

Chapter Three: Risk Analysis



*A flooded road in Canberra, Australian Capital Territory, June 1956
Photo courtesy: National Archives of Australia/NAA: A7973, INT482/23.*

Risk Analysis

Risk analysis involves developing an understanding of risk, which is an important step in the risk management process, and provides the foundation upon which informed decisions on mitigation may be based. Analysing risk allows priority areas to be targeted for mitigation and can assist in the allocation of limited resources. Risk analysis may therefore play an important role in cost-benefit studies, which compare the costs of a particular action or project against its potential benefits.

This chapter provides an overview of risk analysis, with a particular focus on assessing the components of likelihood and consequence. Three factors which contribute to risk—hazard, exposure and vulnerability—are introduced.



*Building damage following an earthquake in Newcastle, New South Wales, December 1989
Photo courtesy: Geoscience Australia.*

*State Emergency Service volunteers remove a tree from a roof following storm damage, New South Wales, January 1991
Photo courtesy: Emergency Management Australia.*

*A destroyed house following a bushfire on the Eyre Peninsula, South Australia, January 2005
Photo courtesy: Geoscience Australia.*

*State Emergency Service flood rescue boat used to transport fodder to stranded stock, northeast Victoria, October 1993
Photo courtesy: Emergency Management Australia.*

Risk

Many definitions of ‘risk’ exist (Kelman 2003; Thywissen 2006). Risk is defined by the risk management standard AS/NZS 4360:2004 as (p. 4):

‘the chance of something happening that will have an impact on objectives. A risk is often specified in terms of an event or circumstance and the consequences that may flow from it. Risk is measured in terms of a combination of the consequences of an event and their likelihood.’

‘Likelihood’ describes how often a hazard is likely to occur, and is commonly referred to as the probability or frequency of an event. ‘Consequence’ describes the effect or impact of a hazard on a community. Both likelihood and consequence may be expressed using either descriptive words (i.e. qualitative measures) or numerical values (i.e. quantitative measures) to communicate the magnitude of the potential impact (AS/NZS 4360:2004).

Risk in disaster management has been described by Crichton (1999) as the probability of a loss, which depends on three factors: hazard, exposure and vulnerability.

A ‘hazard’ refers to a single event or series of events which is characterised by a certain magnitude and likelihood of occurrence. ‘Exposure’ refers to the elements that are subject to the impact of a specific hazard, such as houses on a floodplain. ‘Vulnerability’ is the degree to which the exposed elements will suffer a loss from the impact of a hazard. These terms are described in further detail later in this chapter. The reader is also referred to the glossary for definitions of key terms.

Figure 3.1 portrays risk as a triangle. The area inside the triangle represents risk and the sides of the triangle represent the three independent factors that contribute to risk: hazard, exposure and vulnerability in equal

proportions. Changing any one of the three components changes the amount of risk.



Figure 3.1: The risk triangle
Source: Crichton (1999), Figure 3.

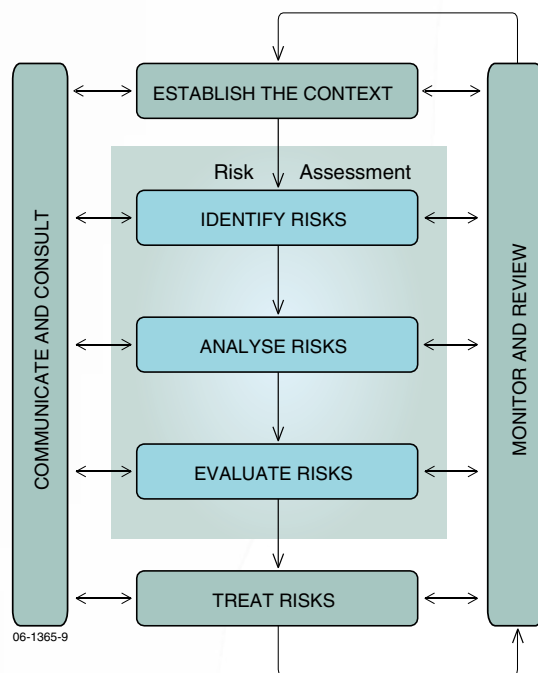


Figure 3.2: Risk management process
Source: AS/NZS 4360:2004, Figure 2.1.

Risk Management Process

The risk management standard AS/NZS 4360:2004 provides a framework for managing the risk posed by hazards. The broad steps involved in the risk management process as outlined in the standard are shown in Figure 3.2.



*Damage caused by a bushfire on the Kings Tablelands, Blue Mountains, New South Wales, December 2006
Photo courtesy: Will Barton Photography.*

The steps include: establish the context, identify risks, analyse risks, evaluate risks and treat risks. Throughout each step of the risk management process, it is essential to communicate and consult with stakeholders, and monitor and review the process. The steps in the shaded subsection—identify risks, analyse risks and evaluate risks—form the risk assessment process.

As AS/NZS 4360:2004 is generic, individual disciplines and persons have tailored individual sections to suit their areas of expertise and responsibility. For example, Emergency Management Australia (EMA) has developed a detailed risk management process for emergency management (EMA 2004), and the Australian Geomechanics Society (AGS 2007) has developed guidelines for landslide risk management.

The reader is referred to AS/NZS 4360:2004 and its companion guide HB 436:2004 for further information on the steps in the risk management process.

Risk Analysis

This report focuses on the third step in the risk management process, risk analysis, as defined by AS/NZS 4360:2004 (p. 4):

'the systematic process to understand the nature of and to deduce the level of risk. It provides the basis for risk evaluation and decisions about risk treatment.'

The type of risk analysis varies depending on the situation being considered. This is succinctly described in the standard AS/NZS 4360:2004 (p. 18):

'Risk analysis may be undertaken to varying degrees of detail depending upon the risk, the purpose of the analysis, and the information, data and resources available. Analysis may be qualitative, semi-qualitative or quantitative or a combination of these, depending on the circumstances.'

A risk analysis is usually conducted to identify adverse consequences, although it may also be used proactively to identify and prioritise potential opportunities (AS/NZS 4360:2004).

Risk Evaluation Criteria

The development of a set of risk evaluation criteria against which risk levels and the effectiveness of suggested treatment strategies can be measured is one component of establishing the context, the first step of the risk management process (AS/NZS 4360:2004). Developing risk criteria requires decisions to be made on specifically which risks are to be evaluated, and may be based on any number of types of criteria, such as humanitarian, social, environmental, operational and financial.

The risk analysis should be consistent with the risk evaluation criteria established up front. The

evaluation criteria against which the level of risk is assessed will play a part in defining the methods used to analyse risk (HB 436:2004). Important evaluation criteria which should be considered are: the consequences that will be addressed (e.g. number of people killed or injured), how likelihood will be defined (e.g. qualitatively or quantitatively), and how it will be determined whether the risk level is such that further treatment activities are required (HB 436:2004).

Setting the evaluation criteria will also focus the risk analysis. For example, if the priority is to protect human life before considering economic loss, an economic analysis should take second place. Setting the evaluation criteria also assists in defining levels of risk acceptance.

Examples of possible risk criteria for managing the impact of natural hazards include establishing the tolerable number of fatalities and injuries, and the tolerable number of damaged or destroyed public infrastructure assets and facilities or private assets. ‘Tolerable risk’ is described in the handbook HB 436:2004 as (p. 65):

‘The concept of tolerable risk derives from Sir Frank Layfield who in 1987 noted that ‘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.’ Thus individuals are prepared to ‘tolerate’ some risks under certain circumstances in return for specified benefits.’

Other examples include criteria related to impacts on cultural heritage and the natural environment, or the long-term impact on the local economy. An example of the development of specific criteria along these lines as part of a multi-hazard risk assessment is the report on risk management for Newcastle, New South Wales (Institute for International Development 2007).

Risk Factors

An understanding of three factors—hazard, exposure and vulnerability—which contribute to risk is vital in determining the potential impact or consequence of a hazard on a community or society. The hazard has been described by EMA as (1998, p. 59):

‘a source of potential harm or a situation with a potential to cause loss. It may also be referred to as a potential or existing condition that may cause harm to people or damage to property or the environment.’

A hazard may affect different places independently or in combination. Some hazards are influenced by seasonal weather conditions. Hazards may also vary in duration, intensity and severity (some examples are provided in Chapter 2).

Exposure refers to ‘the elements that are subject to the impact of a specific hazard’ (Middelmann and others 2005, p. 1). The elements at risk are described by EMA as (2004, p. 48):

‘the population, buildings and civil engineering works, economic activities, public services and infrastructure, etc. exposed to sources of risk.’

The elements at risk may be divided into tangible, intangible and institutional elements (Granger 2007). Examples of tangible elements include people, buildings and infrastructure related to power and water supply. Examples of intangible elements include heritage, personal memorabilia and community relationships. Both tangible and intangible elements are discussed further in Chapter 2.

Institutional elements include aspects such as the capacity to share information and the effectiveness of emergency management plans and coordination arrangements. However, institutional elements are rarely considered properly, because of sensitivities.

Any number and range of elements can be considered. The more elements at risk considered, the more comprehensive the risk analysis.

For a more rigorous assessment of risk, information on the vulnerability of the elements at risk to a particular hazard is required. As for risk, there are numerous definitions for vulnerability (e.g. Brooks 2003; Handmer and others 2007; Villagrán 2006). Two definitions are provided below:

'the degree of susceptibility and resilience of the community and environment to hazards' (COAG 2004, p. 104).

'The characteristics of a person or group in terms of their capacity to anticipate, cope with, resist, and recover from the impact of a natural hazard. It involves a combination of factors that determine the degree to which someone's life and livelihood is put at risk by a discrete and identifiable event in nature or in society' (Blaikie and others 1994, p. 9).

Risk analysis, as defined in this report, focuses primarily on biophysical vulnerability which is experienced by the elements at risk as a result of an encounter with a hazard (Adger and others 2004). Biophysical vulnerability models aim to determine the impact of a hazard on the elements at risk, such as people, buildings, infrastructure and the economy.

Social vulnerability considers a person and/or society's inherent characteristics, such as social, economic and political background. Social vulnerability can be viewed independently of a hazard, as it refers to the characteristics of individuals which are shaped by the processes around them. For example, the loss of a house in a bushfire would not affect all individuals in the same way. This is because their situations are different, and their access to support networks such as family, friends and the community are different. The ability of individuals to recover financially from disaster also varies greatly.



*Destruction caused by Tropical Cyclone Tracy in Darwin, Northern Territory, December 1974
Photo courtesy: Bureau of Meteorology.*

A definition of vulnerability focused toward social vulnerability is (Twigg 2001a, p. 2):

'vulnerability is the human dimension of disasters. To understand what makes people vulnerable, we have to move away from the hazard itself to look at a much wider, and a much more diverse, set of influences: the whole range of economic, social, cultural, institutional, political and even psychological factors that shape people's lives and create the environment that they live in.'

The difference between biophysical vulnerability and social vulnerability is described by Adger and others (2004, p. 30):

'In summary, biophysical vulnerability is a function of the frequency and severity (or probability of occurrence) of a given type of hazard, while social or inherent vulnerability is not. A hazard may cause no damage if it occurs in an unpopulated area or in a region where human systems are well adapted to cope with it.'

There is a tendency for researchers to focus on only one aspect of vulnerability, depending on their expertise. Engineers tend to focus on building vulnerability models incorporating considerations such as structural type, building use, building codes and engineering assessment (Douglas 2007; Dale and others 2004). Economists develop models focusing on economic losses and the impact of government expenditure on recovery and mitigation options to reduce risk (Mullaly and Wittwer 2006). Social scientists focus on people, communities, access to services and organisational and institutional measures (Dwyer and others 2004; Twigg 2001b).

A comprehensive assessment of risk should consider all aspects; however, constraints in resources mean this is seldom done in practice.

A study conducted by Wittwer (2004) on modelling the economic impacts of a hypothetical earthquake in the Perth metropolitan region

demonstrates the integration of building vulnerability models and economic models.

A notable example where biophysical vulnerability has been combined with social vulnerability is the 'hazards-of-place' model developed by Cutter and others (2000). Another is the development of combinations of geophysical parameters and census demographic data by Granger (2001).

The approach described by Granger (2001) breaks the elements and their vulnerability into five broad groups, relating to the setting, shelter, sustenance, security and society. The approach was applied in a case study for southeast Queensland (Granger and Leiba 2001; Granger and Hall 2001). The five broad groups are:

- the setting: basic regional data including information on the physical environment (e.g. climate and topography), access (e.g. external links by major roads and telecommunications infrastructure), administration arrangements (e.g. local government and suburb), and population and its distribution
- shelter: the vulnerability of buildings to various hazards and access to shelter
- sustenance: utility and service infrastructure, including the supply of power and telecommunications; infrastructure related to water and public health, such as water supply, sewerage and storm water; and logistic resources, such as surface transport, ports and airports, used for the distribution and transportation of items such as food, clothing and fuel
- security: a community's wealth and health, and level of protection provided, including the prevalence of access to key facilities such as hospitals, nursing homes and emergency services
- society: more intangible aspects of vulnerability which contribute to social cohesion, such as language, religion, education and involvement of groups within the community.

The elements potentially exposed to hazards remain the same, while the hazards and the vulnerability of the elements at risk vary. For example, buildings may be hazard dependent, while the vulnerability of people and economies tends to be independent of the hazard. The spatial and temporal distribution of disasters is described in Chapter 2.

The methods used to assess likelihood and consequences vary between the hazards. They also vary within a hazard type, depending on the purpose of the analysis and the information, data and resources available. The current process for assessing likelihood and consequence is described in the following chapters for tropical cyclone, flood, severe storm, bushfire, landslide, earthquake and tsunami and, where appropriate, for the secondary phenomena that they cause.

Beyond Likelihood and Consequence

This report highlights the current processes involved in analysing risk in terms of likelihood and consequence. However, the importance of extending beyond likelihood and consequence to evaluate and treat risk is acknowledged.

For example, the 'SMUG' approach (seriousness, manageability, urgency and growth) has been adopted by the New Zealand Civil Defence Emergency Management Groups to provide a more detailed risk analysis and evaluation process than that outlined in AS/NZS 4360:2004 (Cunningham 2006).

The SMUG approach is based on an earlier approach, 'SMAUG', developed by Kepner and Tregoe (1981) where 'A' is for 'acceptance'. A similar dimension called 'outrage' was proposed by Sandman (2007) to account for the political aspect of disasters, emergencies and risk.

Based on these approaches, an alternative, seven-factor risk analysis scheme, 'FSMAUGO' has been proposed by the Institute for International Development (2007). The first two factors,

'frequency' and 'seriousness', are equivalent to 'likelihood' and 'consequence' as outlined in AS/NZS 4360:2004. An additional factor has been added to account for the critical importance of community awareness of the risks posed before the impact. The factors proposed by the Institute for International Development (2007) include:

- frequency: how often a hazard is likely to occur
- seriousness: the relative impact in physical, social or economic terms
- manageability: the relative ability to reduce the risk through managing the hazard, the community or both, for example, through warnings and emergency management plans
- awareness: the level of awareness of the risks posed within the community and emergency management spheres before the hazard impact
- urgency: the measure of how critical it is to address the risk, such as how critical it is to implement a mitigation measure to address the problem
- growth: the potential or rate at which the risk will increase. This may be through an increase in elements exposed to the hazard via development and population growth, and/or an increase in the probability of an extreme event occurring, for example via the influence of climate
- outrage: the political dimension of risk. This becomes particularly evident after a disaster, as a community expresses its outrage at what it believes to have been an inadequate response or lack of preparedness on behalf of the authorities. As a result, time is spent addressing community outrage rather than community safety.

The process of risk analysis is just one step of the risk management process. Even the risk assessment stage is not the end point of the process, but should be used in making decisions about risk treatment. The evaluation criteria established at the start of the process need to be

examined in the light of the risk assessment, and strategies need to be prioritised to achieve the desired target levels of risk reduction.

Risk reduction or treatment strategies are generally confined to three areas of activity (Granger in draft):

- **Emergency management:** this can be divided into proactive and reactive strategies and the recovery process. Proactive strategies are equivalent to the prevention and preparedness stages of PPRR (prevention, preparedness, response and recovery) often used by emergency managers, while reactive and recovery strategies are equivalent to the response and recovery stages of PPRR. Proactive strategies include areas such as warnings and community education. Reactive strategies focus on the activation of response agencies, such as the fire service and state emergency service, and evacuation from affected regions. Recovery includes post-event analysis aimed at identifying the strengths and weaknesses of the existing emergency management system
- **Land use planning:** this strategy is largely proactive and can have only limited impact on established development
- **Construction standards:** these are essentially proactive and include engineering codes, construction standards and maintenance levels.

Applying one or more strategies from these three groups will reduce the overall risk. However, some residual risk will remain. Once these treatment

strategies are in place, insurance and government disaster relief programmes may also be considered as means of addressing the residual risk. In this case, the risk is transferred to a third party or to the population as a whole as a means of distributing the risk and thereby reducing the impact to those most affected by the hazard event.

Conclusion

Risk analysis is the third step in the risk management process. It is a systematic process used to understand and assess the level of risk. In the context of this report, the risk analysis process assesses the likelihood and consequence of a natural hazard event. Likelihood involves assessing frequency or probability and can be measured either qualitatively or quantitatively. The consequence is examined by considering the elements exposed to an event or series of events, and their vulnerability. A good understanding of hazard, exposure and vulnerability is therefore essential in any rigorous analysis of the risk posed by natural hazards.

Setting the evaluation criteria in the early stages of the risk management process will help to establish the focus of the risk analysis and define levels of risk acceptance. To minimise the consequences of natural disasters, a better understanding of the risk and potential impact is vital. Risk analysis provides essential inputs to planning the emergency management response and prioritising resources for sound mitigation decisions.



*A flood in Nyngan, New South Wales, April 1990
Photo courtesy: Emergency Management Australia.*

