Workshop report: The Role of Science in Good-enough Disaster Risk Assessment

Abstract

This report provides an overview of the findings from a workshop entitled ‘the role of science in good-enough disaster risk assessment’. Two key reports were published by the UK Government in 2012 which sought to identify where improvements could be made in disaster risk reduction interventions. These reports raised two important questions: what constitutes good-enough risk assessment? And what role can science play to achieve a good-enough risk assessment?

A number of organisations jointly ran a workshop to convene both scientific experts as well as experts in disaster risk management. Over three days, the workshop used learning from five international case studies to establish what roles science can play during different time periods in relation to a hazardous event. In addition to this, three cross cutting themes were identified which provide the entry point for science into the risk assessment process, at any point in the disaster cycle. While there are several roles for science to play in good-enough risk assessment, further research is required to corroborate these findings, as well as establishing what more can be done to inform disaster preparedness over longer time scales.

Contents

Introduction

The workshop was the second two workshops initiated by the Science and Innovation Network (Houston) which aimed to explore what concrete steps could be taken to improve science delivery and usage in Disaster Risk Reduction (DRR) for natural disasters. The initiative was instigated following the publication of two reports by the UK Government Office for Science in 2012: 'The Use of Science in Humanitarian Emergencies and Disasters'[1] (SHED) and 'Reducing Risks of Future Disasters: Priorities for Decision Makers.'[2] These reports examined the way UK Government plans and prepares for international humanitarian emergencies.

The 2012 Foresight report, 'Reducing risks of future disasters: Priorities for Decision Makers', involved horizon scanning the field of DRR. It identified the challenge of articulating what constituted a 'good-enough risk assessment'. In order to reduce the risks from future disasters, evidence based DRR interventions should be underpinned by a robust and rigorous assessment of the risk from natural hazards. However, there are occasions where limited response time, as well as access to financial resources and/or technical capacity, constrains the ability to undertake robust and rigorous assessments.

Whilst other organisations had conducted relevant research - the Overseas Development Institute (ODI), the Global Platform for Disaster Risk Reduction and the UK Department for International Development (DFID) - there was a consensus that a unique voice on the subject of the roles that science can play was required.

Therefore, the UK Department of Business, Innovation and Skills (BIS) and the Foreign and Commonwealth Office (FCO) supported Science and Innovation Network (SIN), in collaboration with the UK Collaborative on Development Sciences (UKCDS), the UK Government Office for Science, Research Councils UK and La Salle University, organised an international and interdisciplinary workshop to explore the question of the role of science in good-enough disaster risk assessment.

[1] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/278694/12-848-use-of-science-in-humanitarian-emergencies-disasters.pdf
[2] https://www.gov.uk/government/publications/reducing-risk-of-future-disasters-priorities-for-decision-makers

Workshop Aims

To address the role of science in good-enough disaster risk assessment, the workshop aimed to:

a. Identify the circumstances in which rapid and 'good-enough' scientific risk assessments are needed;
b. Increase researchers' understanding of practitioner needs and therefore best practice in access to data and how it is presented for ease of use;
c. Produce guidance on scientific methodologies that can be adopted in situations when it is necessary to produce rapid or 'good-enough' risk assessment.
d. Develop a recommendation on what constitutes a 'good-enough' scientific risk assessment, supported by case studies and areas for improvement;
e. Achieve greater networking of researchers and practitioners of scientific risk assessment and establish an initial network of DRR practitioners willing to engage in pilot risk assessment (hazard, exposure and vulnerability) activities;
f. Suggest guidelines and/or a check list of key issues to consider when undertaking rapid and good-enough risk assessments.

Structure of the workshop

The workshop took place on the 24-26 February 2014, in Bogotá, Colombia. It was hosted at the Unversidad de La Salle.

Attendees of the workshop came from Colombia, Costa Rica, Indonesia, New Zealand, Thailand, United Kingdom and United States of America.

Represented among the participants were researchers (both from universities and research institutions), national, regional and international policy organisations and disaster risk management organisations. Collectively, the scientific experts covered the breadth of physical, natural and social sciences relevant to disasters. By having a diversity of participants from different sectors it was possible to discuss the role of science from their sectoral perspectives in the preparation of risk assessments.

The overarching research question was considered in the context of three different time points in relation to a disaster:

- Weeks-to-days prior to a hazardous event
- Hours-to-minutes prior to a hazardous event
- The time following a hazardous event.

Case studies were used to address the workshop aims, including:

- Typhoon Haiyan, Philippines (2013)
- Nevado del Ruiz Volcano eruption, Colombia (1986)
- Tungurahua Volcano eruption, Ecuador (2006)
- Landslides in Gramalote, Colombia (2010-11)
- UK Windstorms (1987 and 2013)

In addition, there were panel sessions as well as breakout sessions to further explore the issues raised by the case studies.

Schedule of the workshop

Monday 24 February	
0930-1000	Participants arrive
1000-1030	**1. Welcome and introduction** **Carlos Costa Posada** Dean of Engineering at Universidad de le Salle, Colombia **Tony Regan** Deputy Head of Mission, British Embassy Bogotá
1030-1145	**2. Good-enough risk assessment: setting the scene** **Aims and format of the workshop and roundtable** **John Rees** Risk Research Champion, Research Councils UK **Probabilistic Modelling for Disaster Risk Management. The Case of Bogota, Colombia** **Omar Dario Cardona** Associate Professor, National University of Colombia **Uptake of risk assessments in decision making** **Alonso Brenes Torres** Latin American Social Sciences Institute (FLACSO), Costa Rica
1145-1245	**3. Case study 1: 2013 Bohol Earthquake & Typhoon Haiyan, Philippines** (45 minute joint presentation with 15 minutes Q&A) **Marqueza Cathalina L. Reyes** Technical Advisor, Disaster Risk Reduction, Association of South East Asian Nations (ASEAN) Secretariat, Jakarta, Indonesia
1245-1345	**Lunch**
1345-1400	**4. Recap & afternoon objectives**
1400-1515	**5. Case study 2: Nevado del Ruiz (Colombia) & Tungurahua (Ecuador) Volcanic Eruptions** (1 hour presentation with 15 minutes Q&A) **Marta Calvache** Technical Director, Geological Service, Colombia **Sue Loughlin** Head of Volcanology, British Geological Survey & Strengthening Resilience in Volcanic Areas (STREVA), UK
1515-1530	**Break**
1530-1700	**6. Breakout session**

		Delegates rotate between three groups to discuss the key elements that should be considered when undertaking good-enough and rapid risk assessments in each of the following scenarios: **Group 1: Where it is expected that communities have days to months to respond** **Group 2: Where it is expected that communities have minutes to hours to respond** **Group 3: In the hours to days and weeks to years post event** ***NOTE:*** *Participants will be expected to use the findings from the case studies and their own experiences/case studies during this breakout session.*
1700-1715	**7.**	**Feedback from breakout session**
1715-1730	**8.**	**Wrap up and plans for day 2**

Tuesday 25 February		
0900-0915	**9.**	**Reflections from day 1**
0915-1015	**10.**	**'Rapid fire' panel session: "What is good-enough?" "What shortcuts can we take?"** *Four speakers presenting for 10 minutes followed by facilitated dialogue with plenary.* **Susan Cutter** Carolina Distinguished Professor of Geography, University of South Carolina, USA **S.H.M Fakhruddin** World Meteorological Organisation, Thailand **Victoria Sword-Daniels** Increasing Resilience to Natural Hazards in Earthquake-prone & Volcanic Regions (IRNH) Knowledge Exchange Fellow & University College London, UK **Peeranan Towashiraporn** Department Head, Disaster Risk Assessment and Modelling (DRAM), Asian Disaster Preparedness Centre, Thailand
1015-1115	**11.**	**Case study 3: 2010 Landslide in Gramalote, Colombia – Rebuilding and Relocation** (45 minute joint presentation with 15 minutes Q&A) **Alfredo Martinez** Disaster Risk Management Manager, Colombian Adaptation Fund **Doris Suaza**

	Disaster Risk Management Advisor, Colombian Adaptation Fund **Juanita Lopez** Disaster Risk Management Advisor, Colombian Adaptation Fund
1115-1130	**Break**
1130-1230	**12. Case study 4: UK example** (45 minute joint presentation with 15 minutes Q&A) **John Rees** Risk Research Champion, Research Councils UK **Virginia Murray** Head of Extreme Events, Public Health England, UK
1230-1330	**Lunch**
1330-1430	**13. 'Rapid fire' panel session: Ensuring 'good-enough' risk assessments are used** *Four speakers presenting for 10 minutes followed by facilitated dialogue with plenary.* **Heather Lazrus** Earth Systems Laboratory, National Center for Atmospheric Research, USA **Susanne Sargeant** Increasing Resilience to Natural Hazards in Earthquake-prone & Volcanic Regions (IRNH) Knowledge Exchange Fellow & Seismic Hazard Analyst, British Geological Survey, UK **Steve Jensen** Professor of Emergency Management, California State University, Long Beach, USA **Thomas Huggins** Joint Centre for Disaster Research at Massey University
1430-1445	**14. Wrap up and plans for day 3**
1445-1800	**15. DRR in practice. A visit to the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM)**

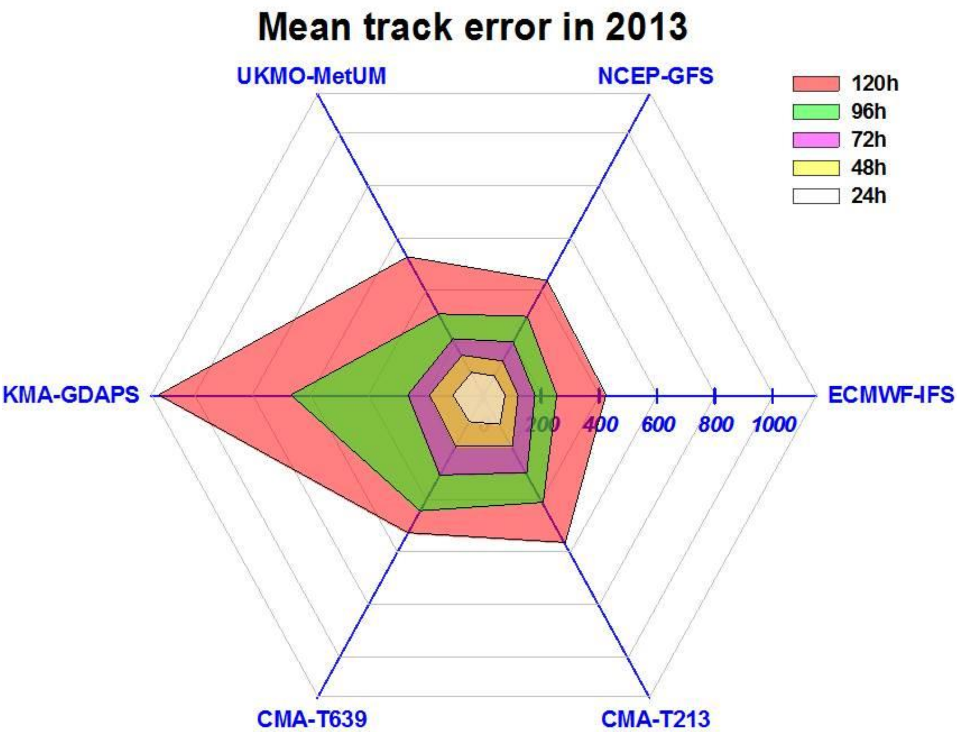
Wednesday 26 February	
0900-0915	**16. Reflections from day 2**
0915-1045	**17. Breakout session** *Delegates rotate between three groups to discuss factors that may act as barriers to the uptake of good-enough disaster risk assessments and potential solutions for resolving these issues.* **Group 1: Governance** **Group 2: Communication**

	Group 3: Decision making under uncertainty ***NOTE:*** *Participants will be expected to use the findings from the case studies and their own experiences/case studies during this breakout session.*
1045-1100	**18. Feedback from breakout session**
1100-1115	**Break**
1115-1230	**19. What are the research gaps and priorities?** *Delegates will split into breakout groups to discuss research gaps relevant to the use of science in good-enough disaster risk assessments. Research gaps should be captured on post-it notes.*
1230-1300	**20. What next? – Conclusions** *Facilitated discussion on what participants will take away and implement from the workshop and what the organisers should do. Discussion led by John Rees, RCUK Risk Research Champion*
1300-1400	**Lunch**
1400	**Participants depart**

Summaries of the case studies

Typhoon Haiyan track and storm surge (November 2013)

Typhoon Haiyan (also known as Typhoon Yolanda) was a tropical storm that took place between 3-10 November 2013. Its development was closely monitored by meteorological organisations in the region. As it gained strength and its track threatened to make landfall in the Philippines, considerable effort was put into running repeated forecasting models to inform authorities of precisely where might be impacted and to what extent. The Filipino authorities were notified of the potentially hazardous event 3-4 days in advance of Typhoon Haiyan making landfall on the morning of Friday 8 November. However, there was less certainty as to where the Typhoon track would cross the Filipino archipelago. As a result, there was little certainty about what action to take at a local level. As shown in the spider diagram below, the level of error (measured in kilometres) in the predictions of all global forecasting models of the track of Typhoon Haiyan, (and therefore the affected areas) decreased steeply over the preceding 120h – 24h before making landfall.



Spider Diagram: B. Fakhruddin, Spider diagram highlighting that there was largely agreement among all six of the global forecasting modelling systems of the final track of Typhoon Haiyan to less than 100km error in the preceding 24h of the Typhoon making landfall.

The repeated running of the forecasting models allowed authorities to ready themselves nationally, and subsequently focus their efforts in gradually more specific regions as forecasting certainty improved.

Nevado del Ruiz volcano eruption (1985)

In late 1984, the Nevado del Ruiz volcano in Colombia started to show increased activity. The nearby communities of Chinchina and Armero were aware that there was a volcano in the region, but because neither town was close enough to actually see the volcano they did not feel that it presented a threat. On 13 November, 1985, the Nevado del Ruiz volcano erupted. While the communities of Chinchina and Armero were not directly affected by the eruption itself, the volcano had been capped with snow. The eruption caused the snow to rapidly melt, causing massive flooding of the Lagunilla River – the river which both the towns were built alongside. Unfortunately, the flooding took the towns by surprise. Armero was destroyed, killing 23,000 people, while Chinchina also suffered severely with 1500 dead. A greater level of education and awareness about the potential wide reaching impact of the volcano (and associated secondary hazards such as the snow melt) may have meant that the communities were able to better appreciate the risk they were exposed to, and take preventative action through temporary evacuation or by strengthening mitigation methods.

Photo: M. Calvache, Armero Town following the flooding in 1985

Tungurahua Volcano, Ecuador (1999- present day)

Tungurahua Volcano became active in 1999, and as result the communities in its vicinity were evacuated for a period of three months. Since 1999, Tungurahua has been persistently active but the communities that live in the area cannot not afford to evacuate every time the volcano shows some activity. In 2006 steps were taken to establish a group of 'Vigias': voluntary watchmen/women who monitor the volcano's activity. To become a Vigia, it is necessary to attend a training session with scientists who discuss the sorts of signs to look out for. Having been trained, the Vigia becomes part of a network that encircle the volcano, and every night at a set time the volunteers call into a central station which collates their observations. In this way, the central station is able to collect a lot more data on the volcano's behaviour, much more frequently. As a result, the local authorities are able to issue warnings only when it is really necessary, and when there is sufficient evidence to support the decision. Furthermore, by having a Vigia in each of the surrounding communities, they are able to act as advocates when a warning is issued, as seen in 2006 when there was the successful evacuation of 3000+ individuals in response to elevated volcanic activity. This has the effect of reinforcing the key risk mitigation messages because their communities respect the work of the Vigia network, which has demonstrated its worth.

Photo: (STREVA project) Individuals of the Vigia network of Tungurahua volcano

Landside in Gramalote, Colombia (2010)

The town of Gramalote in north-east Colombia is situated in an area where multiple streams converge, as well as being on a geological fault line. Due to the effects of La Niña, 2010 saw the wettest conditions in the region in over a century and, on the 16-17 December 2010, resulted in a slow-sliding mud slide which covered vast portions of the town. No lives were lost because there was time to evacuate, and residents even had time to gather some of their most precious possessions.

In response to the event, the Colombian government made a commitment to build a new settlement for the Grameloteras. They chose four potential sites in the region, which they rigorously assessed for geological stability, as well as performing cost benefit analyses. Having balanced a number of factors, the site of Miraflores was selected. However, throughout the process there has been significant pressure from the residents who would like to move to their new location and feel that the rigorous assessment may have taken 'too long'. In this case, due to the amount at stake, 'good-enough' science is in fact the highest standards so that all decisions are defensible. This has come at the cost that some Grameloteras have taken their resettlement into their own hands.

Photo: Fondo Adaptación de Colombia. Aerial image of Gramalote, Colombia showing the extent of the damage caused by the landslide.

UK Windstorms (1987 and 2013)

This case study demonstrated the contrast between the Great Storm of 1987 and St Jude's Storm of 2013. While the meteorology of the storms was relatively similar, there were significant advances in reducing the loss of lives and livelihoods in 2013. A key feature of the 1987 storm was that there was no warning of strong gales on the forecast the night before, although there was mention of heavy rains. The population was therefore unprepared for what was to come, and as a result there were 18 deaths across the UK, and 15 million trees were downed which blocked many transport routes. Several hundred thousand people were also left without power, which was not fully restored until two weeks later.

Having learnt from this experience, there have been several improvements in the intervening years. Coastal defences have been improved, and most importantly forecasting models are able to predict weather conditions with a greater degree of accuracy and further in advance. There are also more ways to disseminate forecasts to reach a much wider audience. With approximately four to six days' notice, there was a much higher level of preparedness, with only four fatalities in the UK.

Conclusions

The workshop reached consensus on a definition of 'good-enough risk assessment'. A 'good-enough' risk assessment was defined as meeting the needs of both the community and the decision makers when time or resources are limited. This definition was refined by dividing the roles of science into two broad categories: some roles of science were specific to the time periods that were explored, whilst other roles of science were found to be applicable across time periods.

The infrastructure that facilitates the integration and uptake of scientific knowledge in good-enough risk assessment cuts across themes and includes:

- political buy-in to the potential benefits of making use of scientific evidence and methodologies in good-enough disaster risk assessment;
- relationship building between scientists and science users;
- engaging local actors to build trust in science and scientific advice.

The conclusions drawn at the workshop were based on the overarching principle that good-enough risk assessment is context specific and dependent on factors such as value systems, risk cultures and behavioural approaches. Similarly, the consensus of the workshop was that 'good-enough' practices were the most relevant to local risk assessments, as opposed to national or regional assessments.

The role of science across time periods

Scientific knowledge and methodologies useful for good-enough risk assessment can range from the highly technical to the very basic. Evidence from technical scientific sources should be presented in an accessible format and language that makes it accessible to the audience, and facilitates rapid understanding and acceptance. In order for scientific methodologies and evidence to be fully integrated, they must be considered from the beginning of the risk assessment process. The precise field of science required will depend on the timing of the risk assessment in relation to the disaster cycle.

Political buy-in to the integration of science in good-enough disaster risk assessment

The workshop concluded that 'Crying wolf' (the concept of false alarms which erodes trust, and in the case of a true emergency, the community doesn't respond) should be avoided. Building on the necessity to avoid the erosion of trust, a clear communication strategy is required to mitigate the risk of inaction when an alarm is raised. As an integral part of the emergency communication strategy, there should be an entry point for scientific information to provide the evidence base for any statements.

Within an emergency communication strategy, areas that should be addressed include the identification of the type of media to be used for communication. In addition, the importance of language is paramount. The choice of written or verbal language depends on the literacy skills of the audience and may mean that symbols or pictures are more universally accessible. In particular, the terminology used to describe a hazard should be given due consideration. At its best, unified, accurate terminology has the ability to clearly convey information clearly and provoke the desired response.

In order to achieve political buy-in, economic or narrative demonstrations can be a useful tool. A cost-benefit analysis may be helpfully substituted for a consequence analysis to better illustrate the predicted impact of inaction, and provide a more compelling reason to take preparatory action. While science is unlikely to be the sole factor for increasing political will, scientific evidence can serve a critical role in presenting evidence of:

- why action is required
- what actions may be appropriate, potentially enhancing the sense of being able to take positive action
- what the consequences of inaction could be.

The development of nested levels of decision making, from the local through to the international, should include how each of those levels will integrate science into risk assessments in a complementary fashion.

Relationship building between scientists and science users

For science to constitute an informative and usable component of the risk assessment, demand needs to come from the community. Community demand creates an imperative to develop the relationship, and a basis for trust between the science providers and science users.

The initial relationship between the science users and the science providers is important to its long term effectiveness. In the beginning of a collaborative relationship, the science provider can facilitate a constructive and potentially advantageous relationship by being transparent and up-front about their credentials and expertise. They should explain clearly how they may be able to assist the community. Similarly, community trust in the science being offered can be fostered by explaining what the practical impacts of its uptake will be, in terms of its benefits, risks and uncertainties.

Furthermore, building a closer relationship with the science provider enables a greater understanding of the community’s information needs. Ultimately, there is a need to enhance more formal education about the hazards relevant to local communities, so that individuals can better understand the risks and how science can contribute to mitigating those risks.

Engaging local actors to build trust in science and scientific advice

In order to engage the relevant local actors for the purpose of building trust, a stakeholder mapping exercise should be undertaken. This would serve to highlight key individuals and groups in the community for science providers to initiate contact with.

While finding entry points at the initiation stage is important, of equal importance is the need to incorporate within the scientific methods, a way to follow up with the community after the end of the project in order to maintain a relationship built on trust. The role of the science provider should include ensuring that any data and findings are left with the community in an accessible format, as well as a physically accessible place. Providing data and findings will spread knowledge gained from the project and build trust for future risk assessment activities.

The use of formal contracts between a science provider and the community to clarify responsibilities and expectations for all stakeholders will ensure that misunderstanding is avoided and tasks are clearly assigned. Furthermore, when a science provider proposes to work with a community on a project to enhance their risk assessments, there is a need to include two elements (as a minimum) in the project proposal:

- An outline of how the community benefits from engaging with the science provider;
- The conduct of the project and its co-ownership.

Considerations for different time periods in relation to a hazard

When considering the role of science, the time available to actors is important as it can determine what actions can be taken.

This workshop examined three different time points in the disaster cycle:

- when there are months-to-weeks to prepare,
- when there are hours-to-minutes to prepare,
- the time to respond following an event.

This final time point was included because the risk landscape changes post-event, which in turn warrants a review of the risk assessment.

Months-to-weeks prior to a hazardous event

There are some types of hazard which may be possible to forecast with a specified level of certainty, such as droughts or disease outbreaks. The role of science in this case is clear: it can inform the models and calculations that result in such forecasts. Science may also focus monitoring systems, such as the area being assessed by satellites, or health databases which inform the forecasting process.

With months to weeks to respond, there are practical interventions to prepare at a household or organisational level. Individuals and institutions could be advised to stockpile water or preserve food or get immunisations prior to a hazardous event. Science could inform this process by suggesting how much food could be required or which members of the community should be prioritized for immunisations.

At a community level, preparation should be focussed on emergency response systems and capacity. The issue of capacity is especially relevant to this time scale.

With months to weeks to mitigate risks, there are tasks that can be undertaken such as improving redundancy in key systems such as local clinics, and coordinating external assistance or imports of food.

The social sciences can contribute by developing a vulnerability map to identify which parts of the community may be at greater risk. The role of the social sciences may be extended to surveying the population for their preferences and capabilities for receiving information - such as literacy rates or quantifying the number of households with a radio. This can help discern the best mechanism for message dissemination, or indeed for a good-enough approach.

A combination of a vulnerability map overlaid onto a geographical representation could be adapted to show essential information such as where stable structures are for shelters, where stockpiles are located and potential areas to avoid. Such information may have been underpinned by scientific evidence, for example flood plains or areas prone to landslide.

Basic education in the sciences can play a key role in preparedness, by promoting understanding of the risks and how to respond appropriately to a hazard. A good-enough approach requires making an appropriate level of education accessible to all members of the community.

In order to ensure the uptake of scientific evidence in the risk assessment process, there is an opportunity to develop a protocol for how scientific data will be shared with the community and national or regional government stakeholders. This could enhance the ability of all levels of decision makers to support the local response and learn appropriate skills in anticipation of future events.

In the time period of months-to-weeks prior to a hazardous event, there is time for a decision on the type of data to be collected before, during and after the hazard, whether that is, for example: hydrometeorological, hydrological, or epidemiological. A good-enough approach would include a priority ranking of the data to be collected, where it would be collated and by whom, depending on the resources available.

Hours-to-minutes prior to a hazardous event

The time period of hours-to-minutes prior to a hazard event incorporates many different hazards, especially those characterised as sudden onset. In such a short time frame, the need to have very clear messaging that rapidly facilitates the decision making process for those in positions of authority is necessary. The concept of ‘good-enough’ is particularly pertinent when there are hours-to-minutes to prepare for a hazardous event, and science may play a key role in the decision making process.

To coordinate what action should be taken in the brief time allowed there should be a plan in place that can be enacted swiftly when warning is given. An emergency plan will have been informed by the overarching risk assessment. With hours-to-minutes to respond, decision makers should feel empowered to take a precautionary approach by responding to a ‘worst case’ scenario which itself is likely to be informed by science. This emergency response plan should have flexibility and scalability built into it, so, that as evidence comes to light, it can be scaled back to a proportional response if appropriate.

In contexts where there is an increased probability of sudden onset hazards, there should be a more habitual process of translating scientific observations into digestible outputs such as briefings. This would ensure the relevant scientific data is available for presentation to decision makers in a timely fashion. Following a decision to implement emergency preparations, there should be a distribution of responsibility to ensure that there is in-built redundancy, as well as preventing any one actor from becoming overwhelmed.

Finally, with hours-to-minutes to respond, it is essential to remind the potentially exposed population of what to do or what they should start doing. Science plays a role in the warning system by providing indications of timescales, what key information should be communicated as well as what forms of communication may be the most appropriate.

Hours, days, weeks and years following a hazardous event

Good-enough risk assessment is as critical following an event as it is in preparation for the same event. In the time immediately after a hazard, communities can be left more vulnerable or exposed to new threats. While there could be many needs to attend to, reassessing the situation by conducting a risk assessment of how the situation has changed should be a priority.

The workshop agreed that the role of science changes significantly as time passes. Immediately following the hazard, the scientific input may take the form of medicine through the identification of health risks, and public health interventions. In rural or hard to reach communities, the mitigating actions of a good-enough risk assessment should include a damage assessment immediately post event. After a longer period following the hazard, it may be that engineering plays a more prominent role in the reconstruction process.

As more time passes following a disaster, an infrastructure assessment or a health needs assessment are examples of how science can be employed to attain an accurate view of emerging issues. This can inform routes that emergency services may be able to use to access remote communities.

The role of science in a post-disaster risk assessment should include due consideration for the collation and curation of data that can be collected. Actions may take the form of recording the extent of the damage, the exposure and anything about the event itself that can inform the recovery process. In this way, the collection of data is a key factor in informing the risk assessment, particularly with regards to identifying how the risk landscape has changed and the mitigation activities that are available to draw upon.

Following on from this, it is important to give due attention to data standardisation mechanisms. By having standardised data formats and collection methods, the data will provide the greatest possible insight to the widest possible audience.

One form of risk mitigation against future hazardous events (whether in the short or long term) is by relocating the vulnerable community. When exploring relocation as a risk mitigation option, science can play a role in informing which sites may serve as suitable alternatives. The use of science in choosing potential sites for relocation includes the use of the social sciences to determine whether any proposed new sites are socially acceptable to the affected community. As part of this, social scientists can seek to identify the strengths in community resilience that can be incorporated into any sort of relocation programme or post-disaster reconstruction.

Throughout the post-event situation, it would be sufficiently ‘good-enough’ if a tool kit was produced that informed emergency responders and decision makers, which would serve to advise on the reconstruction process and where science can inform that process.

Discussion

Meeting the aims of the workshop

The workshop aimed to develop a set of recommendations outlining what role science can play as a constituent of a 'good-enough' risk assessment. Although many guidelines were suggested for the roles of science in 'good-enough' risk assessment, many scientifically informed mitigation activities require significant preparation. Of the mitigation activities that can be implemented in timescales relevant to disaster preparation or recovery, advanced science is not necessarily required to provide the evidence base to guide action.

The workshop provided an opportunity for greater networking of researchers and risk assessment practitioners. By hosting the workshop it was possible to bring together many actors who had not worked with one another. Greater networking of researchers and practitioners also contributed to the aim of increasing researcher understanding of practitioner needs and therefore best practice in accessing data and data presentation. By bringing different stakeholders together it was possible to discuss the benefits of producing different outputs which are tailored to the needs of different audiences, and what form that tailoring may take.

The workshop was successful in collating diverse case studies that showcased how science had been integrated into disaster risk assessments. The case studies illustrated a spectrum from the community produced map in Thailand, through to city level plans as seen in Bogotá, Colombia and whole country integration as demonstrated in the United Kingdom.

One aim that is yet to be fully realised is the production of guidance on the scientific methodologies that can be optimally adopted when it is necessary to conduct a rapid, good-enough risk assessment. The conclusion of this report lists areas of science, both knowledge-based and methodological, that could be used to formulate guidelines. To make guidelines useful and useable, they would have to be categorised by type of hazard, and detail the specific tools and methodologies which could be employed to mitigate the associated risks of the hazard.

Additionally, while work remains to be done, the workshop was able to identify three foundations that should be in place for the successful integration of science into good-enough disaster risk assessment. The foundations included the need:

- for political will to integrate science into the risk assessment process;
- to develop trust between science providers and recipients, ideally prior to a hazardous event;
- for high quality communication channels able to maintain the accuracy of information and ensure that it reaches those most vulnerable in the community.

The workshop adopted a definition of what constitutes a 'good-enough' risk assessment, which was: 'A good-enough risk assessment should facilitate making decisions which are ethically defensible, and balance the needs of the community to preserve life and livelihood'. The adopted definition implies that a risk assessment is not 'good-enough' if risk assessors do not conduct their assessment allowing sufficient time for decision makers to make ethically defensible decisions *and* take into account the lives and livelihoods of the community.

The various roles of science in 'good-enough' disaster risk assessment

The workshop articulated how the role of science changes and elaborated on what those roles entail in relation to the time period associated with a hazard.

It is possible to incorporate science into risk assessment activities prior to a hazardous event by issuing an early warning, providing advice about when to take action, and identifying a location to evacuate to. In contrast, following a hazardous event, the role of science may change to become the provision of advice about the impact of events, such as potential health ramifications, or how to optimise the reconstruction process by advising on the best location for reconstruction and what engineering techniques could be used to 'build back better'.

Throughout the disaster cycle, communication with the exposed population regarding risk mitigation can be challenging. In order to facilitate the dissemination of risk mitigation messages, equipping members of the community with the knowledge needed to understand the consequences of the hazardous event and how they can spread essential messages is beneficial. Employing members of the community in the role of communicators is advantageous because they already enjoy the trust of their communities. Indeed, local communicators may also be able to contextualise information to make it relevant and meaningful in a way that external individuals/ organisations would not be able to. This cooperative way of working with the intended audience can also reduce complacency on the part of the community in the face of false alarms.

Even if the risk assessment occurs late in the disaster cycle, the need to maintain the ethical rigour does not diminish. When choosing which of type of assessment to conduct, it is essential that it takes into account the factors that the community prioritises. Attending to these priorities should help to ensure that the mitigation activities identified are ethically defensible and are more likely to be socially acceptable.

When communicating the science informing a risk assessment, the workshop agreed that in order to attain a standard of 'good-enough', the degree of uncertainty should be reflected in the communication. This might mean using percentages or ratios to describe probabilistic information. Deterministic phrasing, which describes potential outcomes from different actions, as well as the consequences of inaction, could be used as an alternative to probabilistic descriptions. Authorities may have to make a subjective decision (albeit informed by scientific evidence) on what threshold of uncertainty is acceptable in order to trigger action. A subjective threshold would be directly linked to ethical rigour, depending on what level of risk the authorities have accepted, mitigated or avoided. The process of setting a tolerance threshold can be streamlined by producing a range of versatile options for risk management in advance of a hazardous event. As a result, the ethics of each risk management option can be considered prior to the event and evaluated for its ethical strengths and weaknesses.

The necessity of community involvement relates to the finding that ultimately, a ‘good-enough’ risk assessment should be undertaken locally. It follows that for science to be effectively incorporated into the risk assessment process, it must also be scalable from the international and national, down to the local level. In its simplest form, science may take the shape of offering weather forecasts both at the national and local levels that can inform decision makers and emergency planners at the corresponding tiers. In a different context, the scientific output may take the form of ensuring communication of new research findings in, for example, health, and ensuring that these trickle down to local healthcare providers who can incorporate elements in the training given and as part of active outreach. In all circumstances, consideration should be given to how scientific practice and concepts can be scaled and made relevant to the physical and human resources available.

There is an important role for productive dialogue between decision makers and science providers. The workshop identified transparency as a principle that can assist decision makers when balancing evidence to inform a decision. A high level of transparency may contribute to achieving community buy-in to the risk management strategy. It is necessary to include all factors being balanced alongside scientific evidence. Failure to take into account factors such as the social, political or economic context may undermine a mitigation activity recommended by scientific evidence.

Given the range of factors that must be taken into consideration by decision makers, science providers can strengthen their role in disaster risk assessment by translating their findings into decision making tools. The tools may take the form of maps or digestible ‘briefs’, which could be prepared as regular updates as often as the data is collected so that there is always timely evidence available. Again, any briefs, maps or other outputs should include the uncertainty in the data. As a result of effective and informative tools, decision makers can be empowered to take reasonable action effectively using the evidence that there is a high probability of a hazard.

While it is beneficial to facilitate the decision making process to justify a precautionary approach, it is necessary to avoid erosion of trust through multiple false alarms. Fear of overusing emergency responses could be seen to conflict with a policy of ‘no regrets’, the concept of preferentially choosing a full activation of an emergency response in the face of uncertainty. However, the primary goal can be achieved harmoniously if there has been an investment in trust-building exercises and dialogue. The workshop envisaged that trust-building exercises would involve all of the key stakeholders including scientists, the community and decision makers.

Of course, in a community, there are a range of stakeholders in a disaster risk assessment in addition to formal decision makers. A stakeholder mapping exercise can help to produce a more comprehensive picture of the stakeholders. Examples of such leaders could include faith leaders or head teachers who can reinforce messages or present an obstacle to the dissemination of messages they do not agree with. The use of a mapping exercise can also help to ensure that any future work engages with the most vulnerable audiences. With a stakeholder map, the process of developing relationships is facilitated, and efforts can be made to co-design scientifically ‘answerable’ questions that meet the needs of the audience. The co-design of research questions can also help to guide the scientific methodology used to gather the associated evidence, as well as manage expectations about what questions can be answered. Indeed, it may also have the consequence of the community accepting of the outcomes of the science more readily. Therefore, a collaborative approach to designing research can have the outcome of producing tools and methodologies that genuinely meet the needs of the community and have a longer lasting impact in terms of their uptake.

There can be a discrepancy between what a community chooses to call a hazard and its scientific classification. In the conclusions above, it was identified that 'good-enough', and the best practice involves using the correct terminology for the type of event. That might mean using the term 'storm surge' instead of 'tsunami'. The need to use accurate terminology could consequently lead to better education about different types of hazard. A greater focus on hazard education should achieve an understanding among the population of what is meant by different terminology, and ideally, an appropriate course of action. Additionally, with more education about hazards, more individuals may be able to contribute to data collection or data interpretation. However, if a sufficient level of understanding has not been achieved, the scientific community may play the role of interlocutors between the local and international communities, by using the technically accurate terms when referring to a situation.

Another role of science, and specifically scientists, could be as an advocate for disaster prevention mechanisms. Risk assessments underpinned by scientific evidence can be a useful tool in promoting investment in technologies or strategies that will contribute to DRR in the long run. Moreover, if developed in advance, interventions can be developed and selected which will mitigate a range of uncertainties. Engaging community groups with scientific evidence in a bottom up approach can potentially have the benefit of swelling political will and buy-in, particularly where there is an opportunity cost decision to be made.

The principle of working with a community to establish a role for science in disaster risk assessment should extend throughout the lifetime of a programme, and could beneficially continue to contribute in a multitude of ways beyond the programme. One example of a lasting impact could be to present the outcomes of on-going research to the community in an accessible format such as their own language or pictorially. Making research outcomes accessible can create a greater feeling of exchange between the scientific community and local communities, creating an atmosphere that is conducive to working together. Co-design of a programme from the outset can help to nurture the eventual co-ownership of the results, as well as engendering appreciation of the implication of the outcomes. In practice, making outcomes accessible to a range of audiences may equate to writing up the same findings in different formats. For example: a peer reviewed journal publication for researchers and those looking for international best practice; a public pamphlet for the community, including an explanation of how they can implement any findings; an executive summary for local leaders who may have less time for reading, giving a summary of the decision making process and identifying what could happen as a result.

The role of science in good-enough disaster risk assessment prior to a disaster

The workshop found that there were actions appropriate to different periods in the disaster cycle. With a timescale of months-to-weeks to prepare prior to a hazard, there are many more options available for risk mitigation, and indeed integrating science. At the very least, the threat of a hazard can be channelled to focus minds and ensure that everyone is aware of what their own responsibilities are in the event of a hazard. In order to achieve greater efficiency and integrate a level of helpful redundancy, individuals should be aware of the responsibilities of others so that they are able to work as a team effectively.

When there are months-to-weeks to prepare and respond, there is a role for a more concerted public education focus. As noted above, there is continuous and on-going demand for scientific education about hazards. However in the short term prior to a hazardous event, there is an opportunity for 'good-enough' mitigation techniques to include the repackaging of scientific literature into a more accessible format. By reformatting journal literature into media understood by the community, scientists can ensure that consequent risk assessments reflect the latest scientific evidence. A greater awareness of scientific findings can also serve to foster a greater understanding of the resultant risk mitigation options.

The repackaging of scientific evidence for different audiences can be seen as good practice, particularly when considering a timescale of only hours-to-minutes prior to a hazard. The process of producing more frequent, tailored briefings as outputs can assist with ensuring that there is timely evidence, on hand at short notice. To embed the practice of accessible, frequent briefings may require further training of the scientific community, or an external intervention to create something that meets the needs of decision makers. There is evidence of good practice in the realm of meteorology which demonstrates that the theory can be integrated into practice.

Another opportunity that the longer timescale of months-to-weeks prior to a hazard affords is that of analysing the positioning of resources correlating to the vulnerability of the community. The benefits of employing the skills and techniques associated with the social sciences to map the community have been described. A vulnerability map can be cross referenced with the location of emergency supplies, and indeed analysed to see if resources are accessible. A vulnerability map may provide helpful indications of where resources could be repositioned or supplemented, in order to best serve those who may struggle to reach them. Again, if the decision is taken to reposition or add emergency response resources, there is a vital role for education to ensure that the community is aware of the location of emergency supplies.

Another insight that an enhanced understanding of the community can offer, is the ability to distribute responsibility to appropriate parties when responding to a hazard. The distribution of roles can help to promote a widened sense of ownership of the situation so that it does not overwhelm any one actor in the system. Distribution of responsibilities may include members of the government (local, regional or national), scientists or members of the community at appropriate levels.

When considering shorter time periods, such as hours or minutes prior to a hazard a scalable preparation and response plan could be considered 'good-enough' in a risk assessment. As a result of having a scalable response mechanism which includes scalable scientific evidence, decision makers should be able to activate emergency procedures in the knowledge that they will not be penalised financially, legally or through loss of trust by the audience. Having scientific evidence to support a decision to implement emergency response procedures is particularly relevant if it turns out to be a false alarm, as discussed earlier, with regard to mitigating the potential for developing community apathy. Adoption of a scalable approach will ensure that a situation should not arise whereby decision makers would feel so unsure of their ability to act appropriately due to the uncertainty in evidence, scientific or otherwise, that they would take no action.

When there are hours-to-minutes to prepare for a hazard, scientific evidence may help convince members of the vulnerable community of the benefits of the recommended course of action. Enabling the community to understand that a decision is based on scientific evidence to facilitate compliance with an emergency response plan can be of benefit both in the moments prior to a hazard and in retrospective reviews of the event.

The role of science in good-enough disaster risk assessment following a disaster

The role of science in 'good-enough' disaster risk assessment changes substantially following a hazardous event, not least because the role of a risk assessment is to establish how the risk landscape has changed. The post-disaster time period potentially offers an opportunity for data collection to give insight into how better to prepare for future disasters. Research programmes such as the Integrated Research on Disaster Risk's (IRDR) FORIN[3] project looks to assess the causes and aftermath of disasters forensically and, using the post-hazard evidence, facilitate more informed actions to mitigate the impacts of future events. Furthermore, the affected community is much more likely to trust decision makers in the future if they see that there is a lesson-learning exercise to avoid repetition of mistakes or missed opportunities.

Collection of data in the post-disaster situation can be important for informing the immediate risk assessment as well as any future decision making as the rebuilding process begins. The standardisation and sharing of methods for post-hazard data collection can ensure that the data collected can contribute more widely to understanding similar hazards as well as enabling scientists from outside the hazard area to analyse the data. Ultimately, the collection of data in a standardised format means that it can be shared widely. The knowledge gained from analysis can subsequently add to the global community's understanding of different types of hazards which may in turn prove to help the community in the long term.

Health risks such as the spread of disease as a result of poor sanitation of lack of potable water are an immediate concern following a disaster. Ramifications for human health will present the immediate human and community risk which requires assessment by health professionals. Conducting a 'good-enough' risk assessment

[3] http://www.irdrinternational.org/projects/forin/

directly following a hazard may assist in ensuring that an additional and on-going medical disaster is avoided.

Following a hazardous event, rural communities, affected by flooding or landslides, for example, can be in a particularly vulnerable position if it is difficult for the emergency services to reach them. Therefore a level of preparation for the post-hazard period may be required to assist communities cut off from emergency services. Preparations for the time following a hazard may include basic training and awareness of damage assessment techniques so that individuals are prevented from returning to buildings or areas that have become dangerous. While it is ideal to leave damage assessment to formally trained services, it may be the case that there is a significant delay in their arrival, and thus those with some level of training would constitute a 'good-enough' approach. Therefore, the good-enough approach would allow for individuals with basic training to have an authoritative voice in deciding which buildings or areas should be avoided or where to safely congregate. Basic structural assessment of the built environment may provide an entry point for science in the form of civil engineering.

Basic training in structural risk assessments as soon as possible, following a hazard, may make it possible to decide whether buildings can be repaired, or must be demolished. Therefore structural assessments can contribute to longer term thinking about the future resilience of the community.

Institutionalising systems of more accurately measuring the impacts of a hazard may have a range of beneficial and longer term consequences. In addition to gaining a greater understanding of the hazard that has occurred, accurate measurement may enhance the political ability to allocate funding in an existing budget to the recovery or provide access to external funding. Greater access to funds and expertise can then help accelerate the recovery process at a local level.

In some cases, countries and communities have emphasised the role of science in post-hazard response. Examples include Colombia in the case of the Gramalote landslides in 2010, and across Mozambique where 500,000 people have been affected by flooding in 2001, 2007 and 2013[4]. In the case of Colombia and Mozambique, the role of science has been to inform the choice of suitable sites for relocation. Simultaneously, the 'good-enough' aspect has been the need to balance the time required for rigorous risk assessments with maintaining community buy-in.

When considering relocation of communities to mitigate the risk of the same situation recurring, there is the need to be scientifically rigorous in the selection of the new site. As a result, in this situation 'good-enough' actually translates to being the very best risk assessment that can be conducted. Any reconstruction must be more resilient than the previous situation so as to be ethically defensible. Therefore 'good-enough' risk assessment may incorporate engineering principles, use of material science or the geological and hydrological assessment of the ground.

The production of a toolkit advising on the post-disaster reconstruction process, and in what order reconstruction tasks should be carried out, would be good-enough for incorporation into a risk assessment. A toolkit may help with wider alignment so that

[4] http://www.slideshare.net/GRFDavos/j-ribiero-appropriateness-of-resiliency-as-a-national-strategyppt?ref=http://resilienceconference.org/conference-outcomes/

international, national or regional bodies who are able to contribute to reconstruction efforts could see where they fit into a reconstruction strategy.

Future work & research gaps

The workshop opened up a dialogue on the topic of the role of science in good-enough disaster risk assessment, but inevitably, there is more research to be done. This includes further research within scientific fields that can inform risk assessments, as well as research to ensure that science can be fully integrated at all levels of disaster planning. Parallel to this consideration should be given to what improvements can be made to institutions to enable them to deliver effective disaster risk assessments. Four broad themes were identified as requiring further research:

- the appropriate approach to research
- data and data tools
- scientific topics that require further research
- the application and implementation of new and existing research.

Research approaches

In disaster risk assessments, and more generally in disaster risk management, there is hope that high quality research will inform policy and practice. To facilitate the route of research informing policy, a rigorous ethical framework should be developed and adhered to, to support greater accountability and transparency of the policy output. An ethical framework for establishing the contribution of science into disaster management policy would also identify the end users' interests as a key motivator of the science. The need for interdisciplinary working to fully understand the complexity of the local situation is another aspect of the approach to research that should be taken into account. The interdisciplinary nature should include input from the research stakeholders so that they can assist in the design and co-own the research. Therefore future work in this area would include demonstrating best practice in research which has been co-designed by the community for which it is intended.

Data and data tools

Data received from research on hazards or related fields, particularly in science regarding resultant disasters, should be available, in a standardised format to increase usability and transparency. Through the standardisation of data, there may be a greater level of interoperability with interdisciplinary systems for data management. Data collection should also be scalable, from the international to the local. Making data scalable will, in turn, allow it to be interpreted in context. Finally, apart from the type of data and the amount, there are gaps in the data being collected. A useful exercise would be to map what data is currently available for different hazards, and prioritise filling in data set gaps. The need for hazard specific data to be curated in databases is essential to ensure that it is accessible.

Topics that require further research

Each research field within the broader field of hazard research will have its own specific frontier to pursue in the future. However, a cross cutting theme within the topics that should be researched is the need to learn from the mistakes of the past to avoid repetition, as well as the identification of best practice that can be implemented more widely. There is scope to transfer knowledge between fields such as the public health sector which has vast experience in sharing best practice, or from Information Technology techniques for classifying and categorising information. Longitudinal research on how scientific evidence has been incorporated into disaster risk assessments would be of benefit to understand how the practice of integrating science has developed over time.

Implementation of existing research

A greater understanding of the application and implementation of science into disaster risk assessment would be tremendously beneficial. In particular, there would be significant value in a more comprehensive view of the drivers for, and barriers against, the integration of science into disaster risk assessments. This could improve the time to implementation and allow for the pre-emption of obstacles which it may be possible to overcome or remove altogether.

One potential barrier that has already been identified is that of the public understanding of what science is able to contribute to disaster risk assessment. A body of work to overcome this misunderstanding may enable more members of the community to appreciate how science is able to add valuable information to risk assessment and a risk management strategy, which may, in turn, lead to greater acceptance of the outputs.

Sometimes, it is not the case that there is research to do, so much as the need to ensure physical access to data, and training in the understanding of what it shows. The training of willing individuals in the community to be able to analyse and utilise data relevant to their community can promote a positive exchange and acceptance of the value of the research. Training in the understanding of data adds value to the research as a whole, as it allows for much greater impact of the resultant knowledge.

Further work could also include the development of a protocol for data collection during and immediately following a hazardous event. Preparation, on a local scale, of such a protocol, prior to a hazard could significantly enhance a community's ability to receive aid and recover from an event by being able to quantify the amount of damage.

An increase in the number of opportunities for meetings between decision makers and the scientific community should enhance the dialogue between the two stakeholder groups. This dialogue should provide the acceptance that leads to the integration – based on trust of scientific input into risk assessments. Closer relationships between the decision making and scientific communities would also facilitate those in decision making positions to take a defining role in terms of research priorities and pose more questions for scientific research to provide answers to.

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