Abstract

There have been two primary paradigms of safety risk management co-existing uneasily over the last few decades. One is related to hazard based risk analysis driven by technical professionals using target levels of risk and/or safety. The other is the precaution based risk analysis driven by the courts focusing on ‘due diligence’ being a demonstration that all reasonable practical precautions are in place based on the balance of the significance of the risk vs the effort required to reduce it. The publication of the EG-0, *Power System Earthing Guide*, Part 1: Management Principles by Energy Networks Australia in May 2010 supports the hazard based / risk target approach to risk management whilst the impending (2011) national Model Workplace Health and Safety Act requires a positive duty of care for responsible officers to exercise ‘due diligence’. This paper will investigate the underlying conflict between the two positions and the manner of expected resolution using EG-0 as the focus.

1. Introduction

There have been two primary paradigms of safety risk management co-existing uneasily over the last few decades. One is related to hazard based risk analysis driven by technical professionals. The other the precaution based risk analysis driven by the courts.

The publication of the draft Power System Earthing Guide EG-0 by Energy Networks Australia in May 2010 has drawn attention to the potential conflict between the two positions. Energy Safe Victoria (ESV) commissioned R2A to review the situation in 2009 and provide a position paper as to the optimal way to resolve the matter. Much of this paper is based on that work and is used with permission of the ESV.

Energy Safe Victoria is the safety regulator responsible for electrical and gas safety in Victoria. The ESV regulates the safety and technical compliance of energy supply, installations, appliances and pipelines, and raises industry and community awareness of electricity, gas and pipeline safety. Ultimately safety is the responsibility of the proponent organisations and the ESV works cooperatively with organisations to ensure due process so that proponents can demonstrate due diligence. ESV will prosecute but regards any related prosecutions as a measure of regulatory failure.
2. Probabilistic Hazard Assessment

Probabilistic hazard assessment seems to have come of age in the nuclear industry in the 70’s and 80’s with the publication in 1975 of the US Reactor Safety Study known as WASH-1400, formally entitled: *An Assessment of Accident Risks in the US Commercial Nuclear Power Stations*, and the publication in the UK of *The Tolerability of Risk from Nuclear Power Stations* by the UK Health and Safety Executive in 1987. These documents promulgated the concept of objective risk targets supported by quantified risk assessment (QRA) processes as the way to assess and manage technical risk.

2.2 Individual Risk Criteria

Many countries in the world maintain databases on causes of death to their citizens. These can be analysed. A typical result from mortality statistics is shown below.

<table>
<thead>
<tr>
<th>Transportation Risks (average to travellers)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Travelling by motor vehicle</td>
<td>145</td>
</tr>
<tr>
<td>Travelling by train</td>
<td>30</td>
</tr>
<tr>
<td>Travelling by aeroplane</td>
<td>10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Risks averaged over the whole population</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cancers from all causes</td>
<td>1800</td>
</tr>
<tr>
<td>• total</td>
<td>380</td>
</tr>
<tr>
<td>• lung</td>
<td>0.07-300</td>
</tr>
<tr>
<td>Air pollution from burning coal to generate electricity</td>
<td>110</td>
</tr>
<tr>
<td>Being at home-accidents at home</td>
<td>60</td>
</tr>
<tr>
<td>Accidental falls</td>
<td>35</td>
</tr>
<tr>
<td>Pedestrians being struck by motor vehicles</td>
<td>20</td>
</tr>
<tr>
<td>Homicide</td>
<td>18</td>
</tr>
</tbody>
</table>
| Accidental Poisoning                        | 0.1 
| • total                                     | 3 |
| • venomous animals and plants               | 10 |
| Fires and accidental burns                  | 2 |
| Electrocution (non-industrial)              | 0.2 |
| Falling objects                             | 0.1 |
| Therapeutic use of drugs                    | 0.001|
| Cataclysmic storms and storm floods         |   |
| Lightning Strikes                           |   |
| Meteorite strikes                           |   |

*Extract from Risks to individuals in New South Wales*

from NSW Department of Planning, 1990.

From such lists various parties suggest acceptable or tolerable frequencies of death for individuals in critically exposed groups. These numbers are in chances per million per year. That is, in the table above, the chance, on average, of being struck and killed by lightning in NSW is one in ten million per year or alternatively, for an individual, once in every ten million years.

The two key levels seem to lie around road death statistics and the chance of being struck by lightning. In simple terms, it seems that if we believe something is more dangerous than driving a car then the risk is unacceptable (about one chance in 10,000 per year), but that if it is about as likely as being struck by
lightning (about one chance in 10 million per year), then it is probably so low that we don’t expect anyone to do anything about it. In the range between these two figures cost benefit studies to reduce the risk to as low as reasonably practicable (ALARP) are appropriate.

The ALARP principle
(As low as reasonably practicable)

Unacceptable or intolerable region
Risk cannot be justified except in extraordinary circumstances

The ALARP or Tolerability region (Risk is accepted only if a benefit is desired)
Tolerable only if risk reduction is impracticable or if its cost is grossly disproportionate to the improvement gained

Broadly acceptable region (No need for detailed work to demonstrate ALARP)
Avoid avoidable risks
Need to maintain assurance that risk remains at this level

Negligible risk

Individual Risk Levels
NSW Department of Planning (2007)

The Victorian WorkCover Authority, the NSW Department of Planning and the Western Australian Environmental Protection Authority (EPA) have defined individual risk levels. Other Australian States tend to utilise one or other of these criteria when assessing individual and/or societal risk. For example, the NSW Department of Planning has published an advisory paper “Risk Criteria for Land Use Safety Planning” (June 1992) and again in Land Use Safety Planning (Consultation Draft) March 2007 that outlines the criteria by which the acceptability of risks associated with potentially hazardous developments will be assessed. The table below summaries the NSW criteria for the individual fatality risk for new installations.

<table>
<thead>
<tr>
<th>Risk Level</th>
<th>Land Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 x 10^{-6} pa</td>
<td>Hospitals, schools, child care facilities, old age housing</td>
</tr>
<tr>
<td>1.0 x 10^{-6} pa</td>
<td>Residential, hotels, motels, tourist resorts</td>
</tr>
<tr>
<td>5 x 10^{-6} pa</td>
<td>Commercial developments including retail centres, offices and entertainment centres</td>
</tr>
<tr>
<td>10 x 10^{-6} pa</td>
<td>Sporting complexes and active open spaces</td>
</tr>
<tr>
<td>50 x 10^{-6} pa</td>
<td>Industrial</td>
</tr>
</tbody>
</table>

Individual fatality risk-new installations

2.2 Societal Risk Criteria

As the severity of the event increases, we appear to become more risk averse. Particularly, once the death threshold is passed, it appears the community has a much greater aversion to multiple fatality incidents. In many countries this seems to amount to a one hundred-fold decrease in the likelihood of the event.
for a ten-fold increase in the severity of the consequence measured in fatalities. Societal risk analysis combines the consequence and likelihood information with population information. This is presented as a F-N plot, which indicates the cumulative frequency ‘F’ of killing ‘N’ or more people.

![Societal risk criteria graph](image)

**Societal risk criteria**
**NSW Department of Planning (2007)**

The document establishes criteria for societal risk in the form of a log-log F-N plot that results in two parallel lines defining three zones:

i) above the acceptable limit the societal risk level is not tolerable

ii) between the acceptable and negligible limits the societal risk level is acceptable but if the perceived benefits gained by the activity are not high enough, some risk reducing measures may be required. Risk should be "as low as reasonably practicable" (ALARP) or “as low as reasonably achievable” (ALARA).

iii) below the negligible limit, the societal risk level is acceptable, regardless of the perceived value of the activity.

Societal risk criteria have been proposed by a number of authorities including the Victorian WorkCover Authority and the NSW Department of Planning.

### 2.3 Use in Electrical Standards in Australia

#### 2.3.1 CB(1) Appendix G (2006)

Arising from work completed by what was then the HEC (now Transend) in Tasmania, an appendix to CB(1) entitled: *Risk Management of Conductor Clearance* was developed and first published in 1995. (The authors of this paper were involved with this work for the HEC and later Transend). The concept related to an interim phase of work to be completed by the HEC on a risk timeline argument, subject at all times to verification by the electricity supplier’s solicitors. It is noted that this appendix generated concern at the time such as described in Stillman and Sappideen (1996).

These standards provide illustrations of the general principles of as low as reasonably practicable (ALARP) and tolerable risk targets (Annex B) in each case. This includes the ‘dagger’ diagram without quantification.

2.3.2 Power System Earthing Guide EG-0 (May 2010)

This standard appears to define risk limit targets consistent with the NSW DOP guidelines generally described in section 2.2 above and as shown in the table and figure below.

**Table 4-1: Target individual fatality probability limits**

<table>
<thead>
<tr>
<th>Probability of single fatality</th>
<th>Risk classification for public death</th>
<th>Resulting implication for risk treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 10⁻⁴</td>
<td>High or intolerable risk</td>
<td>Must prevent occurrence regardless of costs.</td>
</tr>
<tr>
<td>10⁻⁴-10⁻⁶</td>
<td>Intermediate or ALARA Region</td>
<td>Must minimise occurrence unless risk reduction is impractical and costs are grossly disproportionate to safety gained.</td>
</tr>
<tr>
<td>≤10⁻⁶</td>
<td>Low or tolerable risk</td>
<td>Risk generally acceptable, however, risk treatment may be applied if the cost is low and/or a normally expected practice.</td>
</tr>
</tbody>
</table>

**EG-0 individual risk limits**

- **Intolerable Region**—The risk profile must be reduced.
- **ALARA Region**—Reduce the risk profile whenever possible, and only accept the residual risk on the basis of a risk cost benefit analysis (RCBA) (see Appendix F). The use of the ALARA principle (or ALARP) is clearly intended to form a key part of the Due Diligence process embodied in this Guide. The ALARA principle that requires a designer and asset owner to reduce the risk profile whenever possible provides a consistent yet practical means for managing earthing system related risk.
- **Low or tolerable Region**—Risk generally acceptable, however, risk treatment may be applied if the cost is low and/or a normally expected practice.
3.0 Australian Legal Context

3.1 The Adversarial System

There are several points about the adversarial system that need to be remembered. It is first and foremost a court of law. As the Institution of Engineers, Australia notes in the brochure *Are You at Risk* (1990):

> Adversarial courts are not about dispensing justice, they are about winning actions.

In this context, the advocates are not concerned with presenting the court with all the information that might be relevant to the case. Quite the reverse, each seeks to exclude information considered to be unhelpful to their side’s position. The idea is that the truth lies somewhere between the competing positions of the advocates. Further, courts do not deal in facts, they deal in opinions. Again from *Are You at Risk*:

> What is a fact? Is it what actually happened between Sensible and Smart? Most emphatically not. At best, it is only what the trial court - the trial judge or jury - thinks happened. What the trial court thinks happened may, however, be hopelessly incorrect. But that does not matter - legally speaking.

That is, in court, the laws of man take precedence over the laws of nature. This can be particularly astonishing to engineers.

3.2 Risk in Court

The courts (post event) require a demonstration that all practicable reasonable precautions are in place. The underlying issue is that if something untoward occurs the courts immediately look to establish (with the advantage of 20:20 hindsight) what precaution/s that should have been implemented but were not.

**Precautionary due diligence loop**

**Hazard based risk loop**

**Precautions vs Risk Targets**

Risk is not strictly relevant since, after the event, likelihood is not relevant. It has happened. As an Australian judge has been reported as noting to the engineers after a serious train incident; “What do you mean you did not think it could happen, there are 7 dead?” That is, the notion of risk is really only used to test the value of the precaution it is claimed ought to have been in place.
How risky a situation is before the event is not germane except in so far as an aid to determining the reasonableness of possible precautions.

This means risk control is primarily focused at rare, high consequence events, like major earthing faults resulting in death/s. Arguments capable of legal scrutiny need to be developed.

### 3.3 The Model Work Health and Safety Act

The Australian, State, Territory and New Zealand Workplace Relations Ministers' Council (WRMC) at a meeting on 18 May 2009, agreed to a framework for uniform OHS laws across Australia. The model Work Health and Safety Act was consequently prepared by the Parliamentary Counsel's Committee and the latest revision approved revision is dated 26 November 2010. It is planned to be implemented in most Australian jurisdictions (potentially excluding NSW and WA) on 1 January 2012. This imposes a requirement to positively demonstrate due diligence on responsible officers as follows:

#### 27 Duty of officers

(1) If a person conducting a business or undertaking has a duty or obligation under this Act, an officer of the person conducting the business or undertaking must exercise due diligence to ensure that the person conducting the business or undertaking complies with that duty or obligation.

The Act specifies that: officer of a body corporate means officer within the meaning of Section 9 of the Corporations Act 2001 of the Commonwealth. The Act also notes that:

(1) A person who makes, or participates in making, decisions that affect the whole, or a substantial part, of the business or undertaking of a Government department, public authority or local authority is taken to be an officer of the Crown or that authority for the purposes of this Act.

(2) A Minister of a State or the Commonwealth is not in that capacity an officer for the purposes of this Act.

The penalties under the act are severe for responsible officers. For a reckless breach (knew or made or let it happen), responsible officers can be fined up to $600,000 and/or sentenced to 5 years jail.

A general definition of due diligence is described:

(5) In this section, due diligence includes taking reasonable steps:

(a) to acquire and keep up-to-date knowledge of work health and safety matters; and

(b) to gain an understanding of the nature of the operations of the business or undertaking of the person conducting the business or undertaking and generally of the hazards and risks associated with those operations; and

(c) to ensure that the person conducting the business or undertaking has available for use, and uses, appropriate resources and processes to eliminate or minimise risks to health and safety from work carried out as part of the conduct of the business or undertaking; and
(d) to ensure that the person conducting the business or undertaking has appropriate processes for receiving and considering information regarding incidents, hazards and risks and responding in a timely way to that information; and

(e) to ensure that the person conducting the business or undertaking has, and implements, processes for complying with any duty or obligation of the person conducting the business or undertaking under this Act; and

(f) to verify the provision and use of the resources and processes referred to in paragraphs (c) to (e).

The authors suspect that the courts will be unable to use the above as a final definition of due diligence and will inevitably revert to case law for inspiration, especially the opinion of the High Court described below.

3.4 Due Diligence Case Law

Ultimately case (common) law in Australia is determined by the High Court of Australia as the highest court in the land. In an appeal to the High Court of Australia (1980) (Shipping Corporation of India Ltd v Gamlen Chemical Co. A/Asia Pty Ltd), Stephen J noted:

This appeal involves interpretation of the Hague Rules. During heavy weather in the Great Australian Bight, the severity of which was unusual but not unforeseeable, a number of drums of cleaning solvent stowed in a ship's hold broke adrift, were damaged and their contents lost. The means of securing them in place in the hold had been inadequate.

Under the Hague Rules (to which Australia is a signatory), Article IV Rights and Immunities states:

1. Neither the carrier nor the ship shall be liable for loss or damage arising or resulting from unseaworthiness unless caused by want of due diligence on the part of the carrier to make the ship seaworthy, and to secure that the ship is properly manned, equipped and supplied...

   Whenever loss or damage has resulted from unseaworthiness, the burden of proving the exercise of due diligence shall be on the carrier or other person claiming exemption under the section.

Reynolds J.A. summed up the conclusion of the Court of Appeal of the Supreme Court of NSW in the following words:

Loss or damage does not arise or result from perils of the sea where negligence is a concurrent cause. Where negligence allows or facilitates the perils of the sea to inflict damage on cargo, then in all relevant respects the loss or damage arises or results from the negligence. The perils of the sea must be guarded against by the use of due care.

The judges of the High Court unanimously dismissed the appeal to the High Court and supported the view of the NSW Court of Appeal summarised by Reynolds J.A. above.
4. **Precaution Analysis Paradigm Shift**

The two conflicting risk paradigms are summarised in the table below.

<table>
<thead>
<tr>
<th>AS/NZS ISO 31000 (Hazard based)</th>
<th>Due Diligence (Precaution based)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Establish the context</td>
<td>Establish the context</td>
</tr>
<tr>
<td>Risk assessment (hazard based):</td>
<td>Risk assessment (precaution based):</td>
</tr>
<tr>
<td>(Hazard) risk identification</td>
<td>Identify credible, critical issues</td>
</tr>
<tr>
<td>(Hazard) risk analysis</td>
<td>Identify precautionary options</td>
</tr>
<tr>
<td>(Hazard) risk evaluation</td>
<td>Risk-effort balance evaluation</td>
</tr>
<tr>
<td>Risk treatment</td>
<td>Risk action (treatment)</td>
</tr>
</tbody>
</table>

**Hazard vs Precaution based risk assessment**

The idea of target-levels-of-risk or safety used in the hazard paradigm has been under intellectual siege for some time, probably commencing from the early nineties with the failed attempt by the UK Health & Safety Executive to introduce target levels for individual and societal risk. The question often asked is “What does the determined risk number actually mean?” This is very difficult to answer. There are several issues.

Firstly, risk is not a scientific concept. Two risk experts seldom agree on the risk associated with identical scenarios. The reason seems to be that risk is not wholly a property of the natural-material time-space universe. There are elements of human values embedded throughout. The future uncertainty under consideration is a human one with all of the encoded value systems this implies.

Secondly, risk targets are not objective. The traditional way to determine them is to consider mortality statistics. But they are just that, statistics. The numbers change according to the exposed group selected. For example, the lightning strike death rate of around 1 in 10 million (for the whole population) is often selected as the lower limit to risk scrutiny. However, if the mortality figures for the group of people who play golf during lightning storms is considered, it will be much higher. Which number ought to be used?

Further, the inconsistency in individual and societal risk criteria between states, especially Victoria and NSW dating from the mid-nineties is problematic. The flexible choice of societal risk criteria for the land use planning criteria by NSW Department of Planning (DoP) for the Kurnell Peninsula QRA in the 2007 study has made some people wonder as to the exact meaning of such criteria.

Thirdly, risk calculations are always imperfect especially with regard to human failings and management systems. Quoting Mark Tweeddale (2003):

“In the case of the process industry, most of the major disasters in recent years have resulted primarily from failures of management systems, which would not have been included in the quantitative assessment of risk, and not from random equipment failures such as are statistically assessable using data from data banks. This is a most serious limitation...”

The introduction of the model Workplace Health and Safety Act by 2012 will complete in statutory terms the risk management paradigm shift from hazard to precaution analysis consistent with the common law.
The point of the paradigm shift is to ensure that all reasonable practicable precautions are in place, rather than to achieve an indefensible target level of risk or safety, which is the typical result of using the hazard based approach.

4. **Demonstrating Due Diligence**

Precautionary, due diligence risk assessment requires three key steps to be completed as described in the ‘Y’ model below.

![The ‘Y’ Model diagram](image)

4.1 **Identification of all Credible Critical Issues**

Firstly, an argument has to be mounted as to why all credible, critical issues have been identified. This can be done in a number of ways. R2A favour the use of the threat and vulnerability technique which is derived from the military intelligence community. In essence this asks the question: What are the exposed groups that are to be protected, and what are the credible threats to which they are exposed? An exposed group can be vulnerable to a number of threats.

4.2 **Identifying all Practicable Precautions**

Again, this can be done in a number of ways. The objective is to describe all practicable precautions to enable a decision to be made as to which are reasonably practicable. The authors believe that threat-barrier (sometimes known as bow-tie) diagrams are one of the best ways to demonstrate this. The basis for the technique and its use as a defence to demonstrate due diligence in court is described in the R2A Text\(^1\) (2010) and has not been re-presented here.

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A sample for a due diligence study for Energy Safe Victoria is shown below. The review was commissioned in response to safety concerns associated with abnormal voltage rises on metallic water pipes. Historically in Victoria metal water pipes were electrically bonded to the earth. If the earth fails and an electrical fault occurs then the pipes can become live and expose householders and water utility workers replacing water meters to shock.

Threat-barrier diagram

The loss of control point was defined as the point at which a exposed person, typically a plumber or water utility worker broke the conductive pipe carrying the current and was exposed to an abnormal voltage rise. The overall view was that 5 volts greater than a nearby reference ground was problematic.

The diagram shows the threat mechanisms which brings about the loss of control at the water meter. The barriers (the vertical lines) show precautions (before the loss of control point) and mitigations (after the loss of control point). The point is that this is a precaution assessment, not a hazard assessment. It describes all the barriers that could be implemented. The next step determines which can be justified.

4.3 Barrier Implementation and Quality Assurance

Barriers (or combinations of barriers) which can be justified, on the balance of the significance of the risk vs the effort required to reduce it, can then be implemented. This decision can involve quantitative risk assessment on a relative risk basis.

Some form of quality assurance system also needs to be shown as being in place to ensure that the relevant precautions are sustained over time.
5. Conclusion

The due diligence process described in this paper specifically rejects the target level of risk approach described in EG-0. And when the Model Work Health and Safety Act is implemented later this year in most Australian jurisdictions, it would seem to the authors that designers who use the target level of risk approach would be considered ‘reckless’ under this legislation and subject to the full penalties of the Act, in the event of a death or injury arising from that design.

Glossary

The following is a reduced glossary adapted from Risk & Reliability: Engineering Due Diligence (8th edition 2010).

ALARP As Low As Reasonably Practicable. That principle which states that risks, lower than the limit of tolerability, are tolerable only if risk reduction is impracticable or if its cost is grossly disproportionate (depending on the level of risk) to the improvement gained. ANCOLD (2003).

Common (Case) Law The unwritten law derived from the traditional law of England as developed by judicial precedence, interpretation, expansion and modification (Butterworths Concise Australian Legal Dictionary 1988)

Criticality The measure of the absolute consequences of a credible event, ignoring likelihood.

Due Diligence A pre-event argument that all statutory and common law requirements have been met. The standard of care necessary to minimise the likelihood of being held liable for negligence.

Individual Risk The frequency at which an individual may be expected to sustain a given level of harm from the realisation of specified (IChemE 1985).

Liability A person’s present or prospective legal responsibility, duty, or obligation (Butterworths 1998).

Likelihood A term to describe the probability or frequency of an occurrence.

Negligence Negligence is an action in tort law, the elements of which are the existence of a duty of care; breach of that duty; and material damage as a consequence of that breach of duty. A duty of care is a legal obligation to avoid causing harm, and arises where harm is foreseeable. The type of damage, not the extent must be foreseeable: Hughes v Lord Advocate (1963) AC 837. The plaintiff (as an individual or as a member of a class of plaintiff) must also be foreseeable for the duty of care to arise. The defendant breaches this duty if he or she fails to avoid the risk where a reasonable person would have done so. A proximate relationship is an additional factor to foreseeability in determining the existence of the duty of care. Proximity may be physical, (the parties being close in time
and space), circumstantial (due to the relationship between the parties), or causal (the injury being a direct consequence of the negligent act or omission): Jaensch v Coffey (1984) 155 CLR 549; 54 ALR 417. (Butterworths 1998).

Paradigm A universally recognised knowledge system that for a time provides model problems and solutions to a community of practitioners (Kuhn T S 1970).

Precautions Measures taken beforehand to ward off possible adverse events.

Risk Future uncertainty. A part of the paradox of the human condition.

Risk (Pure) The potential realisation of the unwanted consequences of an event from which there is no prospect of gain. Commonly referred to as “downside” risk.

Societal Risk The relationship between frequency and the number of people suffering from a specified level of harm in a given population from the realisation of specified (IChemE 1985).

Statute Law Law created by legislation, that is, made by Parliament (Butterworths 1998).

Tolerable Risk Risk that is not regarded as negligible or something that can be ignored, but must be kept under review and reduced further still (HSE (1988). The Tolerability of Risk From Nuclear Power Stations.).

References


NSW Department of Planning (March 2007). Hazardous Industry Planning Advisory Paper No 10. Land Use Safety Planning (Consultation Draft)

