Risk

Core Body of Knowledge for the Generalist OHS Professional

Safety Institute of Australia Ltd

Australian OHS Education Accreditation Board

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The OHS Body of Knowledge for Generalist OHS Professionals has been developed under the auspices of the **Health and Safety Professionals Alliance**

The Technical Panel established by the Health and Safety Professionals Alliance (HaSPA) was responsible for developing the conceptual framework of the OHS Body of Knowledge and for selecting contributing authors and peer-reviewers. The Technical Panel comprised representatives from:

The Safety Institute of Australia supported the development of the OHS Body of Knowledge and will be providing ongoing support for the dissemination of the OHS Body of Knowledge and for the maintenance and further development of the Body of Knowledge through the Australian OHS Education Accreditation Board which is auspiced by the Safety Institute of Australia.

Synopsis of the OHS Body of Knowledge

Background

A defined body of knowledge is required as a basis for professional certification and for accreditation of education programs giving entry to a profession. The lack of such a body of knowledge for OHS professionals was identified in reviews of OHS legislation and OHS education in Australia. After a 2009 scoping study, WorkSafe Victoria provided funding to support a national project to develop and implement a core body of knowledge for generalist OHS professionals in Australia.

Development

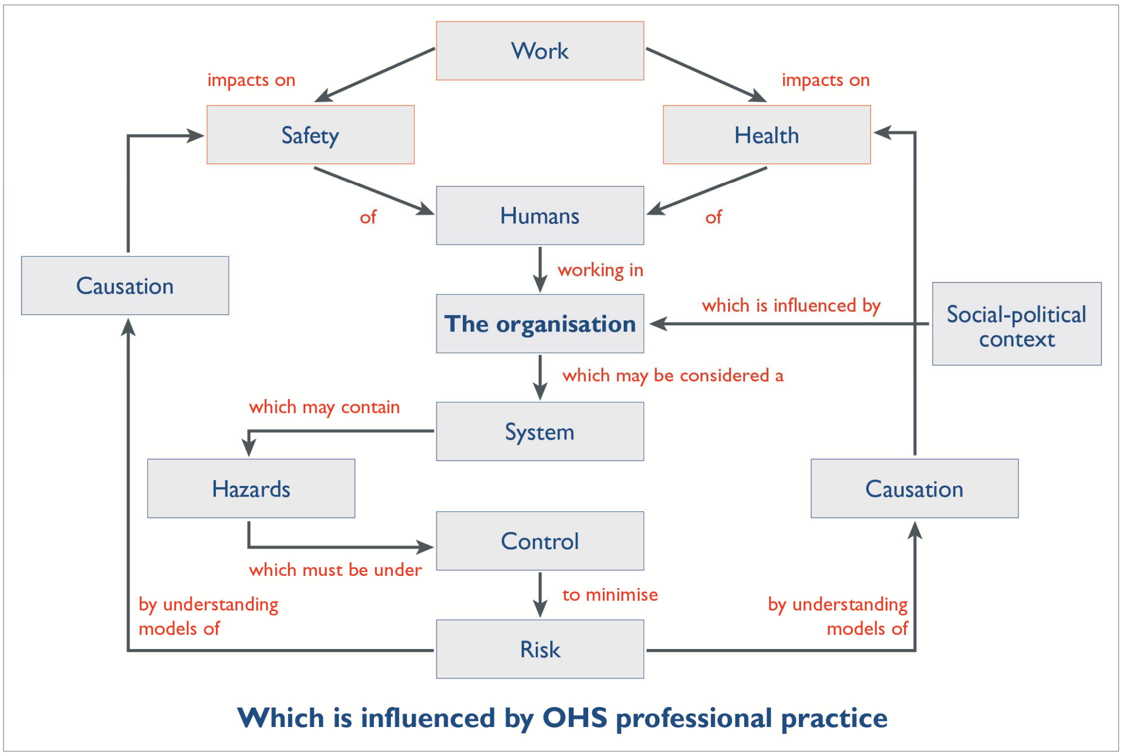
The process of developing and structuring the main content of this document was managed by a Technical Panel with representation from Victorian universities that teach OHS and from the Safety Institute of Australia, which is the main professional body for generalist OHS professionals in Australia. The Panel developed an initial conceptual framework which was then amended in accord with feedback received from OHS tertiary-level educators throughout Australia and the wider OHS profession. Specialist authors were invited to contribute chapters, which were then subjected to peer review and editing. It is anticipated that the resultant OHS Body of Knowledge will in future be regularly amended and updated as people use it and as the evidence base expands.

Conceptual structure

The OHS Body of Knowledge takes a ćconceptualô approach. As concepts are abstract, the OHS professional needs to organise the concepts into a framework in order to solve a problem. The overall framework used to structure the OHS Body of Knowledge is that:

> **Work** impacts on the **safety** and **health** of humans who work in **organisations**. Organisations are influenced by the **socio-political context**. Organisations may be considered a **system** which may contain **hazards** which must be under control to minimise **risk**. This can be achieved by understanding **models causation** for safety and for health which will result in improvement in the safety and health of people at work. The OHS professional applies **professional practice** to influence the organisation to being about this improvement.

This can be represented as:



Audience

The OHS Body of Knowledge provides a basis for accreditation of OHS professional education programs and certification of individual OHS professionals. It provides guidance for OHS educators in course development, and for OHS professionals and professional bodies in developing continuing professional development activities. Also, OHS regulators, employers and recruiters may find it useful for benchmarking OHS professional practice.

Application

Importantly, the OHS Body of Knowledge is neither a textbook nor a curriculum; rather it describes the key concepts, core theories and related evidence that should be shared by Australian generalist OHS professionals. This knowledge will be gained through a combination of education and experience.

Accessing and using the OHS Body of Knowledge for generalist OHS professionals

The OHS Body of Knowledge is published electronically. Each chapter can be downloaded separately. However users are advised to read the Introduction, which provides background to the information in individual chapters. They should also note the copyright requirements and the disclaimer before using or acting on the information.

Risk

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Abstract

The purpose of this chapter is to discuss the meaning of risk in its broader organisational and societal context and the implications this has for managing occupational health and safety (OHS) risks. Risk is a complex concept, but we often try to describe a risk in only a few words and represent its magnitude as a single value. The validity of the assumptions normally made in recording and assessing risks are explored with a quantitative example used to explain some of the problems. The most important part of managing risks in the workplace is not to measure it (qualitatively or quantitatively) but to understand the nature of risks, their causes and consequences and to use this information to control risks. This chapter aims to explore terminology issues, discuss the concept of risk and how risk is assessed then consider how to apply a risk management process in a safety context.

Keywords

Occupational Health and Safety, OHS, risk, uncertainty, likelihood, consequence, risk assessment, risk analysis, level of risk, risk management

Contents

1 Introduction

The national model Work Health and Safety Act (WHSA) (Safe Work Australia, 2011) requires that people with management control ensure so far as is reasonably practicable that the workplace is without risks to the health and safety of people. Model Regulations also require that duty holders identify hazards and assess risks. This chapter discusses the meaning of the terms óhazardô and óriskô and how risks can be assessed to develop information for their control.

Managing risks to peopleôs health and safety in the workplace and communicating about them is made more difficult by the complexity of the concepts surrounding risk and its measurement, by the use of confusing and inconsistent terminology, and by differences in perceptions about risks. To communicate clearly and unambiguously a single language is needed with each concept referred to by a different word and that word not also used for other quite different concepts. ISO Guide 73 (ISO, 2009) attempts to achieve this but many safety standards (including SA/SNZ, 2001) predate this Guide and do not follow its definitions. This chapter follows the terminology used in Guide 73 (also used in AS/NZS, 2009) but also demonstrates how this fits with other ways of expressing the same concepts.

Before discussing the concept of risk and its measurement and management it is worth distinguishing between three basic concepts:

- The source of potential harm. This is generally referred to as a hazard but the breadth of concept that is encompassed by the word hazard varies.
- The nature of the harm and how it occurs (both the word risk and hazard are used for this concept).
- The magnitude of the risk (which depends on the magnitude of the harm and its likelihood). This is called either the risk or the level of risk.

When the word hazard is used it is often unclear whether concept 1 or 2 is meant and when the word risk is used it could mean either concept 2 or 3. The national model Work Health and Safety Act (WHSA) (Safe Work Australia, 2011) attempts to overcome this confusion between hazard and risk by referring to hazard/risk throughout. This makes sure sources of harm and their outcomes are both identified and analysed, but gives the impression the words hazard and risk are synonymous when there are two quite different concepts which need to be communicated.

1.1 Hazards[1] and Risks

The term hazard is defined in ISO standards as the source of potential harm (ISO, 2009). However this can be interpreted narrowly as a source of damaging energy (Haddon, 1970) or very broadly such as in Makin and Winder (2009), where it is argued that hazards should include ómanagerial hazardsô where risk is associated with their absence. Viner points out that the energy definition does not correspond to colloquial use:

> ñColloquially a brick on the floor or a stationary unlit truck at the side of the road are regarded as hazards However if the brick trips a person up it is not the bricks energy that results in damage but rather the gravitational potential energy of the body of the person who was trippedò. (Viner, 1991)

To the engineer for whom energy, by definition means something which has the ability to do work, the concept of energy cannot be applied to toxic materials or psychological hazards.

On the other hand the very broad definition of Makin and Winder is useful when identifying risks but can lead to problems when trying to estimate the level of risks (as will be discussed later). In this chapter the word hazard is used to mean something which has the direct property of being harmful; something which is a source of energy or causes stress to the body. The brick and unlit truck are included but the causes for why they in a dangerous position are not. The fundamental test for whether something is a hazard is that if it is eliminated there is no risk. For example lack of training is not a hazard because the source of harm (for which training is a control) is still there. There is still a need for a way of referring to other problems, tangible and intangible that gives rise to risk. In this chapter the term ñsource of riskò will be used. Whatever the precise interpretation of the word hazard, it is a source of harm rather than some expression of its effect, which is the risk.

2 Definitions of Risk

Risk is a complex concept difficult to define in a single sentence, According to Friedrichsen in the Shorter Oxford English Dictionary (3rd Edition 1973) the word óriskô was first used in the English language in the 17th century and probably evolved from the Italian or French word meaning to run into danger. Early usage of the word as a noun is in the sense of exposure to mischance or peril, or the chance of loss. This dictionary also records early usage of the verb óto riskô as to venture upon, or to take the chance of. Today the word risk is used in multiple ways in the English language; (e.g. Hamilton, Adolphs and Nerlich 2007). Often in common usage the words risk, danger and hazard are used synonymously. In technical and safety publications more precision is needed.

Hansson (2004) identified five common uses of the word in technical publications:

[1] See *OHS BoK* Hazard as a Concept

- Risk as an unwanted event which may or may not occur.
- Risk as the cause of an unwanted event which may or may not occur. (This is also a definition of a hazard.)
- Risk as the probability of an unwanted event which may or may not occur.
- Risk as the statistical expectation value of unwanted events which may or may not occur. [A statistical expectation value is the sum of the values of each possible outcomes multiplied by its probability].
- Risk as the fact that a decision is made under conditions of known probabilities (ñdecision under riskò).

Hansson illustrated these uses of the words risk using the example of lung cancer where one may talk about the risk of getting lung cancer (an event); the risk of cigarette smoke (a cause or a hazard); the risk of having oneôs life shortened by smoking as at least 50% (a probability); or that the total risk from smoking is higher than from any other cause (the statistical expectation value); and the decision to smoke knowing the risks can be considered a decision under risk.

In addition to Hanssonôs meanings, the word risk is used to mean a consequence when we talk about the risk being death. óTaking a riskô means undertaking an activity to seek benefit where there is a chance of a negative outcome. Finally, in the financial arena, risk can be a measure of the level of uncertainty. Thus a high-risk stock is a volatile stock where the variance or fluctuations from the mean value are high.

There are two distinct meanings in the list of usages of the word provided above:

- a description of something that is uncertain and may not be an event or an outcome (it might be both or it might be an exposure)
- a measure to which a number or rank can be ascribed related to the extent to which potential outcomes are of concern to us.

These two meanings are reflected in different standards and regulations. Whereas business and engineering applications (e.g. COSO, 2004; ISO, 2009; ISO/IEC, 2009) define risk as a description of what might happen, environmental, food safety, bio-security and World Health Organization (WHO) standards and regulations define risk only as a measure, using the word hazard for uncertain events and outcomes as well as for sources of risk. OHS regulations and standards are mixed in their definitions and often apply both meanings to the word, regardless of the stated definition. This lack of agreement on whether risk is a description of what might happen or a measure adds to the confusion surrounding an already complex concept.

2.1 Risk as a description

Although dictionaries still define risk as a negative concept, in the field of risk management, most modern definitions associate risk with uncertainty and allow for the outcome to be either positive or negative. For example definitions include:

> ña situation or event where something of human value (including humans themselves) has been put at stake and where the outcome is uncertain (Rosa, 1998, p. 28)
>
> ñthe chance of something happening that will have an impact on objectivesò (SA/NZS, 2004)
>
> ñthe effect of uncertainty on objectivesò (SA/NZS, 2009)
>
> ñexposure to a proposition that is uncertainò (Holton, 2004, p. 22).

These definitions recognise that the purpose of risk management is not to reduce loss at all costs, but to achieve objectives as effectively as possible. In OHS, as in other areas, managers should be actively seeking to take advantage of things that might happen to achieve OHS objectives, as well as looking for things that might go wrong.

Also common to the four example definitions is the element of uncertainty. They differ as to whether the uncertainty relates to an outcome, an exposure, or a situation, or an event. Three of the definitions relate the outcome of uncertainty to objectives, which ties the meaning of risk to human values. This idea is explored further in section 4 of this chapter.

In practice, focusing on events, exposures or outcomes provides a language shortcut. Regardless of the formal definition of the word, to describe a risk to those who are exposed to a risk or must manage it, all the information covered by these definitions is needed. The information that there is a risk of death is uninformative without a description that includes who or what is affected and the circumstances that might give rise to the death.

As illustrated in definitions used by the standards agencies as described above there was a change in the definition of risk in Australian standards between AS/NZ 4360 (SA/SNZ, 2004) and AS/NZS/ISO 31000 (SA/SNZ, 2009). The shift in emphasis from an event to an effect, and in particular the effect on objectives, makes it clearer that managing risk is directed to achieving objectives and clarifies the fact that not all uncertain consequences arise from discrete events. (Uncertain outcomes can arise from continuing situations or chronic exposures with no discrete event.) The focus on effects on objectives and on outcomes is also better suited to how risk is measured, i.e. a combination of the likelihood and magnitude of specified consequences (not the likelihood of an event and its consequences)

2.2.1 Components of risk

A simple model of these components of risk that derives from Haddon (1973) and is often used in OHS as well as others of health and safety is depicted in Figure 1.

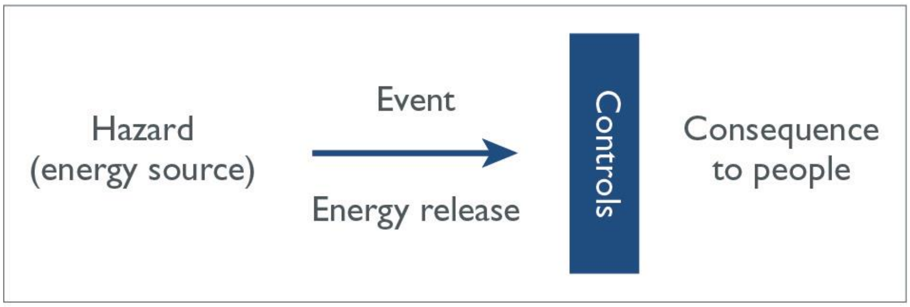

Figure 1: A simple representation of a safety risk

This model starts with the presence of a hazard. An event (or gradual exposure) occurs where control of the hazard is lost, and energy (defined very broadly) is released and impinges on a person causing injury (Haddon, 1973; Viner, 1991). This assumes that there is one hazard and one event leading to one consequence. While this can be useful in some contexts, it is an oversimplification that can lead to problems when risks are recorded for the purpose of assessment and control. There are few hazards that have only one possible outcome and the same outcome may arise from multiple different hazards or events. As well as pain and suffering of individuals there are impacts on an organisation's safety, financial and legal objectives. Barriers may control one or many hazards or may mitigate one or many consequences. There may be domino or 'knock-on' effects[2].

A rather more sophisticated, model of a risk is the bow tie model (Figure 2). This first appeared in internal training materials in the petrochemical industry and is normally attributed to Shell. The starting point is still the hazard, which, as a result of one or more mechanisms, leads to a critical event where control is lost. A range of different consequences may follow the event affecting different stakeholders and different objectives. The bow tie model recognises that there may be multiple pathways to a critical event (the left side of the bow) and that the event may lead to a variety of consequences with several different areas of impact (the right side of the bow). Preventative controls are separated from controls that change consequences after the critical event has occurred. The model also incorporates influencing factors and control failures[3]. Table 1 explains the model components in more detail.

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[2] See *OHS BoK*: Hazard as a Concept

[3] See also *OHS BoK*: Models of Causation: Safety

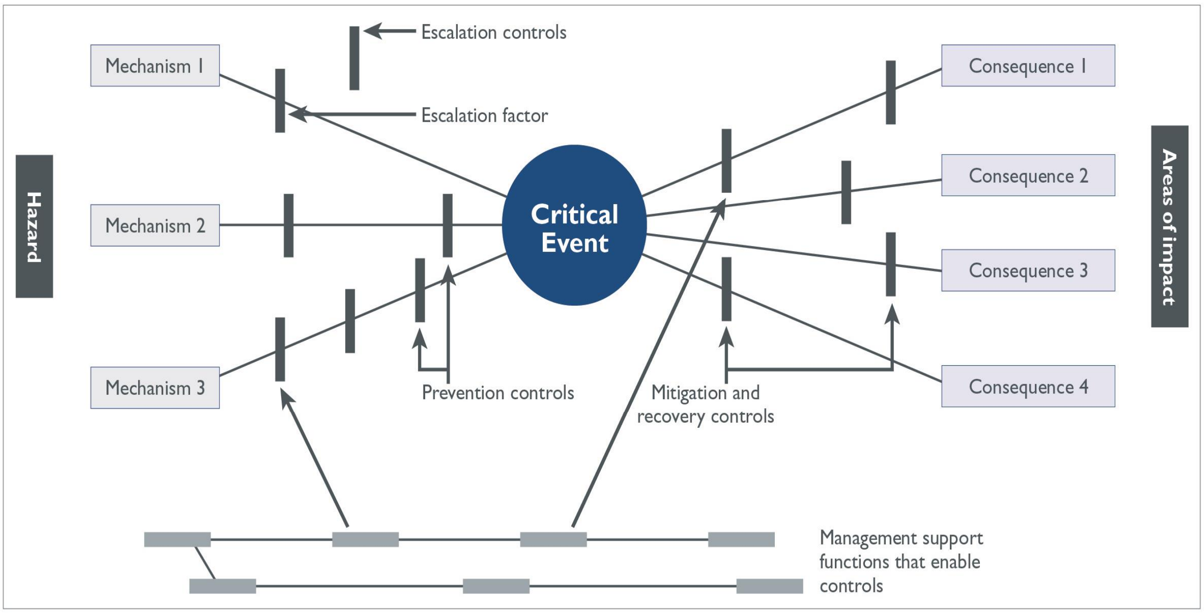

Figure 2: Bow tie model of risk (modified from Hudson & Guchelar, 2003)

Table 1: Components of the bow tie model of risk

Component	Explanation
• Hazard	• In some situations, a distinct hazard can be identified, in others, this is not applicable or useful. For example, in road safety the hazard is nearly always the moving car and it is more useful to focus on the different mechanisms by which the critical event (e.g. a collision) may occur.
• Mechanisms	• These are discrete events, changes, or ongoing situations that lead to the critical event occurring.
• Critical event (also called ‘top event’)	• This is the point at which control is lost and controls change from prevention to mitigation.
• Consequences	• The different types of outcome that might occur.
• Areas of impact	• The people, facilities and objectives affected.
• Controls to change likelihood	• Controls that reduce the likelihood of the source of risk being present, the mechanism occurring or the mechanism leading to the critical event.
• Controls which change consequences	• Controls that prevent consequences following the event or reduce the consequences
• Management support functions that enable controls	• It is useful to distinguish between controls that directly change likelihood or consequence and management functions that facilitate controls (Hale et al., 2007). For example, a procedure may change the likelihood of an event occurring so is a control. Training in itself does not; rather it supports the procedure, so is a support function rather than a control.
• Influencing factors	• Traditionally, these are factors that may lead to changes in the effectiveness of controls and may also be useful to include factors which may influence the probability of a mechanism occurring.

The bow tie model of risk can be used in several ways:

- To support effective visual communication about a particular hazard or critical event, showing multiple mechanisms and outcomes
- To check that each mechanism has a control and that the controls for each mechanism are effective
- To help illustrate what is and is not a valid description of a risk; for example the failure of a control is a different concept than a risk. The importance of a control failure cannot be found by estimating a level of risk, because the importance of a control depends on the level of risk associated with the mechanism or critical event it controls and the effectiveness of other controls in the pathway
- As a basis for recording data about risks. For example, Hale et al., (2007) demonstrated how this model can be used to classify incident data using the components of the bow tie as data fields.

While a more sophisticated and versatile conception of risk than the model depicted in Figure 1, the bow tie model is still simplistic in that:

- It assumes that mechanisms and consequences are independent, whereas for some types of risk the consequence depends on which mechanism occurs
- It does not adequately consider events that result from a combination of mechanisms or from causal chains, or consequences that arise from a combination of events
- It assumes that consequences follow a discrete event although it can be adapted to suit a situation where consequences arise from continuous exposure to a set of circumstances, such as ongoing exposure to chemicals
- In its usual form it does not cover chains of events, although it is possible to cascade bow ties by making the mechanism, of one bow tie the critical event of the next to further explore causes.
- It does not include a model of causation so implies that risks can always be dealt with by barriers rather than by seeking and addressing root causes.

To fully understand a risk the causes of the bow tie elements and the relationships between them should be explored in more detail. The bow-tie model can be considered to be a simplification of more detailed methods of analysing a risk where the left hand side of the bow tie is a simplified fault tree and the right hand side an event tree, with the whole representing a cause-consequence analysis.[4]

So far the discussion has been limited to consideration of individual risks. A second important concept in OHS management is that of óriskiness.ô Investigations of many

[4] See *OHS BoK*: Models of Causation: Safety

incidents reveal that, rather than the failure of a single barrier, incidents result from one or more underlying problems within the management of the organisation, such as lack of staff, run-down equipment, or issues with priorities and decision making. Rasmussen (1997) discussed the weaknesses of simple models of risk and incident causation, and considered incidents to result from ña general migration towards the boundaries of acceptable riskò. Commissions of inquiry have uncovered a host of problems within an organisation and sometimes outside it, which resulted in the failure, or absence, of appropriate controls (Hopkins, 2005). These underlying issues cannot be specified as particular risks and allocated a priority in a risk register because no specific consequences can be defined. They are not even failures in a safety management system. They are decisions made within the general management activities that lead to an increase in the level of risk across all risks in a way that is not quantifiable. Dealing with these factors is referred to as ñresilience engineeringò (Hollnagel, Woods and Leveson, 2006) or mindfulnessô(see for example Weick & Roberts, 1993; Hopkins, 2005).

2.2 Risk as a measure

The concept of measuring risk by combining consequences and likelihood is attributed to Pascal in the 17th century who, in discussing the risk of being struck by lightning stated that ñour fear of some harm ought to be proportional not only to the magnitude of the harm, but also to the probability of the event" (Arnauld in Buroker, 1996, pp. 274-275).

More recent definitions of risk as a measure include:

- A function of the probability of an adverse health effect and the severity of that effect, consequential to a hazard(s) in food (FAO/WHO, 2011)
- The probability that a particular adverse event occurs during a stated period of time, or results from a particular challengeò (Royal Society, 1983).
- The probability of adverse effects resulting from exposure to an environmental agent or mixture of agentsò (USEPA, 2011).

The level of risk then is some function of consequence and the likelihood it will occur. The Royal Society (1983) definition appears to define level of risk as the probability of an event combined with its consequence. However the definition is accompanied by a clear description, which specifies ña) identification of the outcomes; (b) the estimation of the magnitude of the associated consequence of these outcomes; and (c) the estimation of the probabilities of these outcomes.ò The magnitude of a risk is found not by combining the probability of an event with an arbitrary or average consequence but as the sum of the probabilities of each consequence. The level of risk attributed to a disease does not relate to how often one contracts the disease but how often one dies from it. Similarly the level of risk associated with a fall depends not on how often one falls but on how often the injury is serious.

3 Estimating a level of risk

3.1 Introduction

For clarity and to distinguish ŕiskô the description from ŕiskô the measure, in the rest of this chapter the term risk will be reserved for its descriptive meaning and the measure will be referred to as ďevel of riskô. This is in accordance with the definitions in AS/NZS ISO 31000 and the ISO Guide 73.

Much effort and attention is often given to estimating a level of risk as a basis for making decisions about risk. This section discusses some of the theoretical problems with producing a meaningful value for level of risk that is compatible with the descriptive understanding of the concept of risk as used in section 2.

Representing the magnitude of a risk as the product of consequence and their likelihood has the following issues:

- It assumes a specified consequence has a unique value which is the same to all people
- Probabilities are difficult to comprehend ï particularly for low likelihoods
- It assumes that likelihood and consequences are of equal importance and are combined as a simple product
- It assumes that a single representative consequence and likelihood can represent a risk
- It does not consider uncertainties in the estimates of consequence and likelihood as part of the definition of risk.

3.2 The value of consequences

The 17th century assertion that risk is about our fear of harm (Arnauld in Bukoker, 1996) demonstrates the point that risk is about our individual appreciation of the consequence. For example, assume there are two individuals, one is poor and only has $100; the other is rich with millions in the bank; and there is an equal probability that each will lose $100. The level of this risk for the poor person is greater because $100 is of more value to them. This is in line with the definition of risk in AS/NZS ISO 31000 where risk is the effect of uncertainty on objectives. (It is assumed $100 will have more effect on a poor personôs objectives than a rich). A level of risk can be calculated by combining a measure of consequence with the likelihood it will occur but the importance of this risk has no intrinsic value outside of the particular context and each individualôs objectives.

The probability of death is often used as a measure of risk in health and safety; however even this does not produce a unique measure of consequence. For example death can be measured as years of living lost (which attributes more value to the young than to the old)

or as number of fatalities (which gives equal weight to both, but treats an immediate fatality as equivalent to a fatality that may occur after a latent time period) (Slovic, 1999).

Economic theory provides a method of dealing with differing values placed on consequences by relating the consequences to a utility scale.[5] Using a utility scale to represent the value of consequences:

- Better represents the fact that risk is about the importance of the consequence in the context
- Takes account of the different values that different stakeholders assign to a consequence
- Allows for a disproportionately high (or low) value to be given to higher consequences (Ben-Asher, 2008)
- Allows risks where consequences have different units to be combined.

In practice establishing a valid utility scale is time consuming and unlikely to be practicable in most situations relevant to OHS although they are used in the public health and environmental context. (see, for example, Hofstetter and Hammit, 2001)

3.3 Issues with defining likelihood

While consequences, even when known precisely, may have different values to different people, likelihood should be factual and based on data. The practical issue with estimating likelihood is lack of data concerning events that have not happened yet, or happen only rarely. In the absence of such data, estimates of level of risk usually rely on perceived likelihoods, but experts and non-experts alike have a poor perception of the likelihood of low-probability events and a poor appreciation of what low probability values mean in practice, (see Desalles, 2006). There is evidence that the perception of likelihood varies depending on how the statistical data is presented. For example, Bonner and Newellôs (2008) investigation of how the numerical framing of statistical information can influence risk perception found that risk ratings were higher for a óyearô than a ódayô format, i.e. ó36,500 people die from cancer every yearô was judged more risky than ó100 people die from cancer every day.ô

Not only are estimates of absolute probabilities notoriously poor, but perceptions of relative probabilities do not tally with data. There is, for example, evidence that individuals overestimate the probability of low-probability risks and underestimate high-probability risks (Gonzales, 1999; Tversky & Khaneman, 1974). Both Gonzales and Tversky &

[5] Utility can be defined as: ñPleasure or satisfaction (value for money) derived by a person from the consumption of a good or service or from being in a particular place, and for the maximization of which all economic actions are motivated. It is the subjective or psychic return which cannot be measured in absolute or objective termsò (WebFinance, 2011).

Khaneman mostly dealt with probabilities rather higher than the ranges relevant to personal safety and Tversky & Kahneman also showed that at very low probabilities probability is given zero weight in decisions. While many people may perceive a frequency of 1 in 100 years to be a low likelihood Table 2 shows that in an OHS context this frequency is many orders of magnitude higher than the actual frequency shown by data.

Table 2: Some frequencies of death by different causes

	Frequency	Source
Death all causes aged 20-25	5 10^{-4}/year	US Social Security Admin (2011)
Death in accident at work all causes 2006/2007	2.6 10^{-5} /year (2.6 in 100,000 people / year)	Safe Work Australia (2006-7) and ABS (2011)
Death at work falling from a ladder 2006/2007	2 10^{-7}/year 2 in 10 million people/year	Safe Work Australia (2006-7)
Killed by lightning (Australia)	2.5 ï 5 10^{-7}/year Between 2.5 and 5 in 10 million people per year	Bureau of Meteorology (2011)

Although the statistics show that the probability of death at work from any one hazard is low (and in most cases less than the probability of being killed by lightning), there are very many different hazards at work and millions of workers. The end result is that too many people die through work-related activity.

3.4 How consequence and likelihood are combined

Often, the level of a risk is taken to be the product of a consequence and its likelihood; however, there is no reason why consequence and likelihood should be combined by this simple formula and it is questionable whether the formula properly represents what is meant by the magnitude of a risk. A simple product of consequence and likelihood means, for example, that a 1% chance of losing $10000 is the same risk as a 100% chance of losing $100, which few would agree to be the case. Intuitively, a high-consequence, low-likelihood loss seems to be more important than a high probability of a low loss and does have a greater effect on organisations. This is not an irrational misperception of risk with the formula consequences x likelihood giving the ócorrectô value, but an indication that the true function for combining consequence and likelihood to represent the effect of uncertainty on objectives is not linear.

A simple product matches the conceptual understanding of the magnitude of a risk for moderate consequences and probabilities so is useful, but fails for low probability situations which are often those of highest consequence.

3.5 Risks with multiple possible values of consequence

A further complication in finding a simple estimate for level of risk by combining a consequence and its likelihood is that the outcome of an event (or of chronic exposure to a hazard) is often very variable. A fire may result in anything from no injury to multiple deaths and it is difficult to find a single consequence and likelihood pair to represent this situation.

The extent of this problem can be illustrated by considering a quantitative example where there is a single type of consequence with a range of different outcomes such as the distribution of insurable financial losses experienced by an organisation in a year as shown in Figure 3. The column labelled óMoreô includes a single loss of $225,000, 24 losses between $10,000 and $100,000, and 250 losses of less than $1000. There is the possibility of a maximum loss of $10 million, but this has not happened in the past so there is no means of assessing the probability of it occurring in the future. This type of distribution with many low losses and progressively fewer higher value losses is typical of several types of loss and can be compared with Birdôs Triangle in OHS (see Bird & Germain, 1985). The objective is to try to represent this distribution of losses with a single number representing the level of risk.

If by level of risk we mean the expectation value for how much we are likely to lose, then the theoretical level of risk in dollars/year is the sum of the products of the frequency of each consequence (including those values extending beyond $30,000 up to the theoretical maximum loss for which there is no likelihood data). This is the sum of the shaded boxes in Figure 4, but extended to higher losses where the shading is omitted for clarity in the figure.

This can be calculated analytically if the shape of the distribution is known or calculated from sample data using a computer. However there is a problem including the possibility of a very large loss for which there is no data. Often performing this calculation is too time consuming to be practicable or data is not sufficient and one needs to seek a proxy for this level of risk that could be used to compare risks. There are a number of options as follows:

- Take the most probable loss (the mode of the distribution) and multiply by its probability. This is to take the area of the first column in Figure 4 rather than the sum of all the shaded areas which is clearly a very significant underestimate.
- Take the most serious consequences experienced and multiply by the likelihood of this consequence occurring. This requires likelihood to be estimated without good statistical evidence because this type of event does not occur. It will also underestimate the total risk because both lower losses and losses that have not yet occurred are ignored. (In fact, for this particular data set it turns out that over the years this approximation gives just under 50% of the total annual loss value.)
- Take the highest credible loss and multiply by its probability of occurrence for which there is no supporting data. This can never be more than a guess.

- Take the standard deviation of the distribution shown in figure 3. This is a measure of the probability that there will be a loss where the consequence is a long way from the mean. Although the shape of the distribution is not known there may be sufficient data to obtain summary statistics from which a mean and standard deviation (or other measure of dispersion) can be found. This measure is used frequently in finance where there may be either a gain or a loss and distributions are less skewed than in this example or in the OHS context. It is not used in OHS, but it does represent a measure of risk that would be useful to decision makers. Routine losses can be obtained from the mean of data and the standard deviation provides a measure of the probability that something much more serious might occur. This is the only proxy value that allows for a finite probability of loss beyond historical data, but it does intrinsically make an assumption about the shape of the tail of the distribution which is unlikely to reflect the true shape.
- Take the consequence of the highest possible loss and multiply it by the probability of any loss occurring which would grossly over estimate the level of risk since the majority of losses are low consequence.

The extent to which any of the above proxy values for level of risk is a fair indication of the total level of risk represented by the distribution depends on the shape of the distribution. For a set of risks with different distributions, ranked by level of risk, the order could be expected to change depending on the choice of proxy measure.

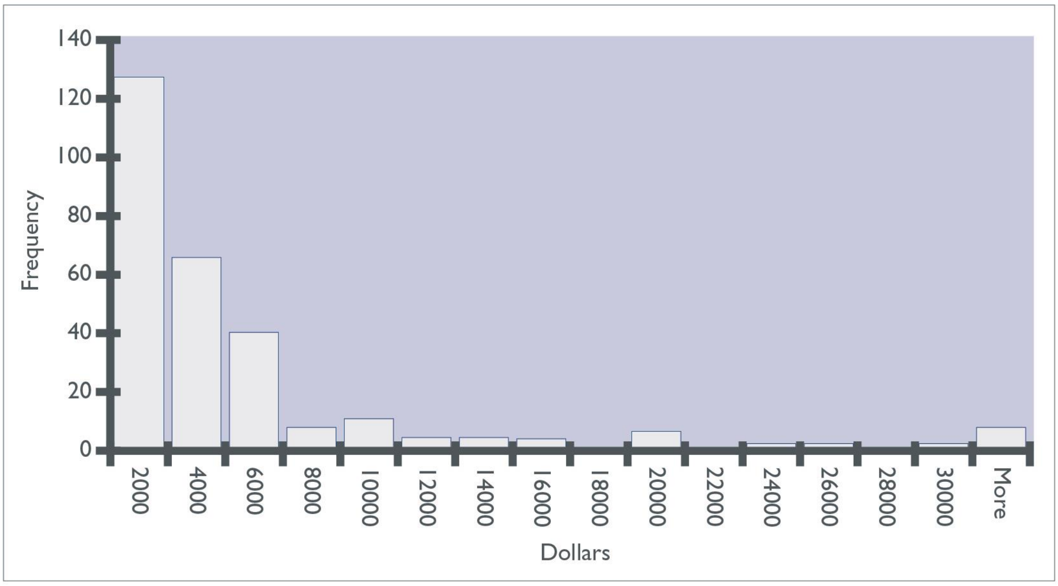

Figure 3: Sample distribution of loss data from an organisation

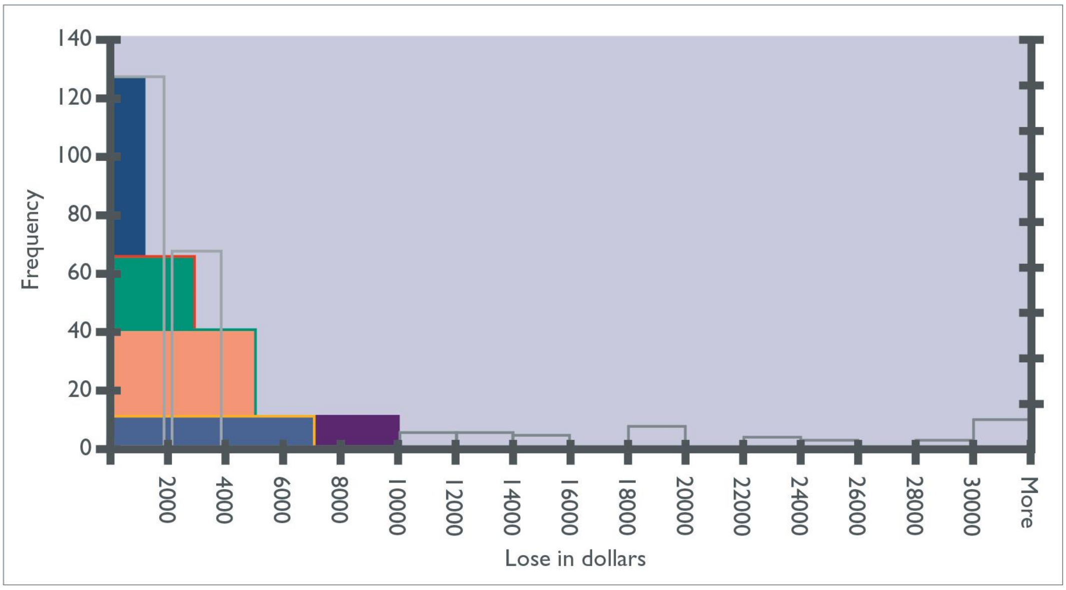

Figure 4: Level of risk derived from analysis of loss data

3.6 Risks with multiple types of consequence

In most situations, as well as varying values of consequence, there are varying types of consequence. For example, a building fire may result in death or injury of inmates, destruction of property and hence financial loss, disruption of the organisationǒs business, pollution to the environment and injury to fire fighters. There may also be situations where different types of consequence are relevant to different stakeholders. When a major hazards facility is built local residents may face a risk that their property values will decrease. This risk does not apply to other stakeholders. In theory the total level of risk is the sum of the probabilities of each consequence across all stakeholders; however consequences are usually measured in different units so risks will also have different units and cannot be added unless they are related to a common utility scale as discussed in section 3.2.

It is also possible to use principles of cost-benefit analysis to assign a dollar value to all consequences even when they are intangibles. Some of the difficulties of this approach, particularly in an OHS context are illustrated by the wide range of estimates for the dollar value placed on a life, which can be obtained by different methods and which are used by different government agencies (Bellavance, Dionne and Lebeau, 2009; Viscusi and Aldy, 2003).

A common way of dealing with multiple types and values of consequence in practice is to focus on a single consequence of particular significance and express the risk as the

probability of that outcome occurring, ignoring other possible outcomes. This will only be valid for decision making if that one particular consequence far outweighs the importance of all other possible consequences.

3.7 Risks with gradual or time delayed consequences[6]

Some consequences such as those which arise from chronic exposures to a hazard may be delayed or have a gradual onset. The estimated level of risk needs to take into account that, in most cases, people perceive delayed consequences as preferable to immediate harm.

One example of a chronic risk in OHS is exposure to a chemical where the likelihood of a particular consequence depends on the dose received. The level of risk of a particular exposure can be expressed as the probability of experiencing the specific chemical-related disease within a normal life span. This measure for level of risk relies on various assumptions about the shape of a dose response curve and the validity of rats or other test species as a model for humans. For chemicals, where there is accumulation in the body, the time dependence of the level of risk differs from that of chemicals which do not accumulate.

Manual handling and noise present similar issues. The injury occurs over time, the extent of injury depends on dose (or its equivalent) and the exposure levels may change with time.
Picking a single consequence likelihood pair for any chronic exposure where onset is time delayed or gradual is problematic, making comparisons of these risks with risks with more immediate consequence difficult and a matter of judgment rather than a formula.

3.8 Qualitative considerations

The problems of representing level of risk by combining a single consequence and its likelihood, which has been illustrated above with quantitative examples (section 3.4), also applies when a level of risk is estimated qualitatively or semi-quantitatively. Any ranking based on a combination of a consequence and its likelihood will depend on which particular consequence/ likelihood pair is selected. There is no one right answer for this choice. Estimates of consequence and likelihood in particular situations rely on various conventions, models and judgments. In all cases, to arrive at a single level of risk a complex situation is simplified and assumptions are made. Many real situations are too complex to be adequately represented by a single consequence-likelihood pair and there are many equally valid choices that could be made about how to do this if an estimate is required.

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[6] See also *OHS BoK*: Models of Causation ï Health Determinants

Risks may have multiple consequences but different types of consequence cannot be aggregated unless they are measured quantitatively and in the same units. Using ordinal rating scales, to rate different risks then adding them is not valid, and provides very misleading results.) Holton (2004) argued that there is no such thing as a true level of risk because one must always ask ñrisk to whomò. He concluded: ñIt is meaningless to ask if a risk metric captures risk. Instead, ask if it is usefulò (p. 24).

4 Risk and decisions

The main use for levels of risk is to provide information for decisions so that objectives can be achieved with an óacceptableô level of risk. Decisions involving risk may concern how to deal with risks (e.g. whether to spend more on treatment) or may concern some choice between options where there are different costs, benefits and uncertainties and hence different risks (for example whether to purchase new equipment or expand into new areas).

Decisions made by organisations and by individuals take account of risk in different ways. Organisations need to be able to define decision criteria that will result in consistent decisions across the organisation that match with organisational policy and attitude to risk. Decisions need to be as objective as possible and justifiable on logical grounds. It is likely that organisational decisions about whether a risk needs action will rely on criteria that are formula based and depend as little as possible on perceptions. Because they can be easily understood and universally applied organisations may choose to use either consequence alone or consequence-likelihood pair as a first level decision criteria. However the organisation needs to understand the full extent of a risk to manage it effectively.

Individuals, on the other hand, are able to be more subjective in the way they reach a decision. They can take into account their personal perceptions of consequences and likelihood and do not need to rely on a universally agreed value for these. These perceptions are likely to be based on personal experience rather than external data. They can consider potential positives and negatives and take these into account in complex subjective ways in reaching their decision. Generally, the outcome is referred to as a perceived level of risk; however, when individuals make a decision, risk is incorporated into overall thinking with a variety of other factors and may not be the primary basis for decision making. In dealing with the public on community health and safety issues, communicating about risks to individuals or judging worker perception of workplace risks, OHS professionals must be finely attuned to the way individuals think about risks and potentially risky situations.

4.1 Defining Acceptable level of risk

4.1.1 Legislated criteria

Health and safety legislation in Australia does not prescribe a universal level for acceptable risk. For some hazards legislation or standards set acceptable levels of risk through prescriptive limits that relate indirectly to risk. For example a noise dose of 85dbA per 8 hour day is set on the basis that the percentage of the population that will suffer industrial deafness at that level is acceptable but in most cases there is an absolute requirement to ensure health and safety to the extent reasonably practicable.

The legislation (WHSA s 17) refers to risk in the following terms:

> A duty imposed on a person to ensure health and safety requires the person:
> (a) to eliminate risks to health and safety, so far as is reasonably practicable; and
> (b) if it is not reasonably practicable to eliminate risks to health and safety, to minimise those risks so far as is reasonably practicable.

Reasonably practicable is defined in the WHSA (s 18) as:

> In this Act, ***reasonably practicable***, in relation to a duty to ensure health and safety, means that which is, or was at a particular time, reasonably able to be done in relation to ensuring health and safety, taking into account and weighing up all relevant matters including:
> (a) the likelihood of the hazard or the risk concerned occurring; and
> (b) the degree of harm that might result from the hazard or the risk; and
> (c) what the person concerned knows, or ought reasonably to know, about:
>   (i) the hazard or the risk; and
>   (ii) ways of eliminating or minimising the risk; and
> (d) the availability and suitability of ways to eliminate or minimise the risk; and
> (e) after assessing the extent of the risk and the available ways of eliminating or minimising the risk, the cost associated with available ways of eliminating or minimising the risk, including whether the cost is grossly disproportionate to the risk.

This indicates that the test for acceptability is not the level of risk that is achieved, but what more it is reasonably practicable to do. The duty holder is required to take into account the likelihood of harm occurring and the degree of harm and the extent of the risk but not necessarily to define a ólevel of riskô. (Extent of risk is undefined but the word would normally have a broader interpretation than magnitude of risk).

The UK Health and Safety Executive (HSE) explained the meaning of reasonably practicable (in the context of both the terms óas low as reasonably practicableô and óso far as reasonably practicableô) as follows:

> ñIn most situations, deciding whether the risks are ALARP involves a comparison between the control measures a duty-holder has in place or is proposing and the measures we would normally expect to see in such circumstances i.e. relevant good practiceò (HSE, 1988)

An indication of levels generally considered acceptable can be taken from other jurisdictions and other countries. Generally two levels can be defined: a lower, broadly

acceptable level of risk, where there is no need for detailed work to demonstrate that risks are as low as reasonably practicable and an upper intolerable level beyond which risk cannot be justified except in extraordinary circumstances (Figure 5). Between these levels a case must be made to justify that risks have been reduced so far as is reasonably practicable.

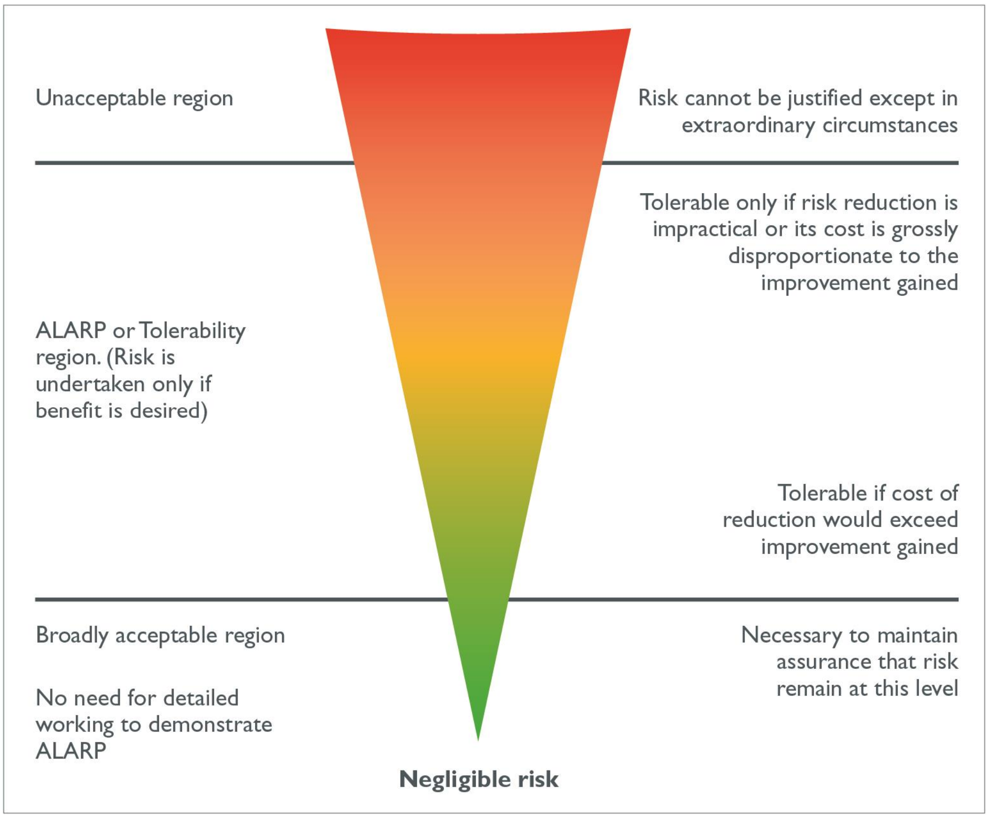

Figure 5: Levels of Risk and ALARP (modified from HSE, 1988)

This idea was first developed by the UK HSE in the context of the tolerability of risk from nuclear power stations (HSE, 1988). The principle also includes the idea of a sliding scale for how much it is reasonable to spend improving safety. Close to the broadly acceptable level a strict cost benefit comparison is permitted. Close to the unacceptable level it is expected that a risk will only be accepted if the cost of further control is grossly disproportionate to the improvement gained. The HSE now only refers to this diagram in the context of major hazards regulation where it sets an upper level of tolerable risk as 1 in 1000 fatalities per year for a worker and 1 in 10000 fatalities per year for a member of the public and a lower bound of 1 in 1 million for all (HSE, 2011b).

Departments of planning across Australia have picked up this principle. For example the NSW Department of Infrastructure and Planning sets the limits defined in Table 3.

Table 3 Individual fatality risk criteria (NSW Government, 2011)

Land use	Suggested criteria Level of risk to an individual of death/year
Hospitals, schools, child-care facilities, old age housing	0.5×10^{-6}
Residential, hotels, motels, tourist resorts	1×10^{-6}
Commercial developments including retail centres, offices and entertainment centre	5×10^{-6}
Sporting complexes and open space	10×10^{-6}
Industrial	50×10^{-6}

Hazardous facilities have the possibility of killing more than one individual and society tends to have a greater concern about scenarios where there are multiple fatalities or injuries. Criteria which apply to this situation are referred to as societal risk criteria. A graph can be drawn with probability against number of fatalities with two lines drawn to represent the lower and upper bounds of acceptability. (See, for example, Figure 6).

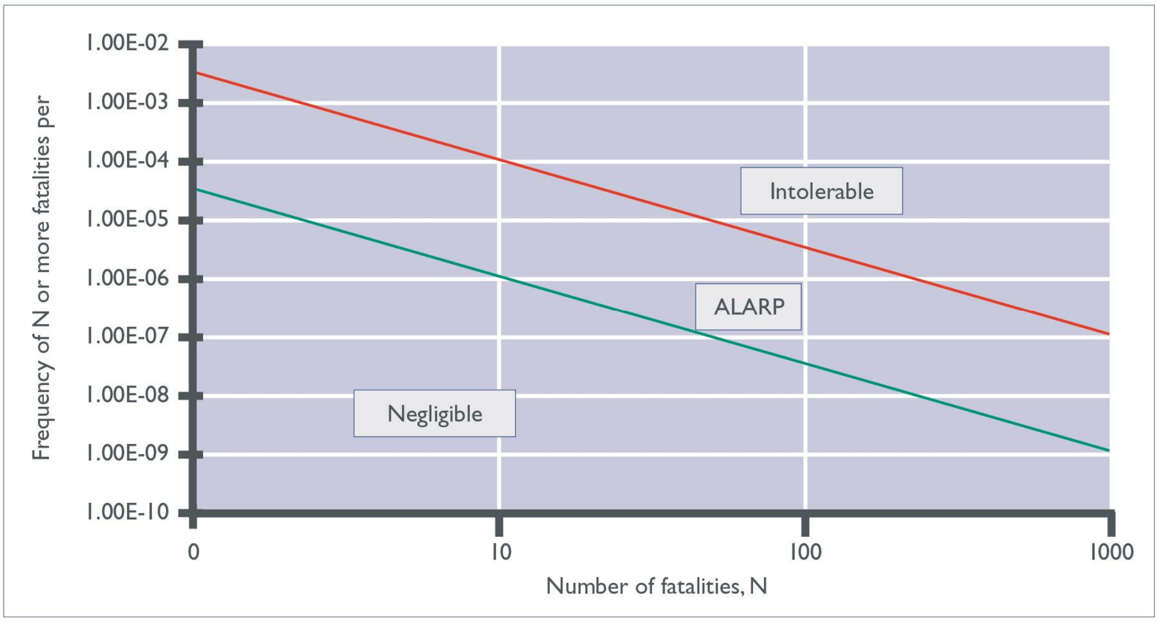

Figure 6: Societal risk criteria (modified from NSW Government, 2011).

In this figure the lower, broadly acceptable level of risk for 1 person is about 20 in a million not 1 in a million and the upper bound is about 2 x 10^{-3} or 1 in 500. Generally it is considered that the acceptable probability for 10 deaths in a single event should be more than 10 times lower than the acceptable probability for a single death. However there is much debate about how much lower (HSE, 2001). In the NSW Department of Planning example (Figure 6) the acceptable probability of death is 20 in a million for 1 fatality and 1 in a million for 10 fatalities.

Another way of looking at acceptable risk to life is to see what is considered to be a reasonably practicable amount to spend to reduce risk (OBPR, 2008). In the case of loss of life, Australian guidance suggests a value of about $3.5 million (at 2008 $ value). Disabilities can also be costed in this way by weighting injuries as fractions of the value of life (Mathers et al., 1999).

4.1.2 Criteria in Organisations

Management in organisations set risk criteria explicitly and implicitly in a number of ways:

- Through policy and risk statements (such as a zero accidents policy)
- By complying with prescriptive acceptable levels of a hazard or risk such as threshold limit values or occupational exposure standards
- By the organisational culture which defines how people behave when faced with decisions involving risk
- Through levels of delegation and responsibility (who can make decisions about risks in what circumstances)
- Through risk assessment tools such as a consequence-likelihood matrix which is associated with decision rules for required actions at different risk levels.

In general risk management there is a concept of ‘risk appetite’. The amount of risk an entity is willing to accept in pursuit of value (COSO, 2004). This implies that more risk can be taken if the value achieved by taking the risk is higher. For example an organisation with a high appetite for risk might choose to innovate even though this results in more financial risk. In safety legislation, and in theory, the benefit gained by taking a risk to health is not a consideration in deciding what is reasonably practicable. In practice benefit may be included in deciding the upper limit of acceptable risk or the intolerability level. For example the defence forces will have a higher level for intolerability during combat than during exercises and will have a higher level of risk where work must stop than many other organisations because of the need to train people for very dangerous situations. Similarly risk to safety of students during field trips could be eliminated by eliminating field trips, but the loss in educational benefit would in most cases outweigh the small residual risk once proper controls were in place.

If managers and employees are to make consistent decisions in line with policy, guidance is needed for the ALARP limits, i.e. when to stop work because the risk is intolerable and when risks need no explicit justification that controls are as good as practicable. In the region between these two, legislation requires that risks are eliminated or minimised so far as is reasonably practicable and justification of reasonably practicable concerns the availability and suitability and effectiveness of controls rather than an argument that any particular level of risk is acceptable.

4.1.3 Individual perception of acceptable risk

Generally there is not a clear distinction in the risk literature between an abstract determination of perceived level of risk and the extent to which the risk is deemed to be acceptable. The way that risk is perceived by individuals depends on the nature of the risk (including the potential benefits) and a range of demographic, cultural and socio-economic determinants (Whyte, 1983; Sandman, 1993; Slovic, Fischoff and Lichtenstein, 1979; Douglas and Wildavsky, 1982). Kasperson et al., (2003) referred to this as the ñsocial amplification of risk.ò There is a large body of work that addresses how the context in which risk arises affects how risky it is perceived to be. Some of the components or modifiers to level of risk identified by different authors are listed in Table 4 (Covello et al., 1984; Griffiths, 1981; Slovic et al., 1979; Wilson and Crouch, 2001).

Table 4 Perceived risks:

Perceived Higher Risk	Perceived Lower Risk
• Involuntary/coerced	• Voluntary
• Industrial	• Natural
• Exotic	• Familiar
• Immediate effect	• Delayed effect
• Memorable	• Not memorable
• Dreaded	• Not dreaded
• Not understood	• Understood
• Catastrophic	• Chronic
• Controlled by others	• Controlled by self
• Unfair	• Fair
• Widespread	• Only affects a few

Slovic (1993, 1999) identified trust in the analyst as an important component of how a level of risk is perceived and demonstrated the ñdifferential impact of trust-increasing and trust-decreasing eventsò (Slovic, 1993). Wilson and Crouch (2001) point out that the way trust is lost is not always consistent. For example, people retain a trust in air travel despite

accidents; however, the Three Mile Island incident that caused no deaths and an insignificant radiation leak resulted in a loss of trust in nuclear power (see, for example, Holzman, 2003).

In addition to factors related to the nature of the risk there are cognitive factors that affect how individuals perceive risks, such as how they obtain information about risks, how they decide which information to select from the various sources they have access to and how they process that information (Renn & Swanton, 1985). Tversky & Kahneman (1974) discussed three ways that information is processed cognitively resulting in bias in the interpretation of levels of risk:

- Representativeness: i.e. a tendency to assume that a small sample within oneôs experience represents the whole
- Availability: i.e. a tendency to assess probability by the ease of recollection of events
- Adjustment from an anchor: i.e. a tendency to use first estimates of a numerical value (possibly based on little data) to define the psychological range within which subsequent estimates will fall.

They showed that the way people respond to a question about risk depends on the way the question is posed. For example, choices are affected by whether the alternatives are framed as losses (people dying of a disease) or gains (people being cured). (Tversky & Kahneman, 1981).

Both Whyte (1983) and Sandman (1993) proposed dealing with perceptions by modifying the simple equation for level of risk (level of risk = consequences x likelihood) by a perception factor. For Whyte, this involved multiplying the product of consequence and likelihood by a factor ónô representing social values and, for Sandman, it involved the addition of an óoutrage factor.ô However, Wilson and Crouch (2001) argued that such factors introduce an excessive degree of subjectivity on the part of the analyst, and that where decisions involve public perceptions of risk the analyst should present an objective view, detailing where assumptions and judgments have been made and allow the decision maker to then incorporate the views of the public in a qualitative way.

It is unlikely that any simple formula that tries to take account of perception could adequately represent the complex thought processes involved when individuals make choices about risks. Furthermore, such an approach ignores the weaknesses inherent in the basic formula for level of risk discussed above and may well overemphasise the extent to which consequences and likelihood play a part in an individualôs decision about risks.

Much of the work on risk perception has focused on risks to which the public are exposed involuntarily, for little benefit and where they have very little perceived control, e.g. risks

from major hazards facilities. There has been less work on perception of risk in a work context. Perception of risk is often considered to be part of a measure of safety climate (presuming that a higher appreciation of risk produces a better safety climate). However, there is research which demonstrates little or no correlation between safety behaviours and perceived risk (Arcury, Quandt and Russell, 2002; Meliá, Mearns, Silva and Lima, 2008). In an investigation of optimism bias in OHS, Caponecchia (2010) found that "people tend to think hazardous events at work are less likely to happen to themselves compared to others doing the same job." This may be a manifestation of perceived control, which makes things appear less risky (see Table 4), or that personal experience of a hazard with no immediate consequences lowers the perceived level of risk.

5 Implications for practice

In practice the main role of an OHS professional is to understand OHS risks, communicate about them, and facilitate effective management of the risk. The responsibility for managing risks lies with managers. The OHS professional is the technical expert and facilitator who helps provide the framework for managing risk and provides technical advice on risks and risk management while being aware of the broader organisational context. This section reviews how the theoretical consideration of the earlier sections influences these roles.

5.1 Definitions of risk

Confusion surrounding the definitions of hazard, risk and risk assessment leads to poor communication about risks and how to manage them. A particular practical problem occurs where the word hazard is used to mean a source of harm and risk is used to mean the measure of level of risk. The legal requirement to identify hazards and assess risks does not explicitly require the nature of harm and how it occurs to be identified (although this is clearly intended by the detail of regulations and codes). This leads to the poor practice of identifying a hazard and then labelling the risk as high, medium or low, but not saying what harm occurs or why. This provides no information on the nature of the problem to either those who must manage risk or those exposed to it. AS/NZS ISO 31000 solves this problem by using the word 'risk' for the description of hazards, events, causes and consequences and 'level of risk' for its measure[7].

As described in section 2, modern definitions of risk take a neutral view and do not assume that the word relates only to loss. The idea of risk as potentially positive is at first thought an anathema to safety, implying that taking a risk where the possible outcome is harm to people can be a good thing; however, this is not what is meant. There is no direct equivalent of a hazard for a risk with positive consequences, but there is the potential for

[7] However this can create further confusion in the OHS context. See *BoK*: Hazard as a concept

change and the uncertainties which go with it to have a positive effect on safety. These need to be managed as well as negative events. By accepting the same definition of risk and risk management process as are used for managing other organisational risks, safety becomes part of mainstream management. Another practical advantage of considering both positive and negative outcomes is that it recognises that decisions about whether a risk is acceptable is not made in isolation from the benefits, which may arise from taking the risk. Inevitable tradeoffs are made explicit. For example, purchasing new equipment to automate an industrial process will introduce new risks to both production and safety, but it also has the potential to remove the possibility of some negative outcomes and to provide other direct benefits. The decision-making process must consider all the expected costs and benefits and the less-expected, but possible, positive and negative outcomes.

5.2 Risk management

Risk is managed within the general management systems which an organisation sets up to achieve its objectives. AS/NZS ISO 31000 refers to a risk management framework as the elements of a management system needed to manage risk effectively. The organisational arrangements needed involve defining accountabilities, responsibilities, budgets and resources, establishing training and communication mechanisms so that everyone knows their role in managing risks and is able to fulfil them. Risks should be managed as an integral part of the way business is done and not as a separate system (AS/NZS ISO 31000, Section 4) so requirements for managing risk are incorporated into the general management system requirements.

Application of the risk management process is sometimes seen as one element of a Safety Management System (SMS) but it can also be argued that the SMS should be tailored to an organisationʼs risks. This is the approach taken in preparing a safety report (or safety case) for major hazards facilities, where the primary aim is to demonstrate to the regulator that the organisations understands its risks and has the technical and management systems in place to control them.

Risks are managed at different levels in an organisation and on different occasions following a standard risk management process. There are many formulations of this process with slightly different terminology. All involve a standard decision making process such as outlined by Harrison (1995):

- Set objectives.
- Search for alternatives through scanning the internal and external environment of the organisation for information.
- Compare and evaluate the alternatives by formal and informal means.
- Practice the art of choice.

- Implement the decision when the choice is transformed from an abstraction into an operational reality.
- Follow up and control to ensure that the implemented decision results in an outcome in keeping with the objectives set in the first stage. [8]

Three different diagrams representing the process are used in standards relevant to health and safety; the risk management process described by AS/NZS ISO 31000 (Figure 7); the process used in food safety standards and some standards on chemicals safety (Figure 8); and the USEPA process of (Figure 9).

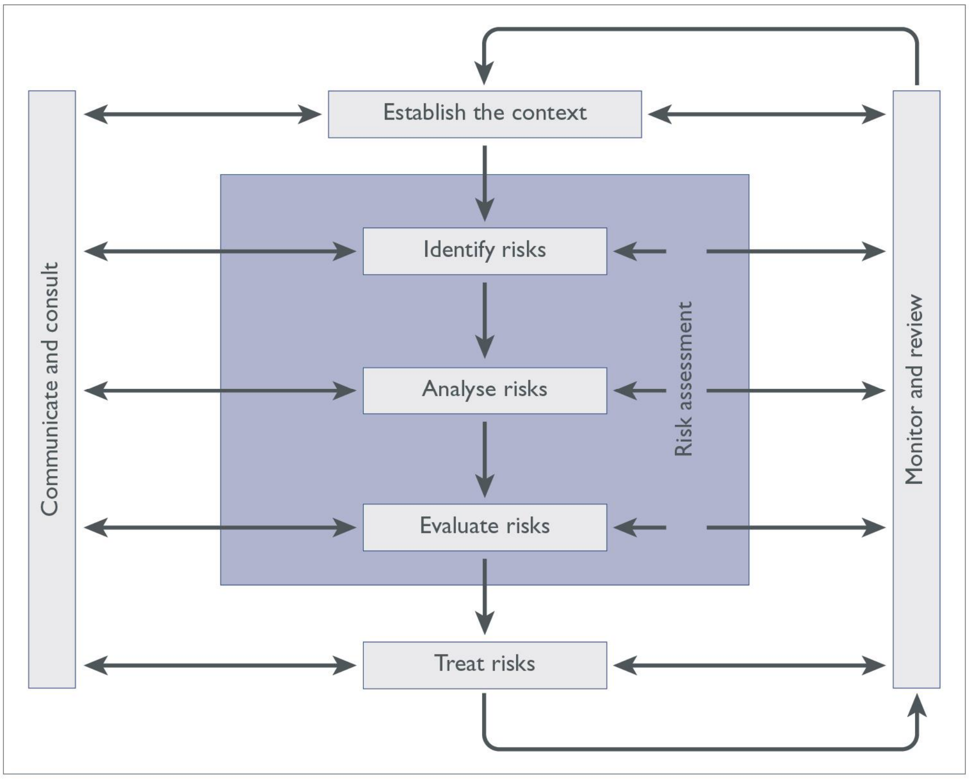

Figure 7: Risk management process [Modified from AS/NZS/ISO 31000 (SA/SNZ, 2009)]

[8] See *BoK*: Model of OHS practice

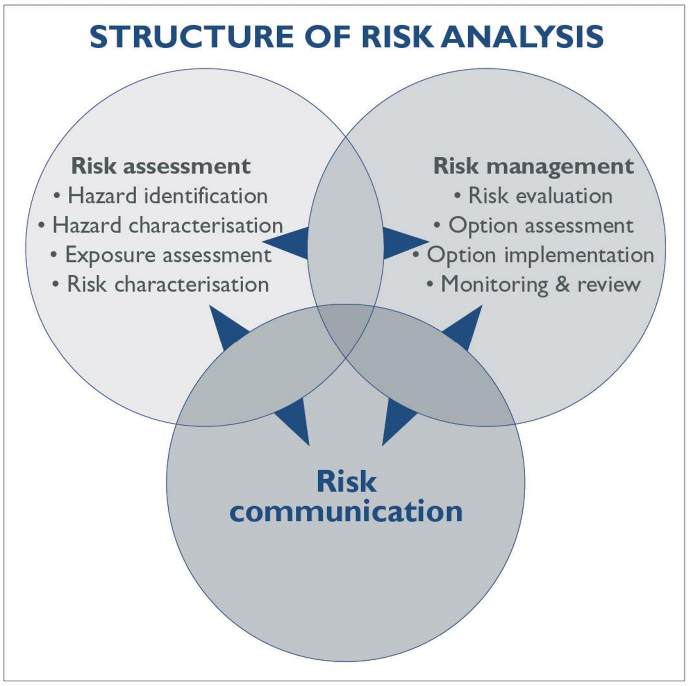

Figure 8: FAO risk analysis process (Modified from FAO/WHO, 1997)

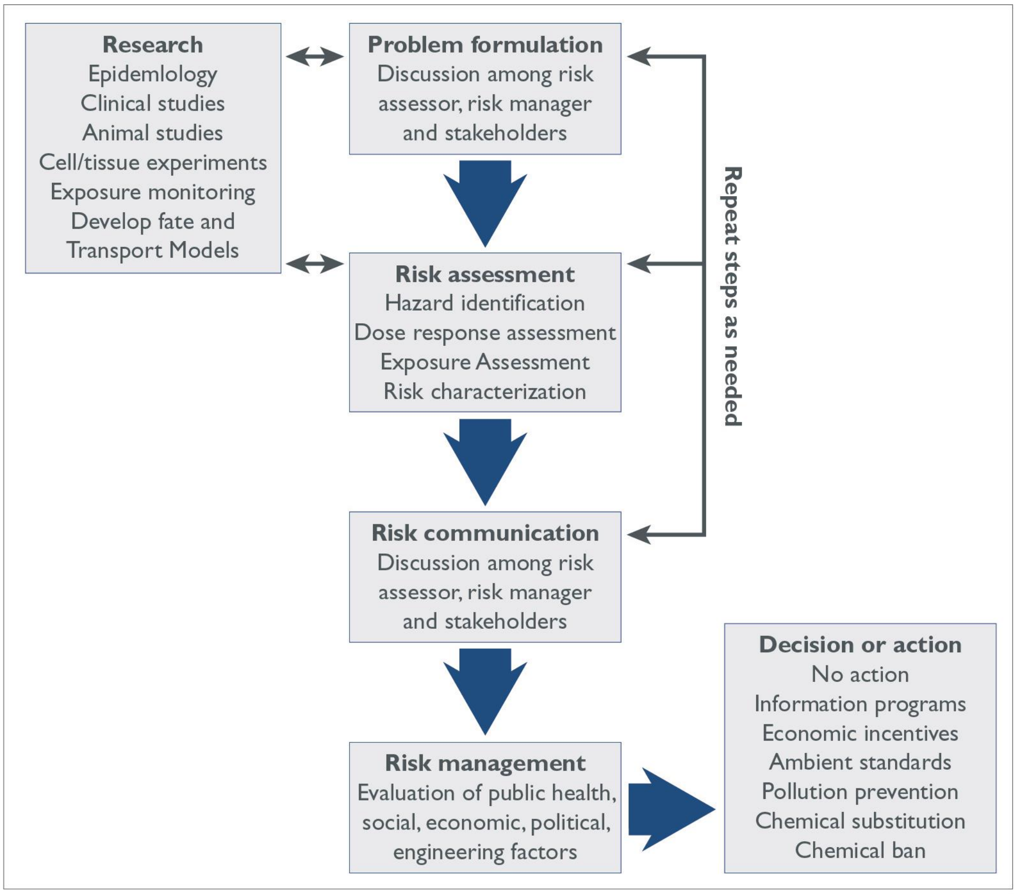

Figure9: USEPA risk analysis process (Modified from Brown, 1998)

The most notable difference between Figure 7 and Figure 8 and 9 is that in the food safety and USEPA terminology the whole process is called risk analysis and the term risk management is used for making decisions about risk. In AS/NZ ISO 31000 the whole process is called risk management and risk analysis is one part of risk assessment.

5.2.1 Communication and Consultation

Communication and consultation are an essential part of managing risk and involve seeking views and informing people of decisions. All discussions of the risk management process recognise this central role. Consultation is a legislative requirement in OHS but it also makes good sense. A wide range of views and expertise is needed to identify risks effectively and people are more likely to accept new treatments/controls if they have been part of deciding the need and the treatment. Communication is also important in convincing managers and employees about the importance of OHS risks[9]. In both cases the mere assurance by an OHS professional that a risk is high is unlikely to be convincing.

5.2.2 Establish the Context

Another significant difference is inclusion of a context step in Figure 7. In AS/NZS ISO 31000, ‘Establish the context’ includes:

- Articulating the objectives of the organisation, the activity to which the process is being applied and the purpose of applying the risk management process
- Understanding the internal and external environment[10]
- Defining the scope, and planning the risk management activities that are to occur
- Defining the criteria which will be used to evaluate the significance of risks
- Defining and describing the subject of the assessment, the particular conditions relating to it and how the assessment is to be done.

With risk defined as “the effect of uncertainty on objectives” (AS NZS 31000, 2009), explicit articulation of all relevant objectives is required. Otherwise, risks may not be identified and treatments/controls may not be effective or may control one risk at the expense of another. The external and internal environments of the organisation are important because they are a source of much of the uncertainty. For example, if the economic climate has a negative effect on a manufacturing company’s sales, staff may be cut and maintenance standards may slip; alternatively, during an upturn the opportunity may be taken to improve safety through expenditure on new safer equipment. Knowledge of the organisation’s weaknesses or biases also provides an understanding of sources of

[9] See *BoK*: The Human: Principles of Social Interaction.
[10] This is called environmental analysis in most strategic planning texts.

risk that are the root cause of many failures and knowledge of an organisationôs strengths and values can help provide persuasive arguments for improvements.

At the more detailed level, a context statement describing who was involved in a risk assessment, its scope and how it was done is needed so the assessment can be audited monitored and reviewed. By describing the subject of the assessment and background information any changes in circumstance that might affect the assessment can be recognised and the implications assessed.

5.3 Risk assessment

The three risk management process examples (Figures 7, 8 and 9) all use the term órisk assessmentô to include identifying risks and analysing them. AS/NZS ISO 31000 also includes risk evaluation (i.e. judging the significance of risks) within risk assessment. The processes depicted in Figures 8 and 9 place evaluation within the management/response step. OHS text and regulations often define risk assessment as the combination of risk analysis and evaluation (e.g. Commonwealth of Australia, 2008). Common usage often interprets risk assessment only to involve determining a level of risk. For example the wikepedia definition is:

> the determination of quantitative or qualitative value of risk related to a concrete situation and a recognized threat (also called hazard).

This confusion means it is difficult for people to understand what they are required to do when asked to óassess risksô and OHS professionals should be careful how they use the term.

In particular a focus on determining a level of risk distracts from the primary aim of risk assessment which is to understand the risk and the effectiveness of its controls sufficiently to determine whether more can be done to control them.

5.3.1 Identifying risks

Risks are identified so that resources can be allocated to managing uncertainties and threats so that objectives can be achieved without unwanted outcomes. Proactive consideration of what might happen takes time and resources but overall is more effective than dealing with problems when they arise. New opportunities to improve health and safety are likely to be missed if there is no active process to recognise them.

The model WHS Act (Safe Work Australia, 2011) requires hazards/risks to be identified but does not define these terms. The food safety and environmental standards also require risks to be identified because the term ñhazard characterisationò includes describing the nature of the adverse health effects.

AS/NZS ISO 31000 describes risk identification as identifying :

- Sources of risk
- Areas of impacts
- Events (including changes in circumstances)
- Their causes and
- Their potential consequences.

In the context of OHS, sources of risk include hazards and hazardous situations and can also be interpreted to include root causes of failures, such as organisational behaviours and other factors that lead to risk. Investigation of incidents, particularly incidents with very serious consequences, invariably reveal multiple organsational problems as contributory causes (e.g. Reason, 1997.) Proactive risk management needs to include processes to identify these sources of risk as well as hazards.

Check lists, inspections and brainstorming can be used to identify common OHS risks at the workplace level; however more in depth procedures are needed to challenge assumptions and think imaginatively about risks. Formal identification procedures generally involve breaking the subject of the assessment into smaller components, each of which is considered in turn, using a combination of research, and imagination. Thinking prompts and guide words can be helpful as long as they encourage broad and imaginative thinking. Tools such as failure mode and effect analysis, fishbone diagrams and fault trees[11] (ISO IEC 31010, 2009) can be useful ways of thinking through possible failures and their causes in a logical but imaginative way. Fishbone diagrams and success trees (Clemens and Simmons 1998) can also be used to seek opportunities to improve health and safety outcomes.

Risks are usually recorded in a register of risks. At an organisational level this is increasingly a data base rather than paper system. Its purpose is to inform stakeholders (including those affected by risk and those who must manage it) about the risks and how they are controlled. The risk register, or a linked risk treatment plan, also tracks actions where improvements in controls are required. As new treatments are implemented the data base is updated to reflect the new controls. It is also useful to record why the controls are deemed to be the best reasonably practicable. This avoids unnecessary duplication of effort when the risk register is reviewed as well as demonstrating that the issue of reasonably practicable has been considered for compliance purposes.

[11] See *OHS BoK* Models of Causation: Safety

Section 3 outlined the range of information that may be needed to fully describe a risk. The way in which this information is best recorded and communicated, and how much of this information should be in a register of risks will depend on the context.

In addition to risk registers which are primarily management information tools there may be simpler more focussed registers relating to particular hazardous activities (such as confined space entry or a particular construction task) or to items of equipment. These risks may be referred to in general terms in a high level risk register with the detailed assessment used to define the specific controls. The nature of information required may differ depending on the purpose of the assessment. For example, where the aim of a risk assessment is for a contractor to demonstrate that they understand the risks of their task and have appropriate controls, the task may be broken down into detailed steps but for each step it may be sufficient to record the hazard, how the hazard might cause harm, the nature of the harm and how the risk is to be minimised. When a risk assessment is required to set priorities for improving health and safety across an organisation such activities may be treated as a whole rather than step-by-step but more information might be required, with most of the fields of the bow-tie diagram populated. In all cases the nature of the harm, who or what is harmed, and how such harm might occur is critical.

It is important that information is stored in the correct fields (or under the correct headings in a paper based system) and that sources of risk, risks and control failures are not confused.[12] This enables information to be sorted and reported more effectively and helps ensure that any estimates of level of risk are valid.

5.3.2 Analysing risks

In all three processes the second part of risk assessment is developing an understanding of the risks. This is described in more detail for the particular case of toxic chemicals and food contaminants in Figure 8 and Figure 9 than it is in Figure 7.Risk analysis is about understanding the risks and their possible causes and consequences in more detail than was ascertained when the risks were identified. It also involves analysing the effectiveness of existing controls (including checking that they are as high up the hierarchy of controls as practicable and that they work) and considering other factors that might affect consequences or their likelihood. A full analysis of a risk would involve considering all aspects of the bow-tie diagram of Figure 2, and extending it to analyse underlying causes. This is generally not practicable for all risks so an initial ranking may take place so that attention is focussed on the most important risks.

Risk analysis may be qualitative resulting in a descriptive report with such data as is available incorporated as appropriate, or may be quantitative including modelling

[12] See also *OHS BoK*: Hazard as a Concept

consequences and calculating probabilities. Qualitative analysis involves obtaining a good qualitative understanding of risks and should not be confused with allocating a single qualitative descriptor to consequence and/or likelihood and so risk.

Risk analysis may involve determining a level of risk by combining consequences and likelihood, however, section 3.2 demonstrated the difficulty of attempting to do this in a meaningful way, and it may be more useful to provide information about consequences and likelihood separately using a combination of data and descriptive information. One problem with an excessive focus on defining a level of risk is that systemic organisational issues cannot be usefully analysed by considering consequences and likelihood so they tend to be overlooked. Underlying organisational problems are not in themselves risks; they are sources of risk and causes of control failures. Organisational weaknesses cannot be allocated a single consequence and likelihood pair. They act to make all other risks higher. Analysing control failures and organisational issues are an important part of risk assessment. They can be recognised from a risk register as commonly appearing causes or sources of risk but then they must be analysed in detail rather than treated as separate risks with a single level of risk.

All standards make it clear that risk analysis is about data and evidence and not guesswork. Although a level of risk may be produced as one outcome of analysis, the important output of the step is understanding a risk and its causes so that it can be treated appropriately. The guiding principle for how risk is analysed is that the output of the analysis should provide the information needed to make the decisions which are required.

5.3.3 Risk evaluation and decisions about risk

Although it is sometimes assumed that the level of risk is the primary criteria for decisions this is in fact not the case. One does not need to know the magnitude of a risk to consider whether further treatment is reasonably practicable, nor to decide how best to control the risk. An estimated level of risk may not even be the best way to decide priorities for treatment. For example, one may set priorities by considering consequences alone or by considering the extent to which the level of risk can be reduced by the proposed controls rather than the initial level of risk. There is little point pouring more resources into a high risk which is already reduced as far as is reasonably practicable even though it remains high.

Because risk is essentially a subjective concept, decisions about risk will take into account factors other than estimates of consequence and likelihood. In general, decisions about acceptability of risk and priorities depend on:

- Ethical considerations: i.e. what is the right thing to do?
- Equity considerations: i.e. who will gain and who will lose?

- Legal considerations: i.e. what are the legal requirements?
- Financial considerations: i.e. what is the most cost effective thing to do?
- Risk-based considerations (usually both the maximum credible consequence, and the level of risk).

5.3.4 Ranking risks The consequence-likelihood matrix

In many fields of risk management, risks are compared qualitatively using a consequence-likelihood matrix such as the example in Figure 10. The qualitative level of risk produced provides one input to decisions about priorities and can help draw attention to risks that are perceived to be the most important or help to exclude minor risks from further attention.

Likelihood \ Consequence	1	2	3	4	5
A	S	S	H	E	E
B	M	S	S	H	E
C	L	M	S	H	E
D	L	L	M	H	E
E	L	L	M	S	H

E = Extreme, H = high , S = Significant L = Low

Figure 10: Example of a consequence-likelihood matrix

This example is colour coded as in the ALARP diagram of Figure 5 and lines could be drawn to delineate the intolerable and broadly acceptable levels of risk, with the central area representing the area where it is required to justify that risks are reduced so far as is reasonably practicable. The example also shows labels in the boxes which give an alternative indication of level of risk where consequences are given a higher weight than likelihood. Clearly the importance of the risk, whether represented by the colour or the letter, will depend on how the consequence and likelihood scales are defined. This needs to be tailored for a particular organisation and its risks. The matrix is a way for management to indicate the actions they wish to be taken for any particular consequence-likelihood pair, so scales must be carefully defined and unambiguously stated to give a common understanding of what is required.

Although risk matrices have serious limitations that dictate they should be used with caution (Cox, 2008), they can indicate a general ranking based on a selected consequence-likelihood pair. The priorities are very subjective and will depend on the way in which the matrix is designed which is largely arbitrary.

Consequence and likelihood can also be represented on numerical rating scales which are then combined by some formula. Often the numbers are multiplied, but it could be argued that the scales represent logarithmic values of consequence and likelihood, and that an additive formula is more appropriate.

A clear distinction must be drawn between ordinal numbers that represent rank as used in semi-quantitative analysis and the numbers from ratio scales which represent true values based on data as used in quantitative analysis. The numbers chosen for rating scales are arbitrary and do not bear any true relationship to the actual values of consequence or likelihood. Mathematical expressions applied to such scales have no mathematical meaning; for example two consequences allocated level 1 do not correspond to one consequence of level 2. Even the rank order obtained by combining semi-quantitative scales depends on the way the scales are set up and how they are combined.

Semi-quantitative methods have little value over qualitative scales for combining two values. They can be useful when level of risk can be related to several factors (such as separating likelihood into components representing the intrinsic danger of the hazard and the level of exposure). However the fundamental limitations of semi-quantitative scales remain, so such systems should always be tested with a range of examples to check their validity.

With semi-quantitative scales one cannot assume that a percentage decrease in consequence or likelihood represents that percentage decrease in risk and one cannot aggregate risks by combining their ratings.

Defining a scale in terms of a percentage or a cost does not make it a quantitative rather than semi-quantitative, unless those numbers have units and can be justified by data. A particular example is where a rating scale for likelihood has as its lowest value a value such as < 1%. This is meaningless unless it is stated what the percentage refers to, e.g. does it mean 1% of workers over the life of a project, or 1% of years for a stated population, or 1% of workers each year? Comparison with the data in Table 2 for fatality risks and Table 3 for acceptable risk criteria shows that in fact a fatality rate of 1% of people per year is 10 times higher than the intolerable level and 10,000 times higher than the generally accepted lower acceptable limit of 1 in one million person years, i.e. a lower limit of 1% does not fit with data and cannot be used as a quantitative scale relevant to health and safety.

Basing decisions on the result of combining a consequence-likelihood pair is problematic because:

- A single likelihood consequence pair is a proxy measure which does not represent the full picture. (This was discussed in detail in section 2). In particular, where there are multiple consequences, basing priorities on only one may give quite different priorities to that estimated when the full range of consequences is included.
- Many decisions about risk do not depend on level of risk. For example, in deciding which risks to treat first the relevant criteria is rationally the amount of risk reduction that can be achieved rather than the initial level of risk.
- Subjective issues such as perceptions of risk and equity considerations concerning who bears the risk are relevant and should not be excluded from decision making.
- Most risk registers will contain risks with differing degrees of detail and disaggregation that cannot be validly compared
- A level of risk can only be used for true risks where a particular consequence directly arises from a hazard or hazardous situation. It cannot be used to rank control failures because these depend on the probability of the hazard existing and the event occurring, and the effectiveness of other controls. Also, it cannot be used to rank weaknesses in the management system, such as poor training, because these increase the level of multiple risks rather than being a single risk in themselves.
- Where the risk analysis concerns decision about a choice of actions, such as which item of equipment to buy, the relevant evaluation is a comparison of the risks and opportunities that each option represents. A consequence-likelihood matrix is of no value because what is required is a cost-benefit analysis that combines and compares risks and opportunities and not a ranking of risks for each option.

Cross and Trethewy (2002) sum the issue up as follows

> ñCurrent practice in risk assessment is highly unreliable.... a simple qualitative description of magnitude of risk does not perform the function (of requiring mangers to understand and take responsibility for the risks in their workplace)... Legislation requires employers to eliminate hazards and minimise all risks to health and safety. Ranking risks is an administrative convenience to allow a sensible consideration of where to start when a range of actions are required, but it has become the core of OHS risk management activity....ò

The purpose of a ranking tool is to draw attention to the most important risks and to risks that might need more detailed analysis. Ranking is a starting point for analysis not the end result.

5.4 Risk Treatment

AS/NZS ISO 31000: 2009 uses the term risk treatment to refer to actions which are required to improve controls. Risk controls are covered in another chapter of the Body of

Knowledge[13] however it is important to note here that recommending treatment is not the end of the process. Treatments may introduce new risks which need to be identified, analysed, evaluated and controlled. Unless hazards have been eliminated there is nearly always some residual risk after treatment so there needs to be a new evaluation that these risks are now acceptable and an updating of the risk register to reflect the changes.

6 Summary

This chapter has reviewed how definitions and terminology relating to risk and its management are used particularly in standards and legislation relevant to OHS. The concept of risk as a description of effects of uncertainty was discussed. In theory this concept is able to be given a value or level of risk based on consequence and their likelihood, but there are problems with trying to define a single level of risk for real risks that have multiple consequences and causes. In most cases there is no true single value for level of risk and one of several proxy values is used in decision making.

The way in which acceptable risk is defined in legislation, and by organisations and is perceived by individuals was introduced. There is a vast literature on individual risk perception and how people make choices that involve risks which could only be touched upon here. Implications for practice primarily focussed on the risk management process and particularly the risk assessment process within it. Risk assessment involves understanding risks and how well they are controlled and deciding what to do about them. Finding a level of risk is in all cases problematic and often highly subjective. Qualitative or semiquantaitive ranking may be useful to highlight serious risks, or exclude minor risks from attention and can provide one input to deciding priorities but should be a minor part of the risk assessment process.

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[13] See *OHS BoK*: Control, prevention and intervention

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