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Understanding risk: what makes a risk assessment successful?

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Abstract

Purpose – Understanding risk is more than just modeling risk; it requires an understanding of the development and social processes that underlie and drive the generation of disaster risk. Here, in addition to a review of more technical factors, this paper aims to discuss a variety of institutional, social and political considerations that must be managed for the results of a risk assessment to influence actions that lead to reductions in natural hazard risk.

Design/methodology/approach – The technical approaches and the institutional, social and political considerations covered in this paper are based on a wide range of experiences gleaned from case studies that touch on a variety of activities related to assessing the risks and impacts of natural hazards, and from the activities of the World Bank's Global Facility for Disaster Reduction and Recovery.

Findings – Risk information provides a critical foundation for managing disaster risk across a wide range of sectors. Appropriate communication of robust risk information at the right time can raise awareness and trigger action to reduce risk. Communicating this information in a way that triggers action requires an understanding of the developments and social processes that underlie and drive the generation of risk, as well as of the wider Disaster Risk Management (DRM) decision-making context.

Practical implications – Prior to the initiation of a quantitative risk assessment one should clearly define why an assessment is needed and wanted, the information gaps that currently prevent effective DRM actions and the end-users of the risk information. This requires developing trust through communication among the scientists and engineers performing the risk assessment and the decision-makers, authorities, communities and other intended users of the information developed through the assessment.

Originality/value – This paper summarizes the technical components of a risk assessment as well as the institutional, social and political considerations that should be considered to maximize the probability of successfully reducing the risk defined by a risk assessment.

Keywords Risk management, Community-centred, Risk analysis, Built environment, World bank, Disaster prevention

Paper type Conceptual paper

Introduction

Actions underlying a successful risk assessment can be divided into two complementary categories: technical and social. Actions in the first category are associated with the scientific, technical and economic expertise required to develop and use the hazard, exposure, vulnerability and loss components of a risk model. The actions in the second category associated with understanding and managing the political, social

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and institutional dynamics are involved with initiating and undertaking a risk assessment, communicating and understanding the results, and implementing the actions that will reduce risk.

Numerous risk management projects focus on producing a high-quality analysis of risk, focusing predominantly on the first category of actions. But, neglecting the second category of activities will almost inevitably lead to a risk assessment that becomes an isolated technical exercise that uses time and money and produces little or no response. A risk assessment conducted as an exercise among scientists and engineers will be ignored unless the users of the risk assessment results have: agreed on why the risk assessment is needed; a sense of ownership of the process; access to the data used in the analysis; and an understanding of the results.

Here we review some scientific, engineering and economic considerations associated with catastrophe risk models. We furthermore discuss institutional, social and political considerations that should be considered to facilitate the use of risk assessment results in decision-making aimed at reducing natural hazard risk. A variety of Disaster Risk Management (DRM) activities can be supported by risk assessments that are valued by users. Examples of DRM activities include:

- investments in structural and nonstructural measures to reduce risk and the identification, communication and raising awareness of risk;
- disaster preparedness activities including the creation of early warning and emergency measures and contingency planning;
- financial protection through the development of disaster risk financing products and insurance; and
- resilient reconstruction to guard against future damage and facilitate recovery.

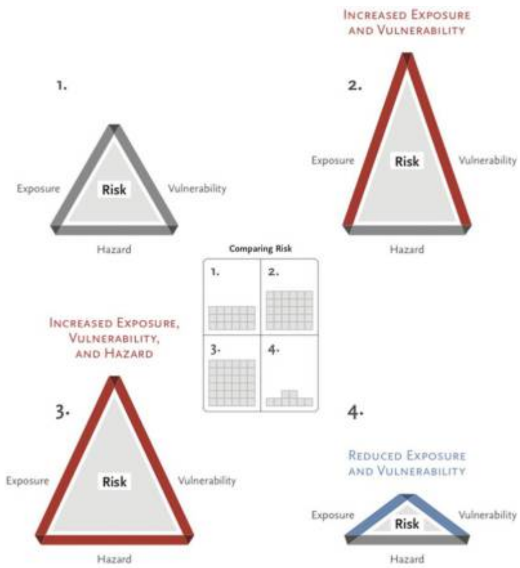
For a more in-depth discussion and a wide array of case studies, please see GFDRR (2014a, 2014b, 2014c).

Technical factors in risk modeling

A schematic representation of risk of loss from natural hazards is given by the area of the risk triangle, described by Crichton (1999), whose sides represent hazard, exposure and vulnerability (Figure 1). An increase in hazard, exposure or vulnerability can be represented by longer sides on the triangle which leads to an increase in the triangle's area and the corresponding risk. Similarly, a decrease in exposure, hazard and/or vulnerability is represented by a shortening of the triangle's sides and thus a reduction in the triangle's area and its corresponding risk.

As an example, consider the risk of flooding along a river. Increasing population or infrastructure along a river's flood plain will increase the exposure to floods. The increase in exposure could be offset by reducing vulnerability through actions such as building structures with uninhabited ground floors and utilities on the roof. Flood hazard could increase as a result of climate change, the construction of upstream flood defences such as levees and/or increases in the extent of impermeable surfaces in the upstream basin.

The impact of a hazard event is determined by the intensity and spatial extent of a hazard, the population and assets exposed to the hazard, and the vulnerability of the exposed population and assets. Typically, risk is determined from an analysis of the



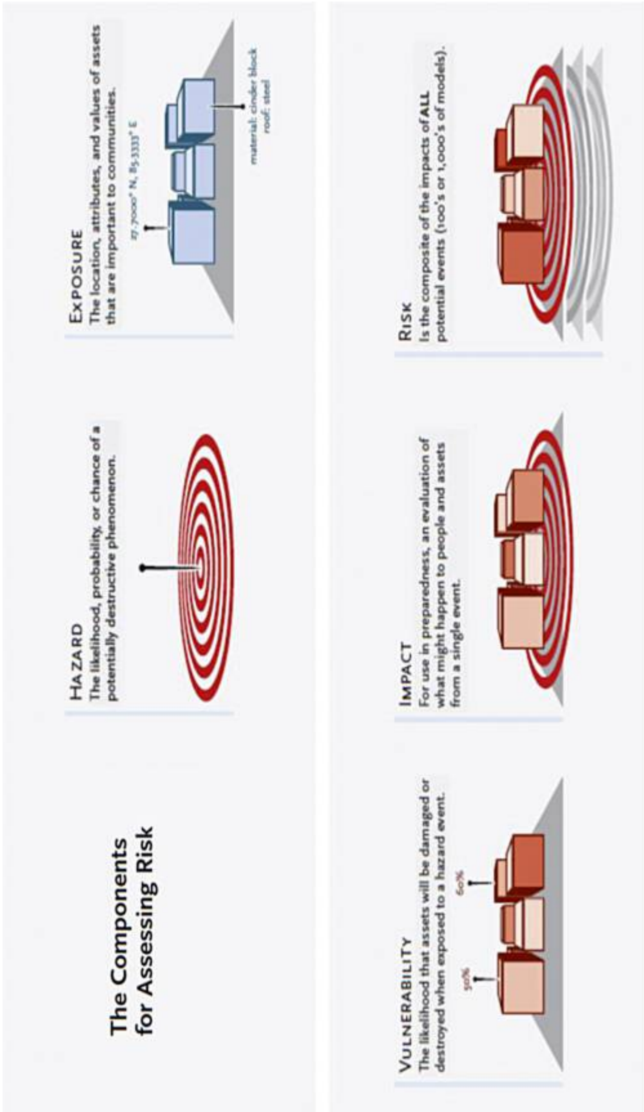
Notes: Triangle 1 shows a schematic of existing contributions to the risk equation; triangle 2 shows an increase in exposure and vulnerability, leading to increased risk (as in rapidly urbanizing cities); triangle 3 shows increased hazard, exposure and vulnerability, leading to increased risk (as in a rapidly growing coastal city where the effects of climate change are increasingly felt); triangle 4 shows controlled exposure and vulnerability (such as through proactive DRM), leading to lower overall risk (GFDRR, 2014a, 2014b, 2014c)

Figure 1.
Risk is a function of hazard, exposure and vulnerability

impact of multiple (real or synthetic) events (Figure 2). Risk is often quantified in terms of exceedance probability: the probability of exceeding impacts (e.g. losses or fatalities) beyond a specific threshold.

Hazard

Once the peril(s) of interest for a risk assessment is (are) defined, the first step in the risk assessment is the computation of the probability, intensity and geographical distribution of the hazard. Data on the geological, meteorological and hydrological processes that cause the hazard (e.g. storm tracks for cyclones, rainfall patterns for floods and fault lines for earthquakes) form the basis of such an analysis. Historical events, in particular their date, location, extent and maximum intensity provide critical information used to develop and validate the modeled hazard characteristics. Historical events are also analyzed to estimate changes in risk over time through growing exposure (i.e. what would be the impact of the historic event if it would occur today, given the present population density and urbanization?).



Source: GFDRR (2014a, 2014b, 2014c)

Figure 2.
The components for assessing risk and the difference between "impact" and "risk"

Some hazard models, especially those focused on earthquake and cyclone hazard, produce a stochastic *hazard event set*. A hazard event set is a large collection of modeled hazard events with statistical characteristics consistent with the historical record. Such event sets typically include thousands or tens of thousands of potential events and are intended to define the full range of potential events for a hazard. For each event in an event set, a combination of observational data and theory is used to define an event's spatial characteristics (e.g. the wind field from a tropical cyclone or the ground motion from an earthquake). A catalog of the characteristics for events in an event set is termed a *hazard catalog*.

The events in a hazard catalog and an event set can be used for deterministic or probabilistic analyses. A typical deterministic analysis would use an event that represented a historic event, a worst-case scenario or a possible event that would be expected for a selected return period. A probabilistic analysis would require an event set that contains a sufficient number of events for the estimate of the risk to converge at the longest return period, or the smallest probability, of interest. In other words, a probabilistic risk model contains a compilation of all probable "impact scenarios" for a specific hazard and geographical area.

Other hazard models, such as some global flood hazard models, assess the probability of the hazard based on the probability distribution of the driving factors, rather than by using event sets. These flood hazard models generally produce potential hazard maps for different return periods[1], based on a statistical analysis of the historical distribution of rainfall. For any specific location, a 100-year return period flood map is an approximation of the inundation extent of a flood that is expected to happen once every 100 years (i.e. a flood with an annual probability of 1 per cent).

Hazard models complement any available historical information on hazard occurrence. For most regions of the world, there are insufficient detailed and closely spaced observations for many types of perils. And even when there is a relatively dense observational network, it is difficult to obtain high-quality measurements: the number of observational platforms is limited, existing observation stations are not sited optimally and a station may fail during an event. Modeling approaches can transform such observations into a full probabilistic overview of hazard occurrences and footprints. For example, wind speed and pressure measurements from a few observing stations can be used to estimate a cyclone's maximum wind and the radius of maximum wind. Surface pressure measurements of the cyclone are easier to collect, and the gradient between minimum central pressure and the pressure of the surrounding environment has a large influence on maximum wind speeds. Wind speed, central pressure and radius of maximum winds are used with empirical relationships to define a tropical cyclone's wind field.

A wide range of expertise is needed to collect and/or generate the data for a hazard assessment. For example, knowledge of the distribution of soil types is required to model the spatial variation of ground acceleration (shaking) from an earthquake; values for surface roughness are needed to define the distribution of wind speed from a tropical cyclone; and a digital elevation model (DEM) is needed to determine flood depth. Fortunately, multiple perils often require the same data. For example, topography as defined by a DEM is required for modeling floods, tsunamis, sea-level-rise inundation, landslide susceptibility, storm surges and detection of earthquake fault lines.

Most hazard analyses are developed region by region. Exceptions include the global earthquake event set generated by the Global Earthquake Model, and the tsunami, volcanic eruption, cyclone and drought hazard event sets developed as part of the global risk model under the leadership of the UN Office for Disaster Risk Reduction (UNISDR, 2015). There are also a number of efforts to develop global flood models, which will use a global flood catalog; one model, GLOFRIS (GLObal Flood Risk with IMAGE Scenarios), is already in use (Ward *et al.*, 2013; Winsemius *et al.*, 2013).

In the past decade, there has been substantial progress toward creating and providing open access to many global and national data sets critical to understanding and modeling hazard. Moreover, significant advances have been made in generation of so-called synthetic catalogs of hazard events, which are used to ensure that the full range of hazard events are captured and the likelihood of different events assigned. Significant challenges in acquiring and using hazard data remain, however. Consensus is emerging on the urgent need, particularly in developing countries and high-risk coastal areas, for digital elevation data at the appropriate level. Recently, the US Government has started the gradual public release of the 30-m Shuttle Radar Topography Mission DEM for the globe[2], which is now available for the majority of the world's countries. Similarly, the paucity of historical hydrometeorological data in digital format poses significant challenges in quantifying current and future hydrometeorological risk in low- to middle-income countries. Finally, there is an emerging move toward integrating climate change scenarios into risk modeling to account for future changes in hazard intensity, whereas this provides important insights in the drivers of changing risk, it also adds significant additional uncertainty into the modeled results.

Exposure

The resolution and type of exposure data ranges from the spatial distribution of population and gross domestic product (GDP) on a national level to detailed site-specific information on construction and contents. The typology and resolution of exposure data vary among risk models. The required resolution of the exposure data for a risk assessment depends on the how the results of a risk assessment will be used. For example, when developing emergency management plans such as evacuations, the detail required for exposure data is much less than that required for supporting the pricing of insurance. Data on the distribution of population by locality may be sufficient for planning evacuation routes, whereas building-specific information on construction characteristics and occupancy could be required for developing insurance programs.

The source and quality of requisite exposure information also varies with the spatial scale of an analysis. In many cases when developing risk assessments on a global scale or in data scarce areas, exposure data must be derived using relatively coarse satellite information, proxy data and empirical relationships. At more local scales, crowdsourcing can be used to develop detailed data when there is no pre-existing information. A prime example of a crowdsourced exposure data set used for risk assessment is OpenStreetMap (OpenStreetMap_Wiki, 2014). Athough crowdsourced data may have limitations regarding its quality and type, crowdsourcing can be an invaluable method for tracking changes in exposure in regions undergoing rapid development. There is growing interest in using drones, or unmanned aerial vehicles, to develop exposure data. The technology is rapidly evolving because of the deployment of arrays of multiple satellites[3] and through the use of drones[4] (Daniel *et al.*, 2009).

The availability of global data sets on population, building types, satellite imagery and so on is providing significant opportunities to model global exposure at higher and higher resolutions. Over the past five years, such new data sets have enabled first estimates of global exposure to storm surges (Hallegatte *et al.*, 2013), earthquakes (Dilley *et al.*, 2005), river floods (Jongman *et al.*, 2012) and hurricanes (Peduzzi *et al.*, 2012). Satellite imagery is increasingly becoming available for use in assessing and understanding risk. Meteorological data collected using satellite imagery, for example, are increasingly being used to determine flood and drought risks at global and national scales.

At national and subnational levels, data and information from government ministries (such as statistics authorities, transportation and infrastructure departments, and education and health departments) are increasingly being used to understand community, city and national exposure. In addition, the release of satellite imagery to the crowd is increasingly being used to map building footprints, roads and other characteristics of the built environment or disaster-impacted area – often by mappers thousands of kilometers away.

Underpinning these efforts has been the rapid rise of the open data movement. The Global Facility for Disaster Reduction and Recovery (GFDRR) and World Bank launched the Open Data for Resilience Initiative in 2011 to foster and catalyze the open data movement for climate and disaster resilience. Under this initiative, Web-based geospatial platforms (GeoNodes) in more than 20 countries have been used to open more than 1,000 geospatial data sets to the public and to catalyze community mapping of buildings and infrastructure using geospatial platforms such as OpenStreetMap.

Vulnerability

Vulnerability is typically quantified using functions that describe damage or loss to a given exposure (a commercial, public, or private structure) caused by a hazard with a specific intensity (e.g. the ground acceleration of an earthquake or the inundation depth of a flood). Engineers use "fragility" functions to determine the damage to an asset and vulnerability functions to estimate loss. Fragility functions commonly estimate damage ratios ranging from 0 (no damage) to 1 (complete destruction). The actual loss can be determined by multiplying the damage ratio by the present value of the structure.

Damage and loss to a structure can be defined using techniques that range from empirical relationships derived from past events to detailed dynamical simulations that account for a structure's engineering design. When modeling losses at a site-specific level, other factors can become important. For example, changes in the distribution of population and property (e.g. cars) through the course of a day will influence the damage caused by an event.

There are vulnerability functions for a wide range of exposure types. Both structural (i.e. physical) vulnerability and socioeconomic vulnerability are relevant to risk assessment. At one extreme, vulnerability functions may require detailed information (e.g. a detached, residential structure and its date of construction, number of stories, nail spacing and roof slope, shape and composition) or simply use information on construction class and occupancy (e.g. masonry and residential). In addition, vulnerability functions for other sources of loss (damage to contents, business interruption, damage to appurtenances, etc.) are often based on the damage to a structure. At the other extreme where only aggregate information is available, vulnerability functions can be used to estimate aggregate regional loss. Aggregated loss can be in terms of GDP, fatalities, economic loss or other metrics. Generally, functions are defined using mean values and a coefficient of variation (CV) that vary as a function of hazard intensity. The CV tends to decrease with more information regarding the exposure.

Collecting and analyzing damage and loss data from previous disasters provides insight on physical, social and economic aspects of vulnerability. Collecting information post-disaster can build damage scenarios to inform planning processes, assess the physical and financial impact of disasters, develop preparedness measures and facilitate dialogue for risk management.

Local engineers are increasingly dedicating themselves to understanding the vulnerability of their local building stock (which varies significantly from country to country and within countries) to different natural hazards. However, opportunities continue to be lost through the incomplete collection and curation of damage and loss data following disaster events. In addition, efforts to quantify socioeconomic vulnerability and poverty remain limited, and information of this kind is rarely integrated into risk assessments.

Social factors in risk modeling

A high-quality risk assessment that accounts for the important technical factors will result in a more precise assessment of risk. However, society will benefit from the assessment only if a variety of social factors are properly considered so that decision-makers understand the information generated by the assessment and use it for DRM. The social factors that determine a society's response are encompassed by the political, social and institutional dynamics involved with initiating and undertaking a risk assessment, communicating and understanding the results, and implementing the actions that reduce risk. Below we outline a number of steps that increase the value and effectiveness of users acting on the results from a risk assessment. While all these steps involve technical factors associated with a risk assessment, it should be emphasized that the best outcomes are likely to occur when social factors are considered so that those investing/paying for the risk information work in concert with those carrying out the risk analysis and those who will act to implement actions in response to the analysis.

Define who and why

An important first step is to clearly define the purpose of the risk assessment before the risk analysis starts. Tailoring the assessment to the specific purpose and users of the information and involving the users in this process, increases the value of the results for decision-making. The definition process should involve the intended users to maximize the potential of the results being useful. Moreover, if the "why" and "who" for a risk assessment are not clearly defined, then the risk assessment may be needlessly costly because of it being over-engineered for its purpose, or worse, not fit for its desired purpose. Experience shows that when risk assessments are commissioned in response to a clear and specific request for information, they tend to be effectively used to reduce fiscal or physical risk (Cortes *et al.*, 2012; GFDRR, 2014a, 2014b, 2014c; Miyamoto *et al.*, 2014; Nkoka and Waalewijn, 2014).

Cultivate ownership

Working with the funders and intended users to define why an assessment should be done and who will use the results allows users to cultivate a sense of ownership and helps promote subsequent efforts to mitigate risk. Ownership is critical for ensuring that knowledge created through a risk assessment is perceived to be authoritative and therefore acted upon. It is certainly possible for risk specialists to generate risk analysis without ever engaging with local authorities, but regardless of the sophistication or accuracy of their analysis, without engaging users there will likely be very limited uptake of this information. Successful projects often partner risk specialists with country counterparts to design, implement and communicate the results of the risk assessment.

Another mechanism for promoting ownership is to get users involved in the generation of exposure data that will be used for the risk assessment. Citizens now have the ability to create detailed maps of cities using platforms such as OpenStreetMap. This has proven to be effective after major disasters such as the 2010 Haiti earthquake, where over 600 people added local information to OpenStreetMap within one month after the event, making it the accepted and default basemap for disaster response in the affected area. Additionally, when authorities are engaged in the mapping process that generates exposure data for the risk assessment, the risk assessment results are perceived to have greater value.

Create and use open data

Experience gained in the past decade strongly speaks to the need to encourage the creation and use of open data. The analysis of natural hazards and their risks is a highly resource- and data-intensive process, whereby the return on expended resources (time and money) can be maximized if the data are created once, used often and iteratively improved. Current approaches to developing open exposure data on the location, type and value of assets continue to be improved, and volunteered geospatial efforts and remote sensing products offer new opportunities to collect and update fundamental data.

Communicate

Clear, two-way communication throughout the risk assessment process – from initiation of the assessment to delivery of results and the development of plans in response – is critical for successfully mitigating disaster risk. An exceptionally planned and implemented "Build Back Better" campaign led by the government of Indonesia in the aftermath of the 2009 Padang earthquake demonstrated conclusively that well-targeted education and communication of risk information can increase awareness of natural hazards and their potential impacts (Brown and Griffin, 2014). Notably, this analysis shows that progress from increased awareness to action can be very difficult to achieve, even in a community that has witnessed at first hand the devastation of an earthquake.

The delivery of a risk assessment is only the first step. The completion of the risk assessment marks the beginning of a longer process of broadly communicating risk information to all relevant stakeholders – in a way that is meaningful to them and fit for their purposes. People must be offered the knowledge with the correct combination of timing, technical training, community supervision, and financial and nonfinancial incentives and disincentives. Most importantly, the style of communication should be tailored to the type of information communicated and to the audience.

There is no one right way to communicate risk, instead practitioners need to draw on a toolbox of approaches, ranging from Excel spreadsheets, maps and simple interactive tools, to graphical representation of hazard and risk, to clear action-orientated messages from authoritative and respected voices explaining what citizens, communities and countries can do to reduce risk. Metrics like average annual loss and probable maximum loss, for example, are of interest and relevant to the financial sector, but they are poor metrics for communicating with almost all other decision-makers involved in DRM. For people outside the financial sector, interactive tools that enable people to answer "what if?" questions robustly and simply ("What if an earthquake/cyclone/other natural hazard hit my community – How many buildings would collapse or be damaged?") are an excellent mechanism for communicating risk.

InaSAFE, a recently developed free tool for impact assessment, is a good example of an interactive tool that is now being used extensively at national and subnational levels in Indonesia and elsewhere[5]. That said, there are still immense opportunities to develop a bigger toolbox of interactive, highly graphical visualization tools, which would enable all decision-makers, from individuals to national governments, to meaningfully interact with risk information.

Similarly, the Aqueduct Global Flood Analyzer[6] is an open-access online platform that can be used to visualize flood risk in any river basin or country in the world, and quickly reveal the possible effects of climate change and risk reduction measures. This platform is one example where complicated scientific information is translated into a usable tool, allowing easy communication of risks.

Consult and collaborate

To generate a usable risk assessment product, technical experts and decision-makers must consult with one another and reach agreement on the risk information required for the specific project, and more broadly on the purpose and process of the risk assessment. The actual development of risk information is a multidisciplinary effort that takes place through collaborations ranging from international efforts to multi-institutional arrangements at national and subnational levels. There are many efforts currently under way that speak to the success of this approach. GFDRR's publication on "Understanding Risk" (GFDRR, 2014a, 2014b, 2014c) offers case studies of successful efforts in countries such as Jordan, the Philippines, Indonesia and Bangladesh, where agencies responsible for each element of risk assessment worked together with decision-makers in finance, planning and emergency management.

What the case studies make clear in aggregate is that there is no singular "correct" formula for building multi-institutional collaborations around risk assessment; effective approaches are context specific, build on existing institutional mandates and center on the specific DRM problem being addressed. However, success has been comparatively limited in merging community-level understanding of risk with a national or subnational understanding of risk. This is a missed opportunity wherein a common understanding of the risks and necessary steps to reduce these risks could trigger greater action.

Assume a multi-hazard view of risk

Rarely do countries, communities or citizens face potential risks from only one hazard, or even from natural hazards alone. Our complex environments and social structures are such that multiple or connected risks – from financial hazards, multiple or cascading natural hazards and anthropogenic hazards – are the norm. Just as multi-peril risk calculations are required for many financial applications, assessments of multiple hazards (flood, landslide and earthquake, for example) should be used to reduce risk for territorial planning.

Failure to consider the full hazard environment can result in maladaptation (for example, heavy concrete structures with a ground-level soft story for parking can protect against cyclone wind, but they can be deadly in an earthquake), whereas adopting a multi-hazard risk approach leads to better land-use planning, better response capacity, greater risk awareness and increased ability to set priorities for mitigation actions. Particular caution should be taken with risks in food security and the agricultural sector; these risks should be considered alongside flood and drought analyses.

Keep abreast of evolving risk

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

The frequency, intensity, duration and timing of perils such as floods and droughts are expected to evolve as climate changes (Seneviratne *et al.*, 2012). There is increasing interest in understanding climate change's impacts and calculating losses under future adverse climate events. Using the modeling techniques and approaches developed to model disaster risk, experts have demonstrated the potential to determine future loss under climate change. As the fundamental data sets that enable the risks of today to be quantified are the same as those required to determine the impacts of adverse events in the future, it is critical for both the disaster and climate change communities to collaborate and continue investing in fundamental data and innovation.

Define the uncertainties and limitations of risk information

A risk assessment is not complete without information about its limitations and uncertainties, which can arise from uncertainties in the input data (such as elevation models and exposure information), in knowledge of the hazard and in the definition of fragility and vulnerability functions. Users that fail to consider these can make flawed decisions and inadvertently increase risk. A risk model can produce a very precise result – it may show, for example, that a 1-in-100-year flood will affect 388,123 people – but in reality, the accuracy of the model and the precision of the input data may provide only an order of magnitude estimate. Similarly, sharply delineated flood zones on a hazard map do not adequately reflect the uncertainty associated with the estimate and could lead to decisions such as locating critical facilities just outside the "flood line", where the actual risk is the same as if the facility was located inside the flood zone. It is incumbent upon specialists producing risk information to communicate (see the point above on communication) clearly and simply the uncertainties and limitations of the risk assessment.

Maintain credibility and transparency

Risk information must be scientifically and technically rigorous, open for review and honest regarding its limitations and uncertainties. The best way to demonstrate credibility is to have transparent data and models, and to have results open for review by independent, technically competent individuals. Risk modeling has become very advanced, yet also more accessible and therefore anyone can feasibly run a risk model – but without the appropriate scientific and engineering training and judgment, the results may be fundamentally incorrect and may mislead decision-makers.

Encourage a culture of openness

Over the past decade, immense progress has been made in creating new open-source hazard and risk modeling software. More than 80 freely available software packages, many of which are open source, are now available for assessing the impact and risk of flood, tsunami, cyclone (wind and surge) and earthquake, with at least 30 of these in widespread use (GFDRR, 2014a, 2014b, 2014c). Significant progress has also been made in improving open source geospatial tools, such as QGIS[7] and GeoNode[8], which are lowering the financial barriers to understanding risks at national and subnational levels. Yet all this innovation has created challenges around assessing "fitness-for-purpose", interoperability, transparency and standards. These issues highlight the importance of collaboration (see above) and need to be addressed in a way that continues to catalyze innovation and supports risk model users.

The field of risk assessment is increasingly driven by open data and open-source modeling. There are a number of reasons for the rise of openness. One is the substantial investment of time, money and effort involved in a risk assessment. There is a growing appreciation of the value of the hazard, exposure and vulnerability data and of the assessment's results. Another is that rapid changes in exposure require that data be available for frequent updates. Open data and tools permit communities to help resource-poor governments. In addition, development institutions such as the World Bank, the US Agency for International Development (USAID) and the African Development Bank view openness as a mechanism for inclusiveness and transparency. Finally, as demand grows for risk information at resolutions appropriate for community and city decision-making, the need to collect exposure data at these resolutions has also grown. Crowdsourcing is increasingly being viewed by governments and communities as a solution that enables bottom-up participation in the understanding of risk and a cost-effective solution to an otherwise expensive challenge of data collection.

Closing comments

It is important to recognize that understanding risk is more than just modeling risk; it requires an understanding of the development and social processes that underlie and drive the generation of disaster risk, such as the political and social nature of disaster risk information and its use. For example, the decision of an individual or government to construct a building that is resilient to seismic events will be a result of a complex interplay between awareness of, belief in, and acceptance of the potential risks; the financial and technical capacity to design and construct the resilient structure; and the appropriate (enforced) legal, institutional and regulatory framework (e.g. enforcement of building codes). Similarly, land scarcity in rapidly developing urban environments forces often uncomfortable trade-offs between the urgent needs of today, such as the need to build on vacant land near employment and educational opportunities, and the potential risks of tomorrow, such as a 1-in-20-year flood event.

Moreover, from a public policy perspective, risk information can be sensitive, as it requires government officials, private sector companies, communities or individuals to decide on action (or inaction) to reduce the impacts of a potential hazardous event. The decision – for example, to relocate communities away from high flood risk areas – will come with explicit (e.g. financial/resource) costs and implicit (e.g. political and/or social capital) costs, all of which have to be weighed within a broader context. The chance of risk information translating into action, then, depends to a large extent on sensitive negotiations between public officials, affected communities and financial providers. Hence, the importance of authoritative information, which can be fit into a regulated framework backed by the necessary legal and institutional context.

A disaster risk assessment does not represent the conclusion of a process, but instead provides a foundation for a long-term engagement focused on the communication and use of the risk information. But, for this foundation to be used, there must be communication, ownership and participation by the intended users of the risk information. Proactive responses to new risk information include retrofitting buildings to withstand the assessed seismic risk, developing new land-use plans, designing financial protection measures, and equipping and training emergency responders.

In the context of rapidly growing disaster losses and high-profile catastrophic disasters, it is often difficult to imagine reducing the impact from hazard events. However, societies have successfully overcome similar challenges in the past. For centuries, urban fires were a global concern for the public, private and finance sectors, as well as for the communities directly affected. Urban fires devastated Rome in 64 CE, London in 1666, Moscow in 1812, Chicago in 1871 and Boston in 1872; the 1906 San Francisco fire destroyed nearly 95 per cent of the city and the Tokyo fire of 1923 killed over 40,000 people. Yet we do no longer see massive urban conflagrations, this hazard has largely been consigned to history. The reasons – implementation of modern building codes, land-use planning, establishment and expansion of emergency services, greater citizen responsibility and insurance regulations – are essentially the same levers that we can apply to reducing natural hazard risk.

Notes

1. A 100-year event represents something with a probability of occurrence equal to 0.01 per year. In general, an X-year event has a 1/X probability of occurrence per year. The number of years represented by X is termed the "X-year return period."
2. Available at: www.jpl.nasa.gov/news/news.php?release=2014-321
3. Available at: www.planet.com/assets/themes/planet/press-releases/2014-03-17-pr.pdf
4. Available at: www.facebook.com/notes/uav-and-uas-insurance/how-unmanned-aircraft-could-change-the-way-we-live-work-and-think-about-risk/759893884100943
5. Available at: http://inasafe.org/en/
6. Available at: www.wri.org/floods

7. Available at: www2.qgis.org/en/site/
8. Available at: http://geonode.org/

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