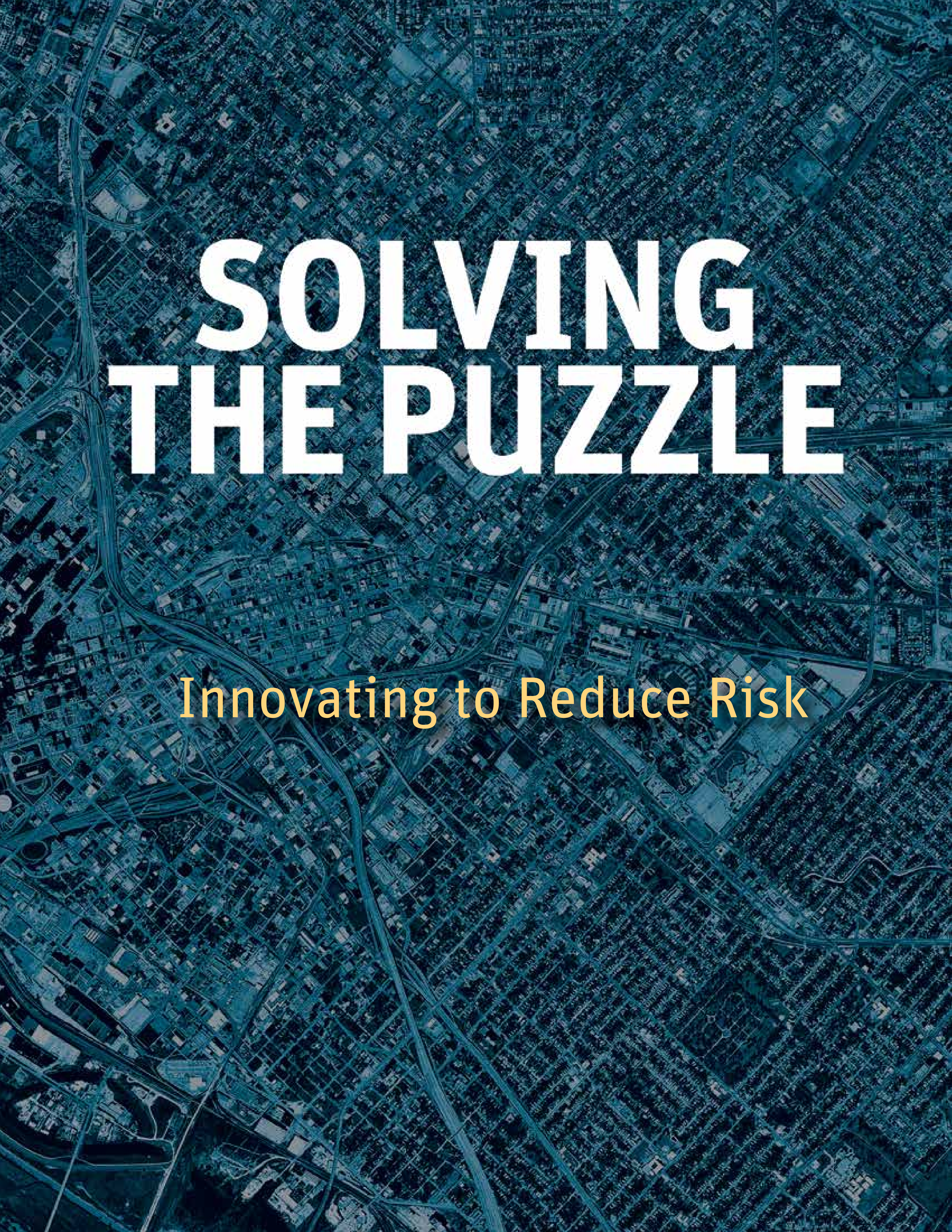
SOLVING THE PUZZLE

Innovating to Reduce Risk



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Collaborators

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Abbreviations

AGU	American Geophysical Union
CAPRA	Central America Probabilistic Risk Assessment
CEPREDENAC	Centro de Coordinación para la Prevención de los Desastres Naturales en América Central
CIA	Central Intelligence Agency
CIESIN	Center for International Earth Science Information Network
DEM	Digital Elevation Model
DFID	Department For International Development
DRM	Disaster Risk Management
GDP	Gross Domestic Product
GED	Global Exposure Data
GEM	Global Earthquake Model
GFDRR	Global Facility for Disaster Reduction and Recovery
GIS	Geographic Information System
GRID	Global Resource Information Database
IADB	Inter-American Development Bank
IT	Information Technology
NSF	National Science Foundation
OSM	OpenStreetMap
RASOR	Rapid Analysis and Spatialisation of Risk
RFP	Request For Proposals
SALB	Second Level Administrative Boundary
SEDAC	Socioeconomic Data and Applications Center
SHELDUS	Spatial Hazard Events and Losses Database for the United States
SRTM	Shuttle Radar Topography Mission
UNEP	United Nations Environment Programme
UNISDR	United Nations Office for Disaster Risk Reduction
WAPMERR	World Agency of Planetary Monitoring & Earthquake Risk Reduction

Overview

This report provides a community perspective on priorities for future collaboration and investment in the development and use of disaster risk information for developing countries. The focus is on high-impact activities that will promote the creation and use of risk-related data, catastrophe risk models, and platforms, and that will improve and facilitate the understanding and communication of risk assessment results.

The intended outcome of this report is twofold. First, that through the community speaking as one voice, we can encourage additional investment in the areas highlighted as priorities. Second, that the consensus embodied in the report will initiate the formation of the strong coalition of partners whose active collaboration is needed to deliver the recommendations.

The material in this report synthesizes the input from individuals representing over 110 institutions. The input was received through a variety of methods including:

- Verbal contributions provided through six consultations:
  - 2014 Understanding Risk conference held in London, UK
  - 2014 American Geophysical Union (AGU) Fall Meeting in San Francisco, USA
  - 2015 bilateral meetings in London, UK with the DRM community
  - 2015 UN World Conference on Disaster Risk Reduction held in Sendai, Japan
  - 2015 AGU Fall Meeting in San Francisco, USA
  - 2016 Understanding Risk conference held in Venice, Italy
- Written contributions from the disaster risk management community. The twenty-five written contributions were received in response to open calls to the Understanding Risk Community and direct solicitation.[1]
- Results from two on-line canvassing efforts:
  - One captured input from twenty-two users with the goal of characterizing how risk-related data are accessed and used
  - The other captured input from thirty-six respondents and explored the risk community's views on the value and feasibility of actions designed to further the ability of developing countries to access, use, and understand data, models and platforms related to disaster risk assessments and then communicate and implement activities designed to reduce disaster risk.

The report starts by presenting the motivation for the effort and an overview of the current state of risk assessment. This is followed by a review, which is based on the written contributions and consultations, of the current challenges for assessing, understanding, and communicating natural disaster risk. The report ends with specific recommendations for action based on community input.

[1] https://understandrisk.org/initiative/solving-the-puzzle/

There is an urgent and growing need for DRM. The need is in response to the increasing trend in the number of events associated with losses), and by the size of the associated losses and fatalities produced by the events.

Introduction

This initiative provides a community perspective on priorities for future collaboration and investment in the development and use of disaster risk information. While recognizing that some of the remaining challenges can be addressed through individual actions, this initiative is based on the belief that more progress can be made by acting together as a community. This section provides the motivation for the initiative and describes the approach used to develop the community views described in the report.

MOTIVATION

There is an urgent and growing need for disaster risk management (DRM). The need is in response to the increasing trend in the number of events associated with losses (Figure 1), and by the size of the associated losses and fatalities produced by the events[2]. The positive trend in the number of events is due to a variety of factors. To a great extent, the increase is related to increases in population, particularly in areas exposed to natural hazards. In addition, climate change may increase the frequency and intensity of some types of hydrometeorological extremes such as heavy precipitation[3]. Finally, in many cases, the populations exposed to natural hazards are highly vulnerable[4,5].

While disaster losses are significant in all regions of the world, they can have a disproportionate and staggering impact on developing countries. Two examples, one geophysical and the other meteorological, illustrate the significant impact of natural hazards. The 2010 earthquake in Haiti caused direct and indirect losses of around $8 billion. This loss was equivalent to ~120% of Haiti's GDP[6]. In 2013, Super Typhoon Haiyan affected nearly 13 million people in the Philippines – over 10% of the country's population. In addition, Super Typhoon Haiyan completely destroyed almost 90% of homes in the hardest hit areas[7]. While these are extreme examples, experience shows that lower income countries suffer disproportionate losses from natural disasters.[8]

In addition to the immediate destruction and injury caused by a natural disaster, there are longer-term impacts. For example, Hsiang and Jina[9] document the lingering, detrimental effect of tropical cyclones on long-term economic growth. More generally, Peter et al.[10] used Munich Re data to show that significant natural

2 See for example, loss and fatality statistics in Swiss Re, *sigma* No 1/2016, http://media.swissre.com/documents/sigma1_2016_en.pdf, and in Munich Re, Topics Geo, Natural Catastrophes 2015, https://www.munichre.com/site/touch-publications/get/documents_E1273659874/mr/assetpool.shared/Documents/5_Touch/_Publications/302-08875_en.pdf

3 Seneviratne, S.I., N. Nicholls, D. Easterling, C.M. Goodess, S. Kanae, J. Kossin, Y. Luo, J. Marengo, K. McInnes, M. Rahimi, M. Reichstein, A. Sorteberg, C. Vera, and X. Zhang, 2012: Changes in climate extremes and their impacts on the natural physical environment. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 109-230.

4 Winsemius, H. C, B. Jongman, T. I.E. Veldkamp, S. Hallegatte, M. Bangalore, P. J. Ward, 2015: Disaster Risk, Climate Change, and Poverty Assessing the Global Exposure of Poor People to Floods and Droughts, World Bank Group, Policy Research Working Paper 7480. http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2015/11/05/090224b0831972af/1_0/Rendered/PDF/Disaster0risk000floods0and0droughts.pdf

5 Climate Change, Disaster Risk, and the Urban Poor: Cities Building Resilience for a Changing World, 2012, J. L. Baker, ed., World Bank Group, Washington, D.C.

6 http://www.worldbank.org/en/country/haiti

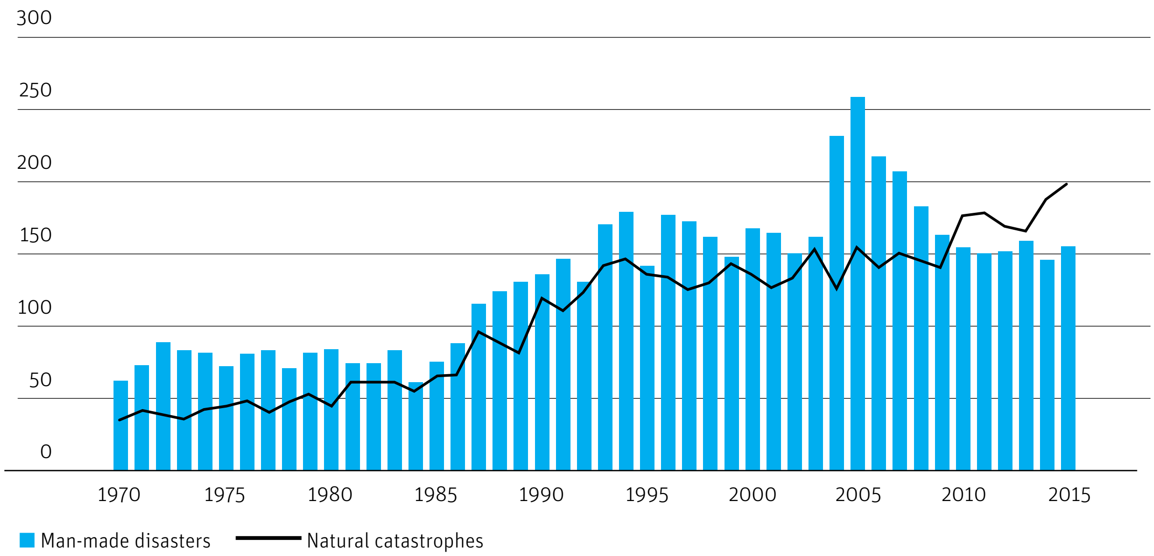
7 http://www.mercycorps.org/articles/philippines/quick-facts-what-you-need-know-about-super-typhoon-haiyan

8 See for example: J. Linnerooth-Bayer, R. Mechler, S. Hochrainer-Stigler, 2011: Insurance against losses from natural disasters in developing countries. Evidence, gaps and the way forward, Journal of Integrated Disaster Risk Management, 1, 59-81 and I. Noy, 2014: A non-monetary global measure of the direct impact of natural disasters, Background paper for 2015 Global Assessment Report on Disaster Risk Reduction, http://www.preventionweb.net/english/hyogo/gar/2015/en/bgdocs/Noy,%202014.pdf

9 Hsiang, S., and A. Jina (2014), The causal effect of environmental catastrophe on long-run economic growth: evidence from 6,700 cyclones, National Bureau of Economic Research, NBER Working Paper Series 20352.

10 G. v. Peter, S. v. Dahlen and S. Saxena (2012): *Unmitigated disasters? New evidence on the macroeconomic cost of natural catastrophes*, BIS Working Papers No 394, Bank for International Settlements.

FIGURE 1 **Annual number of natural catastrophes (black line) and man-made disasters (blue bars) from 1970 to 2015. There is interannual variability in the number of natural catastrophes, but there is an increasing trend over the period of record. Data courtesy of Swiss Re Economic Research & Consulting and Cat Perils.**



Source: Swiss Re Economic Research & Consulting and Cat Perils.

catastrophes (those causing over 100 fatalities or direct losses exceeding US$250 million) are significantly correlated with a cumulative ~4% reduction in GDP after five years. In addition to reducing the number and impacts of disasters, improved disaster resilience should reduce the demand for relief and humanitarian organizations' resources, which have been under considerable pressure in recent years.

The prospects for future increases in population and for changes in population distribution portend a future with an increased risk of loss from natural disasters. For example, Neumann et al.[11] provide estimates of population growth in coastal regions below 10 meter elevation. They estimate the population in the coastal regions will grow from 625 million in 2000 to anywhere from 1.1 billion to 1.4 billion in 2080, depending on which of four future scenarios is used. Most of the estimated population growth will occur in the less developed regions and least developed countries. Given rapid urbanization, much of this growth is likely to occur in and around cities. Without robust actions supported by activities such as risk assessments and DRM, the indicators of a riskier future are likely to be realized.

The outsized impact of disasters on developing countries is likely to continue. According to a recent World Bank report, Shock Waves, climate change is expected to hit the poor hardest.[12] Given that the poor tend to reside in more vulnerable locations, it seems likely that developing countries will continue to suffer the most from natural disasters unless something changes. While we can't control the occurrence of an earthquake, tropical cyclone, or other natural hazard, we can reduce the frequency and magnitude of disasters by helping countries become more resilient to natural hazards, and one way to do this is through more effective efforts at disaster risk reduction.

[11] Neumann, B., A. T. Vafeidis, J. Zimmermann, and R. J. Nicholls (2015), Future Coastal Population Growth and Exposure to Sea-Level Rise and Coastal Flooding - A Global Assessment, *PLoS ONE, 10,* (3), e0118571, doi:10.1371/journal.pone.0118571.

[12] Shock Waves: Managing the Impacts of Climate Change on Poverty (2016) by S. Hallegatte, M. Bangalore, L. Bonzanigo, M. Fay, T. Kane, U. Narloch, J. Rozenberg, D. Treguer, and A. Vogt-Schilb. Climate Change and Development Series. Washington, DC: World Bank.

Investing in disaster risk reduction has benefits beyond the reductions in fatalities and loss included in a typical cost–benefit analysis. The investments can produce a "triple dividend"[13] through:

- A reduction in fatalities and loss,
- An increase in investments that stimulate innovation and economic activity due to the reduction in disaster risk, and
- An increase in social, environmental, and economic synergies that provide co-benefits, even if a disaster doesn't happen.

The co-benefits of disaster risk reduction can occur at a personal level and be direct, for example, employment associated with implementing risk reduction activities. Or, they can be indirect, for example, the social benefits associated with a population's sense of greater personal well-being produced by the knowledge that they are better protected and prepared for disaster. Indirect environmental benefits may include the protection and conservation of biodiversity and the maintenance of ecosystem services afforded by the creation of undeveloped regions dedicated to relieving flood overflow.

Given the clear impacts of natural disasters and the acknowledged benefits of disaster risk reduction in general and risk assessment in particular, this report is motivated by a desire to reduce risk and to make developing countries more resilient through more frequent use of risk assessments and the enhanced communication of the risk assessment results.

Identifying and understanding disaster risk using a disaster risk assessment is a critical step toward implementing an effective DRM strategy, as is evidenced by Priority 1: "Understanding disaster risk" of the Sendai Framework for Disaster Risk Reduction[14]:

Disaster risk management should be based on an understanding of disaster risk in all its dimensions of vulnerability, capacity, exposure of persons and assets, hazard characteristics and the environment. Such knowledge can be used for risk assessment, prevention, mitigation, preparedness and response.

Understanding disaster risk requires a wide array of risk-related data on exposure, hazard, and vulnerability as well as risk models for the hazard of interest. Reference data such as land use, soil type, topography and bathymetry are often required. In addition, the country undertaking a risk assessment should have the capacity to collect or access the necessary data and models, run a model analysis, and understand the model output. Finally, for actions to occur in response to the risk assessment, the results must be communicated effectively to decision makers and the communities of interest.

Thus, performing and using risk assessments to implement disaster risk reduction strategies requires a broad range of efforts and the expertise of multiple disciplines. This report draws upon experts across these many disciplines to assess the status of risk data and models and determine how risk data and models are accessed and used. This information is then used to identify effective actions that would promote the use of risk models and data by developing countries.

APPROACH

To present a consensus view that would be embraced by the community, this report sought to engage the DRM community in order to understand the current state of risk models, data and platforms, and determine the current challenges and needs of the community. The report defines the DRM community as:

- **Donors** that support DRM activities ranging from model development and data collection to risk communication and capacity building;
- **Providers and creators** of risk data, models, analytics, platforms, training, and communication tools; and,
- **Users** of the products and services offered by providers, and who also might be recipients of aid from donors.

Through the course of developing this report, we consulted individuals from more than 110 organizations.

[13] Tanner, T., and J. Rentschler (2015), *Unlocking the "Triple Dividend" of Resilience*, Overseas Development Institute (London) and The World Bank Group (Washington, DC).

[14] http://www.unisdr.org/we/coordinate/sendai-framework

A variety of approaches were used to engage the DRM community, including:

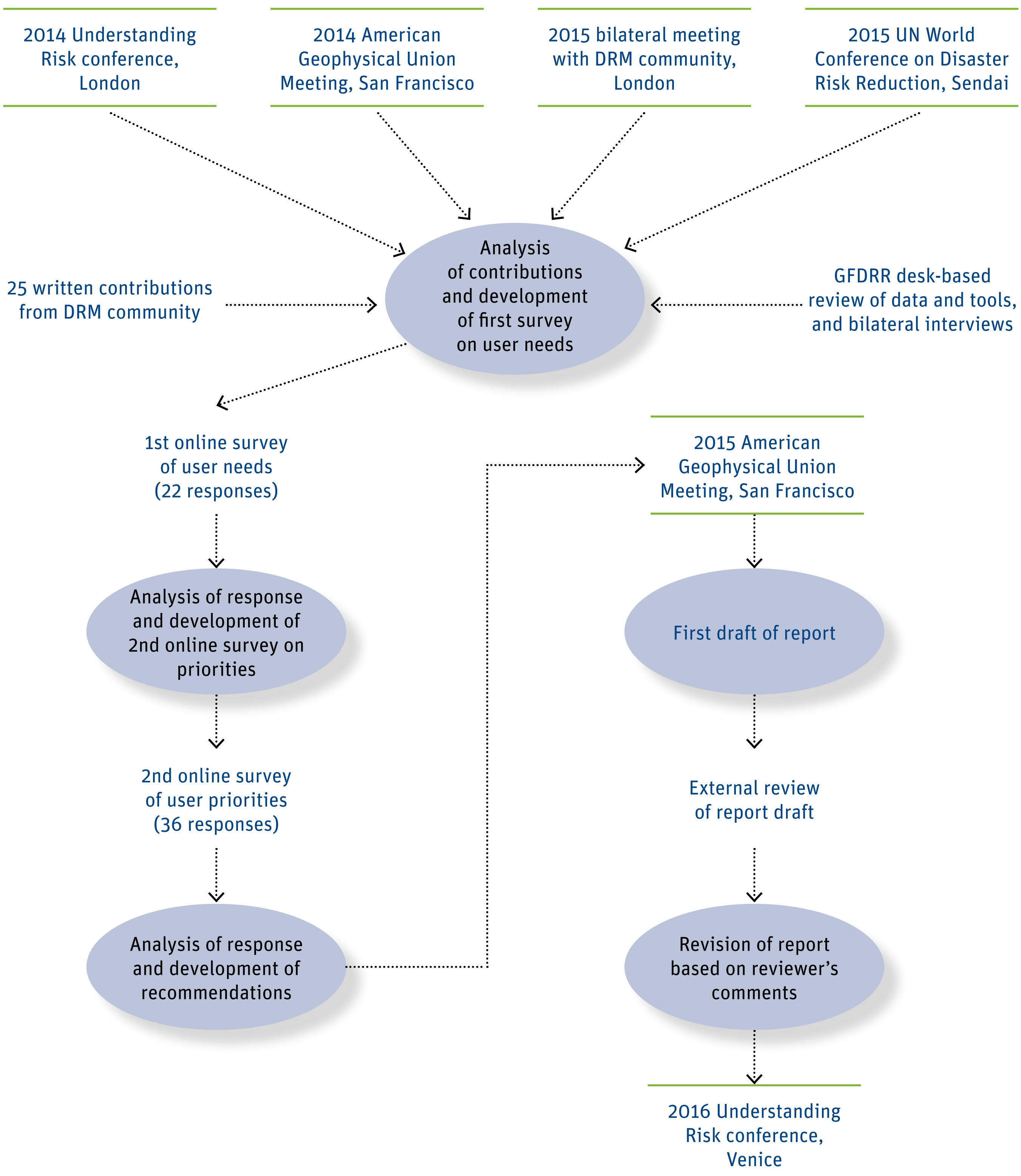
- A series of six consultations in three continents over a course of two years that involved individuals from over 50 organizations.
- Twenty-five written contributions from the DRM community that benefited from the input of 35 organizations.
- Two open, online canvassing efforts that involved over 50 individuals.

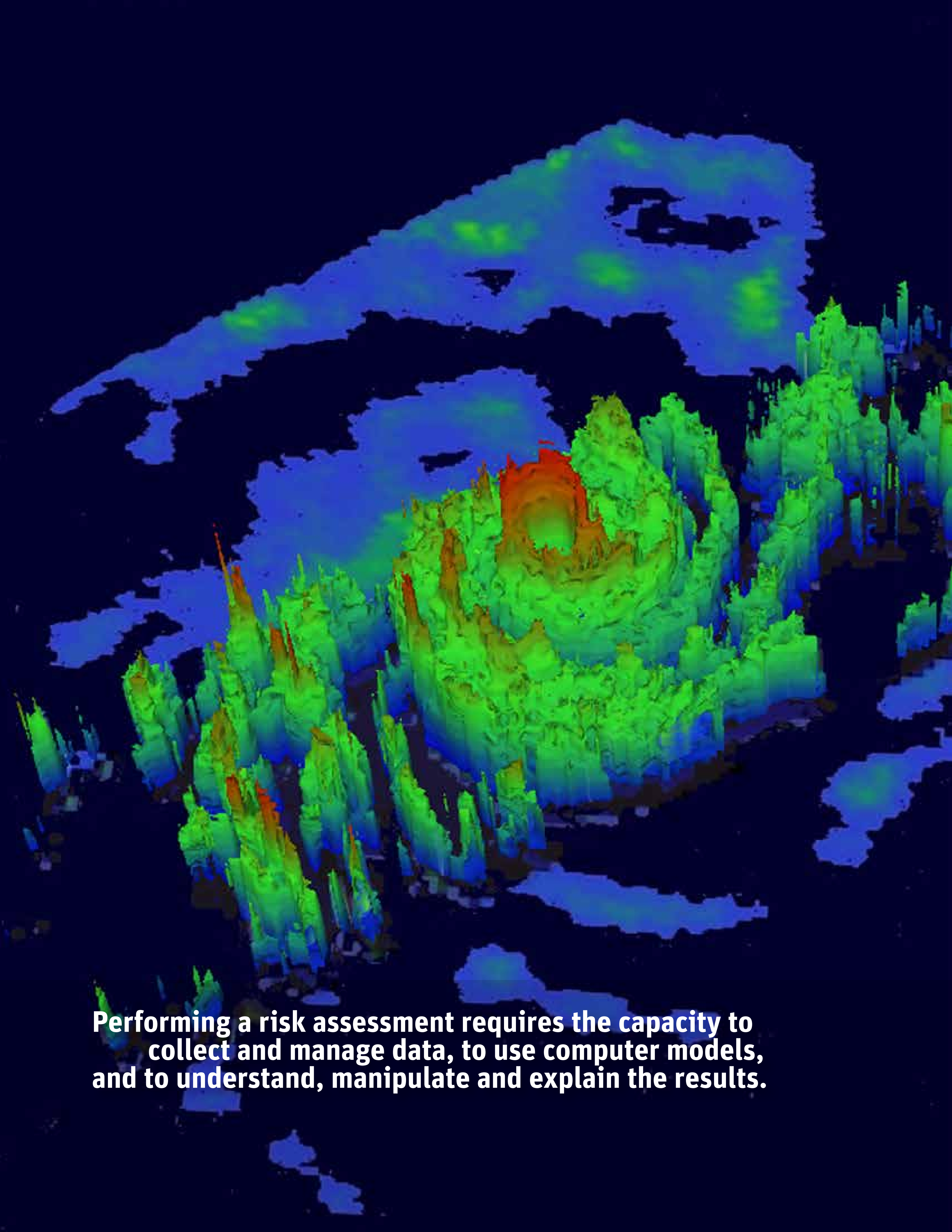
A flow chart of the process used to develop the report is shown in Figure 2. The process started with a set of four consultations, the solicitation of written contributions from the DRM community, and bilateral interviews with the DRM community. Input from the consultations, discussions with the authors of the twenty-five written conversations and the interviews were used to generate the questions for the first online survey. Next, an analysis of the twenty-two responses to the first online survey[15] and the previous inputs were used to generate a second online survey[16]. The were then used to develop a series of recommended next steps. These recommendations were presented for comment and further input at the 2015 AGU Fall Meeting. This input was then used to develop a draft report that was reviewed by eight practitioners. A revised version of this report was then presented for comment and further review at a 2016 Understanding Risk Focus Session.

The process used to develop this report captured a broad sample of the DRM community's view on priorities for future collaboration and investment in the development and use of disaster risk information for developing countries. Based on this guidance, the report provides a roadmap for future investment choices. But, before presenting what needs to be done, we first review the current environment for risk data, models, capacity and communication.

15 https://www.surveymonkey.com/results/SM-SNCC75SJ/
16 http://tinyurl.com/z9xfdfv

FIGURE 2 Schematic diagram illustrating the process used to collect community input for this report. Over 125 individuals from over 100 institutions contributed to the report. The online responses were anonymous and are not included in the counts.





Performing a risk assessment requires the capacity to collect and manage data, to use computer models, and to understand, manipulate and explain the results.

Risk data, models, capacity and communication: availability and challenges

Three requirements for successfully completing a detailed risk assessment are: data, capacity, and models. A detailed risk assessment is a data-intensive effort. Performing a risk assessment requires the capacity to collect and manage data, to use computer models, and to understand, manipulate and explain the results. The models used for the assessment are often proprietary, but there are also open source options. The necessary data span a wide range of topics including: hazards, exposure, vulnerability and loss. In addition, a variety of reference data are required including information on features such as topography, bathymetry, soils, and land use. If the results of a risk assessment are to be used effectively, they must be communicated to decision-makers and the public in a manner that they can comprehend and act on.

In practice, the data, models, and/or capacity needed to complete a risk assessment, and act on the results, are often lacking. When undertaking a risk assessment in a developing country, it is common to discover that data are missing or never collected. Even when data are known to exist, they are often difficult to locate, there are complications regarding who owns or controls access to the data, or the data are costly to obtain. Once the data are in hand, they are often in a difficult-to-use form, such as a hard copy or a non-standard format.

The types of models used for a risk assessment vary depending upon the goal. Results that will be used to support a financial product such as insurance require higher standards than a preliminary national level risk assessment. In many cases, such as when creating a financial product for a developing country, a customized effort is required to adapt a proprietary commercial risk model to the region of interest. However, for other purposes, a risk assessment can sometimes be based on existing open source models and open data, generally extracted from global datasets. But, when using open models and data, adequate loss data to validate the model results are typically not available, and vulnerability functions may need to be adapted to local conditions.

Completing a detailed risk assessment in developing countries often entails a variety of additional challenges beyond collecting and managing data and setting up and executing models. The computational resources that are available may not be adequate for the purpose, internet connections are often slow, and in-country capacity for running, understanding, and communicating results is often limited.

The spatial and temporal scales of the analysis are important factors to consider when identifying and assembling the models and data that will be used for a risk assessment. The spatial scale will dictate the required data resolution. For example, detailed flood modeling requires high-resolution topographic information, whereas basin-scale flood estimates for a large river basin can use coarser resolution topographic data. Exposure data also respond to spatial scale. Some models will be designed to handle population or GDP data at various administrative areas, whereas others will require detailed site-specific engineering information on a structure. The vulnerability functions required for, and loss data produced by, these models will be similarly variable. The spatial scale also affects the choice of model resolution and coverage. A typhoon or tsunami model could encompass all of the North Pacific while a local flood model may only need to consider a small river basin or urban catchment.

Examples of different risk assessment activities at different scales are given in Table 1. The examples show that the spatial resolution required of the data can range from aggregate data at the national level to detailed, site-specific information, and that the types of exposure data can be socioeconomic (for example, GDP and population data) or structural (building occupancy and construction

TABLE 1 Examples of public, private, and nonprofit risk assessments at a variety of spatial scales.

Product	Purpose	Scale	Data Requirements	Cost
Qualitative national risk profile	Advocacy and initiation of DRM dialogue	National	Low: Requires global, regional, and/or national datasets	$
Community-based disaster risk assessment	To engage communities, communicate risk, and promote local action	Community	Low: Typically based on historical disaster events	$
Quantitative national risk profile	For advocacy and initiation of DRM dialogue based on quantitative risk assessment	National	Low-moderate: Requires global, regional, and/or national datasets	$$
Asset-level risk assessments, including cost–benefit and engineering analysis	To inform design of building-level/ asset-level risk reduction activities and promote avoidance of new risk	Building/ infrastructure level	Moderate-high; requires high-resolution local data for large spatial areas	$$
Macro-level risk assessment for risk reduction, including cost–benefit analysis	To inform urban/regional risk reduction measures	Urban/ regional/ national	Moderate-high: Requires moderate to high resolution across large spatial areas	$$$
Risk identification to identify critical infrastructure and establish early warning systems	To inform preparedness and risk reduction, based on understanding of potential damage at the regional/ local level	Urban/ regional/ national	Moderate-high: Requires asset-level information across large spatial areas	$$–$$$
Catastrophe risk assessment for financial planning	For financial and fiscal risk assessment of disasters and to catalyze catastrophe risk insurance market growth	National to multi-country	High: requires high-resolution, high-quality data	$$$

class). Temporal scales are also important. For some purposes only short-term return period information may be needed, e.g., for drought risk, whereas for other perils, such as earthquake or volcano risk, return periods of hundreds or thousands of years might be needed.

In order to provide more details on the concerns related to data, models, platforms, capacity and communication, the following sections review:

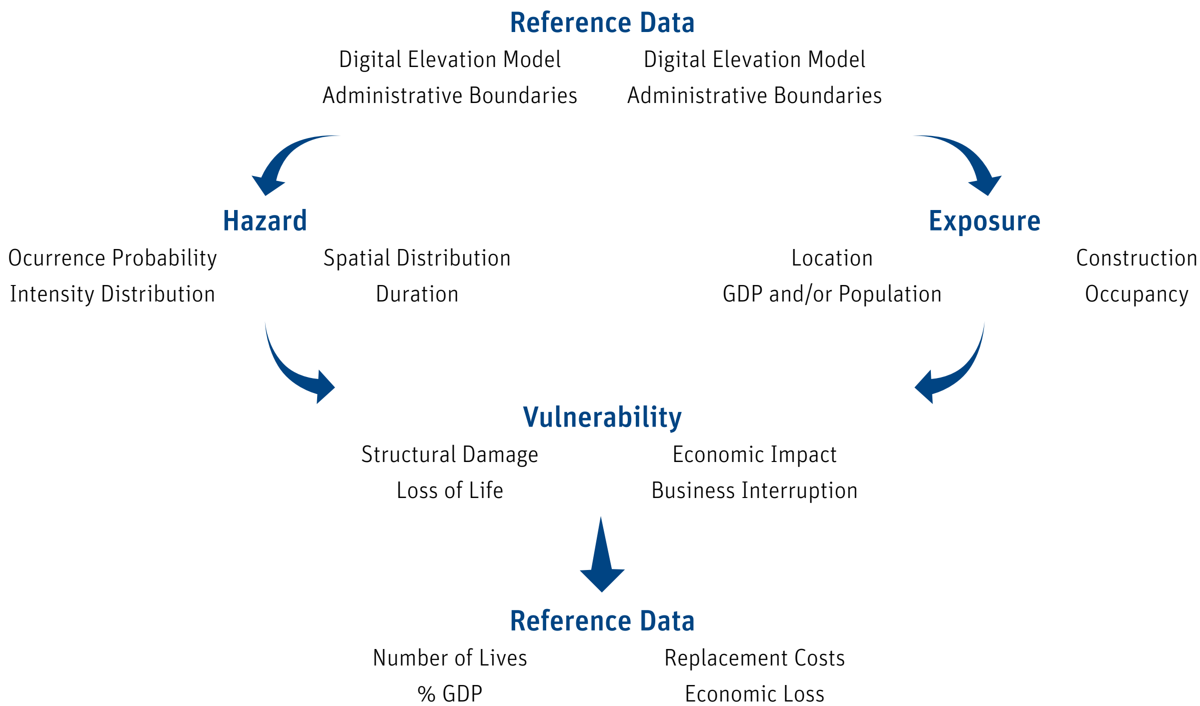
- The components of a catastrophe risk model in order to provide context for the different types of data that are needed for a risk assessment
- Examples of different platforms that are used to deliver data or support model runs
- The different categories of data used in risk assessments, and
- Issues related to capacity and communication of risk that are relevant to the use of risk assessments in developing countries.

Except as otherwise noted by footnotes, the material in this section is based on the experience of GFDRR.

CATASTROPHE RISK MODELS

Catastrophe risk models (cat models) are common tools used to assess natural disaster risk. The models typically have four components: hazard, exposure, vulnerability and loss (Figure 3). Reference data are used to modify a hazard or categorize exposure. The hazard component represents the peril of interest and accounts for factors such as the spatial distribution of the hazard's intensity, its probability of occurrence, and the duration of the event. An exposure

FIGURE 3 **Schematic diagram illustrating the different types of data and model results used with and produced by a typical cat model. Note that the items listed under each category (shown in blue) are meant to be examples of information associated with each category.**



component represents the assets or population of interest that are georeferenced to administrative levels, postal codes, grid cells, or specific latitudes and longitudes. Additional information such as the occupancy and construction characteristics of a structure, or socio-economic information on a population, is commonly included to better describe the exposure of interest. The vulnerability component simulates the response of the exposure to the forces from a hazard event. Finally, a loss component is used to determine the losses in terms of interest (GDP, fatalities, economic loss, etc.).

Cat models can be used in a probabilistic mode to quantify the risk from a hazard. To do this, the hazard component can include thousands (or more) hypothetical hazard events with statistical characteristics consistent with historical observations or with future climate scenarios. The synthetic events are typically derived through a combination of empirical and theoretical knowledge of hazard.

Cat models can also be used in a deterministic mode to quantify the impact of a single event. Single events may be hypothetical or reconstructions of historical events.

A subset of a catastrophe risk model is an impact model, which is essentially a risk model that can only be used deterministically. The impact model uses hypothetical or historical events to simulate "what-if" scenarios that are often used as an aid for disaster planning and management. An example of an impact modeling tool is InaSAFE.[17]

The past decade has seen an increase in the number and capabilities of risk models. Several factors

[17] http://inasafe.org/

contribute to this increase. One is technological and related to the increases in computing power, data storage and cloud computing resources. Another is the associated fall in their associated cost. The combination of these two factors makes complex models more computationally feasible and accessible to more users. An additional factor is the regulatory standards associated with the upcoming implementation of Solvency II in the European Union.[18] The Governance and Supervision pillar of Solvency II requires that insurers "own their risk," one aspect of which is that insurance companies will be responsible for understanding their exposure to catastrophe risk. A complete understanding includes an assessment of the uncertainty in their exposure. One of the best ways to assess the uncertainty in exposure to catastrophe risk is to use multiple catastrophe risk models. There are significant costs associated with licensing multiple catastrophe risk models and with hiring and training employees to understand, use and maintain the models. The growing interest in risk modeling platforms is driven in part by a desire to make it easier and more cost effective to use multiple models.

Most of the (re)insurance and financial industry interested in property cat risk uses proprietary and/or commercial risk models for business purposes. The larger cat modeling companies produce a suite of risk models for a variety of natural hazards that occur in many regions of world. There are numerous smaller companies that often specialize in a specific hazard or geographic area. The geographic coverage and perils covered by the commercial models are driven by market interest. Companies will license models only if they have a business interest in the region. Most developing countries have an immature insurance market and as a result the commercially available risk models tend to be less developed than models for regions with large insurance markets. Developing catastrophe risk models for developing countries typically requires that an existing model be customized for the new region and additional data collection efforts.

A successful commercial model is much more than the core catastrophe model. It must be (relatively) easy to use and provide data and tools that allow a user to manipulate and analyze the model results. Thus, modeling companies also expend significant effort to develop user interfaces, analytical tools and industry exposure datasets.

There are a growing number of freely available and open source models. Many of the software packages include graphical user interface (GUI) and can be installed on a PC with a few mouse clicks. The models vary in complexity, with most tending to focus on a single peril. A GFDRR report[19] offers suggestions for combining models for different perils to produce a multi-risk model with multiple views of a hazard. Acting on such suggestions would be one way to facilitate the use of a multi-model approach for risk assessment activities by developing countries. However, effectively combining models requires the consideration of a variety of issues including model resolution, modeling units, and data compatibility.[20]

The growth in open source and freely available models will benefit developing countries. However, the existence of a "free" model is not full solution. A potential user must be aware of the model's existence, have access to the internet, and know how to download the object code, or know how to compile source code. In addition, most models still require location-specific data such as exposure information or a digital elevation model. Also, varying levels of expertise are required to install, run, and interpret the model results. Finally, the computational hardware required to run the model and to store and analyze model results must also be available.

RISK PLATFORMS

"Risk platform" is a generic term that can mean different things depending on the context. Here we use the term

[18] http://ec.europa.eu/finance/insurance/solvency/solvency2/index_en.htm

[19] GFDRR (2014), *Understanding Risk: Review of Open Source and Open Access Software Packages Available to Quantify Risk from Natural Hazards*, The World Bank, Washington, DC.

[20] A. Hughes and J. Rees, "Visions for the Future: Model Interoperability" and M. Werner et al., "Toward an Open Platform for Improving the Understanding of Risk in Developing Countries". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf Branagan, I. et al. (2014) Plug and play: What will it take to connect the modelling tools?. In: Understanding Risk: Producing actionable information, Proceedings from the 2014 UR Forum, IBRD/World Bank, Washington, DC., 41-45.

platform to describe a website that offers data, models, or computational capabilities. Additional modifiers can be used to describe what the platform offers. A population data platform would act as an online data portal, see for example the population data available at WorldPop[21] and a loss data platform would be a data platform that provides loss-related data such as, for example, DesInventar[22]. Similarly, a risk model platform would be an online source of risk models such as ERGO-EQ[23] and a modeling platform would provide computational resources for modeling.[24]

To date, the most sophisticated platforms for risk modeling have been produced by commercial risk modeling companies. This dominance may be challenged in the future, however, by public or nonprofit ventures. Two promising examples of alternative risk modeling platforms are the open source earthquake platform OpenQuake[25], produced by the Global Earthquake Model (GEM) Foundation, and the Oasis Loss Modeling Framework.[26] A number of other risk platforms are also currently available or under development (Table 2). The Rapid Analysis and Spatialisation of Risk (RASOR Project)[27], for instance, will provide a hosted, open-source platform for doing impact assessments. These platforms are being developed by different combinations of the public, private, and nonprofit sectors and have varying strategies for supporting users. However, many challenges remain to make the platforms compatible with each other and more user-friendly.[28]

While online platforms offer solutions for a variety of data, model, and modeling concerns, they may not be a panacea for developing countries. Bandwidth and connectivity issues are a particular concern. Nonetheless, having a hosted environment minimizes the need for expensive hardware, offers solutions for data and model backup and recovery, and removes the necessity of a user having to install their own model.

RISK-RELATED DATA

The following review of risk-related data is not meant to be comprehensive. Instead, the goal is to summarize the range of data types needed for a risk assessment. Based on the components illustrated in Figure 3, the data needed for a risk assessment can be grouped into five categories: reference, hazard, exposure, vulnerability, and loss.

In general, data can be classified as being either "open" or "closed". The organization Open Knowledge[29] provides a succinct definition for what constitutes open data. Essentially, data are open when they can be freely used, modified, and shared by anyone for any purpose.[30] Closed data are generally proprietary data that cannot be shared and that can often be licensed for a fee.

While the use of open data may seem to be preferable to "closed" data, this is not necessarily true. Consider the case of a digital elevation model (DEM). A global set of open DEM data—for example, the SRTM 90m data[31]—are of insufficient resolution for detailed flood modeling. Higher resolution data are needed to adequately assess flood risk. An example of this is provided by Griffin et al.[32]

Developing countries often use publicly available and open data because of resource limitations. However, open data have other advantages beyond their (lack of) cost — in particular, open data, once obtained, can

21 http://www.worldpop.org.uk/data/get_data/

22 https://online.desinventar.org/ and M. Gall et al., "Understanding Disaster Risk Through Loss Data". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

23 http://ergo.ncsa.illinois.edu/?page_id=356

24 J. Rees and A. Hughes, "Visions for the Future: Multiple Platforms and the Need for Capacity Building". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

25 J. Schneider et al., "Development of an Open Platform for Risk Modeling: Perspective of the GEM Foundation". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

26 D. Whitaker and P. Taylor, "Oasis: The World's Open Source Platform for Modeling Catastrophic Risk". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

27 http://www.rasor-project.eu/

28 J. E. Daniell, "The Current State of Open Platforms and Software for Risk Modeling: Gaps, Data Issues, and Usability", A. Hughes and J. Rees, "Visions for the Future: Model Interoperability" and J. Schneider et al., "Development of an Open Platform for Risk Modeling: Perspective of the GEM Foundation". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

29 https://okfn.org/

30 http://opendefinition.org/

31 http://www.cgiar-csi.org/data/srtm-90m-digital-elevation-database-v4-1

32 J. Griffin et al., "High-Resolution Elevation Data: A Necessary Foundation for Understanding Risk". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

TABLE 2 **Examples of risk model and risk modeling platforms.**

Model or platform	Organization	Description
Oasis	Oasis Loss Modeling Framework	An open architecture loss modeling framework
OpenQuake	GEM	A suite of open-source software comprising a great variety of (desktop) tools for modeling and for accessing and exploring GEM products
RASOR	EU-funded Consortium	A platform to perform multi-hazard risk analysis to support the full cycle of disaster management
EigenPrism	EigenRisk	A platform providing access to high-speed modeling and robust analytical capabilities
RMS(one)	RMS	A proprietary risk modeling platform
Touchstone	AIR Worldwide	A proprietary risk modeling platform
Inhance	ImageCat	A data analysis and validation platform
RiskInsight	Karen Clark and Company	A global platform for catastrophe risk assessment and management
Elements	Impact Forecasting/AON Benfield	A proprietary loss calculation platform that enables insurers to create customized risk management solutions
JCalf 15	JBA Risk Management	A catastrophe modeling platform with multi-peril probabilistic risk models.
FEWS	Deltares	An open data-handling platform comprising a sophisticated collection of modules designed for building a hydrological forecasting system customized to the specific requirements of an individual organization
DEWETRA	CIMA Research Foundation	A real-time integrated system for hydro-meteorological and wildfire risk forecasting, monitoring and prevention
DesignSafe-ci	Natural Hazards Engineering Research Infrastructure (NHERI)	The cyberinfrastructure (CI) component of the NSF (National Science Foundation)-supported Natural Hazards Engineering Research Infrastructure (NHERI)
Ergo-EQ	Mid-America Earthquake Center at the University of Illinois	A seismic risk assessment tool, based on Consequence-based Risk Management (CRM) and developed on the Ergo-Core framework, to help coordinate planning and event mitigation, response, and recovery
CAPRA	CEPREDENAC, UN ISDR, World Bank Group, IADB	A modular software platform to support probabilistic risk analysis related to natural hazards that also supports the design of risk-financing strategies

For more information on specific open source risk models, see the GFDRR publication that provides a comprehensive review of openly available and open source risk models: GFDRR (2014), *Understanding Risk: Review of Open Source and Open Access Software Packages Available to Quantify Risk from Natural Hazards*, The World Bank, Washington, DC.

be reused for other projects and by other ministries. The contribution by Butler provides additional insight into the advantages and constraints of open data.[33] In addition, open data can be supplemented and improved over time through low-cost efforts such as crowdsourcing. One of the best examples of the value and quality of crowdsourcing open data is OpenStreetMap (OSM).[34] OSM is particularly valuable for reference data such as road networks and exposure data such as the location, construction, and occupancy of buildings.

To many people, the expression “more data is better” is almost self-evident. However, we are now in an era of “big data,” when it can be a challenge to find pertinent information hidden in an onslaught of data. A variety of efforts are underway to use “big data” for disaster resilience activities.[35] Typically, big data is not a problem in developing countries. In many instances, the problem is the lack of data. And, when the data exist, they are often incomplete and inhomogeneous.

Barriers to the discoverability of and accessibility to data are commonly encountered and are a major

[33] J. Butler, “Open or Closed? How Can We Square Off the Commercial Imperative in a World of Open and Shared Data? In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

[34] https://www.openstreetmap.org

[35] Alliance, D.-P. (2015), Big Data for Resilience: Realising the Benefits for Developing Countries, Synthesis report.

TABLE 3 Sample reference data used for risk assessments

Data	Example Source		
Digital Elevation Model	Shuttle Radar Topography Mission http://www.cgiar-csi.org/data/srtm-90m-digital-elevation-database-v4-1 http://earthexplorer.usgs.gov/	Open Topography http://www.opentopography.org/	WordDEM http://www.geo-airbusds.com/worlddem/
Administrative Boundaries	Global Administrative Areas http://www.gadm.org/		
Geographic Features	OpenStreetMap http://www.openstreetmap.org/		
Soil Velocities	USGS http://earthquake.usgs.gov/hazards/apps/vs30/		

challenge when undertaking risk assessments in developing countries. Data discovery is complicated because relevant data are often kept by one or more government agencies. After data have been found, it is not uncommon that procedures must be followed to access the data, and once the data are accessible, efforts are often required to make them useable — that is, transform them into format that conforms to a commonly used standard. It is not unusual for data to be available as tables within PDFs or as hard copies of spreadsheets. To be fully accessible, data should be free and without restrictions on use, or at least, they must be unrestricted for not-for-profit purposes. Often, government agencies charge for data or apply restrictions to their use and distribution.

In essence, the availability of risk models is not the limiting factor in disaster risk assessment and DRM activity. The limiting factor is data. Risk modeling could best be improved by better and more complete data. Given the importance of data for risk assessments, the following sections examine different types of data in more detail.

› Reference data

Reference data include information needed to create a model or to run a simulation (Table 3). These data span a variety of features not directly associated with a hazard, exposure, vulnerability, or loss. Instead, reference data can be used to aggregate or analyze results (e.g., administrative boundaries), or to modify a hazard (e.g., surface roughness for wind speeds), to inform vulnerability or exposure data (e.g., information on local building codes), or to modify loss data (e.g., historical changes in economic variables such as exchange rates). One of the most essential types of reference data for a variety of hazards is the surface elevation data defined by a DEM.[36]

› Hazard data

Hazard data used for risk assessments usually are presented in the form of a catalog of hypothetical events with characteristics derived from, and statistically consistent with, the observational record. For example, for a meteorological hazard such as tropical cyclones, the observational data used to develop and validate the events in a hazard catalog include the storm's location, intensity, size, and the speed and direction of forward motion. For geophysical hazards such as earthquakes, the observational data used to develop and validate events include the location of an earthquake's hypocenter, known faults, and tectonic motion derived from geodetic measurements. No specific event in a hazard catalog is required to exactly match specific historical events. However, statistical characteristics of the hazard catalog such as the annual frequency of occurrence, the distribution of intensity, and the distribution of events, should be consistent with observational record.

[36] P. J. Ward et al., "*Usefulness and limitations of global flood risk models*", Nature Clim. Change, 5, 712-715, 2015.

Hazard data with global coverage tend to be of coarse resolution and variable quality. The information from such global databases can, in general, be used for national or regional studies, while more detailed data and models with higher resolution should be used in risk assessments for the design of specific DRM projects.

The availability of hazard data with global coverage is growing as computational and observational resources increase. For example, global catalogs of events now exist for floods, tropical cyclones, and earthquakes. The United Nations Environment Program (UNEP) and the United Nations Office for Disaster Risk Reduction (UNISDR) produce global maps of areas exposed to many hazards, and maps showing the frequency with which a hazard exceeds a specific threshold.[37] Global flood risk can be displayed using an analysis tool,[38] and the GEM has produced a platform that can be used to model earthquake risk throughout the world.[39] In addition to available open data, hazard data can be obtained from a variety of commercial vendors who will license them, sometimes for a fee.

› Exposure data

A wide range of information can be considered risk-related exposure data. To a great extent, what constitutes exposure data depends on the risk that is being quantified, which can vary from large-scale—for example, the risk to a nation's GDP from flooding—to small-scale, such as the risk to a specific structure from earthquake. While exposure data can be obtained from open global data, the resolution and/or completeness may not be adequate for the desired purpose.

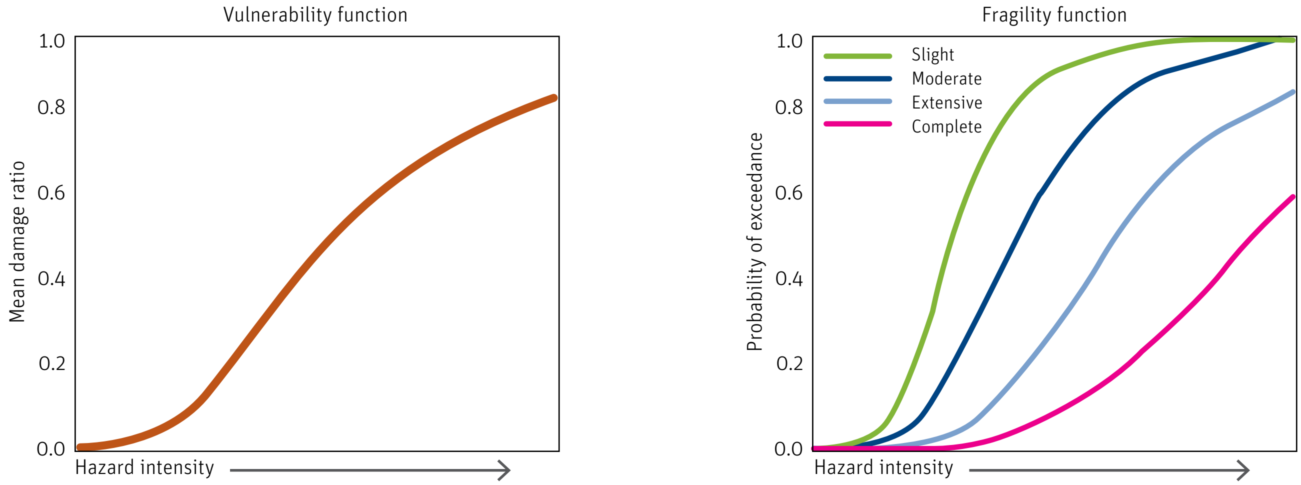
For example, estimates of a nation's GDP and population can be obtained through agencies such as the World Bank[40] or the US Central Intelligence Agency (CIA),[41] but the data are usually not sufficiently detailed for assessing risk from natural hazards. Alternative open sources for population data are typically associated with research institutes, such as universities or government programs; examples include the Gridded Population of the World, which is produced by the NASA Socioeconomic Data and Applications Center (SEDAC) hosted by the Center for International Earth Science Information Network (CIESIN) within the Earth Institute at Columbia University,[42] WorldPop, from the GeoData Institute at the University of Southampton,[43] and the Global Human Settlement Layer.[44]

The UNEP Global Resource Information Database (GRID) offers a variety of geospatial socioeconomic exposure data;[45] however, the data are not always current or complete. Country-specific exposure data can range from extensive and detailed[46] to almost completely unavailable, even if they exist as hard copy in government offices. Gunasekera and others provide a summary of available exposure data with global coverage and comments regarding their relative advantages and disadvantages.[47,48]

At least two open sources exist for structural exposure data: OpenQuake GEM project and OSM. The OpenQuake platform has a global exposure database (GED) that will provide a gridded global dataset on population, building types, and building value.[49] OSM is more easily accessible than OpenQuake, but it is not designed with risk modeling in mind. Both the OpenQuake GED and OSM hope to benefit from crowdsourcing, but they take different approaches. Contributions to the OpenQuake GED must be submitted using a form or through contact with GEM, while OSM uses a more typical crowdsourcing approach where anyone can contribute or edit after registering and creating an account.

37 http://preview.grid.unep.ch/
38 http://floods.wri.org/
39 https://platform.openquake.org/ and J. Schneider et al., "Development of an Open Platform for Risk Modeling: Perspective of the GEM Foundation". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf
40 http://datacatalog.worldbank.org/
41 https://www.cia.gov/library/publications/the-world-factbook
42 http://sedac.ciesin.columbia.edu/data/collection/gpw-v3
43 http://www.worldpop.org.uk/
44 http://ghslsys.jrc.ec.europa.eu/index.php
45 http://geonetwork.grid.unep.ch/geonetwork/srv/en/main.home
46 e.g., US FEMA Hazus data available to users within the US http://www.fema.gov/hazus-software
47 Gunasekera, R., O. Ishizawa, C. Aubrecht, B. Blankespoor, S. Murray, A. Pomonis, and J. Daniell (2015), Developing an adaptive global exposure model to support the generation of country disaster risk profiles, *Earth-Science Reviews, 150*, 594--608, doi:http://dx.doi.org/10.1016/j.earscirev.2015.08.012.
48 C. Huyck, "*The Importance of Consistent and Global Open Data*". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf
49 http://www.globalquakemodel.org/what/physical-integrated-risk/exposure-database/

FIGURE 4 **Fragility function (on right) shows the probability of exceeding different levels of failure as a function of hazard intensity. The vulnerability function on the left shows the mean amount of expected damage as a function of hazard intensity and is based on an average of the fragility function results.**



Adapted from: SYNER-G: Typology Definition and Fragility Functions for Physical Elements at Seismic Risk: Buildings, Lifelines, Transportation Networks and Critical Facilities, 2014, K. Pitilakis and H. Crowley and A. Kaynia, ed.s, Springer, Netherlands.

There are also proprietary exposure datasets that provide detailed information on many countries with established insurance markets. These data can range from aggregate information at a variety of administrative levels to detailed, site-specific estimates that include information on building contents and adjacent structures.

› Vulnerability data

Vulnerability functions quantify how an exposed asset responds to the forces generated by a hazard event. Damage can be defined in many ways, and the definition often depends on the exposure of interest. Damage can be quantified as the fraction of a structure needing repair or replacement, the number of fatalities in a population, the economic impact on GDP, or according to other factors, depending on the exposure and the purpose of the risk assessment. As no specific standard exists for referring to vulnerability functions, a variety of terms are used, sometimes interchangeably, including vulnerability function, damage function, and loss function. If a vulnerability function is used to quantify the fraction of exposure that has been "damaged," then loss is calculated by multiplying the fraction by the total value of the exposure or its replacement cost.

Vulnerability functions are mainly created in three ways: using expert judgment; empirically; and/or analytically.

Vulnerability functions derived using expert judgment generally involve an exercise in expert elicitation. Empirical approaches typically derive the vulnerability function using data from past events; these often provide the most robust estimates, as they represent an "integration" of all the factors that influence loss. Analytical approaches are based on model studies, often using computer simulations. Combinations of these approaches are also possible. There are a number of sources of vulnerability functions including those associated with FEMA's Hazus-MH model[50] and the GEM Foundation's OpenQuake model.[51]

With an analytical approach, fragility functions can be used to construct a vulnerability function. A fragility function is an estimate of the probability that the exposure of interest will exceed a specific damage state as a function of hazard intensity. A vulnerability function provides the mean damage ratio as a function of hazard intensity. Examples of vulnerability and fragility functions for the response of an exposure to ground motion of varying intensity are shown in Figure 4.

[50] US FEMA Hazus data available to users within the US http://www.fema.gov/hazus-software

[50] http://www.globalquakemodel.org/openquake

To be useful for developing or validating vulnerability functions, loss data must be collected along with information related to the local intensity of the hazard—for example, one needs to know the wind speed, water depth, or ground motion that produced the observed damage to a structure.

› Loss data

Loss data are vital for a variety of risk assessment activities. Loss data from historical events are often used to validate the performance of a risk model. When loss data are collected with sufficient detail, and with additional information such as the construction details on a structure and the hazard's intensity at the site, they are crucial for developing vulnerability functions. Records of losses associated with historical events are often used as indicators of resilience, however, these losses are influenced by changes in exposure and other factors such as improvements in building codes and changes in building practice.

The most consistent sets of loss data are produced by the insurance industry. Reinsurance companies and brokers often provide aggregated data on insured loss, and estimates of economic loss, to the public. Site-specific data are rarely available, but they are sometimes provided at a national level, or more rarely at province level, or as a loss to a specific sector (e.g., residential or commercial). The insured loss is typically better quantified than the economic loss because the loss payments are better defined and tracked contractually. Economic losses are often estimated using either "rules of thumb" relating insured loss to economic loss or through compilations of loss records. The U.S. National Hurricane Center, for instance, assumes economic loss from hurricanes is approximately twice the insured losses.[52] Compilations of loss, such as the Spatial Hazard Events and Losses Database for the United States (SHELDUS) or DesInventar and EM-DAT for global coverage, contain records of varying quality and completeness.[53]

Catastrophe risk modeling companies and insurance companies likely possess the largest amounts of loss data that can be used for developing vulnerability functions. Unfortunately, these data tend to be proprietary. Fortunately, as summarized by Gunasekera et al., a number of alternative sources of vulnerability data exist, such as GEM, Hazus, and World Agency of Planetary Monitoring and Earthquake Risk Reduction (WAPMERR).[54] Records of asset values and unit value repair costs are also useful for developing vulnerability functions, particularly when using historical loss data.

Even for a single event, collecting a robust set of homogeneous[55] loss data poses a significant challenge. With existing data, determining whether the data are complete can be a challenge as it is common that few or no metadata are associated with the loss data.

CAPACITY AND COMMUNICATION

There is growing interest in DRM, risk assessment, risk models and data, and as summarized in the previous discussion, there are a significant amount of data, numerous risk models and risk platforms available for use. However, the use of risk assessments has not necessarily kept pace with the interest. There are a number of reasons for this mismatch. Some are capacity-related, some are related to communication limitations, and others are related to a mismatch of expectations between users and providers of risk information.[56]

[52] Smith, A., and J. Matthews (2015), Quantifying uncertainty and variable sensitivity within the US billion-dollar weather and climate disaster cost estimates, *77,* (3), 1829-1851, doi:10.1007/s11069-015-1678-x.

[53] Grasso, V., and M. Dilley (2013), *A comparitive review of country-level and regional disaster loss and damage databases*, Bureau for Crisis Prevention and Recovery, UNDP. M. Gall and S. L. Cutter, "*Understanding Disaster Risk Through Loss Data*". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

[54] Gunasekera, R., O. Ishizawa, C. Aubrecht, B. Blankespoor, S. Murray, A. Pomonis, and J. Daniell (2015), Developing an adaptive global exposure model to support the generation of country disaster risk profiles, *Earth-Science Reviews, 150,* 594--608, doi:http://dx.doi.org/10.1016/j.earscirev.2015.08.012.

[55] Homogeneous data are data that can be considered statistical sample drawn from an unknown distribution with a fixed mean and variance. For instance, a time series of temperature observations would not be homogeneous if the observations came from a weather station that was moved during the time series, or if the weather station's surroundings changed significantly (for example, if the land use changed from rural to urban). The moves and/or changes in surroundings would likely produce different temperature characteristics and different unknown distributions.

[56] e.g., R. Wall, "*Visualizing Risk for Commercial, Humanitarian, and Development Applications*" and M. Werner et al., "*Toward an Open Platform for Improving the Understanding of Risk in Developing Countries*". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

In a manner analogous to the data discussion, for many people it can be difficult to learn of the existence of the resources needed for a risk assessment, to find the resources once their existence is known, and/or to determine what resources are appropriate for their purposes. In general, if a user isn't going to license a proprietary model, then a significant amount of expertise is needed to put together a package of data and models appropriate for a risk assessment. In addition, in developing countries there are often a variety of additional constraints such as: limited funding to license software, inadequate computational resources, and insufficient bandwidth to access data or interact with web-based software.

Risk assessments by developing countries most commonly occur through the use of consultancies that develop specialized analyses. There are a number of reasons for this. One is that existing proprietary models are aimed at countries with significant insurance markets, something many developing countries do not have. Thus, it is often the case that there is no "off the shelf" model appropriate for the region or peril of interest. Another reason is that in order to create models for country or local use, a significant amount of work is required to assemble the necessary exposure data, to create a catalog of hazard events, and identify or create suitable vulnerability functions.

There are few formal educational avenues that result in a degree in "cat modeling" or that would train people to manage or undertake their own risk assessment. Instead, most people enter in the field with expertise in a subset of the skills needed for cat modeling and learn through experience. In many developing countries, when local expertise is developed, the expert is often drawn to other endeavors due to better employment opportunities. When this happens, a government agency must work to develop a replacement, generally a rather prolonged process.

It is not uncommon for the results of a risk assessment to be used only once due to the data and/or models being proprietary. Or, the results are not made available for further use because they are not in a user-friendly format or they exist solely in a paper report. Even when the results are retained and useable, they often aren't discoverable or accessible. Data produced for a risk assessment may be seen as a resource that is sold to supplement an agency's budget, or as a source of personal or institutional power. Alternatively, a holder of data might not want to share because of worries about security or the data's accuracy.

To ensure that the results of a risk assessment are considered and used to induce risk reduction activities, there should be clear and sustained communication between the people that design and conduct the risk assessment and the people that will make decisions and take action on the risk assessment results.[57] Actions based on the risk assessment results will occur only if the information and providers are trusted and there is co-production of the results. A proven way for this to occur is through a communication process that allows for mutual identification and agreement on the goals of the risk assessment.[58]

Communication barriers often exist between producers of assessment results and people in the public sphere that will potentially act on the information.[59] In many countries, one of the barriers for the use of risk assessments is the lack of awareness of the need for DRM. In fact, as noted in one of the contributions, disasters can often be perceived as inevitable and unavoidable.[60] Another barrier is the difficulty of communicating the meaning of results that are expressed as probabilities.

[57] E. Visman and D. Kniveton, "*Building Capacity to Use Risk Information Routinely in Decision Making across Scales*". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

[58] A. T. Jones et al., "*Australia-Indonesia Government-to-Government Risk Assessment Capacity Building*". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

[59] M. Harvey and L. Robinson, "Improving Risk Information Impacts via the Public Sphere and Critical "Soft" Infrastructure Investments". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

[60] A. Arif and I. Rafliana, "Perceiving Risks: Science and Religion at the Crossroads". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

SUMMARY

The current state of risk-related data, risk models, and risk platforms is rapidly evolving. Much of this evolution is in response to advances in remote sensing capabilities, novel methods for collecting data such as crowdsourcing, and the growth in computational capacity. Most of the advances, however, are driven either by relatively ad-hoc, research-related efforts or by commercial companies developing proprietary products. While the research products generally are freely available and often open source, the commercial products tend to be aimed at the insurance market. As a result, the available data, models, and platforms are, in general, not designed for the needs of developing countries.

Current risk models and impact assessment tools are complicated for a non-expert to install and use. To promote the use of risk assessments, the data, models, analytical tools, and access to results, should be as simple to use and understand as an application on a smart phone.

Challenges to advancing disaster risk assessments in developing countries

This section synthesizes the various contributions from the DRM community. The contributions include oral inputs received during the consultations, the results of the online canvassing efforts, and the written contributions.[61] All of these efforts were aimed at better understanding the needs and challenges related to reducing disaster risk through risk assessments in developing countries and identifying a roadmap for overcoming the challenges. While the focus here is on the challenges for developing countries, developed countries face many of the same challenges. Overcoming the challenges, therefore, will benefit everyone.

The comments in this section are based on the community inputs unless otherwise noted. Please refer to Figure 2 for information on the sequence of consultations, online canvassing, written contributions and external reviews.

STARTING CONSULTATIONS

Participants at the consultations held at London, San Francisco, and Sendai identified a number of challenges faced by developing countries interested in disaster risk assessment and discussed potential solutions. Examples of the perceived challenges discussed by the participants are provided in Table 4.

Many challenges were thought to be related to information technology (IT) and communication infrastructure. For example, users in developing countries were perceived as lacking access to secure, stable internet connections that provide sufficient bandwidth for accessing data. Access to computational resources in terms of hardware, as well as financial resources for licensing software, was also seen as problematic for a user interested in running a commercial risk model or using, for example, proprietary GIS (geographic information system) software.

Other challenges existed regardless of the quality of IT infrastructure. For example, based on their own experiences, consultation participants believed practitioners in developing countries have difficulties with discovering, accessing, and using data. Often no centralized data repository exists within a country. Even after the data are located, gaining access to them can be difficult or impossible. And, once the data are accessible, a lack of metadata can make it difficult to determine exactly what they represent.

After their characteristics are defined, the data may well turn out not to be appropriate for the problem at hand. For example, an extensive search may determine that exposure data are distributed among multiple agencies and that in their current form they may not be suitable for the risk assessment. The exposure data may be spatially and/or temporally incomplete, inconsistent in terms of units and measured variables, and/or not digitized. Furthermore, a practitioner who finds the data may confront licensing issues, an inability to convert the data from one format to another, or other problems.

Consultation participants also discussed possible avenues for overcoming these challenges. Some thought a move to cloud computing might alleviate some hardware-related challenges, assuming internet bandwidth was sufficient. In addition, a risk-modeling platform was seen as a possible means of providing tools that would allow a practitioner involved in a risk assessment to explore the sensitivity of model results to changes in different factors.

Participants suggested that some challenges related to data might be overcome if users became aware of existing tools. For example, utility programs are available that can convert data from one format to another. Data security concerns were also mentioned as a challenge

61 https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

TABLE 4 Challenges for assessing risk in developing countries, identified through consultations

Issue Category	Challenge	Examples
Technical	Data issues	Discoverability of data and tools
		Accessibility of data
		Usability of data
	Systemic issues	Security concerns
		Lack of awareness of the need for DRM
Capacity	Lack of data-sharing culture	Data not shared among government agencies
		Data not shared because of worries regarding accountability for data quality
	Limited understanding of DRM	Inability to implement risk reduction actions
	Infrastructure limitations	Internet connectivity
		Bandwidth
		Computational hardware
	Financial limitations	Software licenses
		Proprietary data
Communication	Difficulty explaining results	Proper means of communication not known
		Lack of understanding of the concept of probability
	Difficult to define goal	Results of a risk assessment not used or used only once
	Trust	Decision makers ignore risk assessment results because they are produced by unfamiliar people

that could be overcome if requests to agencies were structured to address specific locations and data types.

Other challenges were more related to the capacity and social conventions of developing countries. With regard to capacity, participants saw a need to build a basic awareness of the need for DRM and, in addition, to increase understanding of the probabilistic nature of some risk information. With regard to social conventions, participants thought the lack of a data-sharing tradition within some countries could pose a challenge. Data might be seen as a resource that could be sold to supplement an agency's budget, or as a source of personal or institutional power. Alternatively, someone might not want to share data because of worries about security or the data's accuracy. The lack of such a data-sharing tradition can also make it difficult to capitalize on opportunities to build on focused efforts to create useful data. For example, during an emergency situation, data are often generated, but they have a narrow focus and are location specific. Extending and scaling up such data collection efforts can be challenging, but would be beneficial over the longer term.

Additional discussion focused on the challenges related to the communication and use of risk-related data and results. Participants thought that, because understanding of disaster risk assessments and assessment results is often limited, a significant effort to develop risk information may be followed by difficulty in communicating the information to decision makers and communities, or even in determining the best means of communication (oral, written, social networks, and so on).

Consultation participants identified a final, key factor that will often override the effectiveness of even an optimally communicated message: trust. How much do the recipients trust the message and messenger? Decision makers and communities are more likely to trust and respond to risk information when they are involved in the design of a risk assessment and provide some of the data and models used to generate the information. (This view on the importance of trust in promoting the use of and response to risk information is consistent with a major point in a recent GFDRR report on understanding risk[62] and in the written contribution by Jones and others.[63])

In sum, as a means to overcome these communication-related challenges, participants emphasized the need for clear communication between the provider and consumer of risk information and the development of trust. True communication enables the provider to design a risk assessment that is responsive to the consumer's intended purpose. It can also result in data (e.g., exposure information and risk zones) that can be used for purposes beyond a single risk assessment.

ONLINE CANVASSING

Two online canvassing efforts solicited the views of users and producers of risk data. Twenty-two people responded to the first survey; thirty-six responded to the second effort.

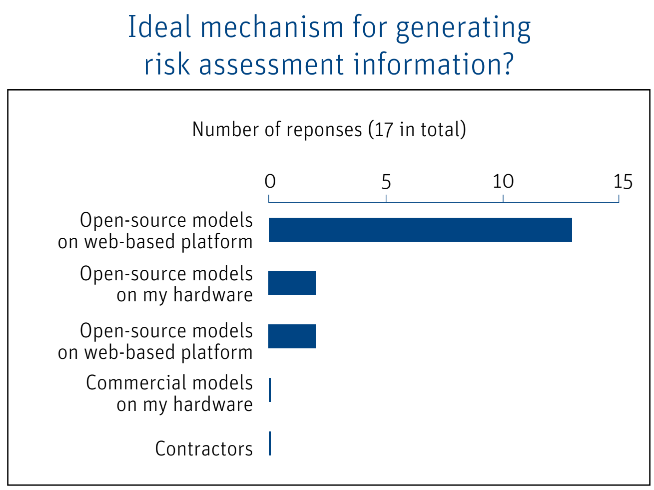
First online canvassing related to user needs

The first online canvassing effort solicited the views of users of risk data. The twenty-two respondents included nine researchers working in Central America, Asia, and Africa, three managers working in disaster management-related activities in the Pacific and Caribbean, students, and ten others working on risk assessments and disaster risk reduction through various government agencies. The responses to the questionnaire provide insight into the activities and needs of DRM practitioners in developing countries, provide some corroboration of the insights offered by participants in the consultations, and further details on how risk assessment data, models and platforms are used.

Fifteen of the 22 respondents said they use information from risk assessments more than once a month. Not surprisingly, the most common means of access was through freely available electronic information, mainly in the form of PDF files and data and/or tools available via the Internet. Most respondents found the risk assessment information either easy or not too difficult to understand. Their ability to act on the information, however, often depended on the availability of resources.

Of the seventeen respondents who answered the question regarding the ideal means for generating risk assessment information, thirteen selected open-source risk models on a web-based platform as the ideal (Figure 5). The most common response regarding the ideal means to access risk information was "via the Internet, through interactive graphics" (Figure 6).

FIGURE 5 **Result from user survey on ideal means of generating risk assessment information. Note the greatest preference is for open source models on a web-based platform.**



One question concerned respondents' interest in improving their ability to access, use, understand, communicate, and act on risk-related information. The least interest was expressed in an improved ability to use risk models in-house and the greatest interest was in an improved ability to access risk data (Figure 7).

Although sixteen of twenty respondents thought understanding risk assessment information was either easy or not too hard, a large fraction of respondents nonetheless selected categories that would help with improving understanding. Many respondents expressed interest that ranged from significant to greatest in response to questions regarding an improved ability to analyze risk data and to understand risk data (Figure 7).

[62] GFDRR (2014), Understanding Risk: Emerging Best Practices in Natural Disaster Risk Assessment, The World Bank, Washington, DC.

[63] A. T. Jones et al., "*Australia-Indonesia Government-to-Government Risk Assessment Capacity Building*". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

Interpretation of results from online canvasing of user needs

Based on the information from the first canvassing effort we infer that users do not see their current means of running models as a significant barrier to risk assessment. Rather, they apparently perceive more benefit from improving access to risk-related data and, once the data have been generated, access to the risk model results.

We also infer from these results that there appears to be interest in an improved capacity for understanding and analyzing risk information. This supports insights from the consultations which suggest that while scientific, engineering, and other technical issues related to reference, exposure, hazard, vulnerability, and loss data are important, efforts focused on the technical issues will be moot if the intended users in developing countries cannot understand, access, and use the data and model results.

On a larger scale, capacity challenges related to risk assessment data fall into three main categories, the capacity to create, analyze, and understand risk assessments. Capacity challenges in the creation category account for the technical requirements needed to generate risk assessment results. This includes the ability to access data and models that are used to generate the results, as well the ability to access the requisite computational infrastructure (for example, internet bandwidth and computer hardware). The analysis category accounts for the capacity to understand, interpret, and analyze the catastrophe risk model results, often with the goal of making the results understandable by decision makers. The understanding category refers to the capacity of decision makers, and the community, to understand the limitations and uncertainty of the risk assessment process and basic concepts related to using risk results, such as exceedance probability and return periods, and the importance of properly characterizing exposure and vulnerability.

FIGURE 6 **The results from the user survey on the best means of accessing risk information. The preference was for accessing the results via the internet with interactive graphics.**

Ideal mechanism for generating risk assessment information?

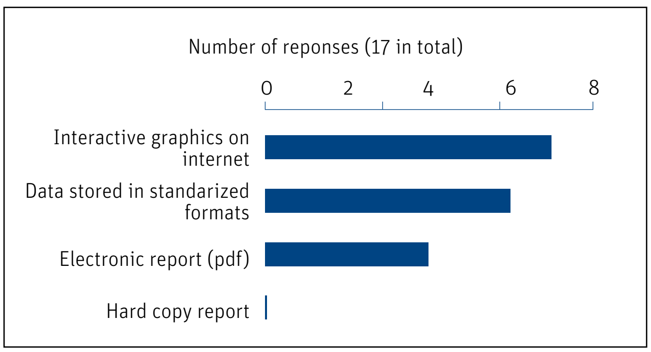
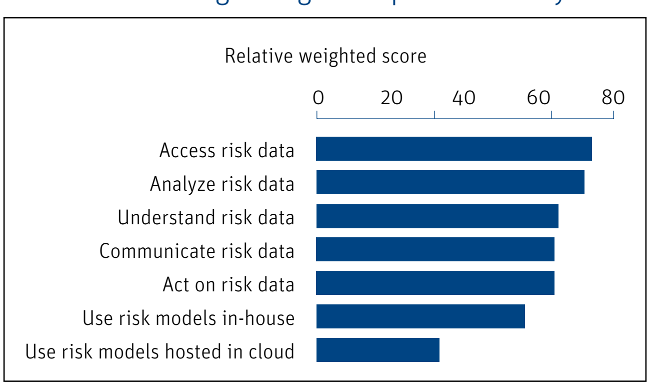


FIGURE 7 **Results from user survey on preference for improving their ability to access, use and understand risk information. Note that the item with the greatest interest is the improved ability to access risk data, closely followed by an interest in an improved ability to analyze risk.**

User needs regarding an improved ability to:



Relevant comments from written contributions

Many of these challenges are also addressed in the written contributions provided for this report. Educational programs can address these three categories of capacity challenges. For example, the programs should include courses targeted to direct users of risk data and tools, along with community members and decision makers.[64] Increasing the capacity of the community and

[64] T. Irvine, "Open Risk Data and Modeling Platform" and S. Safaie, "Required Capacities to Improve the Production of, Access to, and Use of Risk Information in Disaster Risk Management". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

decision makers will facilitate communication of actions based on risk assessments and other DRM activities. One means of conducting these courses is through open, online tutorials; however, their tendency to be in a single language limits their accessibility. In addition to developing courses in more commonly used languages, it may be important to translate the course material into local languages for community consumption.[65]

Limitations imposed by the computational resources and Internet bandwidth available within a country also must be considered when addressing capacity challenges. Models that require a cluster of workstations to run could be useless if such computational resources are not available or if no programmer is present to maintain the cluster. Bandwidth will be a particular concern for large datasets or interactive graphics. If bandwidth is insufficient for a practitioner to download data or interact with models and graphics, neither the data nor the models are of practical use. Also, for users with limited capacity, significant barriers can be imposed by data that are not open, by models and other software that must be licensed for a fee, and by software and data that don't meet widely accepted standards.

Several additional challenges related to building capacity deserve special mention. First, personal and institutional agendas can't be forced upon recipients. Providers can't assume to know what the recipients need. [66]

Second, because risk assessments involve significant expertise, the risk assessment enterprise can be dependent upon a small number of specialists. In countries with little redundancy in expertise and skill in risk assessments, the departure of a single expert can "break" a system.[67]

Finally, in countries where responsibilities overlap, efforts may be duplicated and similar but potentially inconsistent risk products developed. The different messages can confuse users regarding the most appropriate products for their purposes.

As the DRM capacity of developing countries grows, the communication of knowledge and suggested actions to communities and decision makers becomes increasingly important. Simply and clearly communicating the results of risk assessments and promoting DRM activities can be a challenge.

One of the biggest challenges when developing communication tools is to account for how different perspectives can alter the intended message.[68] Perspectives are socially constructed, and messengers may not properly understand the receivers' views. People living in areas at great risk may, for example, accept the risk because they view it as unavoidable, or they may view disasters as God's will or as a punishment for a society's sins. Additionally, residents may not have the knowledge to understand the implications of the risk in terms of the potential for property damage and personal injury associated with it.

Assuming the messenger understands the perspective of the audience, there remains the challenge of creating an effective means of communicating disaster risk. One approach is to exploit the relevance of past disasters still fresh in the public's memory. Finding the hazard and exposure data that would properly communicate the impact of an event in the past and how the impact would change if the same event were to affect current exposure might be difficult, however.

Once having managed to collect this information and determined an effective approach to communicating it, the next challenge is to create the most effective visual aids to communicate the desired message.[69] Often, maps are the best means for helping people visualize the risk

[65] M. A. Salgado-Gálvez, "Understanding Assumptions, Limitations, and Results of Fully Probabilistic Risk Assessment Frameworks". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

[66] A. Hughes and J. Rees, "Visions for the Future: Model Interoperability" and A. T. Jones et al., "*Australia-Indonesia Government-to-Government Risk Assessment Capacity Building*". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

[67] M. Werner et al., "Toward an Open Platform for Improving the Understanding of Risk in Developing Countries". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

[68] A. Arif and I. Rafliana, "Perceiving Risks: Science and Religion at the Crossroads". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

[69] M. Harvey and L. Robinson, "Improving Risk Information Impacts via the Public Sphere and Critical "Soft" Infrastructure Investments" and R. Wall, "Visualizing Risk for Commercial, Humanitarian, and Development Applications". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

and impact from a natural hazard. Finding the resources to pay for the expertise, hardware, and software required to produce and distribute such visual aids can be problematic, though.

Thus, given the inherent resource limitations in developing countries, the availability and use of open data and open models are critical for communicating disaster risk information. Unfortunately, incentives are few for people to develop and promote the use of open risk-related data and open-source risk models.[70]

Second online canvassing related to user preference for next steps

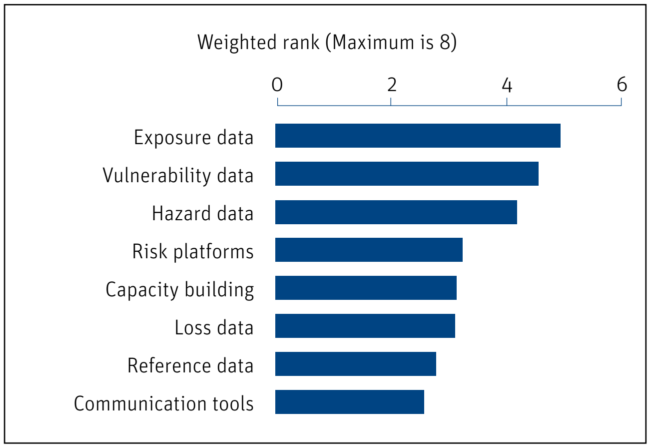
The second online canvas effort asked respondents to rank the desirability of steps that could be taken to promote the use of disaster risk assessments in developing countries and that could overcome some of the challenges related to the creation and use of risk assessments. These questions were based on responses to the first canvassing effort, the consultations, and the written contributions.

Respondents to the second canvas effort were asked to rank their interest in supporting work on different topics relevant risk assessment. Overall, the greatest interest was in improving exposure data and the least interest was in improving communication tools (Figure 8). The strong interest in exposure data is not surprising given the fundamental importance of exposure for assessing risk.[71] The usefulness of a risk assessment is determined to a large extent by the quality of exposure data. Indeed, even a perfect model would produce poor results without good exposure data.

While no definitive conclusions may be based on the views of such a small and non-randomly selected sample, the respondents' answers did hint at regional differences in their interest in the broad categories (Figure 9). For instance, interest in risk platforms was relatively high

FIGURE 8 **Weighted rank of the importance of investing in eight different categories of risk-related data, platforms, capacity and communication. Ranking goes from 1 (lowest) to 8 (highest).**

Relative importance of investing in:



among respondents from Australia/New Zealand and North America but very low among those from East Asia and Pacific and Sub-Saharan Africa.

The canvassing results included specific questions that asked respondents to rank the desirability of a range of projects within the reference, exposure, capacity, communication, and platform categories (Table 5). The highest rated topics, which are listed in the central column of Table 5, were consistent with the concerns identified in the first canvassing and the consultations.

The hazard, vulnerability, and loss categories did not include explicit questions on the relative desirability of different projects. However, the categories of hazard, vulnerability, and loss were highly rated by respondents from all regions (Figure 9). Although they were not asked to rank potential topics within each category, within the hazard category the respondents expressed very strong interest in the development of specific event footprints and a strong interest in developing hazard catalogs and monitoring networks.[72] Questions related to the desirability of projects within the vulnerability and loss categories were comingled. Within these two categories, interest was strong in developing site-

[70] J. Daniell, "The Current State of Open Platforms and Software for Risk Modeling: Gaps, Data Issues, and Usability". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

[71] C. Huyck, "The Importance of Consistent and Global Open Data" and N. Horspool et al., "Data Challenges and Solutions for Natural Hazard Risk Tools". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

[72] See the results here.

FIGURE 9

FIGURE 9. Weighted rank of the importance of investing in eight different categories of risk-related data, platforms, capacity and communication. This Figure is similar to Figure 8 but includes the ranking based on different regions. Ranking goes from 1 (lowest) to 8 (highest).

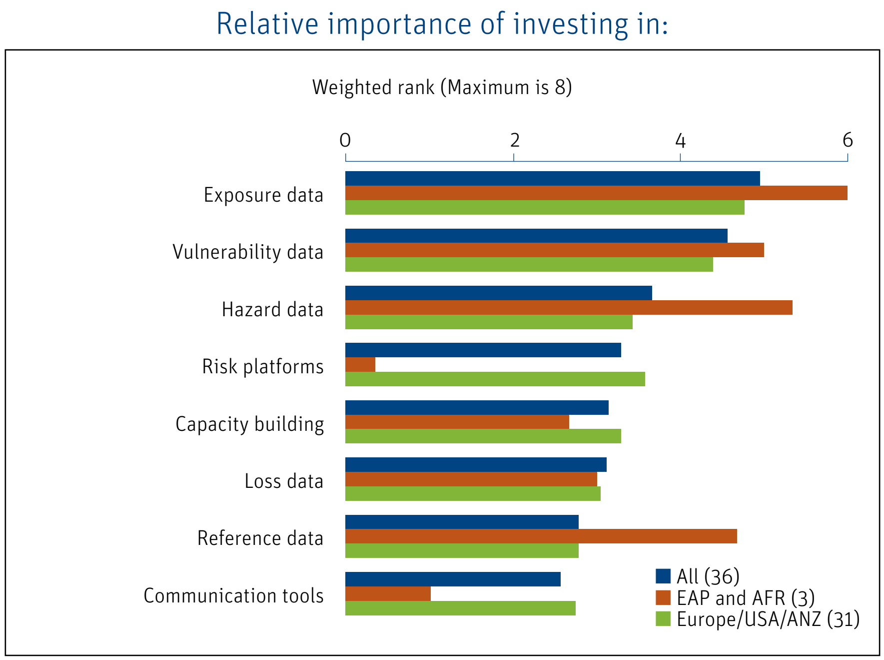


TABLE 5 **Highest ranking topic within a category.**

Category	Topic of greatest interest	Other possible topics
Exposure	Structural data and building value	Population; GDP; infrastructure data
Platforms	Development of standards to support interoperability of risk modeling platforms	Enhancing an existing, open, webbased platform for accessing and running risk models; a new, open, web-based platform for riskrelated data; a new, open, web-based platform for accessing and running risk models; enhancing an existing, open, webbased platform for risk-related data
Capacity	Training in design, management and use of risk assessments	Training in running risk models; creation of online tools; translation of existing material
Reference	DEM	Admin boundaries
Communication	Community of practice	Tools designed for communication

Please see the complete results from the second canvassing effort for more details on the Hazard, Vulnerability and Loss categories that aren't listed. The other topics within each category are listed in order of preference based on the canvasing results. Categories are ordered by ranking from Figure 8.

specific data as opposed to city-, state/regional-, or national-level data.

Consistency of canvassing results with written contributions and consultations

There is consistency among the written contributions and the online responses produced through the canvasing efforts. Input provided by the consultations mainly focused on challenges. Fortunately, to a great extent many of the challenges identified through the consultations (Table 4) would be addressed with the next steps identified by the online respondents and written contributions. For example, the difficulty in explaining results, or a limited understanding of DRM, could be addressed through online education courses. Also, financial limitations imposed by software licenses and access limitations imposed by proprietary data could be addressed through the development of open source models, open data, and open risk modeling platforms.

The highest rated category in the online response (Figure 9) was improved exposure data, particularly for site- and building-specific information. The strong interest in exposure data is consistent with several written contributions.[73] Other types of exposure data of interest included population and public infrastructure. An interesting comment from one respondent was that the focus should not be on the cost of replacing a structure, but on the people in it and the cost of retrofitting the structure to better withstand a hazard.

The second highest rated category concerned improved vulnerability data. The topic of greatest interest within the category was for site-specific vulnerability data for buildings. The importance of vulnerability data was pointed out in the written contributions.[74] Other types of vulnerability that were of interest included economic impacts, fatalities, and other socio-economic impacts at various levels of aggregation. Respondents also expressed an interest in better characterizing the response of lifelines to hazard events, or quantifying other forms of loss, such as business interruption.

The third highest rated category was improved hazard data. Hazard data is clearly of great importance in assessing risk, and each hazard requires a different set of expertise to develop a viable hazard module. The importance of hazard data is reflected by the numerous written contributions focused on hazards including tropical cyclones, volcanoes, floods, and earthquakes.[75]

The written contributions also emphasized the importance of considering the spatial scale of interest and that the value of using deterministic scenarios as opposed to a complete hazard catalog.

The category rated fourth was risk platforms. The online respondents expressed a strong preference for enhancing an existing platform for data or models over developing a new platform, with comments expressing support for the Oasis platform. Nonetheless, there was greater interest in developing standards for model interoperability. The written contributions reflected the online respondent's interest with multiple authors supporting the importance of model interoperability.[76] When using multiple models, an important issue raised by some of the written contributions concerned the certification and rating of models to insure and reflect the model's quality.[77]

It is worth noting that efforts aimed at developing standards for models and platforms are ongoing. For example, OpenMI (Open Modeling Interface) provides a standard for the two-way exchange of data between models whose results depend on each other.[78] In addition, the OASIS Loss Modeling Framework specifies a standard for organizing model components and data.[79] Other ongoing efforts include RASOR and several proprietary offerings. At this time, however, it is difficult to identify which standard is likely to be favored by a broad segment of the risk assessment community.

[73] C. Huyck, "The Importance of Consistent and Global Open Data", N. Horspool et al., "Data Challenges and Solutions for Natural Hazard Risk Tools" and J Schneider et al., "Development of an Open Platform for Risk Modeling: Perspective of the GEM Foundation". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

[74] N. Horspool et al., "Data Challenges and Solutions for Natural Hazard Risk Tools" and J. Schneider et al., "Development of an Open Platform for Risk Modeling: Perspective of the GEM Foundation". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

[75] K. Clark, "Past and Future Evolution of Catastrophe Models", N. Horspool et al., "Data Challenges and Solutions for Natural Hazard Risk Tools", R. Lamb, "Harnessing Innovation for Open Flood Risk Models and Data", S. Loughlin, "Priorities for the Short and Medium Terms: Which Are Better?" and J. Schneider et al., "Development of an Open Platform for Risk Modeling: Perspective of the GEM Foundation". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

[76] D. Badoni and S. Patel, "The Anatomy of a Next Generation Risk Platform", J. E. Daniell, "The Current State of Open Platforms and Software for Risk Modeling: Gaps, Data Issues, and Usability", A. Hughes and J. Rees, "Visions for the Future: Model Interoperability", R. Lamb, "Harnessing Innovation for Open Flood Risk Models and Data" and J. Rees and A. Hughes, "Visions for the Future: Multiple Platforms and the Need for Capacity Building". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

[77] G. Valentine, "Status of Risk Data/Modeling Platforms and the Gaps: Experiences from VHub and the Global Volcano Model". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

[78] J. Rees and A. Hughes, "Visions for the Future: Multiple Platforms and the Need for Capacity Building". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

[79] D. Whitaker and P. Taylor, "Oasis: The World's Open Source Platform for Modeling Catastrophic Risk". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

Capacity building was the fifth highest rated category. By far the highest rated option by online respondents was for training in how to design, manage, and use the results of risk assessments. In addition, 90% of the respondents rated online training as either essential or important. Several of the written contributions also supported the importance of training and suggested the use of online courses.[80] However, other written contributions emphasized the value of learning by doing.[81] Regardless, having the capacity to design and manage a risk assessment is consistent with the observation that a sense of ownership is essential to the acceptance and use of risk assessment results.[82]

Online respondents rated **improved loss data and the sixth most important category**. The value of the loss data is also reflected by the written contributions.[83] Importantly, there was great interest in site-specific loss data, ideally tied to local estimates of hazard intensity. The contributions noted that there are a number of existing loss databases, but these have a lack of standardization and tend to be focused on total loss from an event whereas the value of loss data for risk assessments is greater if it is at a site specific level and includes an estimate of hazard intensity.

For the reference category, the seventh-ranked category, the topic of greatest interest was DEM data with nearly 50% of respondents rating this of greatest interest relative to other types of reference data and almost 90% of respondents rating DEM data as either essential or important. This is consistent with the rationale provided by several written contributions[84]. Another potential topic, information on administrative boundaries, was not of strong interest. Just over 30% of respondents selected other as the choice for reference data. The suggestions for other data included information on soil moisture and ground water levels.

The highest rated topic in the eighth-rated category was communication tools, specifically the creation of a Community of Practice (CoP). Nearly 96% of online respondents thought that it was essential or important to form a CoP. Online comments supported the CoP as a means of promoting the development of a variety of other tools that could advance risk assessments. Several of the written contributions were also supportive of the idea of a CoP.[85] Within this category there was also significant interest in the development of tools that could be used to transform risk model results into a better product for communicating risk.

[80] G. Holland and M. Tye, "Toward Reducing Global Risk and Improving Resilience", T. Irvine, "Open Risk Data and Modeling Platform" and S. Safaie, "Required Capacities to Improve the Production of, Access to, and Use of Risk Information in Disaster Risk Management". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

[81] A. T. Jones et al., "Australia-Indonesia Government-to-Government Risk Assessment Capacity Building" and M. A. Salgado-Gálvez, "Understanding Assumptions, Limitations, and Results of Fully Probabilistic Risk Assessment Frameworks". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

[82] A. T. Jones et al., "Australia-Indonesia Government-to-Government Risk Assessment Capacity Building". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

[83] M. Gall and S. L. Cutter, "Understanding Disaster Risk Through Loss Data" and N. Horspool et al., "Data Challenges and Solutions for Natural Hazard Risk Tools". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

[84] J. Griffin et al., "High-Resolution Elevation Data: A Necessary Foundation for Understanding Risk" and N. Horspool et al., "Data Challenges and Solutions for Natural Hazard Risk Tools". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

[85] J. E. Daniell, "The Current State of Open Platforms and Software for Risk Modeling: Gaps, Data Issues, and Usability", M. Harvey and L. Robinson, "Improving Risk Information Impacts via the Public Sphere and Critical "Soft" Infrastructure Investments" and R. Lamb, "Harnessing Innovation for Open Flood Risk Models and Data". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

The consultations, written contributions from the DRM community, and responses to online canvassing were used to define topics that would advance risk assessment activities in developing countries.

Recommendations

POTENTIAL NEXT STEPS

The consultations, written contributions from the DRM community, and responses to online canvassing were used to define topics that would advance risk assessment activities in developing countries (Table 6). These "next steps" are based on the preferred topics for each category listed in Table 5 and a synthesis of the polling data and written comments from the second online canvassing efforts for the vulnerability, loss, and hazard categories. These steps are intended to address the needs of developing countries, but following them would benefit risk assessment activities for any location. The next steps were designed to form the basis for a Request for Proposals (RFP) for specific projects, perhaps focused on particular topics and regions.

The next steps were reviewed during a consultation at the 2015 AGU Fall Meeting in San Francisco and the 2016 Understanding Risk conference in Venice. There was general agreement with the potential topics, and the participants provided some valuable insights on how to refine the topics. The following comments on the next steps for each category reflect the discussion at the consultation at the 2015 AGU Fall Meeting in San Francisco. The consultation at the 2016 Understanding Risk conference further refined the projects[86].

TABLE 6 Potential "next steps" to promote the use of risk assessments by developing countries.

Category	Potential next steps
Reference Data	Support development of open, high-resolution DEMs for developing countries.
Hazard	Develop a suite of reference hazard events that provide examples of historical and hypothetical events for impact analyses in developing countries.
Exposure	Support the enhancement of an open exposure dataset with structural data and building valuation.
Vulnerability	Develop open databases of vulnerability functions for a variety of exposures (e.g., structural damage and social vulnerability), spatial resolutions, and hazards.
Disaster Loss	Develop an open database of site-specific loss data that includes standards for data collection.
Platforms	Support an effort to develop standards to support risk model interoperability.
Capacity	Create development modules to provide training for the interpretation and use of risk assessment results.
Communication	Formalize a community of practice for open-source disaster risk assessment.

[86] See the results here: http://preview.tinyurl.com/hzxjhxc

› Reference Data

There was support for the development of open, high-resolution DEMs for developing countries. The data that currently exist are vital for many risk assessment purposes. Unfortunately, high-resolution data are expensive and require significant computational resources to use. The development of open, high-resolution data is slowly progressing. The release of the SRTM30 data with global coverage was a significant step forward. However, participants at the consultation noted a caveat: the DEM information needed to be properly combined with other information; for example, to generate realistic flood extents the DEM needed to be manually adjusted to take into account local features, such as drainage systems.

› Hazard

Results from probabilistic assessments can be difficult to understand and require significant effort to generate. An effective alternative for DRM activities is a deterministic impact analysis based on historical or plausible hypothetical events.[87] Thus, developing countries could use open source tools such as QGIS and InaSAFE as well as RASOR to quickly and easily benefit from a suite of hazard scenarios that provide footprints for historical and hypothetical events for impact analyses.[88]

A number of entities use scenarios for impact assessment purposes. For example, Lloyds of London requires its member syndicates to estimate loss from Realistic Disaster Scenarios, and the Engineering for Climate Extremes Partnership at the National Center for Atmospheric Research provides meteorological scenarios[89]. Open hazard catalogs of synthetic events for probabilistic risk assessment would also be useful, but they require more effort to develop and more skills to use.

Consultation participants identified a number of concerns with developing event scenarios and catalogs. For example, the hazard event must be appropriate for the scale of the problem. An intense small storm might have a serious impact if it occurred over a small river basin, but it would be inconsequential for flooding in a large river basin. In addition, when developing catalogs of events for use in risk assessments, temporal variability in the characteristics of a hazard needs to be considered.

› Exposure

Enhancing and extending data on construction characteristics and on valuation were of greatest interest for next steps related to the exposure category. Participants at the consultation that reviewed the next steps agreed with this view.

Rationalizing this choice is not difficult. Exposure data are valuable for modeling loss and managing risk. When estimating the risk of loss, for example, construction characteristics for the exposure are used to select the proper vulnerability function. The value of structure is needed to estimate monetary loss to property. In addition, knowledge of a structure's construction and occupancy, and its value, are important for a variety of DRM activities. For example, estimates of the value of exposure are needed for cost–benefit analyses.

Participants at the consultation also supported improving population estimates. A number of suggestions were made on how to enhance population exposure data, many of them motivated by the observation that population varies spatially and temporally. Currently, most population data are provided as a simple two-dimensional grid. In reality, topography and building height drive important vertical variations in population. In addition, population distributions exhibit somewhat regular temporal variability associated with daily and seasonal movements related to commutes and migrations of people, and unusual, and at times large, changes can occur in transient populations.

As an example of the latter consider the current conflict situation in Syria. In July 2014 Syria's population was estimated to be 17 million[90]. In the 1.5 years between July

[87] K. Clark, "Past and Future Evolution of Catastrophe Models". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

[88] A. T. Jones et al., "Australia-Indonesia Government-to-Government Risk Assessment Capacity Building". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

[89] G. Holland and M. Tye, "Toward Reducing Global Risk and Improving Resilience". In: *The Current State of Risk Information: Models & Platforms*, https://understandrisk.org/wp-content/uploads/Solving-the-Puzzle_Written-Contributions.pdf

[90] https://www.cia.gov/library/publications/the-world-factbook/geos/sy.html

2014 and January 2016 the Office of the United Nations High Commissioner for Refugees (UNHCR) registered approximately 1.6 million refugees, nearly 10% of Syria's population.[91]

Other comments at the consultation suggested that developing proxies for population might be useful. For example, Landsat data, which can be used to define urban and rural areas, could be combined with population data to more realistically distribute population in specific regions. Also, it may be more efficient to develop a tool or tools that can be used to generate population information instead of focusing on specific areas. The tool could then be used by multiple projects to more quickly enhance population datasets.

Finally, there was a perceived need to expand, or define, a multi-peril standard for defining construction and occupancy characteristics for structural exposure. The GEM building taxonomy was a good start, but was somewhat confined to earthquake related descriptions. It would be useful define a single, "universal", multi-peril taxonomy that could be used to define a structure for all perils instead of having to access multiple taxonomies for a single structure and multiple perils.

› Vulnerability

The next step identified within the vulnerability category is development of an open database, or databases, of vulnerability functions for a variety of exposures (for example, structural damage and social vulnerability), a range of spatial resolutions, and a suite of hazards. Participants noted that a limited number of open vulnerability functions already exist, such as those associated with GEM's OpenQuake model and the CAPRA model, but they are focused on a limited set of construction classes and regions. Also, participants noted that in an effort to develop open vulnerability data, a variety of exposure types should be considered including lifelines such as roads and water and power distribution systems. In addition, it would be valuable to develop functions that describe the time required for recovery, i.e., something similar to business interruption. At the consultation, one participant suggested supporting the development of a tool that could be used to develop vulnerability functions by extending the capability of OpenQuake.

[91] http://data.unhcr.org/syrianrefugees/regional.php

› Loss Data

Participants at the consultation noted that the loss data are fundamental for validating vulnerability functions and assessing the value of retrofitting and other DRM efforts. To maximize the value of the data, the database should require consistent standards for collection. Ideally, the database(s) should comprise a variety of data, including replacement costs, economic costs, fatalities, loss to contents, business interruption, and estimates of hazard intensity.

› Platforms

Given the ongoing efforts to develop risk-related platforms, it is not surprising that there was support for the development of standards to enhance risk model interoperability. Participants at the consultation were in general agreement that it was best to support existing open source efforts. However, there were questions regarding the licensing associated with platform software. GEMs creative commons software requires that software based on its code also become open. Some participants hypothesized that this restriction may be limiting the adoption of the code by other providers. Participants noted a different approach is provided by the Delft-FEWS platform. The platform is freely available and can use appropriately licensed software, but the FEWS code is not open source. The rationale is that making the code open source could create problems with managing the quality of future versions of the code.

› Capacity

Among the options for increasing capacity that were mentioned in the online canvassing, by far the dominant choice of respondents was developing training modules for the interpretation and use of risk assessment results. Participants at the consultation were in agreement that developing capacity through open online courses is a good concept. They noted that a number of efforts to develop risk-related courses are already underway. The courses should be designed around the concept of enabling countries to use existing tools to generate their own risk assessment results.

› Communication

While questionnaire respondents expressed a preference for supporting the development of a community of practice for risk assessments, they also thought it is important to create a set of open tools designed to communicate risk information. Comments suggested a robust risk assessment community would naturally create a set of open tools.

While communication efforts were ranked as the lowest priority category, participants at the consultation were in consensus that communication was nevertheless a topic of great importance. One suggestion was to create a community that would bring together users and providers of information to define what users need so that developers would have some guidelines for the creation of new tools. The suggestion to create a community of practice to define best practices was thought to be a valuable means of promoting the development of risk tools that could be used for communication. Participants also recognized that in many cases the problem is not so much the creation of information, but instead the problem lay with the distribution of communication products. It is not uncommon for information to be disbursed only partially because of breaks in the chain of communication leading to individuals in a community.

NEXT STEPS SUMMARY

The purpose of this document was to identify actions associated with risk assessments that would help developing countries bridge gaps among data, models, platforms, capacity, and communication. A variety of inputs from the DRM community have been used to identify a series of priorities for future collaboration and investment. The activities are categorized in a manner that accounts for the different steps in a risk assessment, specifically reference, hazard, exposure, vulnerability and loss data; for the growing importance of risk data and modeling platforms; and risk communication and capacity building. The DRM community ranked activities within each category, not the categories themselves.

A summary of this report and the categories and potential next steps listed in Table 6 were reviewed during a consultation at the 2016 Understanding Risk conference. Consultation participants were in general agreement with the categories of Table 6. During breakout sessions at the consultation participants were asked to rank their top 3 categories of interest and to define potential actions for each category. A summary of the possible actions identified by consultation participants is available here[92]. There is a gratifying similarity between the actions listed in Table 6 and those identified at this consultation.

If these potential actions were funded and completed, the challenges developing countries, as well as others, face when designing, executing and implementing risk assessments would be significantly reduced. Some of the potential actions are likely to be more cost effective than others; thus, prudence would dictate support for pilot projects to test these ideas before launching large programs.

We stress that the potential actions identified in this report and at the 2016 Understanding Risk conference are not the only method of tackling challenges that exist in disaster risk assessment. The actions represent only the top priorities that have come out again and again through the consultations, written contributions, and online canvassing. It is not by any means meant to be an exclusive list. We see these actions as something that the community, as a whole, agrees upon. What is needed now is collaboration and investment to make progress on our broader goals of reducing disaster risk and loss in developing countries.

With financial support for next steps, one way to proceed would be to select an appropriate hazard and region or country of interest and then issue a request for proposals (RFP) based on the potential next steps for one or more categories in Table 6. Obtaining sufficient resources to fund potential actions in all categories from a single donor seems unlikely. A more realistic approach would be to have a variety of donors focus their support on the potential actions that are most relevant to their mission.

New avenues for financial support should not be neglected. Over the last 25 years the (re)insurance industry has developed significant capabilities and expertise in applying natural hazards science to facilitate risk assessment and management decisions.

92 See the results here: http://preview.tinyurl.com/hzxjhxc

These capabilities have been supported by the efforts of commercial modeling vendors and academia. In many instances these capabilities served as sources of competitive advantage between competing insurance companies and model vendors, particularly among early adopters. For this reason access to these capabilities by third parties such as those in the public sector has been a challenge and a hurdle for attempts to connect the public and private sectors. As the insurance industry has matured, expertise in natural hazard risk assessment has become embedded across the industry; as a result, there exist considerably fewer opportunities to generate competitive advantages through superior knowledge of natural risk assessment. Instead, it may be that business opportunities could grow with improved abilities to assess risk in developing countries. The insurance industry could speed the growth of these opportunities through efforts that share knowledge and expertise.

Recent interactions and initiatives such as the industry support and funding of Oasis and the Insurance Development Forum[93] suggest that the perspective of the insurance industry and the commercial model vendors are shifting and there may be a willingness to make their tools and capabilities more accessible. The expertise, experience and standards of the insurance industry are essentially untapped resources that could become available to the public sector. It should not be ignored as the private sector work to apply science to the management of property as well as humanitarian risk decisions.

93 The Insurance Development Forum (IDF) was formed in 2015. The IDF is co-chaired by a senior member of the public sector and the insurance industry. The IDF secretariat is provided by the World Bank GFDRR in Washington DC with support from the IIS.

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