RISK ASSESSMENT HANDBOOK

NEW ZEALAND Aid Programme

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JOINT CENTRE FOR DISASTER RESEARCH

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Glossary

The United Nations International Strategy for Disaster Risk Reduction (UNISDR, 2009) provides the following definitions to promote a common international understanding within Disaster Risk Reduction work.

Acceptable risk: The level of potential losses that a society or community considers acceptable given existing social, economic, political, cultural, technical and environmental conditions.

Adaptation: The adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

Building code: A set of ordinances or regulations and associated standards intended to control aspects of the design, construction, materials, alteration and occupancy of structures that are necessary to ensure human safety and welfare, including resistance to collapse and damage.

Coping capacity: The ability of people, organizations and systems, using available skills and resources, to face and manage adverse conditions, emergencies or disasters.

Corrective disaster risk management: Management activities that address and seek to correct or reduce disaster risks that are already present.

Critical facilities: The primary physical structures, technical facilities and systems which are socially, economically or operationally essential to the functioning of a society or community, both in routine circumstances and in the extreme circumstances of an emergency.

Disaster: A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources.

Disaster risk: The potential disaster losses, in lives, health status, livelihoods, assets and services, which could occur to a particular community or a society over some specified future time period.

Disaster risk management: The systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster.

Disaster risk reduction: The concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events.

Disaster risk reduction plan: A document prepared by an authority, sector, organization or enterprise that sets out goals and specific objectives for reducing disaster risks together with related actions to accomplish these objectives.

Early warning system: The set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss.

Emergency management: The organization and management of resources and responsibilities for addressing all aspects of emergencies, in particular preparedness, response and initial recovery steps.

Exposure: People, property, systems, or other elements present in hazard zones that are thereby subject to potential losses.

Extensive risk: The widespread risk associated with the exposure of dispersed populations to repeated or persistent hazard conditions of low or moderate intensity, often of a highly localized nature, which can lead to debilitating cumulative disaster impacts.

Forecast: Definite statement or statistical estimate of the likely occurrence of a future event or conditions for a specific area.

Geological hazard: Geological process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

Hazard: A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

Hydrometeorological hazard: Process or phenomenon of atmospheric, hydrological or oceanographic nature that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

Intensive risk: The risk associated with the exposure of large concentrations of people and economic activities to intense hazard events, which can lead to potentially catastrophic disaster impacts involving high mortality and asset loss.

Land-use planning: The process undertaken by public authorities to identify, evaluate and decide on different options for the use of land, including consideration of long term economic, social and environmental objectives and the implications for different communities and interest groups, and the subsequent formulation and promulgation of plans that describe the permitted or acceptable uses.

Mitigation: The lessening or limitation of the adverse impacts of hazards and related disasters.

National Platform for Disaster Risk Reduction: A generic term for national mechanisms for coordination and policy guidance on disaster risk reduction that are multi-sectorial and inter-disciplinary in nature, with public, private and civil society participation involving all concerned entities within a country.

Natural hazard: Natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

Preparedness: The knowledge and capacities developed by governments, professional response and recovery organizations, communities and individuals to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current hazard events or conditions.

Prevention: The outright avoidance of adverse impacts of hazards and related disasters.

Prospective disaster risk management: Management activities that address and seek to avoid the development of new or increased disaster risks.

Public awareness: The extent of common knowledge about disaster risks, the factors that lead to disasters and the actions that can be taken individually and collectively to reduce exposure and vulnerability to hazards.

Recovery: The restoration, and improvement where appropriate, of facilities, livelihoods and living conditions of disaster-affected communities, including efforts to reduce disaster risk factors.

Residual risk: The risk that remains in unmanaged form, even when effective disaster risk reduction measures are in place, and for which emergency response and recovery capacities must be maintained.

Resilience: The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions.

Response: The provision of emergency services and public assistance during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected.

Retrofitting: Reinforcement or upgrading of existing structures to become more resistant and resilient to the damaging effects of hazards.

Risk: The combination of the probability of an event and its negative consequences.

Risk assessment: A methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend.

Risk management: The systematic approach and practice of managing uncertainty to minimize potential harm and loss.

Risk transfer: The process of formally or informally shifting the financial consequences of particular risks from one party to another whereby a household, community, enterprise or state authority will obtain resources from the other party after a disaster occurs, in exchange for on-going or compensatory social or financial benefits provided to that other party.

Socio-natural hazard: The phenomenon of increased occurrence of certain geophysical and hydrometeorological hazard events, such as landslides, flooding, land subsidence and drought, that arise from the interaction of natural hazards with overexploited or degraded land and environmental resources.

Structural measures: Any physical construction to reduce or avoid possible impacts of hazards, or application of engineering techniques to achieve hazard-resistance and resilience in structures or systems;

Non-structural measures: Any measure not involving physical construction that uses knowledge, practice or agreement to reduce risks and impacts, in particular through policies and laws, public awareness raising, training and education.

Sustainable development: Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Technological hazards: A hazard originating from technological or industrial conditions, including accidents, dangerous procedures, infrastructure failures or specific human activities, that may cause loss of life, injury, illness or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

Vulnerability: The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard.

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Understanding Risk Assessment in the Context of Disaster Risk Management

South East Asia is one of the most hazard-prone regions of the world. Typhoons are regular occurrences between May and November, bringing high winds, flooding and landslides. Earthquakes are also frequent in the region. Disasters in 2013 caused USD$128 million in damages and impacted 57 million people (ESCAP, 2015a). Disaster risk management (DRM) has never been so important.

The foundation for DRM is understanding the hazards, and the exposure and vulnerability of people and assets to those hazards. By quantifying and understanding the risks and anticipating the potential impacts of hazards, governments, communities, and individuals can make informed risk management decisions. Such information can be used to set priorities for development and adaptation strategies, sector plans, programs, projects, and budgets (World Bank, 2012).

DRM aims to reduce the consequences of disasters by understanding and addressing the probability and impacts of disasters, underpinned by a structured methodology of assessment and treatment of risk. However, a range of challenges and issues conducting, using, and communicating risk assessments have been experienced in South East Asia (Table 1).

Table 1: Summary of issues commonly experienced for risk assessments in South East Asia

ISSUE	EXPLANATION	POTENTIAL WAYS TO RESOLVE THE ISSUE
Scale of assessment	• Different spatial and temporal scales used in risk assessments, means that comparison between risk measures used in different risk assessments can be limited and must be communicated with caution. • Often the scale used in a risk assessment is dependent on data availability and/or limitations, rather than the needs of users of the assessment.	• Work with stakeholders to determine the appropriate risk assessment scale for their purpose. • A caveat should be stated within the risk assessment about the applicability of the risk assessment scale to respective levels of application.
Availability of locally specific vulnerability information	Often physical and social vulnerability information for a local contexts can be limited, if available at all. Therefore some elements at risk (particularly critical infrastructure) should be included in assessments with a degree of caution based on the reliability of the information.	• Conduct a vulnerability assessment for study area in question, if possible (Rossetto et al., 2014). • In lieu of no locally specific information vulnerability information may be extrapolated from nearby or comparable regions. Caution needs to be exercised if attempting this, as vulnerability information is often site or regional specific. This judgement needs to be undertaken by someone who is sufficiently qualified , informed and experienced. • Seek expert opinion on selection of comparable vulnerability information (Rossetto et al., 2014).
Data biases	Spatial: Some localities have limited hazard monitoring infrastructure (e.g. rain gauges, seismographs, tidal gauges, etc.) meaning that inputs to, outputs from, and calibration of hazard models is limited. Temporal: Often historical information is used within risk assessments. However, historical data of disasters in South East Asia is limited largely to the last 40 years and so cannot include all possible manifestations of the hazard process. Further, historical data of disasters in South East Asia is heavily biased towards the catastrophic events, and the more common but less impactful events are largely unaccounted for.	• Use global model (e.g., UN global assessment of risk – note spatial scale caveats) • Expert input • Build customised hazard model (can be expensive) Caution needs to be exercised if attempting any of these options, as data analysis in risk assessments is often site or regional specific. This judgement needs to be undertaken by someone who is sufficiently qualified, experienced and informed

Data management practices and data availability	The information required for risk assessment often comes from a range of sources with variable data collection and management practices, quality and sharing policies. For example: • Reluctance to share exposure data from the census and tax records • Disclosure restrictions due to defence/military reasons • Transboundary data can be difficult to access • Discouragement due to lengthy or complex procedures to access data This means that considerable time and effort may be required for data collection and data processing to compile or format data required for a risk assessment.	Develop quality relationships and data sharing practices with data hosts and within your own organisation Use existing and freely available national and global data sets (e.g., EM-DAT, Desinventar) Judgement is required on the part of the risk analyst (and sometimes the stakeholders) to determine how much effort should be put into acquiring data.
Underutilisation of local knowledge and culture, and stakeholders	• The information required for risk assessment often comes from a range of sources with variable data collection and management practices, quality and sharing policies. For example: • Reluctance to share exposure data from the census and tax records • Disclosure restrictions due to defence/military reasons • Transboundary data can be difficult to access • Discouragement due to lengthy or complex procedures to access data • This means that considerable time and effort may be required for data collection and data processing to compile or format data required for a risk assessment.	Participatory approaches to risk assessment are very important, particularly involving locals as active partners in the risk assessment process (The World Bank, 2012) The nature of community engagement is dependent on the scale of the assessment being conducted. The more local community input though the more rich and relevant the assessment will be. Need to tailor messages to the respective audiences (see Communicating Risk Assessment section of this handbook). Engaging audiences in the risk assessment itself assists in identifying and overcoming communication barriers.
Communication of risk assessment information	• Lack of understanding and communication of risk statements and information from and to decision makers. • Misperception on the sensitivity of risk assessment results leading to poor communication efforts being undertaken.	Need to tailor messages to the respective audiences (see Communicating Risk Assessment section of this handbook). Engaging audiences in the risk assessment itself assists in identifying and overcoming communication barriers.

Utilisation of risk assessments	• There are limited and undefined channels available for disseminating risk assessment results. • Poor utilization of using risk information in planning for development. • Lack of guidelines on how risk assessment outcomes can be used	• One of the first aspects of risk management is understanding the context. It is at this stage that channels for disseminating risk assessment results should be identified. • Take a holistic approach to risk assessment (not just the analysis) to understand the context of why the risk assessment is being undertaken and how it could be used. • Continued education and well communicated risk assessments. Celebrate successes and use best-practice examples. • A range of global reports are useful guides on how risk assessment outcomes can be used (e.g., The World Bank, 2012; GFDRR, 2014; UNDP, 2010a; UNISDR, 2015)

Risk Assessment

In its most simple form, disaster risk is a function of three components (World Bank, 2014):

- **Hazard:** refers to the likelihood and intensity of a potentially destructive natural phenomenon, such as ground shaking induced by an earthquake or wind speed associated with a tropical cyclone.
- **Exposure:** refers to the location, attributes, and value of assets that are important to the various communities, such as people, buildings, factories, farmland, and infrastructure, and that are exposed to the hazard.
- **Vulnerability:** is the reaction of the assets when exposed to the spatially variable forces produced by a hazard event. For example, a building's vulnerability to earthquake increases with the intensity of ground shaking and decreases with improved conformity to seismic design standards. Similarly, socioeconomic conditions can make responding to a hazard event easier or more difficult.

Risk assessment is a process to determine the nature and extent of risk, and is critical for laying the foundations for developing effective policies and strategies for disaster risk management. The process of undertaking risk assessment allows for identification, estimation and ranking of risks. This includes potential losses of exposed population, property, services, livelihoods and environment, and assessment of their potential impacts on society. Generally, the client, regulator or an elected/government representative will then use this assessment to decide upon the course of action to be taken. The concept behind risk assessment is that it is a structured, transparent, scientific process that is independent of politics. This allows it to be repeated, added to, and reused when political priorities change.

Purely technical assessment of risk, however sophisticated and cutting-edge, is by itself unlikely to trigger actions that reduce risk. Successful risk assessments produce information that is targeted, authoritative, understandable, and usable (World Bank, 2014). Thus, the first steps in a risk assessment include understanding why the assessment is needed and wanted, defining the information gaps that currently inhibit DRM actions, and identifying the end-users of the information (World Bank, 2014). The first steps can be completed only if the process of generating and using risk information is integrated with institutional processes, and if there is communication and trust among all involved parties: scientists, engineers, decision makers, governmental authorities, community representatives and communities themselves. A risk assessment designed along these lines will enable the development of information useful for risk mitigation (World Bank, 2014).

The role of risk assessment is to undertake the analysis, estimate the risk and anticipate how it will change under various courses of action and provide guidance in the way of precedents, benchmarks, comparisons and lateral solutions. These can then be further developed and communicated with stakeholders and interested parties (e.g. government and local communities).

Risk information provides a critical foundation for managing disaster risk (as identified by the World Bank, 2012; 2014):

1. **Risk identification:** Understanding, communicating, and raising awareness of disaster risk.
2. **Risk reduction:** Informing policies, investments, and structural and non-structural measures intended to reduce risk.
3. **Preparedness:** Informing early warning systems and emergency measures and supporting preparedness and contingency planning at various levels.
4. **Financial protection:** Developing financial applications to manage and/or transfer risk including insurance
5. **Resilient reconstruction:** Informing early and rapid estimates of damage and providing critical information for reconstruction or relocation.

Key information required for a risk assessment are:

- The context and objectives of the risk assessment;
- The extent and type of risks that are tolerable, and how unacceptable risks are to be treated;
- How the risk assessment fits into disaster risk management processes;
- Methods and techniques to be used for risk assessment, and their contribution to the risk management process;
- Accountability, responsibility and authority for undertaking risk assessment;
- Resources available to carry out risk assessment;
- How the risk assessment will be reported and reviewed.

In order to meet these information requirements it is useful to follow a standardised methodology so that outputs are comparable and transparent for the decision making process. The International Organization for Standardization published an International Standard on risk management (AS/NZS, 2009), of which risk assessment is a key component (Figure 1).

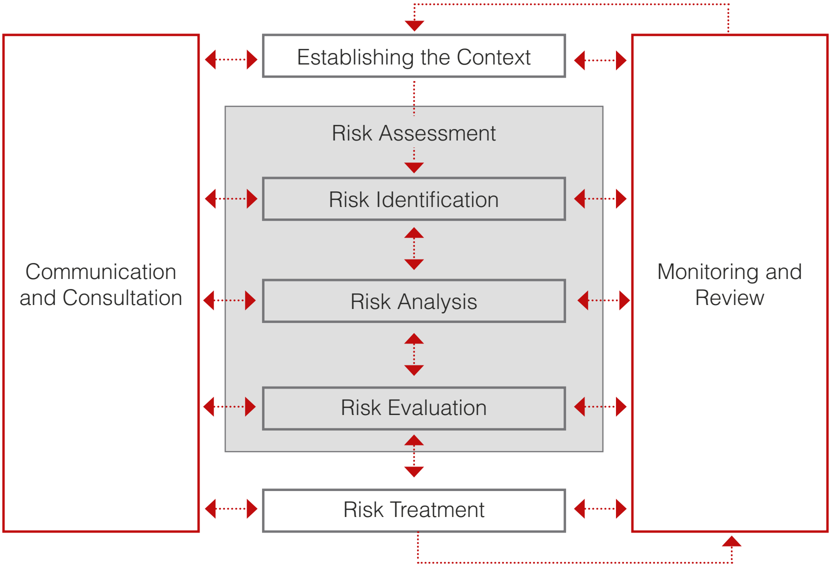


Figure 1: Risk assessment process (AS/NZS, 2009)

The standardised methodology for undertaking a risk assessment involves three steps (AS/NZS, 2009, UNDP, 2010):

1. Risk identification: Identifying risks that need to be assessed.
    - *Understanding of the current situation, needs and gaps:* assess what already exists, avoid duplication of efforts, and build on existing information and capacities. This is done through systematic inventory and evaluation of existing risk assessment studies, available data and information, and current institutional framework and capabilities;
    - *Hazard assessment:* identify the nature, location, intensity, and likelihood of major hazards prevailing in a community of society;
    - *Exposure assessment:* identify population and assets (elements) at risk and delineate disaster prone areas;
    - *Vulnerability assessment:* determine the capacity of elements at risk to withstand the given hazards.
2. Risk analysis: Determine an understanding of the risks.
    - *Loss/Impact analysis:* estimate potential losses of exposed population, property, services, livelihoods and environment, and assess their potential impacts on society.

3. Risk evaluation: Evaluating risks so that decisions can be made based on the risk assessment outcomes.
   - *Risk profiling and evaluation:* identify cost-effective risk reduction options in terms of the socio-economic concerns of a society and its capacity for risk reduction;
   - *Formulation or revision of disaster risk reduction strategies and action plans:* setting priorities, allocating resources (financial or human) and initiating disaster risk reduction programmes.

Risk Assessment for Disaster Risk Management

Disaster risk management encompasses disaster risk reduction and emergency management (Figure 2):

Disaster risk reduction (DRR): 'The concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events' (UNISDR, 2009, p.10-11)

Emergency management (EM): 'The organization and management of resources and responsibilities for addressing all aspects of emergencies, in particular preparedness, response and initial recovery steps' (UNISDR, 2009, p.13).

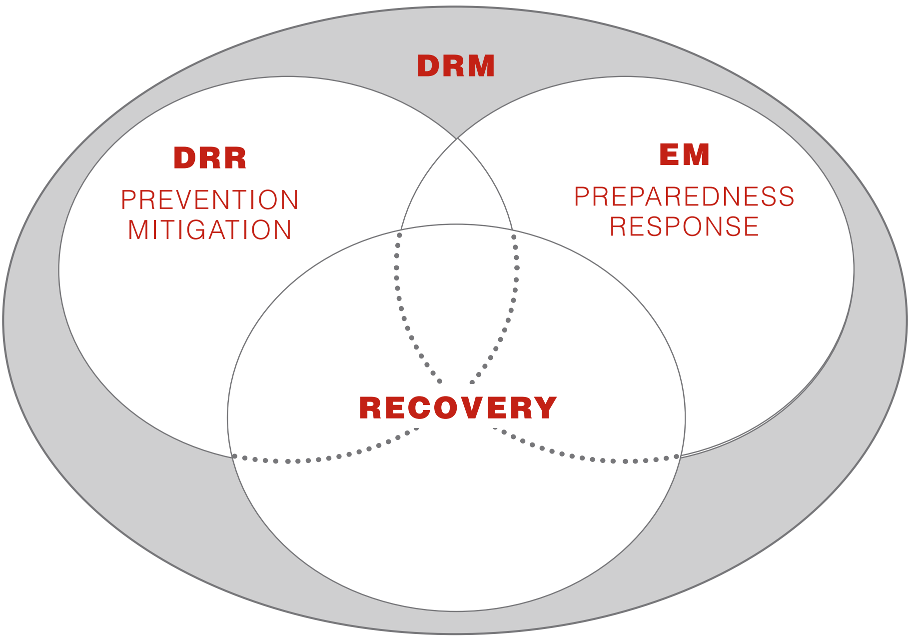


Figure 2: Disaster risk management schematic

Risk information is the critical basis for managing disaster risk. In a complex, dynamic world, disaster risk can easily be overlooked by governments, communities, and individuals – especially as impacts from historic or future disasters are often not known. Appropriate communication of robust risk information at the right time can raise awareness and trigger action. Hazard and risk information may be used to inform a broad range of activities to reduce risk, from improving building codes and designing risk reduction measures (such as flood and storm surge protection), to carrying out macro-level assessments of the risks to different types of buildings (e.g. for prioritizing investment in reconstruction and retrofitting) (World Bank, 2014). Preparedness activities can be enhanced by understanding geographic areas at risk and estimating the impact (e.g. potential number of damaged buildings, fatalities and injuries, secondary hazards, etc.). This informs planning evacuation routes, creating shelters, and development of detailed and realistic plans for better response to disasters. Disaster risk analysis (a part of risk assessment) can be used to help governments manage their sovereign financial risk or support programs that manage individual financial risks (e.g., micro-insurance or household earthquake insurance). But to be effective, they must be informed and updated with risk information (World Bank, 2012). Finally, risk assessment can model the likely impact before an event strikes (e.g. in the days leading up to a typhoon), or it can provide initial and rapid estimates of human, physical, and economic loss in an event's immediate aftermath. This can be critical for resilient reconstruction to inform resilient design and land-use plans (World Bank, 2014).

The four main basic components of disaster risk management are mitigation, preparedness, response, and recovery. Different countries, books, and documents may use different but similar terms; for example, 'readiness' is sometimes used instead of 'preparedness'. Risk assessments provide valuable inputs into each component of disaster risk management.

Risk Assessment for Disaster Mitigation

Mitigation lessens the likelihood of a disaster and disaster impacts by implementing sustained actions to reduce or eliminate long-term risk to people,property, and the environment. This can be done by reducing the exposure (e.g. land use restrictions) or vulnerability (e.g. seismic retrofitting), which demonstrates why risk assessments are an important input for disaster mitigation. Mitigation includes structural and non-structural measures, and overlaps with recovery, preparedness and response. Non-structural mitigation includes any measure not involving physical construction that uses knowledge, practice or agreement to reduce risks and impacts (e.g. building codes, land-use planning laws, research, public awareness programmes). Structural mitigation includes improved construction practice, flood protection levees, evacuation shelters and elevation of structures in flood plains, for example.

Risk Assessment for Disaster Preparedness

Preparedness lessens the severity of disasters by preparing people for disaster, developing plans to ensure an effective response and recovery and training communities and organizations to implement plans when a disaster occurs. Establishing and maintaining early warning alerting and communications processes is a key aspect of preparedness.

Prediction and warning for different disasters is essential to preparedness. It helps to give people time to evacuate and get to a safe place, as well as helping emergency managers to plan. Risk assessment is fundamental to establishing appropriate warning systems as there needs to be an understanding of all components of risk to determine likely lead times and safe areas to evacuate

Risk Assessment for Disaster Response

Response involves the measures and actions taken during and immediately after an event to be ready for, and to provide efficient medical, rescue, emergency supplies, and equipment to those in need. Examples of response include mobilisation, rescue and evacuation, emergency assistance such as medical care, food and water distribution, and shelter.

Risk assessment is useful for disaster response because it is important to know what resources will be required in a disaster. In order to determine resource requirements it is important to understand the potential impacts to the affected society (e.g. how many people affected, number of buildings damaged).

Risk Assessment for Disaster Recovery

Risk assessment is a fundamental aspect of recovery because it is important that redevelopment is conducted in a sustainable way, with an understanding of the potential risks to avoid the disaster repeating or increasing exposure to other risks and hazards.

Recovery actions involve rehabilitation, reconstruction, psychological counselling, and long-term assistance to rebuild the community. Recovery is the implementation of actions to promote sustainable redevelopment following a disaster. This includes new or revised building code standards and land use planning controls.

Stakeholders and Partners

Stakeholders have an interest in and will be affected by the project, but they are not necessarily involved in the project. Partners can actively participate in the planning and implementation of the project, and can also be a good source of data. Many organisations are both stakeholders and technical partners. Some example stakeholders and partners are listed in Table 2.

Table 2: Potential stakeholders and partners for risk assessment

STAKEHOLDERS
Government agencies
Academia, researchers and scientists
International Non-Governmental Organisations (INGOs and UN Agencies)
Domestic Non-Governmental Organisations (NGOs)
Communities
Relevant private sector bodies
Media

Identifying and involving stakeholders throughout the disaster risk assessment process is essential. Consistent with evolving concepts of governance, communities are expecting an increasing voice in decisions that will impact their lives, and with a good understanding of the context, stakeholders can be identified and approached for input in the decision-making process (see Chapter 5: Decisions and Communications). This involvement can take a variety of forms and levels of commitment. Stakeholder participation in a risk assessment exercise, especially when setting the context and identifying risks, has many advantages, such as access to local knowledge and expertise, and building trust. Getting the right level of involvement from the community can result in a much more robust outcome.

In addition to engaging with relevant stakeholders, the experts charged with conducting the risk assessment will also need to collaborate beyond professional boundaries. This is because the competencies required to complete a risk assessment will depend on the hazards being investigated and targeted sectors for vulnerability analysis (Table 3). It then becomes apparent that risk assessments require a collaborative effort between experts and stakeholders.

Table 3: Competencies and professions for risk assessment

TYPE	COMPETENCIES	TYPICAL PROFESSIONALS
HAZARD		
Earthquake	Seismic hazard analysis; fault identification;	Seismologist,Geologist, Engineer
Cyclone	Atmospheric modelling; storm surge modelling	Meteorologist, Coastal Hydrologist, Land-use Planner, Engineer
Flooding	Flood modelling	Hydrologist
Landslides	Geomorphic mapping; land stability analysis; aerial photo interpretation	Geomorphologist, Engineering Geologist, Geotechnical engineer
Drought	Hydrological modelling,	Meteorologist, Climatologist, Hydrologist, Agronomist
EXPOSURE	GIS proficient	Geospatial Analyst
VULNERABILITY		
Physical	Building damage estimation, structural engineering	Engineer; Structural Vulnerability Scientist
Social	Socio-economic modelling, social surveys and interviews	Social and/or Political Scientist
Infrastructure	Knowledge of local infrastructure capabilities and vulnerabilities	Engineer; Land-use Planner
Economic	Understanding of economic factors for the scale (e.g. regional, national) of assessment	Economist, Political Scientist, Lawyer
RISK ANALYSIS	Risk assessment process and broad knowledge of hazard, exposure, and vulnerability factors	Risk Scientist, Hazard Analyst, Emergency Manager

Successful risk assessment and application of the outputs from risk assessment processes requires the involvement of a wide range of individuals and organisations (World Bank, 2014). Risk assessment, other than remote analysis of data, cannot be achieved without a collaborative approach being applied. "…understanding risk is more than just modelling risk" (World Bank. p 19). The range of participants varies from community-based risk assessments, to broader local and regional assessment, and to at state, provincial or national levels of assessment and application.

The range of participants in successful risk assessment includes the communities or stakeholders, or their representatives, at the respective levels within the geographical area being assessed. Participation includes those most suited to lead and deliver the risk assessment process, those best suited to collect, analyse and communicate the inputs to the assessment, as well as those who will manage, apply, and communicate the assessment outputs.

Risk assessment roles include leadership, delivery, support, participation and governance. Some participants in risk assessment processes may best be suited to carry out several roles within various risk assessment functions. Table 4 represents some of the risk assessment roles relevant at each level or scale of assessment, and identifies some of the key roles and responsibilities of participants at each level. The table simplifies the roles considerably, but is useful in communicating the reality that affective risk assessment is highly collaborative.

Table 4: Risk Participants and Functions

	COMMUNITY						LOCAL/REGIONAL							STATE/PROVINCIAL/NATIONAL				
RISK PARTICIPANTS / RISK FUNCTIONS	COMMUNITY MEMBERS	COMMUNITY RESILIENCE LEADERS	COMMUNITY RESPONSE LEADERS	COMMUNITY EMERGENCY SERVICES	COMMUNITY SERVICES / BUSINESSES	COMMUNITY GOVERNANCE	COMMUNITY REPRESENTATIVES	GIS SPECIALISTS – LOCAL / REGIONAL	RISK ANALYSTS – LOCAL / REGIONAL	LAND-USE PLANNERS – LOCAL / REGIONAL	LOCAL RESPONSE MANAGEMENT	LOCAL REGIONAL SERVICES / BUSINESSES	LOCAL GOVERNANCE	GIS SPECIALISTS – STATE / NATIONAL	RISK ANALYSTS – STATE / NATIONAL	STATE / NATIONAL DISASTER MANAGEMENT	NATIONAL SERVICES / BUSINESS	STATE / NATIONAL GOVERNANCE
Risk Identification	L	SP	SP	SP	L	SPG	SP	S	D	SP	SP	SP	SPG	SP	D	SP	SP	SPG
Risk Analysis (Qual' + Quant')	SP	L	SP	SP	SP	SG	S	SP	LD	SP	SP	SP	SG	SP	LD	SP	S	SG
Hazard + Risk Mapping	L	SP	SP	SP	LP	SG	SP	D	L	SD	S	S	SG	D	L	SP	S	SG
Hazard Data Collection	SP	L	SP	SP	SP	SG	SP	D	DL	SP	SP	SP	SG	D	DL	SP	SP	SG
Risk Assessment + Advice	S	L	SP	SP	SP	SG	S	S	D	D	SP	SP	SG	S	SP	SPL	D	SG
Risk Communication	SP	L	SP	SP	SP	SG	SP	S	SP	DL	SP	D	SPG	S	S	LD	D	SPG
Community Engagement	SP	L	SP	SP	SP	SPG	LP	S	SDL	SP	SP	SP	SPG	S	SP	L	DP	SPG
Risk Reduction Planning	SP	L	SP	SP	SP	SPG	SP	S	SP	L	SP	SP	SPG	S	SP	L	DP	SPG
Community Resilience Building	SP	LS	SP	SP	SP	SPG	SL		S	SP	SP	SD	SG		S	S	P	SG
Physical Reduction Activities	P	S	S	SP	SP	SPG	SD	S	S	SL	S	SD	SPG	S	S	SDL	LP	SG
Preparedness Planning	SPD	S	L	LPD	SPD	SPG	LP	S	S	SP	LD	LP	SPG	S	S	LD	PD	SPG
Preparedness Leadership	SP	SP	L	SP	SP	SPG	L	S	S	SP	LD	LP	SPG	S	S	LD	SPD	SLPG
Preparedness Activities	D	SP	L	DP	DP	SPG	PL	SP	SP	SP	L	PL	SPG	SP	SP	LD	SP	SPG
Response Planning	SPD	SP	L	SPD	D	SPG	P	SP	SP	SP	L	P	SPG	SP	SP	LD	P	SPG
Response Coordination	SP	S	L	PD	SP	SPG	SP	S	S	S	L	P	SPG	S	S	L	PD	SPG
Recovery Planning	SPD	LS	SP	SPL	SD	LPG	SP	S	S	S	SPL	PL	SPG	S	S	SLD	PD	SPG
Recovery Management	SP	S	SP	SP	SP	LPG	SPL	S	S	SP	SP	SPL	LPG	S	S	SLD	PD	SPG
Monitoring and Review	S	S	S	S	S	SPG	SP	SP	SP	SP	L	SP	SPG	SP	SP	LD	SP	SPG

(key: L = Leadership D = Delivery S = Support P = Participate G = Governance)

Risk assessment roles include leadership, delivery, support, participation and governance. Some participants in risk assessment processes may best be suited to carry out several roles within various risk assessment functions.

Participants in risk assessment, outlined in Table 4, include:

- Community Members
- Community Resilience Leaders
- Community Response Leaders
- Community Emergency Services
- Community Services / Businesses
- Community Governance
- Community Representatives
- GIS Specialists – Local / Regional
- Risk Analysts – Local Regional
- Land-Use Planners – Local / Regional
- Local Response Management
- Local Regional Services / Businesses
- Local Governance
- GIS Specialists – State / National
- Risk Analysts – State / National
- State / National Disaster Management
- State / National Services / Business
- State / National Governance

The functions outlined here are similar at each level of analysis, but are sufficiently separated in scope and scale to list then separately.

Risk assessment functions represented in Table 4 are:

- **Risk Identification -** A collaborative process, supported by hazard experts, to identify the hazards and risk relevant to a particular location, organization, community, region, state, etc.
- **Risk Analysis (Qualitative + Quantitative) -** The process by which the nature of the potential impacts and estimated return rates or likelihoods of particular hazards are described and analyzed. Risk being a function of Hazard = Consequence X Likelihood. Quantitative risk analysis allows comparison of various hazards and measurement of potential and actual risk treatment activities.
- **Hazard + Risk Mapping -** The process of developing a visual representation of relevant hazard risk for the organization, community or area. May be a physical representation, such as a sand and figure model, a community developed paper map, an expert generated paper map, or an electronic map developed within a simple or complex geographic information system (GIS)
- **Hazard Data Collection -** The process of acquiring information and knowledge from stakeholders and hazard experts to inform the risk assessment process.
- **Risk Assessment + Advice -** The process of assimilating the information collected an evaluated and provided back to stakeholders and decisions makers in the risk assessment process. Comparing relative hazards and risks to develop an adequate risk profile for the respective community, organization or area.
- **Risk Communication -** The process of communicating concepts of hazard risk to stakeholders and community members. An collaborative conversational or otherwise easily accessible approach is more effective than a one-way delivery of risk information.
- **Community Engagement -** An active process of enabling communities to be as engaged as reasonably possible in understanding, assessing and, where possible, managing the risks that may confront them.

- Risk Reduction Planning - The process of identifying opportunities to reduce or mitigate the consequences or likelihood of individual hazards, and securing the resources necessary to realise reduction opportunities and goals. Thereby reducing their risk. Risk reduction/ mitigation may involve social treatments, including changes in behaviour or land-use designed to avoid hazards, or physical risk reduction, including flood protection works, enhanced building codes, removal of at-risk facilities, etc.
- Community Resilience Building - An on-going process of enabling communities to better withstand the impact of hazards when they occur. This can include enhancing community cohesion and communication, emergency preparedness, acquisition of response resources, evacuation planning, etc.
- Physical Reduction Activities - Creation or new structures or modification to existing structures, including flood protection works, enhanced building codes, removal of at-risk facilities, hardening of critical infrastructure, etc., to reduce the consequences or likelihood of a hazard causing damage.
- Preparedness Planning - Planning within and between communities, commercial entities, response and relief organisations, government agencies, etc., in readiness for response activities and transition from response to recovery.
- Preparedness Leadership - Leading the process of establishing, enhancing or maintaining preparedness for emergencies or disasters.
- Preparedness Activities - Preparedness includes a wide range of activities, including response and recovery planning, acquisition of response resources, training, exercising, and monitoring and review of preparedness capabilities.
- Response Planning - The process of developing plans for communities, organisations, government entities, emergency response organisations and others to respond to the range of hazards identified and communicated form risk assessment processes.
- Response Coordination - Coordination between organisations and community groups responding to an emergency or disaster situation. Ideally carried out within a common, agreed set of processes and organizational arrangements. Coordination occurs within and between each level of community and geo-political area.
- Recovery Planning - Planning conducted prior to emergencies or disasters occur, based on the estimated impacts to communities, infrastructure, economic activities, and the natural environment, and the organizational arrangements, information requirements, coordination, leadership, and engagement processes necessary to enable effective regeneration and reconstruction after significant impacts occur.
- Recovery Management - Coordination and leadership of the processes of regeneration and reconstruction after an major emergency or disaster occurs. (See Recovery Planning)
- Monitoring and Review - A systematic process of assessing the effectiveness and sustainability of risk assessment and risk management arrangements and capabilities, with the objective of on-going improvement.

The part that risk assessment plays in all aspects of risk management is reflected in the range of functions. From risk identification, analysis and communication, to risk reduction or mitigation planning and resilience-building, to preparedness or readiness, to response capabilities and effectiveness, recovery planning, capability-building, and delivery, and monitoring and review.

Several of the functions identified may be provided or supported by local, regional or more central government agencies, including departments or ministries, as well as universities and government or private research and consultancy providers, local or international non-government entities, communities or communities of interest, insurers, professional associations, and locally relevant businesses or commercial partnerships. The particular mix of participants will vary considerably depending on local resources, needs, and cultural and political preferences and influences.

Spatial Scales of Disaster Risk Assessment

Global Level

At the global level, disaster risk management is guided by the Sendai Framework for Disaster Risk Reduction 2015-2030. This replaced the Hyogo Framework for Action (HFA). The Sendai Framework has four Priority Areas for Action (UNISDR, 2015):

1. Understanding disaster risk;
2. Strengthening disaster risk governance to manage disaster risk;
3. Investing in disaster risk reduction for resilience;
4. Enhancing disaster preparedness for effective response, and "Building Back Better" in recovery, rehabilitation and reconstruction.

There are 7 targets in the Sendai Framework (UNISDR, 2015):

1. Substantially reduce global disaster mortality by 2030, aiming to lower average per 100,000 global mortality between 2020-2030 compared to 2005-2015;
2. Substantially reduce the number of affected people globally by 2030, aiming to lower the average global figure per 100,000 between 2020-2030 compared to 2005-2015;
3. Reduce direct disaster economic loss in relation to global gross domestic product (GDP) by 2030;
4. Substantially reduce disaster damage to critical infrastructure and disruption of basic services, such as health and educational facilities, through developing their resilience by 2030;
5. Substantially increase the number of countries with national and local disaster risk reduction strategies by 2020;

6. Substantially enhance international cooperation to developing countries through adequate and sustainable support to complement their national actions for implementation of this framework by 2030;
7. Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to the people by 2030.

Sendai Framework for Disaster Risk Reduction 2015-2030 is a guiding instrument used by countries to reduce disaster risk at international, national, and community levels. Agreements are formed regionally to implement the Framework's recommendations. There are several regional agreements in Asia, such as:

- Association of Southeast Asian Nations (ASEAN) Agreement on Disaster Management and Emergency Response (AADMER) (ASEAN, 2005). This is a legally binding agreement;
- South Asian Association for Regional Cooperation (SAARC) Comprehensive Framework on Disaster Management in South Asia (SAARC, 2006).

National Level

Many countries have national laws that relate to disaster risk management. Risk assessment is commonly conducted on a national level to determine which geographical areas are at greatest risk from different hazards. Such assessments are used to assist with prioritising efforts to reduce disaster risk to the nation, and allow for targeted national disaster risk reduction policy frameworks to be implemented (Figure 3), such as:

- Preparedness and emergency response plans;
- Development plans;
- Building codes;
- Resource/land-use/management legislation;
- DRM legislation and plans

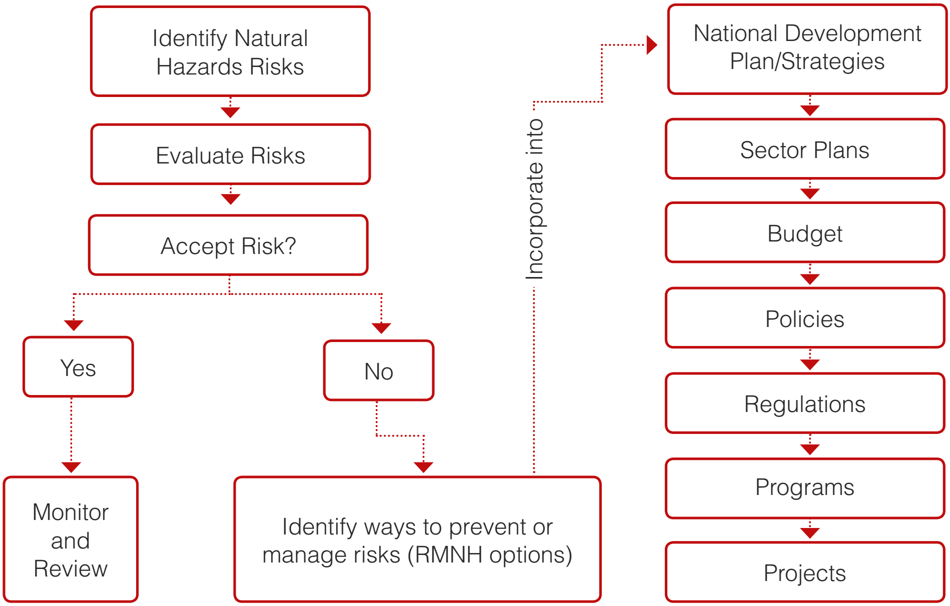


Figure 3: Planning for disaster risks (Bettencourt et al., 2006, p.24)

Local Level

Local level hazard assessments are conducted on a smaller scale than national level hazard assessments. The purpose of assessments at this scale is often to inform land-use decision-making policies and disaster mitigation approaches, such as:

- Location plans;
- Engineered structures or infrastructure plans;
- Evacuation plans;
- Local emergency response plans;
- Community development;
- Recovery plans (pre- and post-disaster

Risk Identification: Data Collection

It can be natural to focus risk identification on the perceived risk of hazards that have occurred within recent memory. However, this misses the possibility of identifying events that occurred hundreds or thousands of years ago or have never occurred before, but have the potential to occur in the future. Therefore, it is important to undertaken a systematic approach to identify all potential risks within the scope of risk assessment. It is important to review what existing information is available to ensure that duplication of work is not unnecessarily occurring. Systematic evaluation of existing risk assessment studies, available data and information, and current institutional framework capabilities can provide a large amount of data and will highlight gaps where further data collection or analysis is required.

Different information types are useful for different aspects of risk identification (Table 5). Historical records can be used to identify areas particularly susceptible to a range of hazard types (e.g. earthquakes, cyclones, floods) and intensities (e.g. flood height and extent). They can also be used to assess building and infrastructure performance under a range of hazard types and intensities which is crucial for determining physical vulnerability characteristics.

Table 5: Data requirements for risk assessment

DATA REQUIREMENTS		HAZARD				
		Earthquake	Cyclone	Flooding	Landslides	Drought
Natural environment	Topological	SA	A	SA	SA	A
	Hydrological	NA	A	SA	SA	SA
	Coastal	A	SA	SA	A	A
	Vegetation	NA	SA	SA	SA	SA
	Soil	SA	NA	SA	SA	A
	Climatological and/or meteorological	NA	SA	SA	A	SA
	Geological	SA	NA	A	SA	NA
Built environment	Building stock	SA	SA	SA	SA	NA
	Infrastructure networks	SA	SA	SA	SA	A
Societal characteristics	Land-use	SA	SA	SA	SA	SA
	Economic	SA	SA	SA	SA	SA
	Population	SA	SA	SA	SA	SA
	Administrative boundaries	SA	SA	SA	SA	SA
Pre-/historical records		SA	SA	SA	SA	SA

(key: SA = strongly applicable; A = applicable; NA = not applicable)

Risk Identification Methodologies

A number of methodologies are available to undertake 'risk identification'. Selection of the appropriate methodology will depend on the context and scope of the risk assessment. A list of common methodologies is presented below:

- *Interviewing* stakeholders about the potential risk;
- *Brainstorming* allows an individual or group to reach a solution creatively in a short amount of time. It is generally spontaneous;
- *Preliminary Hazard Analysis* identifies and ranks all potential hazards based on severity. Results from such an analysis will yield working estimates of hazard severity and allow for focus on important concerns that need more detailed analysis. An example of a preliminary hazard analysis was conducted in Lao PDR (2010) where the preliminary hazard assessment identified a need for an enhanced seismic monitoring system, and that more research focus was needed in the northwest of the country;
- *Ethnographic Analysis:* Capturing community, particularly long-term indigenous, local written, or oral histories and analysis for hazards. This may also identify previous DRM practices.
- *Hazard and Operability Study* (HAZOP) is typically undertaken during the design and engineering of systems (e.g. power plants). HAZOP is undertaken using a brainstorming approach by a group usually chaired by a HAZOP qualified individual and consisting of design engineers and operators of the system;
- *Failure Mode and Effects Analysis* helps identify potential system failures and the effects of failure. To undertake a Failure Mode and Effects Analysis a team of people with knowledge of the system will brainstorm potential modes of failure and the effects of such a failure. The effects of potential failure modes are ranked by severity, likelihood of occurrence, and likelihood of detecting a failure on a scale of 1-10. (1 = insignificant/extremely unlikely/certain to detect, 10 = catastrophic/inevitable/certain not to detect) and multiplied together to get an overall risk priority number;
- *Structured What-If (SWIFT)* is similar to HAZOP, except there is a higher level of focus and less detail. This allows SWIFT to be a quicker method of identifying risks. It typically involves a brainstorming group asking 'what if' or 'how could' questions using a range of guide words (e.g. utility failure, operating error);
- *Risk logs* contain a description of the risk, the potential impact (typically a scale of 1-3, 1 = low impact, 3 = high impact), likelihood of occurrence (typically a scale of 1-3, 1 = unlikely, 3 = inevitable), Risk Score (impact x likelihood), likely response actions, mitigation actions;
- *Catchment area or site-specific investigations* undertaken prior to the site or wider area development or redevelopment. Useful in identifying previously unknown local hazards and in mapping variability of hazards across areas.

A wide range of data can be collected for risk identification. Hazard and exposure need to be identified and assessed for risk analysis and evaluation. There are three main steps for risk identification discussed in this chapter – hazard assessment, exposure assessment and vulnerability assessment (AS/NZS, 2009).

Hazard Assessment

Hazard assessment involves gathering and analysing information and observational data on meteorological, hydrological, geological and/or technological hazards. Hazard assessment is characterised by degree of severity, duration, extent of the impact area, and their relationship. The comprehensiveness of hazard assessment depends on the following factors (ADPC, 2012):

- Availability of disaster event data and geological, geomorphological, demographic data;
- Availability of time and resources;
- Type and characteristics of hazards; and
- Application of hazard assessment to the end users.

Measureable characteristics of hazards, useful for risk identification, include:

- Magnitude/Intensity;
- Frequency;
- Temporal spacing (seasonal/periodic/random);
- Duration;
- Areal extent;
- Speed of onset (timeline of development);
- Spatial dispersion/distribution.

Intensities are generally variables that quantify how hazards are measured and represented. For example:

- Cyclone/typhoon: wind speed.
- Flood: flood height, flow velocity, annual flood, volume and annual flood peak.
- Drought: non-rainy days, precipitation, soil moisture content.

Exposure Assessment

Exposure assessment involves mapping what societal elements (e.g. people, land-uses, infrastructures, economic resources, and natural resources) may be affected by a hazard, often with the hazard intensity information attached. For example, an exposure assessment can detail how many houses will be exposed to what velocity of wind during a typhoon.

An exposure assessment requires two conceptual pieces of information, the hazard layer (spatial representation of hazard extent and intensity) and the exposure inventory (societal elements) (Figure 4). Exposure assessments may be based on maximum hazard zones, scenario-based zones, and comparisons of multiple hazard scenarios. Statistical analysis may be used to identify variations in demographic sensitivity across a community to natural hazards.

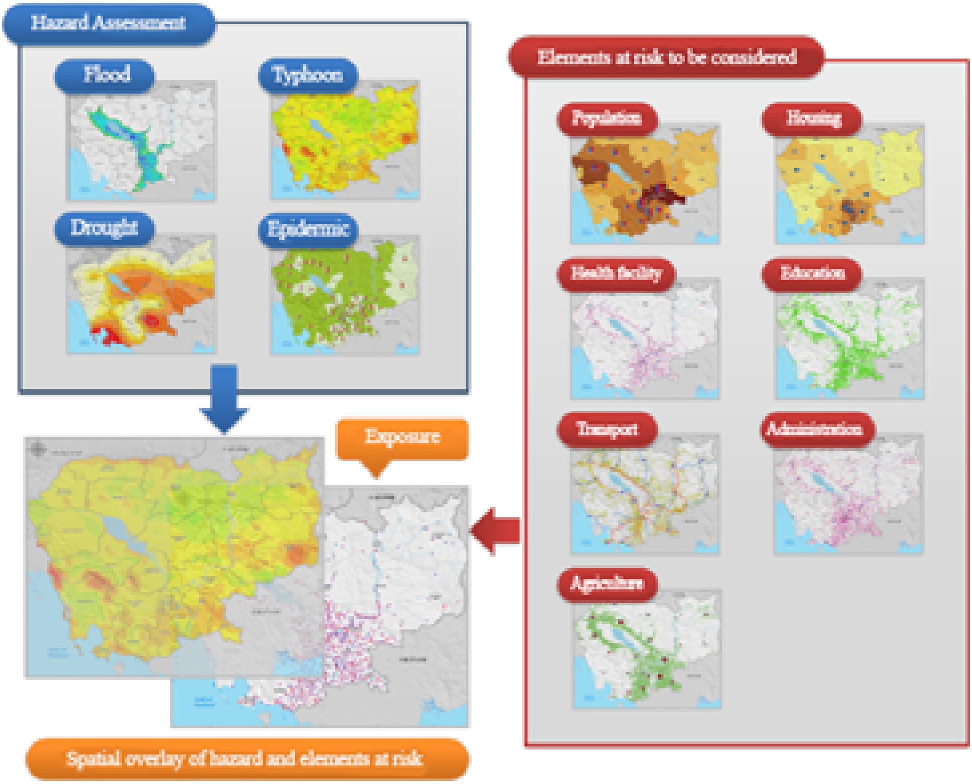


Figure 4: General methodology for exposure assessment (National Committee for Disaster Management, 2014, p.70)

Exposure assessments can be undertaken through time, to analyse current and future socio-economic, land use and other trends. For example, a technical report found some Sri Lankan villages that suffered a high degree of impact due to the 2004 Indian Ocean tsunami are still located in dangerous areas and are there for still highly exposed to tsunami hazards (ADPC, 2015). Accounting for changes in exposure is important as efforts to reduce vulnerability could be negated by increases in exposure.

Vulnerability Assessment

Vulnerability assessment is a systematic and evidence based examination of susceptibility of different societal elements, including buildings, critical infrastructure or facilities, population groups or components of the economy to the effects of hazards. Most commonly in risk assessments in the recent past the concept of vulnerability is only discussed for physical vulnerability and existing elements. For example, the physical damage sustained to a building or person. However, the definition of vulnerability encompasses a much wider range of factors. Vulnerability factors include (Government of Lao PDR National Disaster Management Committee and UNDP Lao DPR, 2010):

- *Physical vulnerability:* the potential for physical impact on the built environment and population. The degree of loss to a given element at risk or set of elements at risk resulting from the occurrence of natural phenomenon of a given magnitude and usually expressed on a scale ranging from no damage to total damage.
- *Human/Social vulnerability:* the potential impact of hazards on groups of people such as the poor, single parent households, pregnant or lactating women, children and the elderly;
- *Economic vulnerability:* the potential impacts of hazards on economic assets and processes;
- *Environmental vulnerability:* the potential impacts of hazards on the environment.

Properties of a particular element can make it more vulnerable to certain types of hazard than to other hazards. For example, buildings constructed with low-strength materials (e.g., unreinforced masonry) will be more vulnerable to flood, cyclone, or seismic hazards than that to drought.

Vulnerability can be estimated for individual structures, for specific sectors or for selected geographic areas, e.g. areas with the greatest development potential or already developed areas in hazardous zones. Characterising the vulnerability of various assets can be very time and resource intensive, requiring extensive technical and scientific inputs (Table 1).

Although significant work has been carried out internationally in the past regarding how to characterise vulnerability, limited work has been carried out in the Southeast Asian context. There is little literature available to quantitatively assess vulnerability (i.e. vulnerability functions – see below) for earthquake, floods and landslides in South East Asia (Table 1). Consequently, the literature that is available for similar geographical and cultural locations must be applied when determining vulnerability. Assessment of vulnerability can also be drawn from experts and field based judgment.

Physical Vulnerability

Physical vulnerability is related to buildings and structures at risk and how these buildings and structures are damaged by a particular hazard, due to physical forces exerted by water (floods), wind (storms), fire, ground motion (earthquakes), ballistics (volcanic eruptions) and droughts.

To assess vulnerability of existing building stock, basic attribute information may include (Table 6):

- Building structural type;
- Number of building stories;
- Building occupancy class; and
- Number of occupants during the day and night.

Table 6: Example of building structural type classification (Government of Lao PDR National Disaster Management Committee and UNDP Lao PDR, 2010, p.28)

NO	TYPE OF HOUSE AS PER WALLS	CHARACTERISTICS OF HOUSING	ATC-13 CLASS	RADIUS CLASS	ARYA ET AL.'S CLASS
1	Brick / RCC	Wall are made up of brick and RCC roofing	FC No 78	Res-4	Type C
2	Wood	Either walls or roof are made with wood	FC No 1	Res-4	Type C
3	Bamboo	Both wall and roof are made with bamboo	N/A	Res-1	N/A
4	Plywood	Light-weight material for walls and roof	FC 1	Res-1	N/A
5	Grass	Light-weight material for walls and roof	N/A	Res-1	N/A

It is rare to find existing building vulnerability databases specific to the South East Asia region, which has often led to studies conducting their own building surveys. There are a range of different survey methods for creating empirically defined building vulnerability databases (Table 6). Comprehensive building surveys may be required to obtain missing information, but these will usually be impossible to survey every building in a city, particularly under budget and time constraints of risk assessments. However, well-designed, comprehensive building surveys carried out at a number of sample buildings or areas can be used to obtain a good approximation of the missing information.

Table 7: Typical observational damage survey methods and their characteristics (adapted from Rossetto et al., 2014)

TYPE	METHOD	SAMPLE SIZE	RELIABILITY	TYPICAL ISSUES
Damage	Rapid survey	Large	Low	Safety, not damage evaluations Misclassification errors
	Detailed engineering survey	Large to small	High	Unrepresentative samples
	Reconnaissance team survey	Very small	High	Unrepresentative samples
	Remotely sense	Very large	Low	Only collapse or very heavy damage states may be reliable Misclassification errors
Economic loss	Tax assessor data	Very large	High	May include data on damaged buildings only
	Claims data	Very large	High	Concentrates on damaged and/or insured buildings only
Casualties	Government Survey	Very large	Low	Possibly unrepresentative samples
	NGO surveys	Varies	Low	Unlikely association with building damage and cause of injuries
	Detailed casualty surveys	Very small	High	

Damage ratios and *damage curves* are common measures of physical vulnerability:

- *A damage ratio* quantifies damage by describing the percentage of damage to the infrastructure based on a hazard intensity (e.g. flow depth of flood, ground acceleration of earthquake, wind speed of typhoon).
- *A damage state* qualifies damage by describing the typical characteristics of damage based on a hazard intensity (Table 7).

Table 8: Building response to earthquake intensity scale (APDC &Norwegian Geotechnical Institute Centre for International Studies and Cooperation, 2010, p.97) MMI Scale used

BUILDING TYPE	INTENSITY VII	INTENSITY VIII	INTENSITY IX	INTENSITY X
Mud and Adobe houses, random stone construction	Most have large deep cracks Few suffer partial collapse	Most suffer partial collapse Few suffer complete collapse	Most suffer complete collapse, Few partial collapse, remaining deep cracks	Most suffer complete collapse, Few partial collapse, remaining deep cracks
Ordinary brick buildings or large blocks and prefab type, poor half timbered houses	Many walls have small cracks in walls	Most have large and deep cracks Few partial collapse	Many show partial collapse Few completely collapse Few minor cracks	Most suffer complete collapse, Few partial collapse, remaining deep cracks
Reinforced buildings, well build wooden buildings	Many have fine plaster cracks	Most may have small cracks in walls Few may have large deep cracks	Many may have large and deep cracks Few may have partial collapse	Most suffer complete collapse, Few Partial collapse, remaining deep cracks

Table 9: Example of damage state categorisation (Government of Lao PDR National Disaster Management Committee and UNDP Lao PDR, 2010, p.28) MMI Scale used

BUILDING TYPE	INTENSITY VI	INTENSITY VII
Brick/RCC type of buildings	Negligible fine cracks	Few have fine cracks in walls Many have wide cracks in walls
Well-built wooden buildings	No damage	Many have fine plaster cracks Few have wide cracks
Bamboo/grass/plywood/other type of light houses	Few/Small cracks in the wall	Most of the walls will collapse

Quantitative analysis and assessment are a desirable components of effective risk assessment (see above sections). A key method used within quantitative risk assessments is the utilisation of numerical fragility and/or vulnerability functions – which quantify vulnerability. Fragility functions describe the likelihood that assets (e.g., buildings, infrastructure, and/or people) will sustain a level of damage dependent on the hazard parameter (e.g., earthquake ground motion). Vulnerability functions differ from fragility functions as they express the likelihood that assets will obtain varying levels of loss or damage over a range of given hazard parameters.

A fundamental requirement for qualitative fragility and vulnerability functions is that they are built from reliable fragility and vulnerability information that is specific to the region in question (Rossetto et al., 2014). This is because vulnerability can vary significantly from region to region (e.g. building practises and standards). Therefore, fragility and vulnerability functions are strongly limited by what knowledge is available, and the resource and time constraints available for the risk assessment work. This presents a significant challenge and major barrier to both the selection and development of effective fragility and vulnerability functions for quantitative risk assessment.

Selecting appropriate fragility and vulnerability functions is an essential aspect of risk assessment as poor selection can cause unsound decision making and unintentionally increase risk (GFDRR, 2014). The selection of appropriate functions is often limited by the availability of functions for the type of risk assessment being conducted. It is highly recommended that expert opinion and review is sought when selecting fragility and vulnerability functions, but some factors that must be considered when selecting fragility and vulnerability functions are presented in Table 10).

Table 10: Fragility and Vulnerability Functions

FACTOR TO CONSIDER	EXPLANATION	EXAMPLE
Type of hazard considered in risk assessment	Fragility and vulnerability of societal elements to hazards will differ depending on the type of hazard.	Different vulnerability functions are used for flooding and earthquake damage (see ADPC, 2013)
Exposed societal elements	Building materials and design characteristics can vary greatly between assets, as such fragility and vulnerability functions specifically developed for that asset type should be used.	The risk to different building classifications based on building materials and construction type is assessed using a different unique corresponding vulnerability function for flooding (see APDC, 2013)
Spatial scale of risk assessment	Some fragility and vulnerability functions are only appropriate for use at large scales. Others might be too detailed for use at a national scale.	ADPC (2013) considers vulnerability of buildings at a national scale. The vulnerability function for this considers replacement cost of the building. If this study was conducted at a finer scale vulnerability might consider the replacement cost of the building as well as loss of contents.

Singular hazard or multi-hazard risk assessment	A risk assessment which considers only one hazard type (e.g. flooding) means that only that risk for only that hazard type has been considered for the exposed societal elements. If other hazards are present, then they need to be considered separately. For these to be comparable, care needs to be taken that the hazard models and the vulnerability/fragility functions assess the same measures. Also, different hazards will often occur simultaneous or in a cascading manner, such as land sliding following an earthquake. Assessing the cumulative impact is challenging and can be complex. True multi-hazard risk assessments are rare due to the complexity of considering the cumulative impact of multiple and variable hazards on a given asset (e.g., ground motion and flooding).	A study to compile a comprehensive risk profile for Timor-Leste considered flood, tropical cyclone, drought, forest fire, earthquake risk separately and then aggregated for an overall risk score (ADPC, 2013). This would not be a true multi-hazard risk assessment, as the cumulative vulnerability of a building exposed to more than one hazard at the same time (e.g., flooding and strong winds) is not captured.

Generally, fragility and vulnerability functions are developed by experts with specific training and knowledge the asset type at risk, ideally in collaboration with other relevant experts (see Table 3). For example, most seismic fragility functions for buildings will be developed by experts skilled in earthquake engineering. Using experts to develop and review vulnerability and risk assessments greatly reduces potential errors that can occur (Rossetto et al., 2014). Broadly speaking, there are two methodologies for the development of fragility and vulnerability functions (empirical and theoretical).

- Empirical derivation of functions requires (1) a damaging event to occur, (2) information to be gathered from this event; and (3) models to be developed which describe the observations from the damaging event. The process for empirical derivation of fragility and vulnerability functions described here is based on guidelines from the Global Earthquake Model (Rossetto et al., 2014). The first step is to gather information based on observations using a range of survey techniques (Table 6). The next step requires selection of appropriate hazard intensity measures and statistical models to represent the information (further details about this process are available in Rossetto et al., 2014). A range of different intensity measures should be tested to select of the most optimum function. The model must then be validated either by comparing results with independent observations or, if no new information is available, cross-validation methodologies can be performed. A major limitation of empirically deriving functions is the requirement of a relevant damaging event to occur. Damaging events can have long return periods, particularly high impact ones.

- In the absence of appropriate empirical data to derive fragility and vulnerability functions, theoretical derivation may occur. Theoretical development of functions is often done using computational simulations and requires a high level of understanding of the performance of asset components under the forces exerted by different hazard types at various hazard intensities.

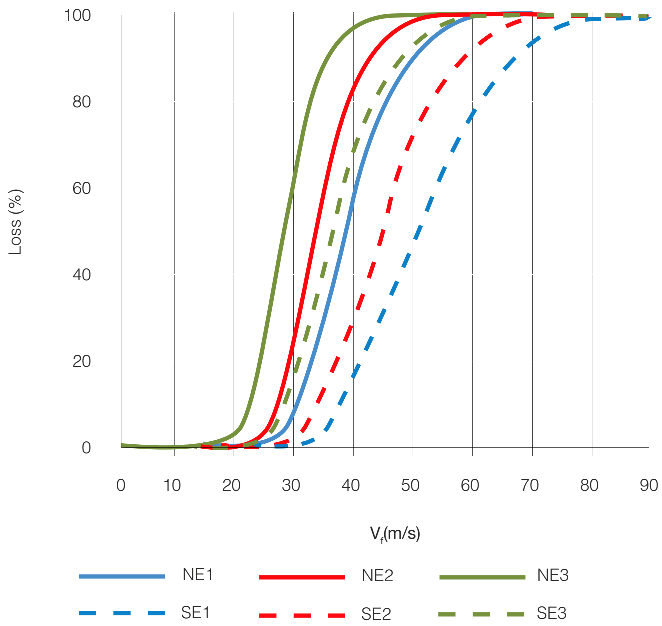


Figure 5: Example of cyclone vulnerability curve for semi-, and non-engineered buildings (based on Goyal et al., 2012). This shows that as velocity (V_f) increases the percentage loss (usually of total building value) of the building increases, but slightly differently for each building class.

Physical Infrastructure Vulnerability

A physical infrastructure vulnerability assessment will assess the ability of specified infrastructure to absorb damage and reductions in functionality. Vulnerability analysis often needs to be assessed for the individual infrastructure systems being considered due to unique designs and operational environments. Reductions in functionality of infrastructure such as transport, electricity, or water can lead to knock-on impacts, which impact other infrastructure sectors. For example, waste water infrastructure often require power supply at treatment centres. Therefore, it could be important to consider interdependencies between infrastructure types. However, this type of analysis is very data intensive and often requires very sophisticated models.

Social Vulnerability

Social, or *human, vulnerability* is impacted by a wide range of factors. These affect the ability of the people or social groups to endure a disaster, and it is important to note the factors are not mutually exclusive. The United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP, 2015) outlines a number of factors being worked on by policymakers to reduce social vulnerability; for example, more accessible health and education services can build resilience. Common metrics used to assess social vulnerability are given in Table 8, but which and how many of these metrics are used will be community specific.

Table 11: Common social vulnerability metrics (adapted from Cutter, Boruff & Shirley, 2003)

CONCEPT	DESCRIPTION	COMMON VULNERABILITY METRIC
Socio-economic status	Ability to absorb impacts from hazards. Wealth usually enhances ability to recover from losses more quickly.	Low socio-economic status
Gender	Women are often impacted more than men in disasters due to lower wages, family care responsibilities, and sector specific employment.	Female
Ethnicity	Language and cultural barriers can be imposed which affect access to post-disaster assistance	Different culture/race
Age	Both old and young are generally more vulnerable to disaster due to mobility to move out of harm's way.	Elderly
		Children
Rural/urban	Rural residents are often more dependent on locally based resources (e.g. agriculture). High density urban areas are complex to evacuate	High density urban
		Rural
Renters	Often lack sufficient shelter options, especially when lodging becomes too expensive to afford	Renters
Occupation	Occupations involving the production and service sector are often disproportionately affected by disasters.	Production sector employment
		Service sector
Family structure	Single parent households or families with a high number of dependents often have limited means to care for dependents.	High birth rate
		Large family
		Single-parent household
Education	It is more difficult to communicate risk to a population with low levels of education, and so the capacity for hazard mitigation is reduced. Additionally, education levels are linked to social mobility and wealth.	Low/ no education
Population growth	The demand for quality housing and social services often exceeds supply when a community experiences rapid population growth	Rapid population growth
Medical services	Medical facilities are often in high demand during disaster.	Low density of medical facilities and/or professionals
Social dependence	People with a high dependence on social services will require more assistance and support during and post-disaster.	High social service dependence
Special needs populations	Special needs populations (e.g., institutionalised, homeless) are often disproportionately affected during disasters, and are often ignored during recovery	Large special needs population

Economic Vulnerability

Fiscal Vulnerability

Disaster risk has the potential to cause significant economic and development consequences. As a result of natural disasters, the area affected experiences direct and indirect tax revenue decreases, investment decreases and long term economic growth decreases through negative effects on a country's credit rating and an increase in interest rates for external borrowing. Natural disasters can be a setback for development in the short- to medium-term. In turn, poor development status of communities and countries increases the vulnerability to disasters.

Disasters can exert significant costs to national governments due to the role they need to assume in dealing with disaster losses and risks. Generally, governments assume responsibility for replacing damaged public infrastructure, providing relief post-event and ensuring rapid recovery of the economy overall. From an economic perspective, governments are exposed to natural disaster risk and potential damages due to their two main functions: the allocation of goods and services (security, education, clean environment and the distribution of income). According to Stern (2007), in many cases, market forces are unlikely to generate an adequate adaptation to disaster risks, broadly because of the following three reasons: 1) uncertainty and imperfect information; 2) missing and misaligned markets; and 3) financial constraints. In case of a disaster event, consequently, there may be substantial contingent liabilities.

Production Sector Vulnerability

The production sector (e.g. rice paddy fields, forestry, fishing/marine farming, and mining) is one of the most important components of the economies of South-East Asian countries, and often serves as an important source of local employment and resources. If aspects of the production sector are unable to produce the required resources, economic impacts, as well as malnutrition, and other knock-on impacts can result. Therefore, the production sector must be considered within vulnerability assessments to determine potential losses due to disaster.

Developing robust vulnerability estimates for the wide range of production sectors can be a challenge, as there are often limited impact records to analyse and production systems may be highly context dependent. This aspect of a risk assessment can be very time consuming and expensive, but if not carried out then it can often be the greatest source of uncertainty.

It is also important to have a clear understanding of the context and purpose of the risk assessment being undertaken. If the risk assessment is for assessing national level risk, it might be appropriate to determine how many farms are at risk of all different hazards. However, if the risk assessment is at a local level, it might be useful to determine how vulnerable specific farms are to different hazards (ADPC, Norwegian Geotechnical Institute, Centre for International Studies and Cooperation, 2010).

Socio-Economic Vulnerability

Socio-economic vulnerability assessment influences the ability of a society to absorb losses and enhance resilience to hazard impacts. Wealth generally enables communities to absorb and recover losses more quickly due to insurance, social safety nets, and entitlement programs. Additionally, the value, quantity and density of commercial and industrial buildings are indicators of the economic health of a community, potential losses in the business community and longer-term recovery issues (Cutter et al., 2003).

Risk Assessment Methods

Qualitative Risk Analysis

Qualitative risk analysis describes risk using defined descriptive terms. Non-numerical labels are given for input parameters, which often represent a numerical range. For example, flood risk at “House A” may be described as:

- Likelihood: *‘LIKELY’* (Annual Probability of Flood = 0.1-0.01)
- Consequence: *‘EXTREME’* (Repair cost as percentage of house value = 80-100%)
- Risk = Likelihood x Consequence: *‘EXTREME’*

Qualitative risk analysis has the benefit of being less time consuming than quantitative analysis. Due to the descriptive nature of qualitative risk analyses, they are often based on expert opinion to determine which risks are most important. This makes comparisons between analyses undertaken by different groups important as there could be disagreements on the relative importance of risks.

A common method of qualitative risk assessment is to estimate risk based on a risk matrix (Table 10). This involves estimating the likelihood of a hazardous event occurring and the potential consequence if it were to occur. Factors, or measures of consequence, to include that will influence the decision are injuries, deaths, economic, and environmental impacts

Table 12: Risk matrix for qualitative risk assessment. In this example, the risk is likely to occur with extreme consequences, which makes the risk rating ‘extreme’

LIKELIHOOD	CONSEQUENCE				
	INSIGNIFICANT	MINOR	MODERATE	MAJOR	EXTREME
Almost certain	Moderate	High	High	Extreme	Extreme
Likely	Moderate	Moderate	High	High	Extreme
Possible	Low	Moderate	Moderate	High	High
Unlikely	Low	Low	Moderate	Moderate	High
Rare	Low	Low	Low	Moderate	Moderate

Possible uses of qualitative risk assessment include:

- Preliminary identification of priority areas for risk assessment;
- Communication to non-experts about risk;
- Training and plans for emergency response;
- Plans for post-disaster recovery.

Quantitative Risk Analysis

Quantitative risk analysis calculates risk numerically. Numerical values are assigned to input parameters, often with a measure of uncertainty. For example, flood risk at "House A" may be described as:

- Likelihood: Annual Probability of Flood = 0.05 ±0.01
- Consequence: Repair cost as integer of house value = 0.83 ±0.2
- Risk = Likelihood x Consequence: (0.05 ±0.01) x (0.83 ±0.2) = 0.04 ± 0.02

As quantitative risk analysis calculates risk numerically, it has the benefit of appearing to a more objective analysis and so has the following advantages:

- Risks assessed for different hazards can be made more directly comparable;
- Uncertainties can be quantified;
- Case-by-case decisions can be avoided in the absence of consistent, objective risk criteria;
- Results can be used for quantitative planning and development, making the planning process simpler and more effective for managing risk.

There are two quantitative risk analysis approaches: deterministic (scenario based) and probabilistic (statistical). There are pros and cons to using deterministic or probabilistic risk analysis, and the decision to use either will depend on the context of the risk assessment process (Kirchsteiger, 1999). For example:

- If the purpose of risk management is to determine appropriate seismic design levels, a probabilistic approach will be required because of uncertainty involved in the analysis;
- If the purpose of risk assessment is to create plans for an emergency response to a disaster, then using a deterministic risk analysis would be more appropriate.

Deterministic Risk Analysis

Deterministic risk analysis assesses risk based on a single scenario. Risks are defined and handled as static entities and outputs have fixed values (i.e. cost, duration, etc.); for example, the likelihood and consequences of Super Typhoon Haiyan impacting on Southeast Asian countries during the next 6 hours. This means that deterministic risk analysis only has a single and specific outcome based on the scenario being assessed. Using a scenario-based approach can be extremely useful for communicating risk assessment results to non-experts.

Deterministic risk assessments may be used for different objectives. For example, the scenario selected may be a 'worst-case scenario' 'maximum-credible scenario', 'most likely scenario', a 'recent scenario event' (i.e. based on a historical event) or even a 'best-case scenario'. It depends on what the purpose and application of the risk assessment is for. Historic events are a useful guide for assessing the viability of scenarios because we can deduce exactly how they will affect a community and we know for certain that these events can happen. However, there may not have been an historic event, and if there has been, the likelihood of the same scenario occurring again in the future is uncertain (Kirchsteiger, 1999). On a cautionary note, compounding conservative estimates, which may be used in worst-case or maximum-credible scenarios, can result in overly-conservative results. It is important for the risk assessor to understand and communicate such aspects.

WORST-CASE SCENARIO

The worst-case scenario is one of the most widely used methods of qualitative and quantitative risk assessment. It assumes that everything that can conceivably go wrong will go wrong. As a consequence, the outputs of a worst-case scenario are often considered to be a (ultra)conservative estimate of the actual risk (Kirchsteiger, 1999).

A considerable limitation of using worst-case scenarios is that it assumes those assessing risk can identify what the worst-case scenario is. This assumption has been shown to be incorrect in a number of cases, such as the 2004 Indonesian and 2011 East Japan tsunamis, during which the hazard events both exceeded the estimated worst-case scenarios (Central Disaster Management Council, 2011). In the case of the 2011 East Japan tsunami, this meant that tsunami walls had not been designed to withstand the size of the waves which were generated and were overtopped. However, depending on the scenario, the likelihood of the worst-case scenario occurring can be judged to be so low that risk analysis outputs may become meaningless to potential users.

MAXIMUM-CREDIBLE SCENARIO

The maximum-credible scenario is the worst event that is credibly likely to occur. These scenarios attempt to determine how large a future event could realistically be, rather than simply determining the 'worst-case scenario'. Determining the criteria for what is a likely event tends to still be subjective and will depend on the risk identification (Kirchsteiger, 1999). These scenarios suffer the same limitations as 'worse-case scenarios', but are often more accepted by risk scientists as their probability tends to be higher (Central Disaster Management Council, 2011).

Probabilistic Risk Analysis

A probabilistic risk analysis differs from a deterministic risk analysis because it considers all possible instances of the hazards over an extended timeframe instead of one specific scenario. For example, instead of assessing likelihood and consequence of a M8.0 earthquake on the Sagaing Fault in Myanmar, an assessment of seismic risk to Myanmar from all potential sources of earthquakes would be conducted. This means that:

- Risk is based on the combination of all possible instances of the hazards. This is particularly useful where there are too many possible scenarios to consider individually;
- Consideration of the complete range of instances of the respective hazards allows estimates of occurrence in space and time;
- Likelihood and consequence are expressed as a probability distribution (as the likelihood decreases, the potential consequences increase). This can be used to prioritise mitigation costs.
- Uncertainty can be included in estimates of likelihood and consequence, which can be represented and incorporated into the estimate of risk;
- Factors are drawn from a probability distribution (i.e. mean, standard deviation);
- Risks have probabilistic outcomes for outputs (e.g. cost, time schedule, etc.);

Because probabilistic risk analysis provides an estimated likelihood of a location being affected by a hazard they are useful for:

- The insurance industry to project annual losses based on the likelihood of having to make payments to customers;
- Developing buildings codes;

However, probabilistic risk assessments can be difficult to understand because it is not always obvious what the consequences from a particular event might be. Using a combination of probabilistic and deterministic methods in a complimentary manner is a favourable approach, if resources permit.

Risk Analysis

Risk assessment requires a combination of risk identification, analysis and evaluation. Risk analysis can be broadly split into two categories: qualitative and quantitative risk analysis. A range of tools are available and have been used within South East Asia for risk analysis (Table 11).

Most risk assessments from South East Asia have elected to use their own risk assessment methodologies, usually to cater for data availability limitations. For this reason, adaptable software platforms (e.g. ArcGIS, QGIS) have been more widely applied for risk analysis.

Table 13: Selected hazard and risk assessment applications and software packages used in South East Asia

MODEL/ SOFTWARE NAME	APPLICATION	CAPABILITY	LIMITATIONS
ArcGIS	Utilised widely for mapping and aggregating risk information	Allows for variable techniques of risk assessment (e.g. qualitative and quantitative).	Requires manual development of risk assessment methodology and data input.
CAPRA	National and Provincial Risk Assessment, Cambodia 2014	Open source platform for probabilistic hazard and risk assessment	Developed for a Central America context. Requires extensive data input relating to locally specific hazard and risk.
CATSIM	National and Provincial Risk Assessment, Cambodia 2014	Risk-based economic framework for assessing economic impact from disasters and the cost and benefit of measure to reduce impacts. More info see Hochrainer et al. 2013 (available here: http://www.preventionweb.net/english/hyogo/gar/2013/en/bgdocs/Hochrainer%20et%20al.%202013.pdf)	Computationally complex and data intensive
EQECAT	Typhoon/cyclone model for Philippines, Thailand, and Malaysia	Stochastic event set for 150,000 events. Detailed vulnerability functions for individual buildings. A basin wide model which can capture impacts in multiple countries	Black box software

GeoNode	Risk Atlas, Cambodia	Web-based platform for sharing geospatial information on hazards, exposure and risk within Cambodia. Allows consistent data management procedures and quality control.	Limited data manipulation capabilities
HAZUS-MH	National and Provincial Risk Assessment, Cambodia 2014	Publicly available multi-hazard risk assessment for earthquake, flood, and hurricane losses. More info available here: http://www.fema.gov/HAZUS	Developed for United States context. Requires extensive data input relating to locally specific hazard and risk.
HEC-RAS	National and Provincial Risk Assessment, Cambodia 2014	Freely available one dimensional flood flow and sediment transport modelling. More info available here: http://www.hec.usace.army.mil/software/hec-ras/	Cannot be applied in highly complex river environments requiring multi-dimensional modelling.
OpenQuake	Earthquake hazard and risk in Greater Manila Area. More info in Allen et al (2014)	Web-based application which allows hazard and risk calculations based on the Global Earthquake Model data sets.	Relies on open source data which can be of inadequate quality in the South East Asia region.
QGIS	Utilised widely for mapping and aggregating risk information	A freely available and open source software. Allows for variable techniques of geospatial risk assessment (e.g. qualitative and quantitative).	Requires manual development of risk assessment methodology and data input.
Riskscape	Dam related flooding in Vietnam. More info here: https://riskscape.niwa.co.nz/vietnam	Create hazard, asset, and aggregation modules	Use in South East Asia currently limited to Vietnam

Mapping

Maps are a useful method of risk assessment as they allow for a visual depiction of the situation. A map is a two-dimensional symbolic depiction of three-dimensional (3D) space. It is a geographical image of the environment and shows the relationships between elements of a space, such as objects and regions. Maps can be a representation of the spatial distribution of a phenomenon or process, people, their lives, and health. They can be prepared on various themes such as climatic, topographic or natural hazards. Humans can see the real world in 3D, but when a 3D view is put on paper, we tend to lose the depth, and visualize in two-dimensions.

The real world is dynamic with varying rates of change. To some extent, dynamics can be addressed in mapping by using a series of maps that each indicates one static condition. In the digital mapping environments, we can reduce the size of interval generating graphics more closely reflecting reality even including 3D.

Maps represent large areas that we cannot otherwise easily see all at once. Since maps represent a large area, they are always scaled down, and for the purpose of different applications, the clarity of the picture can be increased or decreased, and details added or removed. Even though some mapped elements are not exactly similar, we group them into a few categories and represent them with symbols. The elements could be physical properties such as buildings, roads, water bodies, hazards or processes such as wind or temperature. More dimensions or details can be presented on maps using techniques such as colour coding, shading, contours and isoclines. For example, roads can be categorized in different classes by colour. In the digital mapping environment, there are tools that enable zooming in and out more effortlessly.

Maps enable us to interpret the spatial relationships of elements, such as houses within a high flood hazard zone. They also represent processes or phenomena that we cannot see through the naked eye.

The most common way of assessing risk due to natural hazards is through mapping. All maps should contain basic map elements, outlined in Table 12.

Table 14: Fundamental Map Elements

TITLE	The title tells us what is being looked at. It describes the theme or subject. It should be descriptive and specific, indicating geographic, layer and indicator.
LEGEND	The legend shows what symbols mean and is subordinate to the title.
AUTHORSHIP	The authorship can be attributed to an institute or individual, and should also note data sources and a disclaimer on usage limitations.
DATE THE MAP WAS PRODUCED	The date should be the date created and the date effective.
SCALE	Scale indicates distance or area on the ground. A large-scale map covers a small area and is explained by the scale. Examples include: • Verbal: 1 centimetre equals1,000 meters. • Ratio: 1:100,000 (Units don't matter). • Graphic: Bar scale with distances marked in units.
ORIENTATION	Orientation indicates the directions and positioning of the map. It can be North or easting and northing, a coordinate system and projection

Maps can be organised into a variety of categories, by:

- Hazard: Typhoon, flood, etc.
- Administrative boundaries:
  - National: Cyclone hazard, Sri Lanka;
  - Province: Cyclone hazard, Sindh province, Pakistan;
  - State: Storm surge hazard, Rakhine State, Myanmar;
  - District: Cyclone hazard, Tando Allahyar district, Sindh Province, Pakistan;
  - Commune: Tsunami hazard, Kalkudha (Grama Niladari Division), Batticaloa district, Eastern province, Sri Lanka;
- Frequency of occurrence/Return period: 5 year RP, 10 year RP, 50 year RP, 100 year RP, etc.;
- Ordinal scale: e.g. Rare risk (> 50 year RT), occasional risk (10 – 50), frequent risk (< 10);
- Other factors, such as seasonal, severity or triggering factors.

Hazard assessment commonly shows zones of different intensity or probability of certain hazard. Practitioners broadly differentiate between *susceptibility, hazard,* and *risk* maps (BGR and GAI, 2009).

Susceptibility maps provide spatial information on whether a certain terrain is prone to the occurrence of a hazardous event. Susceptibility maps show the spatial distribution of hazard intensities either by graduated scale, intervals (zones) or isoclines. Hazards are driven or influenced by geophysical characteristics of the area. Flood hazards are influenced by river cross-sections, and adjacent elevations, so an elevation map can explain the behaviour of a flood. The term is particularly common for landslides studies, where static parameters such as topography/slope, soil condition and average rainfall can be used to indicate the potential for mass movements.

Hazard maps represent the temporal probability that a hazardous event may occur. For example, a flood hazard map is commonly based on the return period of river flooding levels. Hazard maps are created by data layers; there are base layers and hazard layers. Base layers are the regions or frames that the map is based on. They include administration boundaries, roads, elevation, slopes and water bodies. Hazard layers show intensity and the probability or scenario. These are represented by hazard zones or hazard intensities in graduated colours.

Hazard maps display how a hazard varies over a specified area. This can be measured as:

- Magnitude or intensity;
- Frequency;
- Temporal variance of hazard (e.g. during different seasons);
- Duration;
- Areal extent;
- Speed of onset;
- Spatial dispersion (e.g. spreading of diseases).

Hazard levels, as depicted on maps, will direct us to identify the priorities of control or treatment measures.
Hazard maps can be applied in many ways, including:

- As a tool to communicate information to the public about threats in their living environment;
- For land use, strategic and business planning;
- As the basis for civil engineers and town planers for safe and sustainable development;
- As the basis for developing risk transfer mechanism through insurance and catastrophic bonds.

One example is to assist engineers to locate or design buildings, bridges, highways, and utilities that will withstand disasters in the region.

Risk maps differ from a hazard maps because, in addition to including information about the hazard, they include information regarding the vulnerability and exposure of assets or people (Figure 6). By overlaying all aspects of risk (i.e. hazard, exposure and vulnerability), a map indicating areas of different risk scores can be formed. Risk can be assessed at national and sub-national levels, and can be detailed up to household level.

This is useful because it allows for geographical prioritisation of planning initiatives to different hazards.

Spatial databases are often developed for use as base maps to assist the vulnerability and risk assessments of the study area. All important physical features of the city are usually considered during the database development. Based upon the availability of existing database and information, an appropriate methodology is then developed to acquire missing information by conducting a physical feature survey and attribute information collection.

The baseline data required are:

- Administrative boundaries;
- Vulnerability information about the community (e.g. infrastructure, buildings, health, education, livelihood); and
- Hazard information (e.g. intensity, likelihood, duration, seasonality, areal extent).

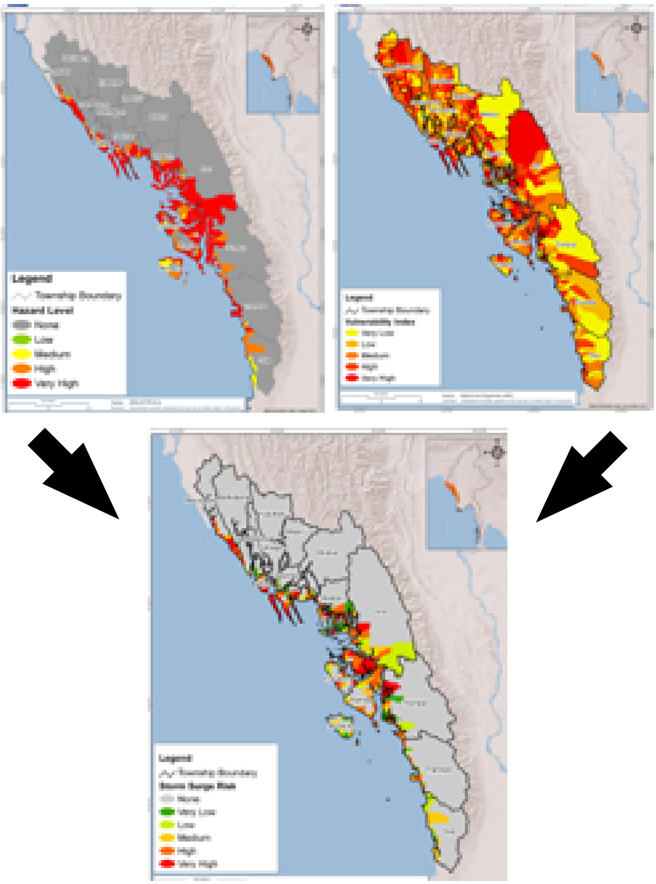


Figure 6: Combining hazard and vulnerability information are critical for risk maps (ADPC, 2011, pp. 37, 92, 121)

Mapping Approaches

There are two types of approaches to hazard assessment mapping, which correspond to the two types of quantitative risk analysis: deterministic and probabilistic.

The deterministic approach looks at:

- Only the consequences or damages;
- Worst-case scenario;
- Physical/Image measurements;
- Incident or community based;
- Real incidents;
- Individual maps.

Examples of deterministic maps include maps prepared by communities by using their experiences and local knowledge, and model results of a single typhoon track and wind speeds (Figure 7).

Figure 7: A deterministic map of a typhoon track and wind speeds

The probabilistic approach looks at:

- Probability and consequences or damage
- Scenarios with return periods;
- Historical measurements;
- Scientific;
- Modelling;
- Map series.

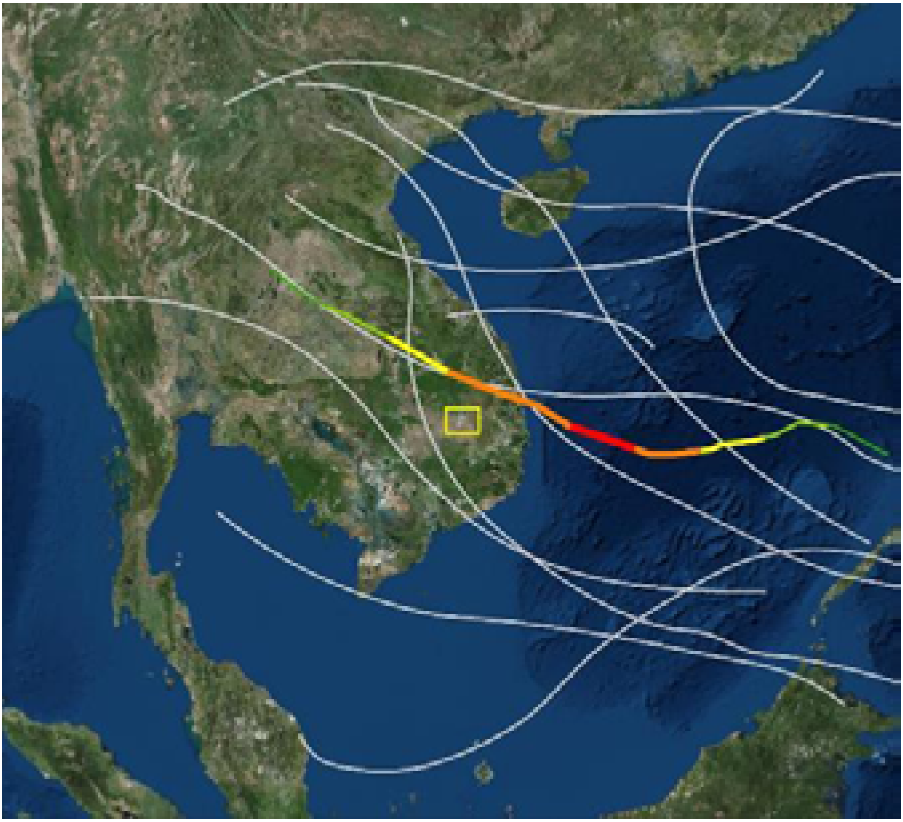


Figure 8: A probabilistic map of a typhoon track and wind speeds – Historical tracks are shown in grey

For example, to create a probabilistic map of typhoon hazard, multiple historical typhoons generated in the Pacific Ocean have to be considered. The statistical analysis is performed and the probabilistic intensities for wind speeds at a given location calculated, as are return periods (Figure 8).

Data Sharing Across Communities

Data sharing across communities, regions and from the national to the local level is really important. Some countries already do this, however some do not. Amongst other things, this information can be used for risk assessments and warning systems.

i-ASSIST

i-ASSIST is a tool that is being developed in Myanmar and Laos for data sharing. i-ASSIST is a geospatial web portal, with several sections:

- i-ASSIST Geospatial web portal: This section provides an overview of the i-Assist Geospatial Web Portal, and is considered a way to feature or promote some of the key features of the system;
- Hazard Profile: This section discusses country hazard profiles, including hazard types, history and other important information related to each hazard type at country level;
- Map: This section provides an overview of and location of all projects that have been done in Myanmar and will automatically link with the information of the project in "What's inside" tab;
- What's inside: This feature discusses the information related to different projects that are published on the web portal;
- Web News and Announcements: This section contains the news from 'Prevention Web RSS' and displays the latest news in the web portal.

Risk Evaluation

The purpose of risk evaluation is to assist with decision-making following the risk assessment process. To make decisions based on the risk assessment, the level of risk found in the analysis needs to be compared with a risk criterion, often in the form of whether the risk is acceptable, unacceptable or tolerable. Deciding on levels of acceptable/tolerable/unacceptable risk will depend on contextual situation of the risk assessment.

Acceptable Levels of Risk

Even though calculated risk, as an objective method, is not subject to risk perception, it cannot tell us the level of calculated risk that is acceptable. Zero risk is impossible. A total relocation of a community can result in a specific risk of zero; they may think that the risk to the specific hazard might be zero, but this does not take into account new risks that emerge because other hazards or opportunities are lost due to relocation. However, depending on many factors, risk appetite can vary hugely. The disaster risk management process allows for the determination of the acceptable level of risk, defined as the loss level that is acceptable without destroying lives, national economy or personal finances. Once the current and acceptable levels of risk are determined, disaster risk reduction plans and strategies could be revised or developed so that they have the measurable goal of reducing the current risk to acceptable levels. There will always be an element of risk in all decisions that are made, but the level of risk can differ depending on different decisions. For example, a decision to build flood embankments or levees has a risk that money could be spent on these structures and a flood still occurs, and a decision to not build flood levees carries the risk that a flood occurs which could have been prevented by flood levees. Therefore, before decisions can be made using risk assessments, the level of risk that is acceptable, tolerable or intolerable needs to be defined.

Risk estimates made by citizens are typically more subjective and socially constructed, particularly in the face of uncertainty (Slovic, 2000). A number of social and cultural values can influence ***perceptions of risk***, including:

- *Voluntary vs. involuntary risk:* An individual's perception of risk can change depending on whether they have agreed to be exposed to the risk;
- *Personal control of risk vs. uncontrolled:* Whether someone has control in a situation or not will influence the perception of risk. An analogy for this is if you imagine you are the passenger in a car being driven by another person, you will think the risk of an accident is greater than if you were driving because you do not have control of the vehicle;
- *Unfamiliarity:* Unfamiliarity with a risk can lead an individual to believe that it poses a higher risk than what it really does. An example of this would be calls to ban the chemical Dihydrogen Monoixide (for example, water);
- *Dread and fears:* When thinking about natural hazards (e.g. earthquakes) people will often take a pessimistic view on what will happen. This results in a perception of the risk being higher than it really is;

- *Catastrophic events vs. many small events;*
- *Long term vs. short term risks/events:* Undertaking activities that take a long time for consequences to manifest (e.g. smoking) are often underestimated by those accepting the risk compared to short term risks (e.g. playing contact sport);
- *Benefits associated with risk:* If there are benefits associated the risk, this can lead to risk being assessed as lower than it really is;
- *Trustworthy information about risk:* Where information regarding risks is sourced is important because if the source is viewed as untrustworthy the information will be less likely to be viewed as truthful;
- *High magnitude low frequency events vs. lower magnitude more frequent events:* High magnitude events are often quite rare, which means that the novelty of them can make them seem more significant than what it really is.

Risk analysis by experts is mostly based on objective analysis of the likelihood of hazard activity and its consequences within a specified area or organization, to derive estimates of *actual risk* (AS/NZS, 2009).

A seminal study of risk perception by Slovic (1987) noted the difference between *actual* risk and *perceived* risk. The actual risk of activities can be surprising. Slovic (1987) compared the risk of harm from travelling by plane or as a pedestrian. Both risks are very low, but the actual risk of harm from air travel is lower, which might be counter-intuitive because of the factors that influence our perception of risk. For example, a pilot controls an airplane, whereas we control ourselves when walking. When in control we feel safer, so the perceived risk is lower. Media reporting on travel accidents can also skew our perception. People have different *perceptions of risk,* and often view risk in subjective ways, based on emotion or personal experiences. This illustrates why it is essential for stakeholders to be engaged in the risk assessment process.

Societal Risk

Individual risk is the risk posed to any one person. *Societal risk* is the risk posed to the society. An important distinction to make is whether fatalities occur in many isolated events or whether fatalities occur in a single event. In general, society will accept many fatalities a year if they occur as single deaths in many events rather than mass fatalities occurring in one isolated event. For example, 3,000 people dying per year in 3,000 road accidents is more acceptable to society than 3,000 people dying in a single flood event. This is because:

- Mass death is unacceptable under any circumstances;
- It is even more unacceptable when the event is inevitable and foreseen;
- The consequences to society would be severe;
- Risks can be unacceptable to society while being acceptable on an individual basis

For example, it might be acceptable to an individual to live in an area at risk to tsunami inundation, as the social and economic benefits outweigh the potential costs. However, it is unacceptable to the government that 100,000 people live in that zone and may die if a tsunami occurs.

So, how do we decide between individual risk and societal risk? As for all risk, this is a matter of context. Generally in a single event, society will accept (see Figure 9):

- 1 death every 10,000 years;
- 10 deaths every 100,000 years;
- 100 deaths every 1 million years;
- Never accept >1,000 deaths per event.

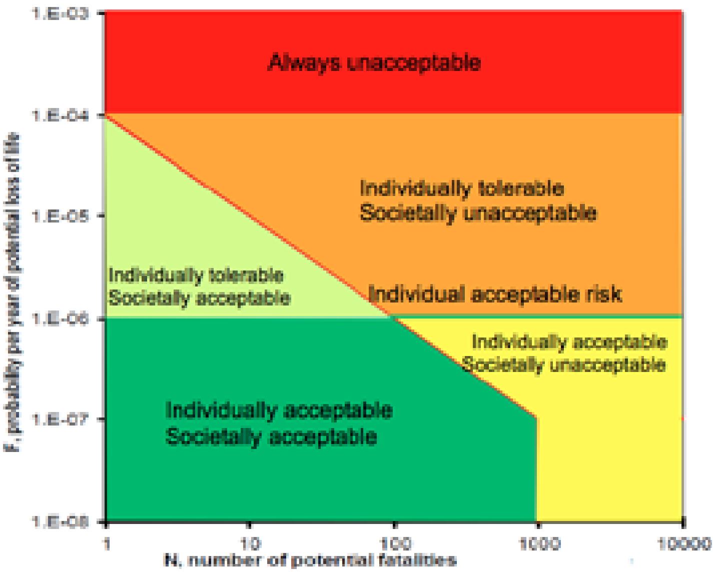


Figure 9: Acceptable levels of societal risk (Adapted from AS/NZS, 2009)

Stakeholders have different levels of tolerance of risk. We often hear that statistically you are more likely to die in an automobile accident than in a plane crash, but many people would perceive the risk of death as much greater in a plane than in a car. This apparent contradiction is a function of human behaviour, as we experience risk in many forms in our daily lives and we create personal values and beliefs based on these experiences. Ultimately, people have differing understandings of what hazards are, what risks they pose, and what they should do about them. Scherer and Juanillo (2003) argue that individual and community concerns and ideas of risk are multidimensional and that the task of incorporating these varied perspectives is complex.

Methods to Determine Acceptable

The role of the risk assessment expert is to undertake the analysis, estimate the risk and its possible changes under various courses of action, and provide guidance in the way of precedents, benchmarks, comparisons and lateral solutions. Comparisons are a particularly useful way to think about acceptable levels of (additional) risk. There are several ways to make this decision. Cost-Benefit Analysis and **A**s **L**ow **A**s **R**easonably **P**ossible are two options.

Cost-Benefit Analysis

One possibility is to undertake cost-benefit risk approach to assess what the benefits of taking an action are against the costs of not taking that action. A common method of reducing risk is to conduct a cost-benefit analysis. This method involves comparing the cost of reducing risk with the benefits of a reduced risk. If the costs of reducing risk outweigh the benefits of a reduced risk then the result of the cost-benefit analysis will be less than 1. If the costs of reducing risk are less than the benefits of a reduced risk then the result of the cost-benefit analysis will be greater than 1. Therefore, the cost-benefit analysis provides an objective approach to evaluating risk. However, not all aspects of a risk assessment can be quantified in monetary terms (e.g. cost of life, elements of cultural or religious significance).

As Low As Reasonably Possible (ALARP)

Layfield (1987), proposed the concept of ***tolerable risk***: *"Although acceptable risk is often used in balancing risks and benefits it does not adequately convey the reluctance with which possibly substantial risks and benefits may be tolerated (p. 58)."*

Individuals are prepared to tolerate some risks that would otherwise be unacceptable in return for specific benefits. Infinite resources could be spent on reducing specific risks, however this is unlikely to yield the best result for managing risk. Therefore, ALARP is a principle to reduce risk to **A**s **L**ow **A**s **R**easonably **P**ossible (ASNZS, 2009). ALARP principle suggests that at some point, the cost of reducing a risk is disproportionate to the additional benefit of reducing the risk. ALARP allows for mapping of various risks on a scale. It is important to consider whether someone is exposed to a risk involuntarily (e.g. due to a natural disaster) or exposed to the risk voluntarily (e.g. car crash). In order to consider this, the threshold for tolerable involuntary risk is 10 times higher than for tolerable voluntary risk. There are three broad zones when using the ALARP principle:

- Where risk is intolerable, risk reduction must be undertaken regardless of the cost to reduce the risk;
- Where risk is tolerable, it will be necessary to balance the level of risk against the cost to reduce the risk;
- Where risk is broadly acceptable, risks are low enough that no additional measures are necessary to reduce risk.

Here is an example of ALARP for flooding risk:

- Risk of death per year due to flooding = number of people killed in an event divided by the number of flooding events per year;
- If a 1 in 10 year flood kills 10 people it has a risk of 1;
- Acceptable risk is where an event can only kill 1 person per million years (1x10-6). Suggesting that the risk of death for a 1 in 10 year flood is not acceptable;
- Tolerable risk is where it can kill 1 person every 1,000 – 10,000 years (1x10-3 – 1x10-4), depending on social context. Suggesting that the risk is intolerable and mitigation measures must be taken.

Decisions and Communications

Who Decides What Is Acceptable?

How society makes social choices is often referred to as governance (Renn, 2008). Governance can also be applied to how any organization runs, how it coordinates with other organizations, and the frameworks in which decision-making occurs. This broader view of governance helps us to understand how decisions tend to be made through a broad range of mechanisms rather than isolated in government.

Generally the client, regulator or an elected/government representative ultimately decides the level of tolerable risk. There are many factors that influence decisions including; (1) Stakeholders' expectations; (2) increasing transparency (3) accountability; and (4) political influences. As such, risk decision-making is complex and difficult, but increasingly critical for economic progress and stability of our communities (Renn, 2008, 2015, Jensen et al., 2015).

There are often many competing interests with different priorities involved in the decision making process. This can lead to:

- Too much emphasis placed on preventing too much risk;
- Large events exceeding capacity to recover;
- Inappropriate consideration of assets with values beyond their monetary value (e.g. cultural or environmental importance);
- Difficulty defining the cost of a human life.

Recent disasters have evidenced that it is increasingly difficult to hide bad policy decisions. We have seen in recent disasters that those responsible may be pursued. Examples include the Christchurch CTV collapse and the Bangladesh factory building collapse. Moreover, a country's reputation suffers when disaster problems are not managed well. Although risk decision-making is complex and difficult, it is increasingly critical for economic progress and stability of our communities.

There are many levels of decision-making that influence risk and they interact simultaneously. In order to assist with decision-making, frameworks are often utilised and then built on. Frameworks are set up to:

- Clarify what is to be achieved;
- Analyse and evaluate the situation objectively to understand the various interactions and information needs;
- Develop options which can help achieve the goals based on outputs from the analysis;
- Evaluate and analyse the shortlisted options;
- Decide on a solution;
- Develop a plan to implement the decision;
- Brief stakeholders on the decision, including the intended outcome, information considered, and how it will be achieved;
- Implement the decision and evaluate the outcomes.

Decision-Making Framework

A decision-making framework provides an agreed process that can be followed, acting as the skeleton to build on to get a better decision. As such, a decision-making process does not need to be overly burdensome. In an emergency it might take only few minutes to run through the basic steps, while larger strategic decisions might require much more deliberation.

The nine step framework presented has been derived from the incident management system developed for New Zealand (New Zealand Fire Service Commission, 2014). The framework is an example and a guide, one which is well proven and can guide decision-making, but does not need to be rigidly followed when a situation indicates otherwise. Other countries practice similar frameworks.

1. ESTABLISH THE MISSION

   The first step in decision-making is to clarify the problem that needs to be addressed, and it should be noted that often the problem is not what it seems on the surface. This is also critical for getting a good level of buy-in.

2. EXAMINE THE CONTEXT

   Developing a deep understanding of the context is critical in the outset. It is a continual process as risk tends to be dynamic and shifts as other decisions are made. Of particular importance is to understand the time frames under which a decision must be made. Usually there is more time than people expect for making a good decision. This is not meant to be an excuse for putting off decisions, but simply opening up proper amount of time for the due diligence that must go into significant decisions.

3. IDENTIFY STAKEHOLDERS

This can include primary and secondary stakeholders. Consistent with evolving concepts of governance, communities are expecting an increasing voice in decisions which will impact their lives. With a good understanding of the context, stakeholders can be identified and approached for input in the decision-making process. Their involvement can take a variety of forms and levels of commitment. It is important to emphasize that getting the right level of involvement from the community can result in a much more robust outcome.

4. EXPLORE ALL OPTIONS

At this point it is vital to get all the options on the table. The best options can be sorted out later. Remember that even odd ideas prompt discussions that can lead to better ideas. Have participants discuss possible options. Encourage them to be creative.

There are a variety of options available to us to help make informed decisions. These include; 1) risk assessments; 2) policy; 3) land use; 4) building standards; 5) non-structural mitigation; 6) insurance and risk transfer mechanisms; 6) education; and 7) preparedness.

5. ANALYSE BEST OPTIONS

There are many perspectives to any decision, which can be legal, economic, urban planning, development, business and others. Decisions can be complicated and may result in unintended consequences. Analysis attempts to find the right combination of actions from a wide range of possibilities and create an optimised system to function harmoniously with other dependent systems, all evolving constructively over time.

Analysis needs to include; 1) finding the right combination of actions from a wide range of possibilities; 2) getting an optimized system to function harmoniously with other dependent systems and 3) ensuring that the plan can actually be executed.

Analysis considerations include using information, data, facts and inferences, analytics, models, and uncertainty.

6. AGREE ON WAY FORWARD

Decision-making can be very complex. There may be multiple stakeholders with a wide range of valid perspectives on a particular initiative. There might also be multiple related initiatives. Thus achieving the right combination of initiatives for a given problem will come down to some level of judgment. With the greater role of judgment comes a greater possibility of error.

There are also a number of ways the problem can be considered to influence the decision-making outcome:

- Simplistic: There is only one answer;
- Deterministic: There is only one correct answer, but the correct formula must be used;
- Random: Different answers are possible, and all can be identified; and
- Indeterminate: Different answers are possible but all are conjectural, so not all can be identified.

Decisions must be based on fact. In the end, achieving the right combination of initiatives for a given problem will come down to some level of judgment. With an increased inclusion of judgment comes a greater possibility of error.

7. GENERATE A PLAN

This could involve a different set of people and skills than were involved in previous steps. The people responsible for building the plan ideally should have been consulted along the way to ensure that the decisions made could be implemented. During the planning process some key questions to address are: Who might be involved in building a plan? How do you ensure that the intent of the decisions made are translated into the plan?

8. COMMUNICATE INTENT

Communications are important throughout the process to ensure communities that risk is being addressed. However, as directions become clear the communications with the communities concerned should be stepped up in appropriate ways. Understanding how people interpret risks and choose actions base is vital to any risk communication. Research has consistently shown that decision-making under conditions of uncertainty is inadequately described by traditional models of 'rational choice' and attention needs to be paid to how understanding of risk is shaped by their own experience, personal feelings, values, and cultural beliefs (Eiser et al., 2012).

9. EXECUTE, EVALUATE AND REVISE

Any good program should be continually evaluated and revised when opportunities for improvements are found. The importance of effective evaluation has been demonstrated the as a function of good governance (Ehler, 2003; Renn, 2008, 2015; Saunders et al., 2015)

Decision-Making Styles

In an effort to get the best possible outcomes in complex problems, decision-making styles have been studied intensively for nearly 80 years since Lewin (1939) identified three different styles of leadership and decision-making: autocratic, democratic and delegative. Later work on decision-making was done by Tannenbaum (1958) expanding on Lewin's three styles. Governance today requires flexibility in decision-making styles. It is important to remember that no matter what style is used it should be a good fit with the community, time frame and situation at hand. Some styles of decision-making are introduced in Table 13.

Table 15: Decision-making styles (Withanaarachchi & Setunge, 2014, p.179)

AUTOCRATIC
Autocratic is when one decision maker makes all the decisions. With individual decision-making the leader must make the decision alone and input from others is limited to collecting relevant information.
CONSULTATION
The leader shares the issues with one or more people seeking ideas, opinions and suggestions. Once they have completed the consultation they make a decision. The leader considers the input of other but the final decision is theirs to make. They can choose to use or not use the ideas presented to them.
DELEGATION
This is when the leader sets the parameters and allows one or more other people to make the final decision. Although the leader does not make the decision, they support it.
DEMOCRATIC
This is when everyone gets an opportunity to have input into the decision-making process.
ANALYTICAL/DIRECTIVE
Decisions are made according to results, empirical analysis and also depends on the decision maker's behavioural patterns.
CONSENSUS/GROUP DECISION-MAKING
The leaders work together with others to reach an agreement. All members buy-in to the final decision and support its implementation.

Different approaches to decision making are required in different situations. Approaches range from analytical decision making based on weighing up the different options to naturalistic decision making, a faster intuitive type of judgement that relies on experience (Flin, 1996; Paton et al., 2009; Doyle et al., 2011). The type of decision making in a crisis is significantly different from that practiced during non-crisis periods, as the a crisis operating environment often requires the making of decisions in high risk and low time contexts that make using the more traditional analytical style less applicable. Many other decision-making styles have been identified, such as recognition primed decision making, procedural based decision making, creative decision making, and distributive decision making (Doyle et al.,2011).

When making decisions related to risk it is important to find the right combination of actions from a wide range of possibilities. This can be complex. However, as Nightingale (2008, p.1) states, "we simply decide without thinking much about the decision process". A constructive approach requires some forethought and transparency in how decisions will be made. Styles, approaches and frameworks may evolve over time, but the main point is that good decisions are made reflecting the best interests of the community.

Communicating Risk Assessment

Information from risk assessments can be used in a variety of situations, such as raising community and organisational awareness about hazards, and informing decision-makers at all levels about risks and potential risk management options. In order for risk to be effectively communicated, practitioners must develop sound communication strategies and work *with* communities to implement them.

Why is risk communication important? In its simplest form, risk communication strategies should make sure that people are aware of the risks that they face. Communication, cultural theorists, public relations and disaster researcher communities have explored the dimensions of risk communication and how differing approaches may influence its success. In general, these communities have advised that we should move away from the old, linear, "transmission" form of communication (i.e., source -> receiver) towards partnering with communities to establish a dialogue which supports diversity in the needs of the audience and builds trust between these groups. The Sendai Framework for Disaster Risk Reduction supports this new approach, encouraging the sectors of society (i.e., public, private and academic sectors) to work together in a 'people-centred' approach to DRR (UNISDR, 2015; pg. 10). The complexity of both the information and intended/affected communities will greatly influence the nature of communication strategy that the stakeholders should consider taking.

This section outlines the basic principles, theories and best practices for science and engineering organisations to communicate risk assessments to stakeholders. Stakeholders can be decision-makers (i.e., emergency managers, businesses), communities (individuals and family of diverse cultural backgrounds), or organization. We discuss risk communication as a broader term which may involve the communication of technical information to diverse stakeholders. The previous knowledge, experience and ability of the various stakeholders to assimilate technical information needs to be taken into account in communication design and practice.

Risk Communication Strategies

It is important that information from risk assessments is properly communicated to the relevant stakeholders. In order to do this, it is important to understand the perceptions and behaviour of the audience the information is intended for.

Once a risk analysis and assessment is completed, risk communicators can begin to develop messages and partnerships with the stakeholders through a variety of approaches. One method is the mental models approach (Fischhoff, 1995; Morgan et al, 2002). This model ensures that, if people choose to, they can "understand how the risks they face are created and controlled, how well science understands those risks, and how great they seem to be" (Morgan et al., 2002, p.14). This approach recognises the value of what the experts want to communicate with the audience, but also balances the importance that messages need to respect and address community and stakeholder concerns. This is just one example and there are many others.

Many organisations communicate in a linear format, which involves the transmission of information from a reliable 'source' to an audience (a.k.a., the 'receivers' of the information). In this situation, information is brainstormed, composed, edited and delivered. A purely linear approach may actually marginalise those who deserve a major role in the process, lacking an understanding of the people's subjective assessment of the risks that they face. However, new paradigms of risk communication have emerged which support engagement of the public as a partner. These approaches seek to form a dialogue with those whose risks are being discussed (Hadden, 1989).

Dialogues and discourse can help hazard specialists and those conducting risk communication programmes work with stakeholders to develop and establish mutual goals and relationships, which in turn, breed trust – a crucial component to successful risk communication. Hadden (1989, p.307) states that "information alone is not adequate; because of the inevitable gaps and uncertainties about how to evaluate risks, risk communication depends upon trust among all parties to the communication." Because "[s]cientific assessments are neither trivial nor invincible, they must be sustained in community infrastructures where dialogue privileges various views and concerns" (Heath and O'Hair, 2009, p.8). It should be noted that institutional and cultural boundaries may exist between communities and risk communicators. In these cases, participatory approaches can be more difficult to establish, but where they are all the more important. Whether your organisation chooses a dialogic or linear model of communication, the information and delivery of the message must be carefully considered.

Purpose and Goals of your Communication

To begin with, your organisation should know what risks occur, what their probability is, who they are most likely to affect, under what circumstances are these people to be most likely affected, and with what positive or negative outcomes given the multitude of scenarios that could occur. This will allow you to identify the information that is needed to be communicated and the audience, and their needs.

Next, you should ask yourself two important questions:

1) What is the purpose of the communication?
2) What are the goals (i.e., outcomes) of your communication?

For example the purpose of your communication may be to work with a seaside community to understand the natural and human-induced processes contributing to coastal flooding along a seaside esplanade. The goals may be that the seaside community should: a) be aware of the natural processes at work, b) understand risk reduction/mitigation measures are available, c) understand the risks and benefits of available options, and d) contribute to risk management decision-making and action. In this model, the community members should feel involved in the process and that they have been informed of and meaningfully engaged in the process. Once clear goals have been established, Rowan (1994) suggests determining principle obstacles to those goals and selecting appropriate methods for overcoming or minimising these difficulties and achieving communication objectives.

Practical Considerations

This section highlights some important practical considerations when communicating risk. A wide range of risk information needs to be communicated, including:

- Risks: What hazards can happen here? When will the hazard happen?
- Magnitude: How "big" is the event/risk?
- Duration: How long will it last? When will it stop?
- Location: Where is it happening?
- Impacts: Who will be impacted? What facilities will be impacted? How much damage will there be?
- Assistance: Where to get help? What types of assistance are available?
- Preparedness: What is in a preparedness kit? How to be safe in an event?

Where to Get Help: Information Sharing Protocols

A number of organisations and institutions are responsible for helping vulnerable people. Advice, education and assistance are available for every stage of the disaster risk management process, though during the hazard, communities are sometimes isolated from external assistance. Therefore, during the hazard itself, communities must be self-sufficient. The better prepared a community is for a disaster, the lower the vulnerability.

People get help from a wide range of stakeholders:

- Government: Government is responsible for the wellbeing of the population, and can employ a variety of services to help vulnerable populations, depending upon the judged severity of the hazard. Government acts to advise, educate, legislate, mitigate and recover in regard to natural disasters. Examples of government agencies that may have risk and vulnerability information include ministries or departments of statistics, housing, transport, and health;
- Academia, researchers and scientists: Academics have the best understanding of the hazard. They can work with other organisations and the community throughout the disaster risk management process;
- Non-Governmental Organisations: NGOs work to prepare communities for and recover from natural hazards;
- Media: The media play a crucial role in communicating hazard forecasts, advice and official statements;
- Relevant private sector bodies: It may be in the interest of private sector bodies to offer (in some cases impartial) advice on the disaster management process. For example, it is in the interest of a consultancy that is paid by a government to undertake a flood hazard risk assessment to educate communities about their hazard so that the government sees a benefit of undertaking the risk assessment and commissions more in other areas. However, it is important to be aware where private sector bodies are not impartial;

- Communities: An individual's experience with a hazard means they are better able to make an assessment of the likely consequences and respond appropriately. Pooled perspectives often result in a better assessment of the danger and so response. People can act to warn each other of hazards and share experience. Friends and family are also often the most trusted information source, meaning their advice is usually acted upon. However, if this advice contradicts official advice the population may be placed at increased risk. Social media has acted to amplify the effect of this informal form of communication. People within the vicinity of a disaster will also be the first to be able to respond and mount rescue and recovery operations.

Forms of Communication

In modern society, communication occurs in a multitude of forms and contexts. Traditional media transmits statements in print, radio, and television. Dialogic communication (i.e., two-way communication) can be done through social media, press conferences, and panel discussions. Each method of communication has a range of benefits and limitations (Table 14). In a crisis situation, if information is intended for the whole of society (e.g., to advise of an approaching typhoon) it will be necessary to use multiple methods of communication (e.g., a combination of print, radio, television, social media, internet, SMS messaging) to ensure that everyone receives the message.

Table 16: Benefits and limitations of different media platforms for risk communication

MEDIA/MEDIUMS	BENEFITS	LIMITATIONS
Risk Communication Workshops	• Direct contact with communities and/or stakeholders • Interaction between stakeholders • Allows for two-way communication – stakeholders and experts	• May be difficult to organise • Particular interests may be over-represented • Experts input may be overly technical • Response organisations may downplay risk
Community-Led Risk Meetings	• Community ownership of risks and assessment process more likely • Assessment can occur in context • Allows for two-way communication – stakeholders and experts	• May be difficult to organise • Particular interests may be over- represented or dominate discussions • Experts input may be overly technical • Response organisations may downplay risk
Information/ Interpretation Boards / Signs	• Information accessible to stakeholders • Can be seen in hazard risk context • Able to be updated readily • Not time dependent	• One-way communication • Susceptible to environmental or deliberate damage • Development, construction and maintenance costs

MEDIA/MEDIUMS	BENEFITS	LIMITATIONS
In-School Education and Engagement	• Receptive audience • Potential to communicate from small groups to wider community • Opportunity to school projects • Encourages inter-generational risk knowledge and action	• Information needs to be re-cast in terms children can engage with • Curriculum and school priorities may not permit time required • Effective risk communicators in short supply
Print	• High credibility • Available for future reference • Can target an audience	• May require multiple languages • Limited space • Limited to people who have the ability to read • Brochures and a poster will not send the message by itself.
Radio	• Can broadcast in local language / dialect • Covers a large area • Allows for repetition of message • Audience can call in • Can be made available immediately • Can reach parts of community that print cannot (e.g. site impaired or illiterate)	• Prior education to inform community on what radio frequency to listen to • Limited to people with the ability to hear • Often commercial pressures to sell advertisements
Television	• Can broadcast in local language • Covers a large area • Allows for repetition of message • Audience can call in • Can be made available immediately • Can reach parts of community that print cannot (e.g. site impaired or illiterate) • Visuals can be dramatic • Can humanise the message by giving viewers something to relate to • Works in low literacy areas	• Prior education to inform community of which television channel to watch • Deaf and blind cannot be reached • Often commercial pressures to sell advertisements • Graphic images can desensitize viewers, can invite a demand for action that is limited by the quality of the vision – a good visual makes a good story.
Websites and social media	• Builds relationships between emergency management and community through increased interconnectedness, including trust • Builds preparedness by pointing people towards further information, resources and tools • Helps monitor public opinion • Can share information quickly in an emergency situation • Helps build situational awareness during event • Information can be requested by the community	• Many different social media platforms • Limited to people with internet and social media access • Difficult to distinguish legitimate sources (may need prior education to inform community which social media channels to follow).

Emergency management and supporting agencies should establish guidelines for use of media. Suggested guidelines for all media (Table 15):

- No method should be used in isolation;
- Risk information and data sharing needs to be consistent. To ensure consistency there should be standard operating procedures. Each type of media should have its own procedure;
- There needs to be a standard point of contact for the media. This person will be able to develop a relationship with the media;
- There should be regular communication with the media to help strengthen this relationship and build trust. It can also be used to build awareness during no disaster times.

Table 17: 7Cs Key features of 'Best Practice' science and risk communication(adapted and influenced from Weingart, Engels, & Pansegrau, 2000; Miller, 2008; Fisher, 1991; Amberg & Hall, 2010)

7 CS KEY FEATURES OF 'BEST PRACTICE' SCIENCE AND RISK COMMUNICATION	
COMPREHENSIBLE:	Simple, jargon-free, clear, concise, logical, but not condescending
CONTEXTUALISED:	Acknowledges and reflects diverse, complex sociocultural contexts. Acknowledges different knowledge bases and disciplines
CAPTIVATING:	Entertaining, engaging, salient, and relevant to everyday life
CREDIBLE:	Believable, open, does not overpromise, and acknowledges uncertainty
CONSISTENT:	Backed by evidence, confirmable, coordinated and collaborated sources of information
COURTEOUS:	Compassionate, empathetic, and respectful
ADDRESSES CONCERNS:	Empowers action and response; Forms a dialogue, Consider it an ongoing process
CONCISE:	avoids superfluous information
CONFIRMABLE:	checkable – links to other information
CONCRETE:	linked to solutions and actions
CREDIBLE:	transparent, acknowledges uncertainty

Challenges to Risk Communication

We have to rethink what we know and what we practice about communicating risk because what we have done historically does not work. This has led to some damaging misconceptions. What we have learned is:

- Using fear as a way to motivate people does not work;
- Consequences alone do not necessarily mean that people will care or do anything about the risk. There are several examples of where consequences have been discussed but it has done nothing towards solving the problem, such as with drug use, smoking, and health: science tells us that smoking is harmful and yet people still smoke;
- Some experts are great communicators, and are well-received by audiences; others are not. They must be seen to be credible and appealing to the audience they are trying to communicate to. They must be liked.
- Experts must make sure their information is current as it is important to remember that over time information changes.

To effectively communicate and address some of these issues, the following list of recommendations should always be followed:

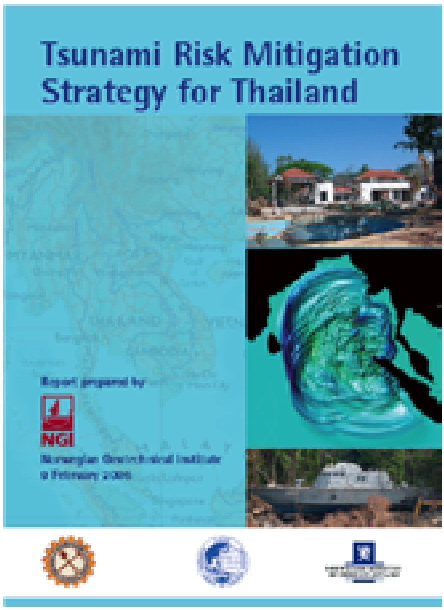
- Make an effort to *understand your audience* this includes the cultural context (i.e. indigenous populations);
- *Be approachable to the audience.* For example, in a community meeting the layout and setting must be welcoming. Having a group of officials sitting behind a table, talking down to the audience is not going to engage community relationships;
- *Admit when things go wrong.* This happens in the emergency management sector and it is important to communicate problems sensitively and professionally;
- *Admit when you don't know the answer.* If you do not know the answer to the questions it is fine to say "I don't know" but you need to find out the answer as soon as you can and provide it to them;
- Return enquiries from the community in a *timely manner.*

Success of a Risk Communication

Once a communication process has been completed, an organisation may consider the job is done, with information in the hands of those who need it. But, how do we know that the information has been received and understood in the manner in which it was intended? And how can we define "success"?

In 1989, the United States National Research Council (NRC) stated: “We construe risk communication to be successful to the extent that it raises the level of understanding of relevant issues or actions for those involved and satisfies them that they are adequately informed within the limits of available knowledge” (NRC, 2006, p.3). Based on these parameters, risk communication researchers and public relations would consider a more educated and satisfied audience, as an indicator of success. However, this view is limited, as a public may be aware of the scientific principles but fail to act or make critical decisions, due to their personal beliefs. Organisations should be cautioned that awareness does not necessarily lead to a successful risk communication strategy. Therefore, it may be more useful to view the quality of a risk communication could be gauged by how it connects to the community and their individual needs and concerns. To determine success of a communication initiative, focus groups (and other appropriate methods) can be used to measure diverse people’s (i.e., your target audience) mental models (discussed above) of risk, before and after viewing/reading/engaging with the intended communication.

Researchers and practitioners of the past have compiled many “recipes” for risk communication best practice. Heath and O’Hair (2009) describe a common suggestion: “Get a credible spokesperson who can deliver a knowledgeable message in a clear manner. Communicate in ways – dress, manner and posture – that encourage audiences to identify with risk communicators. Be clear to be understood. Be sensitive to audience members’ outrage and concerns.” This advice focuses primarily on the mechanics of a singular communication and communicator. It incorporates suggested behaviour and delivery. Recent work by Vivienne Bryner at the University of Otago (New Zealand) takes a more holistic and comprehensive approach to risk communication best practices.



Following the 2004 Indian Ocean tsunami, a report was produced by the Norwegian Geotechnical Institute (2006) to help the Thai government develop short and long term plans for future tsunami risk. The report outlines:

- The science of the December 26, 2004 tsunami
- Future earthquake and tsunami risk in Thailand
- The risk assessment and its design criteria
- Recommended risk mitigation measures
- Case study areas of: Patong City, Bang Niang, Nam Khem

There are several notable strengths to this report:

- The authors start the report with the catastrophic event, which sets a 'scene' for why the reader should care about tsunami risk in Thailand. This is important, because as scientists, we may sometimes forget that if people have not experienced or researched these phenomena, sometimes people need a reminder of the destruction that can be done. Also, the use of narrative (i.e., story-telling) is helpful for readers to connect to the scientific information presented within.
- Large, colourful, well-labelled, and simplistic images and maps are used throughout. Maps and images are very effective for non-science audiences. It shows them the information, rather than describing it. It situates the reader in the geographic location, and shows them the extent of the spatial features. *Note*: Be sure to vet your imagery with non-science audiences. The use of colour, labels, scale, and symbols can all be sources of confusion and lead to misleading interpretations of the diagrams.
- The report comfortably uses scientific terms and concepts. Often risk communicators may feel that they should avoid jargon and technical terms completely, providing audiences with a 'dumbed down' version of the information. This is an incorrect assumption. Your audience may have a range of literacy and scientific backgrounds. It is best to use the exact terms, concepts, and numbers which *tell the story* of the risk assessment, but can be modified or explained (using analogies, stories, and examples) to help the reader understand the meaning of these concepts. If a reader does not understand one of the concepts, they can refer to other online resources to learn more.

The key points to remember when communicating a risk assessment are:

- Use the risk assessment process to establish *credible scientific knowledge and expertise.*
- Define the *purpose and goals* of the communication.
- *Know your audience,* and their information needs. Engage them in a participatory manner (if possible). Get feedback from your audience: Did they get it?
- Use a respectful and *considerate* approach to develop trust between the risk communicators and the community.
- *Be aware of language* use in your written and oral communication; Use technical language when appropriate, but be sure to explain it well if you do. Don't 'dumb down' your information. Your audience is intelligent, but not experts in the field you are describing.

Recommendations for Future Risk Assessments

The planning, execution and utilisation of disaster risk assessments is an increasingly pertinent topic for DRM practitioners. A number of challenges stand in the way of greater widespread use and application of risk information. So recent publications by intergovernmental institutions have attempted to. The report 'Understanding Risk in an Evolving World' by the World Bank (2014) offers a useful and up-to-date synthesise of recommendations for disaster risk assessment users and undertakers for future risk assessments:

1. Clearly define the purpose of the risk assessment before analysis starts: Where risk assessments have been commissioned in response to a clear and specific request for information, they have tended to be effective in reducing fiscal or physical risk.

2. Promote and enable ownership of the risk assessment process and efforts to mitigate risk: Ownership is critical for ensuring that knowledge created through a risk assessment is authoritative and therefore acted upon.

3. Cultivate and promote the generation and use of open data: Experience gained in the last 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 and used often, and if they are iteratively improved.

4. Make better communication of risk information an urgent priority: Clear 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.

5. Foster multidisciplinary, multi-institutional, and multi-sectoral collaboration at all levels, from international to community: To generate a usable risk assessment product, technical experts and decision makers must consult with one another and reach agreement on the risk information that is required by the relevant development program, and more broadly on the purpose and process of the risk assessment.

6. Consider the broader risk context: We know that failure to consider the full hazard environment can result in maladaptation (heavy concrete structures with a ground-level soft story for parking can protect against cyclone wind, for example, but 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.

7. 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.

8. **Understand, quantify, and communicate the uncertainties and limitations of risk information:** Once risk information is produced, all users must be aware of and knowledgeable about its limitations and uncertainties, which can arise from uncertainties in the exposure data, in knowledge of the hazard, and in knowledge of fragility and vulnerability functions. Failure to consider these can lead to flawed decision making and inadvertently increase risk.

9. **Ensure that risk information is credible and transparent:** Risk information must be scientifically and technically rigorous, open for review, and honest regarding its limitations and uncertainties, which may arise from uncertainties in the exposure data, in knowledge of the hazard, and in knowledge of fragility and vulnerability functions. The best way to demonstrate credibility is to have transparent data, models, and results open for review by independent, technically competent individuals.

10. **Encourage innovations in open source software:** In the last 5 to 10 years, immense progress has been made in creating new open source hazard and risk modelling software. Yet this innovation has created challenges around assessing "fitness-for-purpose," interoperability, transparency, and standards. These need to be addressed in a way that continues to catalyze innovation and yet also better supports risk model users