to strengthen the resilience of urban communities through consumer technologies, including solutions that are (or will become) directly accessible to individuals. This workshop is part of a two-year initiative to consider the humanitarian application of emerging technologies, field test promising ideas, and develop policy recommendations.

Our approach is forward-looking and focuses less on existing technology (such as mobile phones and applications) than on the potential of emerging technologies that, in the future, could support decentralized urban disaster risk management and strengthen community resilience. With climate change and rapid, haphazard urban development increasing the risk and impact of disasters, mega-disasters are happening more frequently; and so-called everyday crises and other stresses are heightening vulnerability and undermining coping capacities. These trends, coupled with growing urban populations, make it essential for organizations to better support community resilience. Doing so will empower people living in urban areas to prepare for and help themselves when shocks and stresses occur.[1]

The Red Cross has identified six characteristics of safe and resilient communities: these communities are (1) knowledgeable and healthy, (2) organized, and (3) connected; they (4) have infrastructure and services, (5) offer economic opportunities, and (6) can manage their natural assets. (See the text box for more detail about each.) A variety of emerging technologies and their novel applications could enhance these characteristics in urban areas.

But any use of technology by communities to strengthen their resilience must be based on real-life situations. In other words, the starting point should not be the technology, but rather the communities themselves, and specifically their core needs and any challenges they may face in managing disaster risk. Needs highlighted by session participants included food security, transportation, shelter, access to soil and green space, land rights, child protection, education, health and nutrition, and water; and challenges included child abuse, forced marriage, refugee situations, chronic displacement, and ongoing disasters.

At the same time, it is important to look at what technology is making possible. The changing role of mobile networks, the use of biometrics as a tool to identify beneficiaries and reduce corruption, and other new technologies—augmented reality, unmanned aerial vehicles, 3-D printers, smart homes/cars, wearables—could all play a role in strengthening community resilience and responding to future disaster situations. Humanitarian organizations may need to begin engaging more directly with private sector producers of technologies. Certainly, it will be important to think about which technologies would be accessible and useful for urban communities, particularly the most vulnerable groups, in the future.

The potential of emerging technologies to strengthen urban resilience is great, but so may be the challenges associated with using these technologies. Challenges likely to be faced include a community's potential lack of trust in the new technologies; a community's diverse capacities and languages; power and political struggles within a community; potential conflicts among communities or community members; increased expectations for rapid response; regulatory shifts and spectrum changes; potential for technology to exacerbate vulnerabilities and divides; low levels of skill in communications and use of technology; resilience of the technology itself (and absence of redundant or fall-back systems); and limited power sources.

Experts point out that any new technologies used by communities to improve resilience should be easily integrated and ideally should be dual-purpose so that they are already in people's hands before (and not only useful during) a disaster. This point is also vital in considering financing, a topic that needs to be addressed if emerging technologies are to be operationalized for disaster risk management and humanitarian response.

In order to successfully harness emerging technologies for resilience, questions about resourcing and implementation will need to be addressed. Who should be financially responsible for the design, prototype development, and trial of new technologies? More thought must be given to new models of cost-sharing that incentivize the private sector and humanitarian organizations to collaborate and invest in this space. One possibility is that large and well-established humanitarian aid agencies could leverage their brands in order to promote trust in these new solutions.

Though the future is always difficult to predict, a few things are indisputable: organizations need to understand emerging technologies and be open to their potential value, and private sector partners and humanitarian agencies need to collaborate to ensure that solutions are driven by the needs of real communities.

Contributors to the session

Co-leads

Abi Weaver, Director, Global Technology Project, American Red Cross

Hugh MacLeman, Head of Humanitarian Policy, British Red Cross

Ryan Freeman, Urban Disaster Risk Reduction and Management, International Federation of Red Cross and Red Crescent Societies

Kyla Reid, Head of Disaster Response, GSMA

Panelists

Samuel Carpenter, Humanitarian Policy Advisor, British Red Cross

Ravi Mattu, Deputy Editor, *Financial Times* Weekend Magazine

Jonathan Cole, Managing Director, Skotkonung Ltd.

Linda Raftree, Co-founder, Kurante

Endnote

1 For a discussion of the challenge of assessing risk in rapidly evolving urban settings, see "Rome May Not Have Been Built in a Day, but Urban Exposure Now Changes Daily" in this publication.

A safe and resilient community . . .

1. Is **knowledgeable and healthy**. It has the ability to assess, manage, and monitor its risks. It can learn new skills and build on past experiences.
2. Is **organized**. It has the capacity to identify problems, establish priorities, and act.
3. Is **connected**. It has relationships with external actors (family, friends, faith groups, government) who provide a wider supportive environment and supply goods and services when needed.
4. Has **infrastructure and services**. It has strong housing, transport, power, water, and sanitation systems. It has the ability to maintain, repair, and renovate them.
5. Has **economic opportunities**. It has a diverse range of employment and income opportunities and financial services. It is flexible and resourceful and has the capacity to accept uncertainty and respond (proactively) to change.
6. Can manage its **natural assets**. It recognizes their value and has the ability to protect, enhance, and maintain them.

Source: "Understanding Community Resilience and Program Factors That Strengthen Them: A Comprehensive Study of Red Cross Red Crescent Societies Tsunami Operation," International Federation of Red Cross and Red Crescent Societies, Geneva, 2012.

Brainstorming on the Uses—and Users—of Technology

When participants in the workshop session voted for their favorite technological innovations, six key ideas bubbled to the top: the use of virtual reality to better communicate risk and preparedness measures; building on existing "shared economy" ideas to improve disaster resilience; use of sensors for early warning; community-owned 3-D printers; solar charging of mobile phones and other appliances; and various uses of civilian drones.

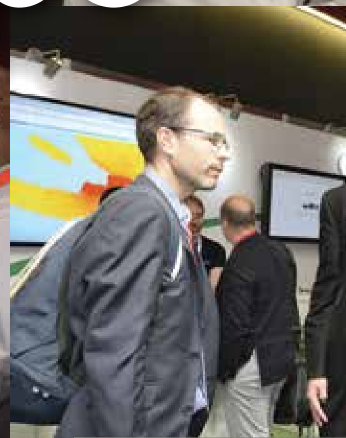
Participants formed five groups (in the end no one joined the 3-D printer group, so this was eliminated) and began to consider the potential users of the prototypes they were developing; to help them stay focused, each group was presented with a composite character (based on real people interviewed by the Red Cross in several countries). Groups worked for 45 minutes to develop their plans and then shared their ideas:

- **A virtual reality platform that could support risk assessment.** It would be geared toward supporting individuals' need to access timely information on risks, but would also feed into a wider system where larger patterns could be identified.
- **The use of shared economy systems that exist pre-disaster to offer support post-disaster.** These systems might include tuition support, skills sharing, incentives, and insurance—all of which are needed in normal times. The shared economy systems could then be repurposed during times of disaster.
- **A system of sensors that could measure noise and alert people to crowds and violence.** This would allow people to navigate around areas of higher potential for violence. The sensors could be useful in normal times to share traffic information, for example, and then convert to violence sensors if circumstances warranted.
- **A mobile charging solution that could be placed inside a motorcycle helmet with a solar panel on top.** The charger would encourage motorcycle taxi drivers to wear helmets, and would help them earn money in normal times, because passengers would seek them out in order to charge their phones during the ride. During an emergency, the helmet would also be available for charging phones to access information and support a community response.
- **A number of uses for drones.** Drones might be used for mapping dangers and services; identifying bodies and sensing where people were alive and trapped based on mobile phone signals; and delivery of aid, including SIM cards, power packs, and information packs.

Further resources

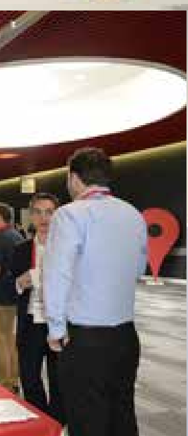
- A Global Dialogue on Emerging Technology for Emerging Needs website at http://tech4resilience.blogspot.com/.
- *World Disasters Report 2013: Focus on Technology and the Future of Humanitarian Action* (Geneva: International Federation of Red Cross and Red Crescent Societies, 2013), http://www.ifrc.org/PageFiles/134658/WDR%202013%20complete.pdf.

Partnerships




World
Reconstruction
Conference 2


Understanding
Risk forum
Producing actionable information




Understanding
Risk forum
Producing actionable information

Photo: Dr. Stephen Yeo

Can Flood Resilience Be Measured?

An Innovative Collaborative Approach May Do Just That

David Nash, Flood Resilience Community Impact Manager, Zurich Insurance Company Ltd.

Introduction

Increased severe flooding globally has focused attention on finding practical ways to improve flood risk management. As part of this effort, Zurich Insurance Group (Zurich) launched a global flood resilience program in 2013. The program aims to advance knowledge, develop robust expertise, and design strategies that help communities strengthen their resilience to flood.

To implement the program, Zurich has formed a multi-year, interdisciplinary alliance with the International Federation of Red Cross and Red Crescent Societies (IFRC), the nongovernmental organization Practical Action, the International Institute for Applied Systems Analysis (IIASA), and the Wharton Business School's Risk Management and Decision Processes Center (Wharton) in the United States. This alliance of risk experts seeks to improve the public dialogue around flood resilience while demonstrating the benefits of pre-event risk reduction, as opposed to post-event disaster relief.

The Measurement Challenge

The program's impact will be seen in communities' enhanced resilience to flooding. But demonstrating this impact presents a particular challenge: measuring resilience is not as easy as it sounds.

There are many approaches to measuring resilience that have grown up over the last 10 years, any of which could potentially be applied to our efforts. However, a recent survey conducted for the United Nations Development Programme concluded that "no general measurement framework for disaster resilience has been empirically verified yet."[1]

This finding highlights a key challenge for any resilience-building efforts: if resilience cannot be empirically verified, how do you empirically measure whether a community is more resilient as a result of your work? By combining the expertise of all our partners, we have set out to address this challenge.

Breaking Down the Challenge

It is a truism that what gets measured, gets done. Thus if we can find a way to measure enhanced community resilience to flooding, we are likely to be able to design interventions that contribute to such an enhancement. In order to measure something, though, we must first define it.

Measuring "resilience" per se is very complicated, and we have concluded that we should look at **resilience in the face of a specific event** (e.g., flooding). We have also concluded that "resilience" should be understood as an outcome that ensures that a community can continue to thrive and develop. In other words, a community will be able to continue to function and grow if it has resilience. However, resilience can come from many sources. It is important to look holistically at these sources of resilience if we hope to know in advance of a flood whether a community will be resilient. This approach has allowed us to concentrate on appropriate measurement factors—the sources of resilience.

Measuring a community's resilience also requires us to define a "community." Potentially, a "community" could be defined geographically (perhaps in rural contexts) or by administrative boundaries (which may work in more urban situations). However, no single community will "feel" like another and there may be cultural aspects to consider, too. As a result we have concluded that when it comes to ground reality, a community largely defines itself.

Alliance Contributions

Each of the alliance institutions has a different expertise that makes a distinct contribution to the measurement model.

The Insurance Partner

Zurich's expertise is in managing risk. Its risk engineering teams have developed a set of technical risk grading standards (TRGS) that offer an objective view of the impact of numerous hazards and allow them to make recommendations about actions that can be taken to reduce risks.

It is a truism that what gets measured, gets done. Thus if we can find a way to measure enhanced community resilience to flooding, we are likely to be able to design interventions that contribute to such an enhancement. In order to measure something, though, we must first define it.

Risk engineers compare data gathered from site visits with the definitions in the TRGS to make a judgment about how to manage the risks at issue. The TRGS provide a consistent benchmark against which to quantify those risks. Effective risk management can reduce overall losses, which in turn allows customers to cope with any residual losses more easily—that is, to rebuild more quickly after a catastrophe, and with less business interruption. Effective risk management should also mean that the cost of insurance is lower, and in some cases that the losses Zurich incurs from claims are lower.

This measurement methodology can be adapted in the context of communities' enhanced resilience to flooding. The approach brings together quantitative and qualitative data about the factors that contribute to resilience, making it possible not only to "grade" these factors (using the TRGS approach) but also to identify actions for enhancing resilience.

The Academic Partners

Through a comprehensive review of current techniques and thinking on resilience, our academic partners **Wharton** (in the United States) and **IIASA** (in Austria) have drawn up a framework around which a measurement tool can be built. The framework combines thinking developed at the Multidisciplinary Center for Earthquake Engineering Research (MCEER) at the University of Buffalo, New York, and the Sustainable Livelihoods Framework of the Department for International Development (DFID).[2] This "systems analysis" approach takes into account the quality of life, interactions, and interconnections at the community level, and provides consistency in identifying and testing potential sources of resilience.

The framework is based on four separate properties related to community resilience (the "Four Rs" defined by MCEER) and five types of community capital (the "Five Cs" from DFID's Sustainable Livelihoods Framework). The

"Four R-Five C" framework can be applied to virtually any community.

The Four Rs (resilience properties) are

- **Robustness** (ability to withstand a shock)
- **Redundancy** (functional diversity)
- **Resourcefulness** (ability to mobilize when threatened)
- **Rapidity** (ability to contain losses and recover in a timely manner)

The Five Cs that characterize communities are complementary forms of capital that can help to improve inhabitants' well-being. Judicious use of these resources can increase personal and collective wealth, provide a sense of security, and enhance environmental stewardship. From an analytical perspective, the Five Cs provide greater richness of data about a community's sources of resilience than any single metric (e.g., average income). Thus they provide a more holistic picture of a community's resilience.

The Five Cs are

- **Physical** (things produced by economic activity from other capital, such as infrastructure, equipment, improvements in crops, livestock, etc.)
- **Financial** (level, variability, and diversity of income sources and access to other financial resources that contribute to wealth)
- **Human** (education, skills, health)
- **Social** (social relationships and networks, bonds aiding cooperative action, links facilitating exchange of and access to ideas and resources)
- **Natural** (natural resource base, including land productivity and actions to sustain it, as well as water and other resources that sustain livelihoods)

This framework provides a system and a type of matrix to measure the sources of community flood resilience. It allows comparisons within and across communities to empirically validate resilience and to measure in clear, concise terms how resilient a community is to floods. The framework also makes it possible to test how a change in one of the Five Cs affects a community's overall resilience level.

The Community Partners

Having a methodology for building a measurement tool (the TRGS) and a framework to determine the potential indicators (Four R-Five C) can help us build a theoretical model for resilience measurement. But to ensure that our model is not merely theoretical but also has relevance to real communities, the role of Practical Action and the Red Cross is key. These partners have on-the-ground experience that forms the basis for specific indicators that are highly relevant to communities. Both partners make use of data-gathering tools to help them understand the communities they are working with, and these have been adapted for use in our model to ensure that all the data needed to measure resilience are available.

The Future

Over the course of 2014, the Zurich flood resilience alliance team has built an initial iteration of a measurement tool and through programming work in Mexico has gathered data to test it. The data will be analyzed using the tool, and the results will help us to evaluate how well it works. Further iterations of the tool will continue into 2015, with the aim of having a comprehensive documented model available for use in the alliance's community projects.

We believe that we are on the way to producing a model that empirically measures community resilience to flooding, and that this model could eventually be the basis for a comprehensive resilience measurement approach.[3]

Contributors to the session

Saad Mered, Global Chief Claims Officer, General Insurance, Zurich Insurance Company, Ltd.

Dr. Erwann O. Michel-Kerjan, Executive Director, Wharton Risk Management and Decision Processes Center, the Wharton School, University of Pennsylvania

Reinhard Mechler, Senior Research Scholar Risk Policy and Vulnerability, International Institute of Applied Systems Analysis (IIASA)

Colin McQuistan, Senior Policy and Practice Adviser, DRR and Climate Change, Practical Action

Mohammed Omer Mukhier, Head, Community Preparedness and Risk Reduction Department, International Federation of Red Cross and Red Crescent Societies

Left: Obrenovac, Serbia before the floods. Right: Obrenovac, Serbia May 21, 2014. Photo: CNES/ASTRIUM; DIGITALGLOBE/GOOGLE.

Endnotes

This publication has been prepared by Zurich Insurance Group Ltd and the opinions expressed therein are those of Zurich Insurance Group Ltd as of the date of writing and are subject to change without notice. This publication has been produced solely for informational purposes. The analysis contained and opinions expressed herein are based on numerous assumptions. Different assumptions could result in materially different conclusions. All information contained in this publication have been compiled and obtained from sources believed to be reliable and credible but no representation or warranty, express or implied, is made by Zurich Insurance Group Ltd or any of its subsidiaries (the 'Group') as to their accuracy or completeness. Opinions expressed and analyses contained herein might differ from or be contrary to those expressed by other Group functions or contained in other documents of the Group, as a result of using different assumptions and/or criteria. This publication is not intended to be legal, underwriting, financial, investment or any other type of professional advice.

1 Thomas Winderl, "Disaster Resilience Measurements: Stocktaking of Ongoing Efforts in Developing Systems for Measuring Resilience," United Nations Development Programme, February 2014, http://www.preventionweb.net/files/37916_disasterresiliencemeasurementsundpt.pdf.

2 For MCEER, see "MCEER's Resilience Framework," October 2006, http://mceer.buffalo.edu/research/resilience/Resilience_10-24-06.pdf. For DFID, see "Sustainable Livelihoods Guidance Sheets," April 1999, http://eldis.org/vfile/upload/1/document/0901/section2.pdf.

3 For a further look at the challenges of promoting flood resilience, see "The Role of Ecosystems in Reducing Risk" in this publication. For a discussion of flood modelling, see "'Mission Impossible': Using Global Flood Risk Assessments for Local Decision Making" in this publication.

Further resources

- Zurich Insurance Group website at http://www.zurich.com/en/corporate-responsibility.
- IFRC website at http://www.ifrc.org.
- Practical Action website at http://practicalaction.org/.
- IIASA website at http://www.iiasa.ac.at.
- Risk Management and Decision Processes Center at the Wharton School website at http://www.wharton.upenn.edu/riskcenter/.

OF INTEREST

Development of a Global Probabilistic Cost-Benefit Analysis Tool

Marc Forni, Senior Disaster Risk Management Specialist, World Bank

Disaster risk management (DRM) projects are a cost-effective ex ante approach to minimizing risk from extreme events and increasing a society's resilience. Though they provide significant long-term returns, justifying support for DRM projects can often be a difficult task for governments and the World Bank, as these projects compete with others whose returns are more immediate, even if generally smaller. Within this context, a tool that provided realistic estimates of the return from DRM projects would be a highly useful asset for governments seeking to quantify and assess the value of potential investments.

A team from the World Bank is developing a cost-benefit analysis (CBA) calculator to meet this need. The tool will leverage the work being done by the Global Facility for Disaster Reduction and Recovery to develop a hazard screening tool (specifically, it will use the same global hazard data sets) and should serve a range of practitioners in the risk community.

The UR Forum offered an opportune occasion for soliciting feedback on the tool and brainstorming about what elements should be part of a robust design. In an effort to ensure the development of a CBA calculator that meets users' needs and is scalable in nature, the World Bank team sought inputs from experts in economics, risk modelling, and risk financing during a workshop. Some of the recommendations received were the following:

- The calculator should be thought of not as a World Bank tool, but as a tool for the DRM community as a whole.
- The tool should be modular to ensure its flexibility and long life; it should be able to use updatable components, to include local models when they are available, and to incorporate subjective expert judgments and local information.
- The purpose of the project—be it high-level or local-level analysis—should be established.
- To ensure uptake of the tool, all analysis should be transparent, uncertainties should be well communicated, and results should show the benefits of investment compared to maintaining the status quo.
- The tool should use modelling structures that the DRM community is accustomed to (hazard * exposure * vulnerability = risk), rather than a loss-cost approach, which is less familiar to potential users and would not save much computation time in any case.
- The tool should be developed so that it can fully integrate the contributions of climate change and urban growth to future risk. Consideration should be given to also including social and economic performance, mortality and morbidity rates, and both proprietary and freely available hazard catalogs.

The development team has lots of work ahead of it. Team members will need to conduct an extensive literature review prior to tool construction, meet frequently with internal and external experts to report on progress as the construction proceeds, and seek and borrow lessons learned from other industries. Throughout, we will need to clearly articulate the tool's purpose and make sure that its capabilities are accurately represented to potential users.

Contributors to the session

Marc Forni, Senior Disaster Risk Management Specialist, World Bank

Yohannes Kesete, Disaster Risk Management Specialist, World Bank

Richard Murnane, Senior Disaster Risk Management Specialist, GFDRR

Annegien Tijssen, Disaster Risk Management Specialist, GFDRR

Photo: Mahfuzul Hasan Rana

Beyond Physical Risk

Looking through a Socioeconomic Lens

Christopher Burton, Senior Scientist and Coordinator for Social Vulnerability and Integrated Risk, GEM Foundation
Nicole Keller, International Relations and Partnerships, GEM Foundation
John Schneider, Chair, Governing Board, GEM Foundation

By including socioeconomic metrics of vulnerability and resilience in risk assessments, we can understand, manage, and eventually reduce risk more effectively.

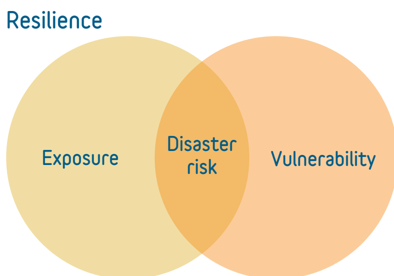
The difference in impact between the 2010 Haiti and 2011 Christchurch earthquakes makes obvious that socioeconomic factors influence how risk is distributed and perceived. Combining measurements of socioeconomic characteristics with analysis of physical risk, expressed in terms of damage and loss to structures and people, would improve our efforts to manage and reduce risk. Our ability to measure socioeconomic characteristics is still limited. But efforts are under way to improve it and move toward a more complete picture of risk.

Measuring and Understanding Social Vulnerability and Resilience

To manage disaster risk, we need to manage both exposure and vulnerability. Figure 1 depicts how the concepts of disaster risk, resilience, vulnerability, and exposure are linked. Vulnerability comprises physical factors (such as damage to buildings and injury to people) and socioeconomic factors (such as poverty and gender). Vulnerability is a function of the intersection of multiple characteristics and how they play out geographically over time. Populations' resilience helps to lessen exposure and vulnerability, and thus reduces risk.

But how do we move beyond acknowledging the importance

Figure 1. How understanding physical and social vulnerability is key to understanding and managing disaster risk and increasing resilience.



Source: Adapted from Susan Cutter.

of social vulnerability and other socioeconomic factors to measuring them? How do we include these measurements in risk assessments? To meet these challenges, the Global Earthquake Model (GEM) Foundation is partnering with CEDIM (Center for Disaster Management and Risk Reduction Technology) and others to develop scientifically sound, state-of-the-art measurement tools and data that can be combined with physical risk models to develop an integrated view of risk.

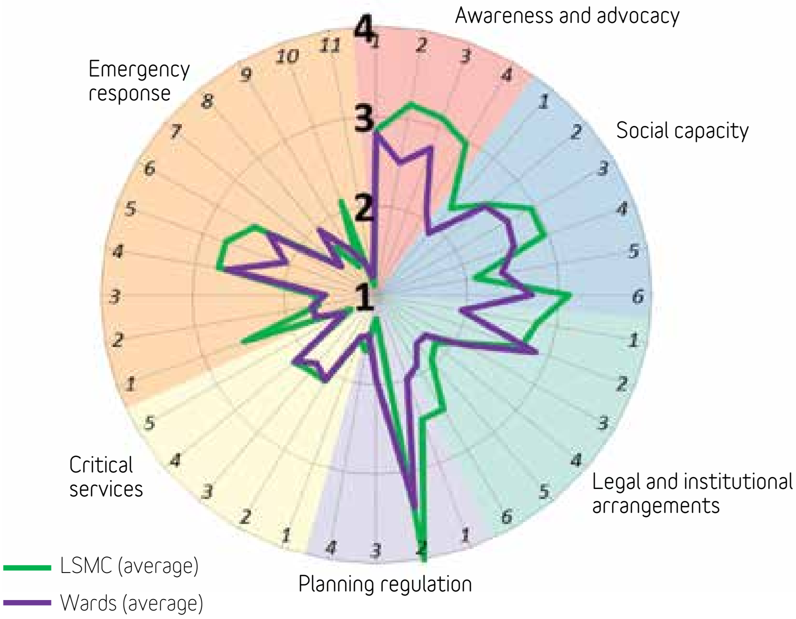
The tools and resources under development are targeted at those responsible for understanding and managing disaster risk, and use both "top-down" and "bottom-up" techniques. Decisions about whether a top-down or bottom-up approach is preferable will depend on users' needs and desires and on what data are available.

The "top-down" method uses statistical data from censuses and other sources; within the scope of GEM, large socioeconomic databases are being developed for use at national level and for some regions at the subnational level. For the top-down technique, an Integrated Risk Modelling Toolkit is being developed to allow users to combine data from the socioeconomic databases with more detailed local data. The toolkit allows users to apply their knowledge of the local context in weighting various characteristics, and then to derive indexes or models for social vulnerability, (indirect) economic vulnerability, or resilience.

For measuring and understanding resilience in areas where data are lacking, or where it is possible or desirable to have local decision makers and managers directly participating, a "bottom-up" and participatory approach can be adopted. This approach is used in a self-evaluation tool for earthquake resilience in Nepal. Building upon the Hyogo Framework for Action and other UNISDR guidelines,[2] GEM partnered with the Nepal Society of Earthquake Technology (NSET) to develop the tool (or scorecard), which was tested at the city and subcity level in Lalitpur, Nepal. The tool asks users to rate their city in six areas: social capacity, awareness and advocacy, legal and institutional, planning and regulation, critical infrastructure and services, and emergency preparedness and response. The groups that were invited to participate in the testing—local ward representatives and municipal (city-level) officials and policy makers—used hand-held devices to jointly answer questions (shown in figure 2). Participants enjoyed the exercise (the technology made it fun); and more significantly, the approach seemed to create a sense of ownership in the stakeholders, which suggests they will be more likely to act to improve resilience. This participatory process, along with the outcomes (scores are shown in figure 3), also fostered discussion among the stakeholders, which promoted a common understanding of earthquake resilience. The data collected from tools of this kind may be aggregated to model the resilience of cities and combined with other data sources.

Figure 2. A participatory self-evaluation tool for measuring and discussing disaster resilience being tested in Lalitpur, Nepal.. Source: Christopher Burton

Figure 3. The plot summarizes the self-evaluation scores of the Lalitpur municipal officials (green) and the city ward representatives (purple) and shows the differences in how the two groups assess their city's resilience.



Source: Johannes Ahorn, Christopher Burton, and Bijan Khazai.

Integrated Risk Assessment: Combining the Physical and the Social

Once a model of social vulnerability, economic vulnerability, and/or resilience is defined, it can be combined with a physical vulnerability and exposure model to obtain an integrated view of the disaster risk in the area. The Integrated Risk Modelling Toolkit mentioned above allows social vulnerability, economic vulnerability, and/or resilience indexes to be combined with physical risk measures, such as average annual loss or fatalities estimates. This combination (a sample is shown in figure 4) produces a new picture of risk that contributes to improved risk management.

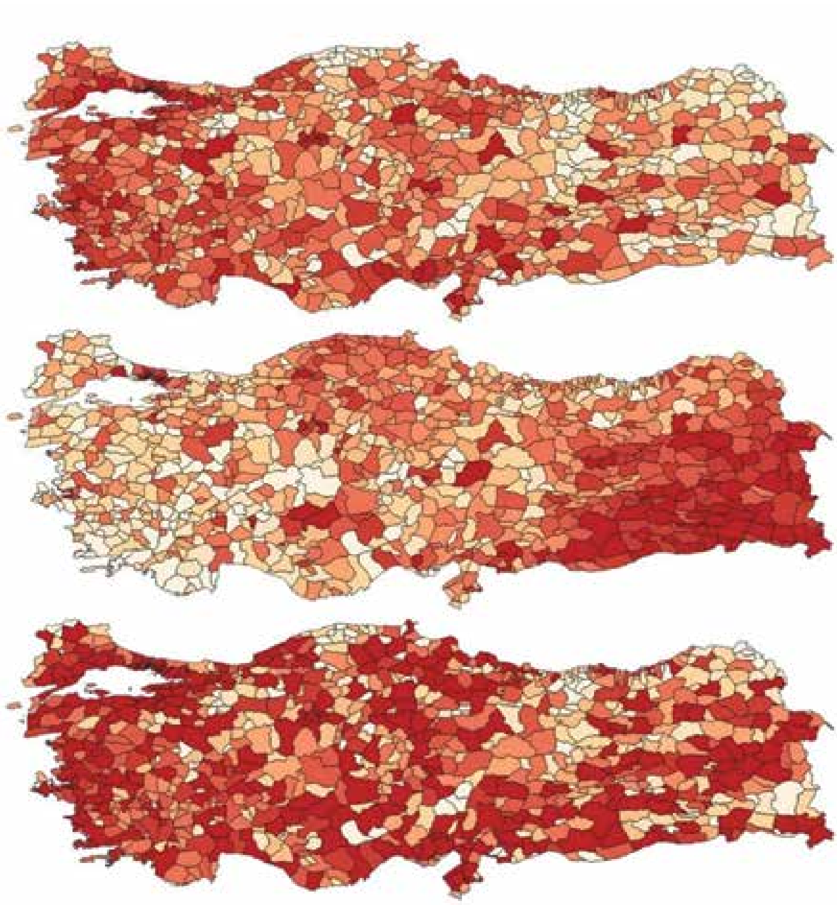


Figure 4. Integrated earthquake risk mapping for Turkey. In order to get a complete picture of risk, or an integrated risk map (bottom map), physical risk estimates for average annual economic loss (top map) are combined with social vulnerability estimates (middle map).

Source: © Sevgi Ozcebe, IUSS, UME School, Pavia. Used with permission; further permission required for reuse.

Note: These maps of Turkey were developed by Sevgi Ozcebe, a PhD student, using tools and data developed in the context of GEM and are to be considered work in progress. The physical risk map (top) is the result of combining an earthquake hazard model (past earthquakes and active faults) with models of exposure and vulnerability of the building stock, which also incorporate data from past disasters.

The integrated risk map (bottom) shows that risk is not mainly concentrated in the west of the country, and that many eastern provinces would be affected by an earthquake.

Case Studies

Manila. Photo: gionnixxx

Public Sector Case Study: Quezon City.

Quezon City, the largest city in Metro Manila, is a notable success story in risk assessment. Efforts to establish a disaster risk reduction and management (DRRM) system within the city and to institutionalize DRRM protocols, policies, procedures, and functions within the city government were pursued collaboratively by CEDIM, the Earthquake and Megacities Initiative (EMI), the Quezon City government, and local and national stakeholders. Part of this effort made use of social vulnerability, resilience, and risk indicators, which were selected and implemented through a fully participatory process that included workshops with 40 stakeholders from 21 Quezon City offices and organizations. The successful Quezon City experience informed GEM's development of the Integrated Risk Modelling Toolkit for use in interactive and participatory settings with stakeholders. The risk assessment in Quezon City served as a pilot for how physical risk outputs from GEM's OpenQuake Engine could be integrated with social vulnerability and resilience indicators relevant for emergency planning, preparedness, and policy making in the context of developing country megacities.

Private Sector Case Study: FM Global.

For businesses, four key elements are at risk from disasters: property and other assets, continued operation, shareholder value, and company reputation. The first two elements involve physical risks that can be quantified and are insurable. But how should risk to the two nonphysical elements be managed? The answer lies in investing in resilience. The insurance company FM Global has created a resilience index by examining clients' preparedness strategies. The index, which documents a range of different levels of business preparedness and resilience across countries, also provides a rich source of information on attitudes toward resiliency and the costs and benefits of investing in resilience. It shows, for instance, that companies with strong risk management practices suffer average losses from natural hazards that are 28 times lower than losses of companies with weaker practices. The index helps companies and their employees understand the importance of resilience and devise strategies for a more resilient future.

Conclusion

Understanding and incorporating the socioeconomic context into risk assessment and management is critical for creating a culture of resilience. But there are still many steps required to produce that culture. Experts still disagree about the definitions of and difference between social vulnerability and resilience. Moreover, validating the measurements of these abstract and multidimensional concepts is complex: Are we really measuring social vulnerability or something quite different? Does measuring resilience really get at the ability to prepare for and recover from a disaster? It is hard to tell because we lack the necessary long-term disaster recovery studies that link resilience and vulnerability metrics to long-term recovery outcomes.

Other challenges to measuring "beyond physical risk" include the need for accurate and consistent data on infrastructure and nonresidential buildings at local levels. The self-evaluation tool (bottom-up assessment) seems to work well at city level and makes use of data and knowledge drawn from the people themselves. But its reliance on these data alone becomes a limitation; we do not know whether this approach would still produce valid results at subnational or national level. Another challenge is to develop methods for modelling post-disaster recovery (such as currently exist for damage) to obtain deeper understanding of populations' socioeconomic vulnerability and to develop ways to increase their resilience to disasters. Better tools and methods for estimating the costs and benefits of investing in disaster risk reduction and management measures are also needed, in particular those that take into account various policy interventions and allow the user to see the effect on the integrated risk of a certain geographic area.

To overcome such challenges, we recommend the following:

- Encourage sharing of case studies and best practices on how to measure and incorporate measures of socioeconomic vulnerability and resilience into disaster risk reduction and management activities and policies.
- To facilitate risk ownership at the local level, invest in development of tools, methods, and products that are scientifically sound but also participatory.
- Encourage sharing and opening of data to improve risk assessment and management.
- Make sure that risks are managed with flexible strategies and multiple tools.
- Harmonize existing efforts to measure vulnerability and resilience.

We invite all who are interested in the topic or want to continue the discussion to get in touch with GEM. Leave us a message on our Facebook page or get in touch via email: nicole.keller@globalquakemodel.org.

For more information, go to www.globalquakemodel.org.

Contributors to the session

Herbert Bautista, Mayor of Quezon City, the Philippines

Christopher Burton, Senior Scientist and Coordinator for Social Vulnerability and Integrated Risk, GEM Foundation

Susan Cutter, Carolina Distinguished Professor at the University of South Carolina; U.S. National Academies Chair of Community on Increasing National Resilience to Hazards and Disasters

Amod Dixit, Director, Nepal Society of Earthquake Technology (NSET)

Louis Gritzo, Vice President of Research, FM Global

Bijan Khazai, Senior Scientist, Center for Disaster Management and Risk Reduction Technologies (CEDIM), Earthquake and Megacities Initiative (EMI)

Loy Rego, Learning Practitioner, Mainstreaming Adaptation, Resilience and Sustainability into Development, Global Network of National Councils for Sustainable Development and similar bodies (GN-NCSDs)

Endnotes

1 *Social vulnerability* is here defined as characteristics or qualities within social systems that create the potential for loss or harm. These include economic characteristics such as poverty level and employment status. *Economic vulnerability*, on the other hand, is understood here as the potential for indirect economic losses from hazard events, such as business interruption. Finally, *resilience* is the ability of social systems to prepare for, respond to, and recover from damaging hazard events.

2 See UNISDR, *Hyogo Framework for Action 2005–2015: Building the Resilience of Nations and Communities to Disasters* (Geneva: UNISDR, 2007), http://www.unisdr.org/hfa; and UNISDR, "The 10 Essentials for Making Cities Resilient," http://www.unisdr.org/campaign/resilientcities/toolkit/essentials.

Partnerships

Game Time: Monitoring Changing Riskscapes with GEM and SENSUM Tools

John Bevington, Director, ImageCat Ltd.
Nicole Keller, International Relations and Partnerships, GEM Foundation

Introduction

How can geospatial data be used to create actionable information both before and after a disaster? With a focus on the development of property exposure data, we explored this question through a role-playing disaster risk reduction information game.[1]

The game brought together two high-profile global initiatives that have at their core the use of geospatial tools and imagery: GEM (Global Earthquake Model) and SENSUM (Framework for integrating Space-based and in-situ sENSing for dynamic vUlnerability and recovery Monitoring), a project of the European Commission's Seventh Framework Programme (FP7). Both projects feature software and tools that aim to provide a better understanding of the built environment before, during, and after earthquakes. As players of the game make decisions during pre-earthquake and post-earthquake time periods, and as they look for data to support their decisions, we can learn how software tools, data, and risk models produced using SENSUM or GEM tools might be used to objectively inform disaster-related decision making.

1 For an extended discussion of the role of games and game play in understanding risk, see "GAME OVER: Exploring the Complexity of Actionable Information through Gaming" in this publication.

Tools

Before the game began, panelists presented a series of technical demonstrations on the tools to be used. These included the following:

GEM Inventory Data Capture Tools (IDCTs)

These are a set of open source tools or apps that enable disaster risk management (DRM) practitioners and others to capture data on buildings (inventory) before and after earthquakes. These tools make it possible to transform data from satellite images and other "remote" information on buildings into exposure data sets and models. In a very intuitive way, users can go into the streets with a tablet, phone, or paper form to collect building-by-building data that follow a globally agreed-upon format. The data they collect can then be fed back into global databases of exposure and earthquake consequences. Protocols and user guides are available to help users exploit the tools and extract data from remote sensing images.

OpenQuake Engine

This open source, state-of-the-art hazard and risk modelling software lets users produce measures and products—such as cost-benefit ratio maps, average annual loss estimates, and damage predictions—that support decisions about risk reduction and management. Users need not rely solely on their own data and expert knowledge. At the end of 2014, a community-based platform will become available that connects users and that hosts many tools and a variety of resources, including global data sets and hazard and risk models.

GEM Integrated Risk Modelling Toolkit

This product now in development will allow users to develop indexes of social vulnerability, economic vulnerability, and resilience, based on their knowledge of the local socioeconomic context. Such models can then be combined with physical risk models to produce integrated risk measures (maps, tables, etc.). (Use of the tool is described in this publication in "Beyond Physical Risk: Looking through a Socioeconomic Lens.")

SENSUM Earth Observation (EO) for pre-event exposure mapping

By December 2014, SENSUM will release a suite of free, open source tools as plug-ins to the well-known QGIS environment. The tools aim at extracting actionable, multi-temporal information about

The role-playing game in progress. Participants were asked to play out a fictitious earthquake and describe the types of decisions they would have to make as DRM practitioners. Participants identified which geospatial data products could be used to objectively support those decisions.
Source: Steve Platt.

exposure from the latest moderate- and high-spatial-resolution satellite imagery, particularly from global, freely available products such as Landsat and Sentinel. SENSUM is also conducting a comprehensive comparison and cross-validation of space products that will soon be included in online end-user guidelines.

SENSUM dynamic exposure modelling

The continuous, sometimes abrupt evolution of the urban environment, particularly in developing countries and megacities, calls for a dynamic, iterative, and incremental approach to exposure modelling. A novel sampling framework is being developed to prioritize and optimize in situ data collection, taking into account multiple spatial and temporal scales and exploiting information extracted from remote sensing. Efficient data collection protocols are being developed based on free and open source software tools. A spatial database platform is being realized using open source state-of-the-art solutions to collect and store the produced geospatial information. The platform takes into account the information's full life cycle, from generation to update to disposal, and also incorporates uncertainties.

SENSUM mobile mapping and rapid remote visual screening (RRVS)

To increase the efficiency and flexibility of in situ data collection, a mobile mapping system, including an omnidirectional camera, has been realized and tested in Europe, Turkey, and Central Asia. The system can be promptly deployed and fixed on any car or civil protection vehicle, and provides georeferenced, high-resolution visual coverage of the urban environment. A suite of geographic information system (GIS) open source software tools allows a remote operator to analyze the collected visual stream and save the observed properties of the observed buildings in a format fully compatible with the GEM standards. Data needs for post-disaster recovery will be addressed within the same framework, resulting in a comprehensive methodological solution to the monitoring of time-varying indicators at multiple spatial scales throughout the disaster cycle.

Disaster Risk Reduction Scenario Planning Game

The game organized as part of this session sought to explore what kind of decisions are made, and hence what kind of data and tools are needed, before and after an earthquake.

The game included four different scenarios:

- First response in Van, Turkey (week 1)
- Recovery, planning, and monitoring, in Maule, Chile (up to two years)

- Long-term mitigation planning (developed country) in Tohoku, Japan
- Long-term mitigation planning (developing country) in Kashmir

By inviting participants to act out these scenarios, representatives from GEM and the SENSUM project hoped to generate interest among potential users of their tools, and also to get feedback—particularly from practitioners in developing countries—on tools' format and functionality.

The game at the UR session was played by 30 people, all researchers and academics. Ideally, role-playing games of this kind involve a more diverse group of practitioners (academics, planners, insurers, policy makers, emergency managers). But the game worked reasonably well and the participants found it absorbing.

Challenges

Geospatial data provide valuable contextual information that can be used to better understand risk globally. Data derived from remote sensing can provide an independent perspective on the configuration of the built environment and its exposure to hazards. However, despite the presence of high-spatial-resolution satellite sensors for over 15 years, remote sensing is still an underutilized resource, especially in developing nations. Limited understanding of the benefits and a lack of technical training have made it an often-overlooked or latent resource.

There is another barrier to adoption of remote sensing and other geospatial tools, and that is the culture and practices of risk assessment. Decisions are often not underwritten by evidence-based or even modelled data. Instead they are often based on gut feelings or determined by local or national protocols. Remote sensing combined with the techniques developed by GEM and SENSUM offers an alternative, objective view of pre-event risk assessment and post-event situational awareness—but the prevailing culture will need to become familiar with this approach if it is to be adopted.

Recommendations

A number of recommendations about how to optimize use of geospatial data tools for DRM can be drawn from this workshop.

1. Support efficient exposure data development with smart technology

From handheld applications to mobile mapping systems, from assisted processing of satellite imagery to statistical learning and pattern recognition, viable and efficient technology can boost most of the activities related to exposure modelling. Solutions based upon standard protocols and common formats should be privileged and encouraged.

2. Use data as evidence to underwrite decisions

In situations where technology does not support decision making, there is often a protocol-driven culture in which responsibilities are laid out hierarchically. These frameworks can be made to accommodate use of geospatial data to better inform decision making, but the accommodation needs to occur before a disaster strikes. Organizations (probably wisely) are reluctant to embrace new data or technologies when responding to disaster events. By encouraging a culture of training and trying out new technologies in the pre-event time period, users will become accustomed to generating information from imagery data. Technology-driven capacity building in calm (non-disaster) times can promote the use of data to inform decisions on planning and urban growth. The very same tools can then be used after a disaster to prioritize temporary camps, assess damage, and support needs assessments.

3. Don't overlook the geospatial coordinator

Coordinators of data are practitioners who understand the technical intricacies of turning imagery data into actionable information. It is important that they be aware of the technical capabilities and uncertainties associated with these data, without necessarily having to push the buttons. Coordinators are often consultants or managers of a technical team of geospatial analysts. Critically, coordinators should deeply understand what decisions are being made by policy makers and DRM practitioners. That way, the appropriate resources can be brought to bear on a particular project, and a full understanding of the potential benefits and limitations can be presented.

4. Play games to understand the decisions process.

This workshop demonstrated the ability of role-playing games to stimulate discussion of pre- and post-event data needs. These games have been played in real-life contexts in Central Asia and Turkey. They are most effective when a diverse group of pre- and post-event practitioners are brought together for a one- or two-day in-depth disaster simulation and when participants assume a role they are most familiar with (that is, the one they would play if the event were real). By defining roles and enabling participants to act out the decision making required by the simulation, we can identify those decisions that could be better supported by data. Another benefit of game playing is that it brings group dynamics to the fore—something that does not occur when more traditional survey techniques are used.

Conclusions

Barriers to the uptake of geospatial tools are slowly being removed. A wide variety of medium- and high-spatial-resolution imagery data is available for risk assessment worldwide; software processing tools are being developed using open source development techniques, meaning that these tools can be used throughout the world when training is in place; and training and consultancy opportunities exist to enable "train-the-trainer" activities, thus promoting capacity-building practices.

Proponents of geospatial tools need to work closely with DRM practitioners to understand the work flows and practices adopted throughout the disaster management cycle. This understanding will help to identify areas where data and information can be used to validate decisions and to ascertain the consequences of decisions, and it will also underpin cost-benefit analysis to identify where data will have the biggest influence.

Contributors to the session

Christopher Burton, Senior Scientist and Coordinator for Social Vulnerability and Integrated Risk, GEM Foundation

Fabio Dell'Acqua, Department of Electronics, University of Pavia

Daniele De Vecchi, PhD student, University of Pavia, and Researcher, Eucentre Foundation

Massimiliano Pittore, Senior Scientist, Helmholtz Centre Potsdam, German Research Centre for Geosciences (GFZ)

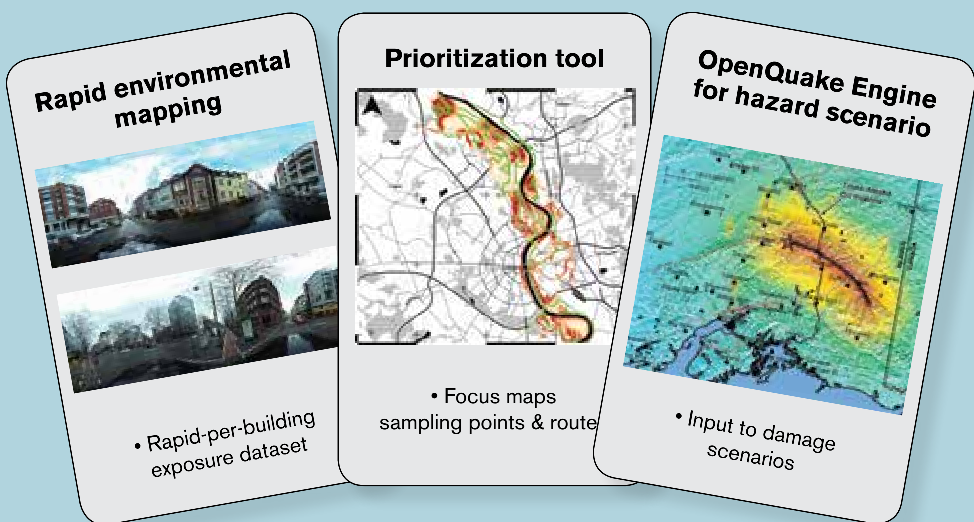
Steve Platt, Director and Chair, Cambridge Architectural Research Ltd.

Emily So, University Lecturer, Department of Architecture, Cambridge University

Vitor Silva, Seismic Risk Coordinator, GEM Foundation

Marc Wieland, Researcher, Helmholtz Centre Potsdam, German Research Centre for Geosciences (GFZ)

Catalina Yepes Estrada, Risk Engineer, GEM Foundation



Cards representing the GEM and SENSUM tools available to participants during the role-playing game.

Illustration: cherezoff/Thinkstock.com

Global Risk Assessment

Toward an Enhanced Vision of Global Disaster Risk

Sahar Safaie, Risk Assessment Officer, United Nations Office for Disaster Risk Reduction

The Global Risk Assessment (GAR) project is a risk modelling project led by the United Nations Office for Disaster Risk Reduction (UNISDR) and conducted by a consortium of technical institutions to support GAR15 (Global Assessment Report on Disaster Risk Reduction 2015) in providing high-level quantitative risk information for all countries around the globe.

A major initiative of UNISDR, the Global Assessment Report is a biennial global assessment of disaster risk reduction that comprehensively reviews and analyzes the natural hazards that too often result in disasters. It contributes to the achievement of the Hyogo Framework for Action (HFA) through monitoring risk patterns, risk trends, and progress in disaster risk reduction, while guiding both governments and nongovernmental actors in how (and why) to reduce disaster risk. Based on original research and a global assessment of risk from natural hazards, GAR seeks to provide high-level basic information on the overall risk landscape to help in identifying the main drivers of risk, prioritizing risk reduction investments (including the required enhanced hazard and risk assessments), and tracking progress over time. The 2009 and 2011 GAR took an observationally based approach to risk assessment using historical disaster databases. Since 2013, with the goal of providing a more comprehensive view of risk at global scale, GAR has taken a fully probabilistic approach using the CAPRA (Comprehensive Approach to Probabilistic Risk Assessment) platform.

UNISDR's GAR global risk assessment will be used by a wide range of public and private sector beneficiaries in tools and applications that tailor the global hazard and risk information to the needs of various sectors. Examples of tools include InfoRM (Index for Risk Management), which applies global risk assessment to strategy, financing, and policy for crisis preparedness and resilience; and RMS One, which is a real-time exposure and risk management platform for the insurance industry that also allows UNISDR governmental partners direct access to public and private sector catastrophe models.

The UNISDR suite of data platforms (such as CAPRA-Viewer and PREVIEW) will host the hazard, exposure, and risk data sets for visualization and download by users in the original formats; this arrangement allows risk to be calculated using the same data sets.

A Leap to Gain an Enhanced Vision of Global Disaster Risk

Probabilistic risk assessment can provide a comprehensive view of risk to populations, assets, services, livelihoods, and the environment from natural hazards, and thus facilitates a prospective estimation of future losses (as opposed to a historical or retrospective view only). For the GAR15 global risk assessment, the goal was to take the leap from various global hazard assessments to a global multi-hazard risk assessment with a harmonized probabilistic approach across regions and countries. With coarse-grain resolution, such an evaluation has low sensibility to uncertainties; it is appropriate for obtaining robust indicators that reflect risk at country level and that can be used in ranking and comparing countries.

The UNISDR GAR global risk assessment includes the following: a global built environment exposure model of 5x5km (1x1km for coastal areas); probabilistic hazard and risk models of tropical cyclone wind and storm surge, as well as earthquake, river flood, and tsunami; the influence of climate change on the tropical cyclone wind hazard in the Caribbean; a global probabilistic hazard model of volcanic ash fall and probabilistic risk model of volcanic ash fall in the Asia-Pacific region; agricultural drought loss in three subregions of Africa and drought models of Africa, the Mediterranean, and Latin America; the influence of climate change on agriculture in three countries in Africa; and landslide risk assessment in two countries. The CAPRA modelling suite was used for earthquake, tropical cyclone, and storm surge hazard modelling, besides risk modelling of all hazards.

The risk results are produced in terms of a loss exceedance curve (figure 1), which makes it possible to determine the average annual loss (AAL) and probable maximum loss (PML) for any return period, as well as the possible definition of loss layers, given that the risk prevention and reduction measures will vary depending on the risk aversion and/or acceptance, among other trade-offs. Because GAR's global risk assessment results have low resolution, they should not be used for any detailed design or decision at national or subnational level.

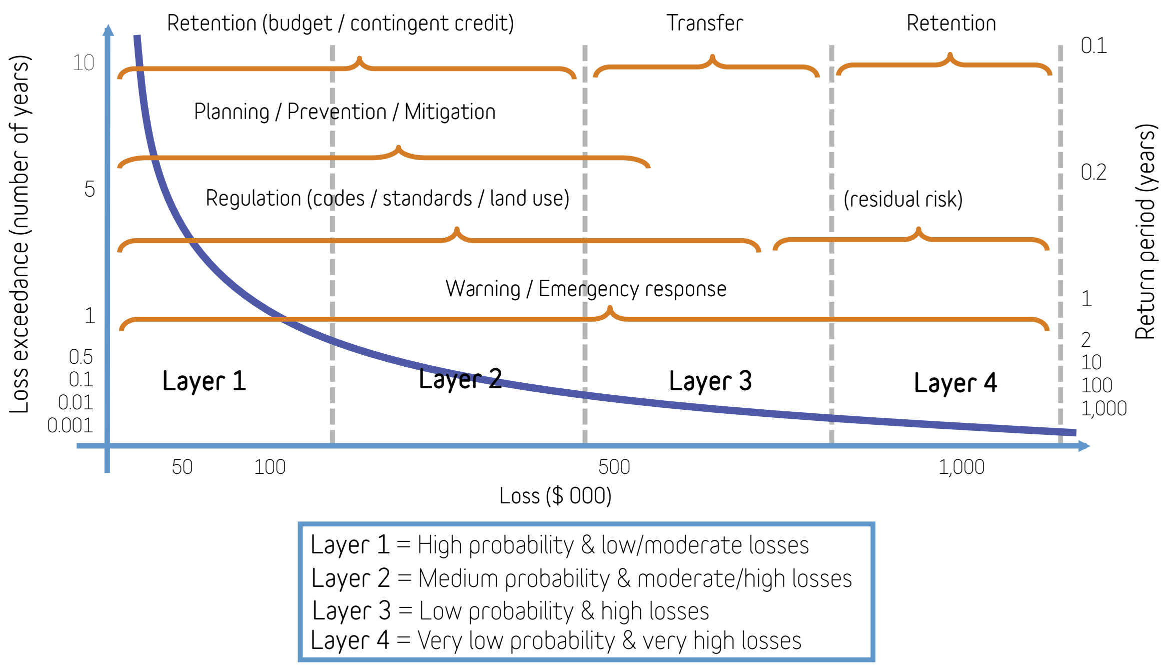
The same methodology can be used for conducting risk assessment at local level (i.e., subnational or city level) to inform disaster risk management (DRM) interventions such as land-use and risk-sensitive urban planning, cost-benefit analysis of retrofitting and risk reduction measures, financial protection and risk transfer, and emergency response planning. But depending on the intended application, the quality and resolution of the needed data will vary, meaning that the overall process and amount of effort required will vary as well.

A Community of Scientists Contributing to Global Risk Information

A multi-hazard probabilistic risk assessment at any level requires scientific and engineering expertise that is both wide-ranging and deep. The UNISDR GAR global risk assessment is the result of a partnership between many technical institutions with expertise in different hazards, exposure, vulnerability, and risk modelling. These partners include the following:

- Arab Centre for the Studies of Arid Zones and Drylands (ACSAD)
- Beijing Normal University
- Centro Internazionale in

Figure 1. A loss exceedance curve is an output of probabilistic risk models. This curve provides probabilities of exceeding various levels of loss. Understanding the frequency of different losses is necessary for deciding on types of measures to prevent or reduce different loss levels.



Source: O. D. Cardona.

Monitoraggio Ambientale (CIMA) Foundation

- International Center for Numerical Methods in Engineering (CIMNE) and INGENIAR
- Famine Early Warning Systems Network (FEWS NET)
- Global Earthquake Model (GEM)
- Geoscience Australia
- Global Volcano Model (GVM)
- Joint Research Centre (JRC)
- Kokusai Kogyo
- Norwegian Geotechnical Institute (NGI)
- United Nations Environment Programme-Global Resource Information Database (UNEP-GRID)
- World Agency for Planetary Monitoring and Earthquake Risk Reduction (WAPMERR)

The World Meteorological Organization (WMO) and UNESCO provide technical peer review of modelling methodologies and input data through their in-house expertise and their global technical network for relevant hazards.

A Community of Public and Private Users

The main goal of the UNISDR GAR global risk assessment is to increase countries' awareness and understanding of the economic imperatives of disasters by presenting the results in the context of countries' economic and population indicators. In addition to countries, the GAR global risk assessment has a wide range of beneficiaries who require different platforms and tools depending on their objectives and technical capacity. The broad range of beneficiaries can make use of the GAR global risk assessment by using data sets and results directly, or in combination with other data sets, or as input to other tools to provide the information tailored to a specific sector (health, housing, energy, education and awareness, crisis management, food security, or insurance industry, among others). Meanwhile, applications of the

current global risk assessment are quite numerous and include the following:

- Raise the awareness of the public, politicians, and practitioners about risk levels and trends, as well as about the spatial characteristics of disaster risk at global level
- Provide the basis for brief country risk profiles that offer a first cut of risk information for estimating national governments' fiscal liabilities
- Offer an operating picture of hazard intensities, exposure, and disaster risk at global level
- Facilitate risk indexing and rankings for comparing hazard and risk levels across countries
- Provide global values useful for the insurance industry and other private sector investors
- Allow monitoring of intensive and extensive disaster risk over time and charting of DRM progress (e.g., outputs for the Hyogo Framework for Action 2)

The brief versions of the national risk profiles are being developed based on both the GAR15 global risk assessment results and (where available) countries' historical loss databases. More comprehensive and refined national risk profiles would require close interaction with national governments and technical experts to access higher-resolution data for various components, sectors, and subnational areas. While some countries already have invested in developing their national risk profiles, the GAR15 global risk assessment will provide many countries, especially low-income countries that lack information on the risk they face, with a first cut for a national risk profile.

UNISDR has been using different platforms and tools, such as PREVIEW, CAPRA-Viewer, and Tangible Earth for GAR, to effectively and comprehensively communicate results, and to share data sets and models with beneficiaries and users. The UNISDR data platform and partner platforms such as RMS One will make it possible to meet three criteria for disseminating the GAR global risk assessment: (1) understandable risk results; (2) open risk assessment data; and (3) an accessible modular risk model.

The Way Forward

GAR15 will be launched in March 2015. All data sets, risk models, and technical background reports will be freely available on the UNISDR PreventionWeb and various platforms. While making a global multi-hazard probabilistic risk model available to user communities represents a major milestone, it is also just the beginning of a coordinated initiative to improve, and facilitate sharing of, risk knowledge.

Considerable capacity exists among international DRM agencies and the private sector, especially in the insurance industry, for understanding assessment results and using data sets and models for various applications. But presenting the results so they can be understood by nontechnical users will require significant effort, as will building capacity in the public sector (especially in low-income countries) for interpreting, digesting, and using the results from probabilistic risk modelling.

Through a project funded by the European Commission, UNISDR is using the outputs of the GAR15 global risk assessment in dialogue with national governments and national technical entities in 40 low-income countries in order to foster more refined risk assessments. The brief national risk profiles offer national governments an advanced understanding of relevant hazards, characteristics of exposure and vulnerability, and levels of risk at national level; they can thus support decisions for national DRM strategy, policies, and activities, including next steps in producing hazard and risk assessments at subnational level, which are required for more specific risk prevention and reduction actions.

The GAR global risk assessment is a living instrument: it should not be considered complete or finished, but rather as under construction and improvable, requiring new and better data inputs and expanding the range of hazards it includes in order to produce better exposure and vulnerability models.

Contributors to the session

Andrew Maskrey, Chief, Global Assessment Report on Disaster Risk Reduction, UNISDR

Omar-Dario Cardona, General Project Director, CIMNE and INGENIAR

Fathimath Thasneem, Deputy Minister, National Disaster Management Centre, Maldives

Madiha Bakir, Associate Director, Price Waterhouse Cooper (PWC)

Paul Vandermarck, Chief Products Officer, RMS

Tom De Groeve, Senior Scientist, Joint Research Centre, European Commission

Illustration: Adobest

OF INTEREST

Urban Risk and Resilience Plenary: I Want to Be a Mayor

James Newman, Disaster Risk Management Specialist

The 2014 Understanding Risk Forum brought together creative and innovative technical and political leaders to pursue an ambitious goal: reach some conclusions about what is involved in producing actionable risk information.

Too often, the fate of risk assessments is to languish on the dusty corner of a bookshelf. Many questions about producing actionable information persist: How do we create and use risk information to propel governments, the private sector, and technical experts of all stripes toward an agenda of resilience? How can decision makers ensure that needed data are collected and—more importantly—used?

Since UR2012, one class of political leader has seen its global stock outperform the rest: mayors. And it's no wonder why: the world is urbanizing, and cities are growing. Nearly 180,000 people join the urban population each day, and by 2030, an expected 5 billion people, or nearly 60 percent of the world's population, will live in cities. New and exciting research conducted by the Brookings Institution, London School of Economics (LSE), Massachusetts Institute of Technology, New York University, University College London, and many others, and increasingly profiled in a range of media,[1] have brought a renewed profile to the lowly city administrator. The fascinating—but concrete and temptingly solvable—problems at the local level have gotten commentators saying, "I Want to Be a Mayor."[2]

But urbanization, along with the economic growth that usually accompanies it, is also driving a complicated web of risk, with more people and assets exposed to hazards in often complex interrelated urban systems that are vulnerable to shocks. Growing recognition of this trend has prompted a number of attempts to quantify the growing risk in cities, including work from Swiss Re and the World Bank.[3] It has also resulted in a host of international programs to promote and institutionalize urban resilience, from the United Nations Office for Disaster Risk Reduction's pathbreaking *Making Cities Resilient: My City is Getting Ready!* campaign launched in 2010, to the Rockefeller Foundation's pioneering 100 Resilient Cities in 2013,[4] while the World Bank, UN-Habitat, Global Facility for Disaster Reduction and Recovery, Inter-American Development Bank, and many others have joined together and scaled up efforts as well.

UR2014's inaugural plenary, entitled "Understanding Urban Risk and Building Resilience," drew on this energy to learn from top officials of three cities—Lianne Dalziel (Mayor of Christchurch, New Zealand), Patricia de Lille (Mayor of Cape Town, South Africa), and Sir Edward Lister (Chief of Staff and Deputy Mayor, Greater London Authority). The three spoke about what risk information they have, how they use it, and what they want more of. Two other speakers, Professor Roman Frigg of LSE and Aris Alip, Managing Director of the Philippine microfinance company CARD MRI, offered views from academia and the private sector, respectively.

The messages were not always hopeful, or did not seem so at first. Risk information is still not always widely available where it is needed, as new risks emerge and old ones shift in urban areas. Better technologies will take our specific local understanding of the potential effects of climate change only so far, while surprising levels of uncertainty may remain an unvanquished foe in our understanding of climate risk for quite some time. Perhaps the least optimistic message: the most effective way to draw attention to risk and catalyze collective action continues to be terrible disasters arising from natural hazards.

Despite this, there was wide agreement on some points, which would be affirmed throughout the Forum. We must redouble efforts to provide high-quality information to policy makers and the public at large. We must present the evidence as clearly as possible, without overstating our case, and make sure to acknowledge the role of uncertainty. We must balance the importance of technological innovation with the value found in the "wisdom of crowds" by seeking consensus among experts to complement the information produced by our most advanced climate models. We must use the political opportunities that disasters afford, but also provide information that allows policy makers and the public to visualize and understand the risks they face—before disaster strikes.

We were reminded of these themes in multiple ways. Familiar London scenes (Tower Bridge, House of Parliament, the city's skyline) were shown under water at one moment and subject to extreme heat and drought at the next, suggesting the wide range of possible scenarios produced by climate change computer models, as well as the difficulty of choosing rational government policy in response to the threat of climate change.

The example of Cape Town made clear the importance of engaging all groups in the city community with risk information and warning systems, and reminded us that poverty and injustice often fuel vulnerability. Apartheid created a land-use system that shunted oppressed South Africans into isolated, risky, and unsuitable housing, and those effects continue to this day.

Mayor Dalziel of Christchurch brought these themes together, sharing her own experience confronting disasters—most notably the earthquake that shook her city in February 2011—and describing the policy struggles entailed in pursuing recovery and facing risk proactively. Despite the notable events that have affected Christchurch, Mayor Dalziel believes that much more must be done to convince constituents of the risks they face and to encourage them to change their behavior.

"I always felt that if you gave people access to expert information and scientific advice, they would be able to make good decisions. But actually, despite all of the publicity on climate change, on sea-level rise, and everything we've experienced in our own earthquake events [in Christchurch], there are still people who want to develop in areas that we should be thinking about in a different light."

But the mayor sees a path forward, in which we move to an issues-based conversation based on high-quality information, "using research and science—coupled with local knowledge—to understand risk and inform decision making, while taking time to work through all the issues, building trust, and eventually making the right decisions—together."

Contributors to the session

Moderator: Matt Frei, Europe Editor, Channel 4 News (UK)

Panelists

Sir Edward Lister, Chief of Staff and Deputy Mayor, Policy and Planning, Greater London Authority, UK

Roman Frigg, Director of the Centre for Philosophy of Natural and Social Science, Professor in the Department of Philosophy, Logic and Scientific Method, and Co-Director of the Centre for the Analysis of Time Series, London School of Economics

Aris Alip, Managing Director, Centre for Agricultural and Rural Development Mutually Reinforcing Institutions

Honorable Lianne Dalziel, Mayor, City of Christchurch, New Zealand

Honorable Patricia de Lille, Mayor, City of Cape Town, South Africa

Endnotes

1 See for example *The Economist*, "The Laws of the City," June 23, 2012; and citylab, which is part of *The Atlantic*.

2 Thomas Friedman, "I Want to Be a Mayor," *New York Times*, July 27, 2013.

3 Swiss Re, "Mind the Risk: Cities under Threat from Natural Disasters," 2013; and Henrike Brecht, Uwe Deichmann, and Hyoung Gun Wang, "A Global Urban Risk Index," Policy Research Working Paper 6506, World Bank, Washington, DC, 2013.

4 For the Making Cities Resilient campaign, see http://www.unisdr.org/campaign/resilientcities/; for 100 Resilient Cities http://www.100resilientcities.org

Francis Ghesquiere, Dr. Alanna Simpson, Emma Phillips, Joaquin Toro, Angela Wyan, Simone Balog, Clio Heslop, Professor M
Lianne Dalziel, Honorable Mayor Patricia de Lille, Dr. Roman Frigg, Sir Edward Lister, Matt Frei, Helen Clark, Kristalina Ivar
Honorable Lord Mayor of London, Alderman Fiona Woolf, CBE; Jeffrey Sachs; Stéphane Jacobzone; Sebastian von Dahle
Abigail Baca, Michael Bonte, Daniel Clarke, Adam Cooper, Jo da Silva, Tiguist Fisseha, Matt Foote, Linda Freiner, Maryam G
Kunreuther, Neil Morisetti, Robert Muir-Wood, Massimiliano Pittore, John Rees, Vica Rosario Bogaerts, Sahar Safaie, Peter S
Adam, Sajid Anwar, Yewondwossen Assefa, Christophe Aubrecht, Trish Barrett, Sofia Bettencourt, Jack Campbell, Ker
Dorling, Edouard Ereno Blanchet, Ruben Graml, Tiguist Fisseha, Marc Forni, Oscar Ishizawa, Yohannes Kesete, David La
Singh, Samanmalee Sirimanne, Annegien Tijssen, Luis Tineo, Vladimir Tsirkunov, Jon Walton, Steven Wong, Olivia Gray, D
Rob Eveleigh, Lynda Judge, Sean McGrath, Ben Stanley, Caroline Windsor, Desy Adiati, Regianne Bertolassi, Miki Fernánde
Simpson, Emma Phillips, Joaquin Toro, Angela Wyan, Simone Balog, Clio Heslop, Professor Michael Arthur, Rowan Dougl
Mayor Patricia de Lille, Dr. Roman Frigg, Sir Edward Lister, Matt Frei, Helen Clark, Kristalina Ivanova Georgieva, Secretar
of London, Alderman Fiona Woolf, CBE; Jeffrey Sachs; Stéphane Jacobzone; Sebastian von Dahlen; Michel Lies, Rebecc
Bonte, Daniel Clarke, Adam Cooper, Jo da Silva, Tiguist Fisseha, Matt Foote, Linda Freiner, Maryam Golnaraghi, Lou Gritzo, De
Robert Muir-Wood, Massimiliano Pittore, John Rees, Vica Rosario Bogaerts, Sahar Safaie, Peter Salamon, Simon Sharpe,
Yewondwossen Assefa, Christophe Aubrecht, Trish Barrett, Sofia Bettencourt, Jack Campbell, Keren Charles, Manuela C
Blanchet, Ruben Graml, Tiguist Fisseha, Marc Forni, Oscar Ishizawa, Yohannes Kesete, David Lallemant, Rick Murnane
Sirimanne, Annegien Tijssen, Luis Tineo, Vladimir Tsirkunov, Jon Walton, Steven Wong, Olivia Gray, Daisy Leitch, Michael
Judge, Sean McGrath, Ben Stanley, Caroline Windsor, Desy Adiati, Regianne Bertolassi, Miki Fernández, Anne Himmelfar
Phillips, Joaquin Toro, Angela Wyan, Simone Balog, Clio Heslop, Professor Michael Arthur, Rowan Douglas, Ed Parsons, Ro
Lille, Dr. Roman Frigg, Sir Edward Lister, Matt Frei, Helen Clark, Kristalina Ivanova Georgieva, Secretary Justin Greenin
Heslop, Professor Michael Arthur, Rowan Douglas, Ed Parsons, Robbie Schingler, Professor David Spiegelhalter, Dr. Aris Al
Clark, Kristalina Ivanova Georgieva, Secretary Justin Greening, Rachel Kyte, Secretary Cesar V. Purisima, Professor Ngai
Sebastian von Dahlen; Michel Lies, Rebecca Moore, Giles Duley, Professor Ian Goldin, Dr. Henry Thomas Marsh, Heather M
Freiner, Maryam Golnaraghi, Lou Gritzo, Debarati Guha, Ashley Gupta, Niels Holm-Nielsen, Alex Kaplan, Nicole Keller, Kama
Sahar Safaie, Peter Salamon, Simon Sharpe, Benedikt Signer, Robert Soden, Pablo Suarez, Philip Ward, Emily Wilkinson, Hes
Jack Campbell, Keren Charles, Manuela Chiapparino, Christophe Chung, John Crowley, James Daniell, Vivien Deparday, E
Kesete, David Lallemant, Rick Murnane, Marc Neilson, James Newman, Ariel Nunez, Shaela Rahman, Robert Reid, Keiko S
Olivia Gray, Daisy Leitch, Michael Stevns, Valerie Bassigny, Barbara Blow, Miranna Budimir, Alice Crocker, Rui Cruz Alves, L
Miki Fernández, Anne Himmelfarb, Katie Moss, Evie Kerman Fiore, Alexandra Popescu, Sabina Sadigova, Francis Ghesqui
Rowan Douglas, Ed Parsons, Robbie Schingler, Professor David Spiegelhalter, Dr. Aris Alip, Honorable Mayor Lianne Da
Georgieva, Secretary Justin Greening, Rachel Kyte, Secretary Cesar V. Purisima, Professor Ngaire Woods, the Right Ho
Michel Lies, Rebecca Moore, Giles Duley, Professor Ian Goldin, Dr. Henry Thomas Marsh, Heather McGregor, Ed Smith
Golnaraghi, Lou Gritzo, Debarati Guha, Ashley Gupta, Niels Holm-Nielsen, Alex Kaplan, Nicole Keller, Kamal Kishore, Howard
Salamon, Simon Sharpe, Benedikt Signer, Robert Soden, Pablo Suarez, Philip Ward, Emily Wilkinson, Hessel Winsemius, Bia
Keren Charles, Manuela Chiapparino, Christophe Chung, John Crowley, James Daniell, Vivien Deparday, Eric Dickson, Lau
Lallemant, Rick Murnane, Marc Neilson, James Newman, Ariel Nunez, Shaela Rahman, Robert Reid, Keiko Saito, Prashan
Daisy Leitch, Michael Stevns, Valerie Bassigny, Barbara Blow, Miranna Budimir, Alice Crocker, Rui Cruz Alves, Laura Dr
Fernández, Anne Himmelfarb, Katie Moss, Evie Kerman Fiore, Alexandra Popescu, Sabina Sadigova, Francis Ghesquiere, D
Douglas, Ed Parsons, Robbie Schingler, Professor David Spiegelhalter, Dr. Aris Alip, Honorable Mayor Lianne Dalziel, Honora
Matt Frei, Helen Clark, Kristalina Ivanova Georgieva, Secretary Justin Greening, Rachel Kyte, Francis Ghesquiere, Dr.
Simone Balog, Clio Heslop, Professor Michael Arthur, Rowan Douglas, Ed Parsons, Robbie Schingler, Professor David
Honorable Mayor Patricia de Lille, Dr. Roman Frigg, Sir Edward Lister, Matt Frei, Helen Clark, Kristalina Ivanova Georgie
V. Purisima, Professor Ngaire Woods, the Right Honorable Lord Mayor of London, Alderman Fiona Woolf, CBE; Jeffrey Sa
Rebecca Moore, Giles Duley, Professor Ian Goldin, Dr. Henry Thomas Marsh, Heather McGregor, Ed Smith, Abigail Baca, M
Fisseha, Matt Foote, Linda Freiner, Maryam Golnaraghi, Lou Gritzo, Debarati Guha, Ashley Gupta, Niels Holm-Nielsen, Alex
Morisetti, Robert Muir-Wood, Massimiliano Pittore, John Rees, Vica Rosario Bogaerts, Sahar Safaie, Peter Salamon, Simor
Ward, Emily Wilkinson, Hessel Winsemius, Bianca Adam, Sajid Anwar, Yewondwossen Assefa, Christophe Aubrecht, Trish
Manuela Chiapparino, Christophe Chung, John Crowley, James Daniell, Vivien Deparday, Eric Dickson, Laura Dorling, Edoua
Oscar Ishizawa, Yohannes Kesete, David Lallemant, Rick Murnane, Marc Neilson, James Newman, Ariel Nunez, Shaela Ra
Sirimanne, Annegien Tijssen, Luis Tineo, Vladimir Tsirkunov, Jon Walton, Steven Wong, Olivia Gray, Daisy Leitch, Michael S
Crocker, Rui Cruz Alves, Laura Drake, Miki Fernández; Francis Ghesquiere, Dr. Alanna Simpson, Emma Phillips, Joaquin Tor
Arthur, Rowan Douglas, Ed Parsons, Robbie Schingler, Professor David Spiegelhalter, Dr. Aris Alip, Honorable Mayor Lian
Sir Edward Lister, Matt Frei, Helen Clark, Kristalina Ivanova Georgieva, Secretary Justin Greening, Rachel Kyte, Francis

Michael Arthur, Rowan Douglas, Ed Parsons, Robbie Schingler, Professor David Spiegelhalter, Dr. Aris Alip, Honorable Mayor
nova Georgieva, Secretary Justin Greening, Rachel Kyte, Secretary Cesar V. Purisima, Professor Ngaire Woods, the Right
en; Michel Lies, Rebecca Moore, Giles Duley, Professor Ian Goldin, Dr. Henry Thomas Marsh, Heather McGregor, Ed Smith,
Golnaraghi, Lou Gritzo, Debarati Guha, Ashley Gupta, Niels Holm-Nielsen, Alex Kaplan, Nicole Keller, Kamal Kishore, Howard
Salamon, Simon Sharpe, Benedikt Signer, Robert Soden, Pablo Suarez, Philip Ward, Emily Wilkinson, Hessel Winsemius, Bianca
en Charles, Manuela Chiapparino, Christophe Chung, John Crowley, James Daniell, Vivien Deparday, Eric Dickson, Laura
allemant, Rick Murnane, Marc Neilson, James Newman, Ariel Nunez, Shaela Rahman, Robert Reid, Keiko Saito, Prashant
Daisy Leitch, Michael Stevns, Valerie Bassigny, Barbara Blow, Miranna Budimir, Alice Crocker, Rui Cruz Alves, Laura Drake,
ez, Anne Himmelfarb, Katie Moss, Evie Kerman Fiore, Alexandra Popescu, Sabina Sadigova, Francis Ghesquiere, Dr. Alanna
as, Ed Parsons, Robbie Schingler, Professor David Spiegelhalter, Dr. Aris Alip, Honorable Mayor Lianne Dalziel, Honorable
ry Justin Greening, Rachel Kyte, Secretary Cesar V. Purisima, Professor Ngaire Woods, the Right Honorable Lord Mayor
a Moore, Giles Duley, Professor Ian Goldin, Dr. Henry Thomas Marsh, Heather McGregor, Ed Smith, Abigail Baca, Michael
ebarati Guha, Ashley Gupta, Niels Holm-Nielsen, Alex Kaplan, Nicole Keller, Kamal Kishore, Howard Kunreuther, Neil Morisetti,
Benedikt Signer, Robert Soden, Pablo Suarez, Philip Ward, Emily Wilkinson, Hessel Winsemius, Bianca Adam, Sajid Anwar,
Chiapparino, Christophe Chung, John Crowley, James Daniell, Vivien Deparday, Eric Dickson, Laura Dorling, Edouard Ereno
e, Marc Neilson, James Newman, Ariel Nunez, Shaela Rahman, Robert Reid, Keiko Saito, Prashant Singh, Samanmalee
Stevns, Valerie Bassigny, Barbara Blow, Miranna Budimir, Alice Crocker, Rui Cruz Alves, Laura Drake, Rob Eveleigh, Lynda
rb, Katie Moss, Evie Kerman Fiore, Alexandra Popescu, Sabina Sadigova, Francis Ghesquiere, Dr. Alanna Simpson, Emma
obbie Schingler, Professor David Spiegelhalter, Dr. Aris Alip, Honorable Mayor Lianne Dalziel, Honorable Mayor Patricia de
ng, Rachel Kyte, Francis Ghesquiere, Dr. Alanna Simpson, Emma Phillips, Joaquin Toro, Angela Wyan, Simone Balog, Clio
ip, Honorable Mayor Lianne Dalziel, Honorable Mayor Patricia de Lille, Dr. Roman Frigg, Sir Edward Lister, Matt Frei, Helen
re Woods, the Right Honorable Lord Mayor of London, Alderman Fiona Woolf, CBE; Jeffrey Sachs; Stéphane Jacobzone;
McGregor, Ed Smith, Abigail Baca, Michael Bonte, Daniel Clarke, Adam Cooper, Jo da Silva, Tiguist Fisseha, Matt Foote, Linda
l Kishore, Howard Kunreuther, Neil Morisetti, Robert Muir-Wood, Massimiliano Pittore, John Rees, Vica Rosario Bogaerts,
sel Winsemius, Bianca Adam, Sajid Anwar, Yewondwossen Assefa, Christophe Aubrecht, Trish Barrett, Sofia Bettencourt,
ric Dickson, Laura Dorling, Edouard Ereno Blanchet, Ruben Graml, Tiguist Fisseha, Marc Forni, Oscar Ishizawa, Yohannes
aito, Prashant Singh, Samanmalee Sirimanne, Annegien Tijssen, Luis Tineo, Vladimir Tsirkunov, Jon Walton, Steven Wong,
Laura Drake, Rob Eveleigh, Lynda Judge, Sean McGrath, Ben Stanley, Caroline Windsor, Desy Adiati, Regianne Bertolassi,
ere, Dr. Alanna Simpson, Emma Phillips, Joaquin Toro, Angela Wyan, Simone Balog, Clio Heslop, Professor Michael Arthur,
alziel, Honorable Mayor Patricia de Lille, Dr. Roman Frigg, Sir Edward Lister, Matt Frei, Helen Clark, Kristalina Ivanova
norable Lord Mayor of London, Alderman Fiona Woolf, CBE; Jeffrey Sachs; Stéphane Jacobzone; Sebastian von Dahlen;
, Abigail Baca, Michael Bonte, Daniel Clarke, Adam Cooper, Jo da Silva, Tiguist Fisseha, Matt Foote, Linda Freiner, Maryam
Kunreuther, Neil Morisetti, Robert Muir-Wood, Massimiliano Pittore, John Rees, Vica Rosario Bogaerts, Sahar Safaie, Peter
anca Adam, Sajid Anwar, Yewondwossen Assefa, Christophe Aubrecht, Trish Barrett, Sofia Bettencourt, Jack Campbell,
ura Dorling, Edouard Ereno Blanchet, Ruben Graml, Tiguist Fisseha, Marc Forni, Oscar Ishizawa, Yohannes Kesete, David
t Singh, Samanmalee Sirimanne, Annegien Tijssen, Luis Tineo, Vladimir Tsirkunov, Jon Walton, Steven Wong, Olivia Gray,
rake, Rob Eveleigh, Lynda Judge, Sean McGrath, Ben Stanley, Caroline Windsor, Desy Adiati, Regianne Bertolassi, Miki
r. Alanna Simpson, Emma Phillips, Joaquin Toro, Angela Wyan, Simone Balog, Clio Heslop, Professor Michael Arthur, Rowan
ble Mayor Patricia de Lille, Dr. Roman Frigg, Sir Edward Lister,
Alanna Simpson, Emma Phillips, Joaquin Toro, Angela Wyan,
Spiegelhalter, Dr. Aris Alip, Honorable Mayor Lianne Dalziel,
va, Secretary Justin Greening, Rachel Kyte, Secretary Cesar
achs; Stéphane Jacobzone; Sebastian von Dahlen; Michel Lies,
Michael Bonte, Daniel Clarke, Adam Cooper, Jo da Silva, Tiguist
Kaplan, Nicole Keller, Kamal Kishore, Howard Kunreuther, Neil
n Sharpe, Benedikt Signer, Robert Soden, Pablo Suarez, Philip
n Barrett, Sofia Bettencourt, Jack Campbell, Keren Charles,
ard Ereno Blanchet, Ruben Graml, Tiguist Fisseha, Marc Forni,
hman, Robert Reid, Keiko Saito, Prashant Singh, Samanmalee
Stevns, Valerie Bassigny, Barbara Blow, Miranna Budimir, Alice
o, Angela Wyan, Simone Balog, Clio Heslop, Professor Michael
ne Dalziel, Honorable Mayor Patricia de Lille, Dr. Roman Frigg,
Ghesquiere, Dr. Alanna Simpson, Emma Phillips, Joaquin Toro

Thank you!

What is Understanding Risk?

Understanding Risk (UR) is a global community of experts and practitioners in the field of disaster risk assessment. UR community members share knowledge and experience, collaborate, and discuss innovation and best practice in risk assessment. The community convenes every two years at the UR Forum.

This publication captures the experiences, lessons, and best practices in disaster risk assessment that were discussed in the 2014 UR Forum, held in London, UK.

"Everyone—from homeowners to policy makers—needs access to reliable information on risk along with access to the means to act in accordance with that information. With a community of almost 4,000 members, the Understanding Risk Forum works to advance climate and disaster risk assessment, helping countries, communities, and companies understand the risks they face and plan for a resilient future."

— Rachel Kyte, Vice President and Special Envoy for Climate Change, World Bank Group

"It was a pleasure to welcome the Forum to London . . . The Understanding Risk Forum provided fascinating insight into how cities from across the world are collaborating to share knowledge and experience in order to reduce risks as they continue to expand."

— Sir Edward Lister, Mayor's Chief of Staff and Deputy Mayor, Policy and Planning, London

"Once again, the Understanding Risk Forum was a huge success. It is difficult to imagine a better mix of subject experts, policy makers, and industry members than those who attended this year. I hope that Understanding Risk continues to provide the space for this critical meeting of minds and sharing of best practice into the future."

— Patricia de Lille, Mayor of Cape Town

"Understanding Risk represents a unique opportunity to share new lessons and experiences that are key to building resilience and reducing vulnerability of different communities. It was a pleasure for me to join such an innovative group of people in the field of disaster risk management. Congratulations on the success of the forum!"

— Col. Mamy Razakanaivo, Executive Director, Department of Disaster Prevention and Emergency Management, Republic of Madagascar

"I really valued the opportunity to participate in UR2014, both as a presenter and as an observer. I met people who are engaged in different countries from a wide range of disciplines. Each of them holds a piece of the puzzle that will create the global solutions we are looking for in understanding and managing risk as part of building resilience."

— Lianne Dalziel, Mayor of Christchurch, New Zealand

GFDRR
Global Facility for Disaster Reduction and Recovery

GFDRR
ACP-EU Natural Disaster Risk Reduction Program
An initiative of the African, Caribbean and Pacific Group, funded by the European Union and managed by GFDRR

WORLD BANK GROUP

www.understandrisk.org