

How Good Do Our People Have to Be? (Or – An Estimate of Reliability Requirements for Surface Coal Mining Trucking in NSW).

Dr Peter Standish¹

Abstract

The quantum of incident opportunities for traffic type losses in NSW’s Surface Coal mines is presented as the “challenge” to be addressed. A model of how these can be addressed using preventative and reactive controls is described – with and without speed and proximity devices in place.

The current death rate due to mobile equipment related incidents in NSW is (approximately) one death every three years (15 deaths from 1960-2005)ⁱ.

Considering the global experience in mobile equipment deaths in surface Coal Mines (for statistical significance) the paper examines the impacts of speed and proximity.

A Risk and Control Chart describes how even poor performing speed and proximity devices could make a significant difference to fatality outcomes.

Mobile Plant Fatalities in Surface Coal Mines

In order to set the scene – it is valuable to consider the types of incident that have led to major losses in the past.

MacNeillⁱ has prepared the data which have been filtered (based on the incident descriptions and analyses of known losses) by the author to consider the basic causes. These causes are largely related to human error.

Of the seventy eight (78) fatalities considered - sixty eight (68) had no indication of any machine fault (as shown in Figure 1 below).

These fatality data can then be analysed further to indicate where the losses are occurring and what type of reactive intervention (or control) could have prevented their occurrence.

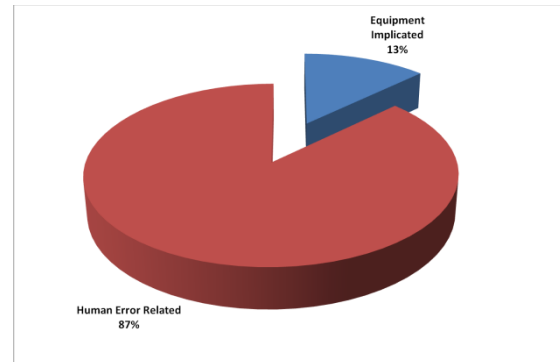


Figure 1 – Basic Causes of Mobile Plant Fatalities

The locations of the fatalities gave some guidance as to their root causes. Dump and Intersection losses and Rail related were largely related to mobile equipment moving too far in an unwanted direction. General Roadway losses were largely related to moving too fast. Table 1 below presents the data points gathered.

Table 1 – Generic Location of Fatal Incidents

Location	# of Deaths
Dump	15
Intersection	4
General Roadway	38
Rail	2

Considering the nature of the failed or absent defenceⁱⁱ as a reactive control type – led to the data presented in Table 2 below. In this table General Control failure indicates losses which could not be addressed by either proximity or speed measures – including failed boom gates and structural failure of the items being operated. Proximity relates to movements “too far” and Speed to movements “too fast” as dominant causes of the losses which occurred.

Table 2 – Type of Failed or Absent Defence

Failed Defence	# of Deaths
General Control	8
Proximity	39
Speed	31

¹ Peter Standish, PhD, B.Eng (Mine), MAusIMM, MIEAust, NPER3 has over 30 years experience in the mining industry having worked in surface and underground coal and metalliferous mines. Peter has been consulting in Risk Engineering since 1997.

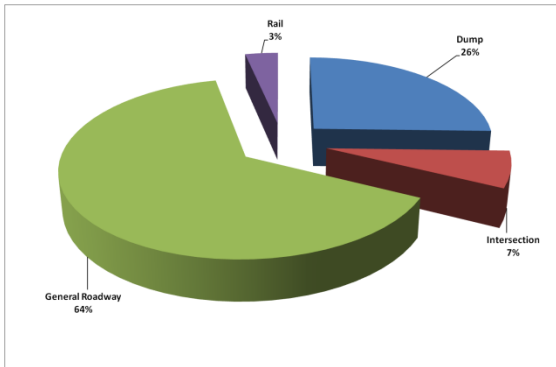


Figure 2 – Distribution of Fatalities

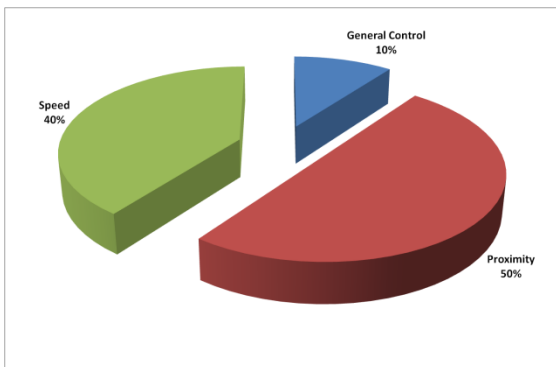


Figure 3 – Failed or Absent Defence Type

NSW Mobile Equipment Data

An estimation approach has been applied to the publishedⁱⁱⁱ production data (as at 2009). And this has been applied to the active surface coal mining operations shown in Figure 4 below.

The quantum of the issues was calculated in order to determine the probability distribution – or number of opportunities – for the various factors of human error and equipment loss to arise.

Table 3 – Estimation of Cause Occurrence Frequencies

Data Item	Value
Coal Production (based on 08-09 data) (tonnes)	118,909,000
Total Material Trucked ² (tonnes)	338,433,308
Truck Trips	1,208,690
Roadway Length (km) ^{iv}	4.5
Total Trucking Hours Required	2,685,979

² This includes waste with an estimate made on the amount moved by drag lines - which reduces the total amount of material moved that is trucked.

Data Item	Value
Hours Per Year (95%)	8322
Operating Trucks	323
Maintenance & Support Vehicles (moving - 1 per 3 trucks) ³	118
Average trips per mine / year	44,766
Number of conflicts (error points) / year	21,940
Maintenance Related Issues (Design Driven) ⁴ error points per year.	8,280

This data is used in the following section – where a risk based model is used to demonstrate the implications of these potential conflict / error



Figure 4 – Location of Coal Mining Operations in NSW^v

³ Author’s observations – based on a critical review of eight open cut coal mining operations during 2010 (unpublished report to SP Solutions’ Clients)

⁴ Maintenance related issues on critical systems were inferred as being equivalent to the failure rates of high reliability mechanical devices (0.5% failure rate potential)

Mobile Equipment – Risk and Control Chart Quantified Analysis

The Author’s company has developed a system of showing how risks can arise that involves developing a chart akin to a bow tie model^{vi} but with an ability to describe the causes and threats in either a qualitative (for example using an A-E / 1-5 matrix) or quantitative manner.

The Risk and Control Chart (RCC) for NSW mobile equipment in surface coal mines is presented in Figure 5 (below).

This Chart does need to be explained.

Like a Bow Tie^{vi} a single “top event” or incident (in RCC terminology) is considered.

In the left most column the Causes of the Incident are presented – and these are based on a critical analysis of any available published, documented or anecdotal (where other sources are absent or weak) information.

For Traffic related threats there are causes related to Human Error, Equipment Faults and Work Environment (road design / condition, lighting etc) factors. Human Error has been further broken down to include Fatigue / Fitness for Work – as this loss type has been consistently highlighted as a significant component in Mobile Plant losses.

The frequency of Human Error has been drawn from the calculated values (in Table 3) and “ranged” to allow for a reasonable spread due to the estimation methods applied for this study. This gives values from 15,000 to 30,000 “error opportunities” for mobile equipment operators – with the “most likely” value being that calculated – 24,300.

Equipment faults are also a credible cause of loss and the failure rates chosen align with industry statistics and would indicate a potential threat rate of 8,000 to 9,000 occasions per year – again with the “most likely” value being chosen as the calculated 8,280.

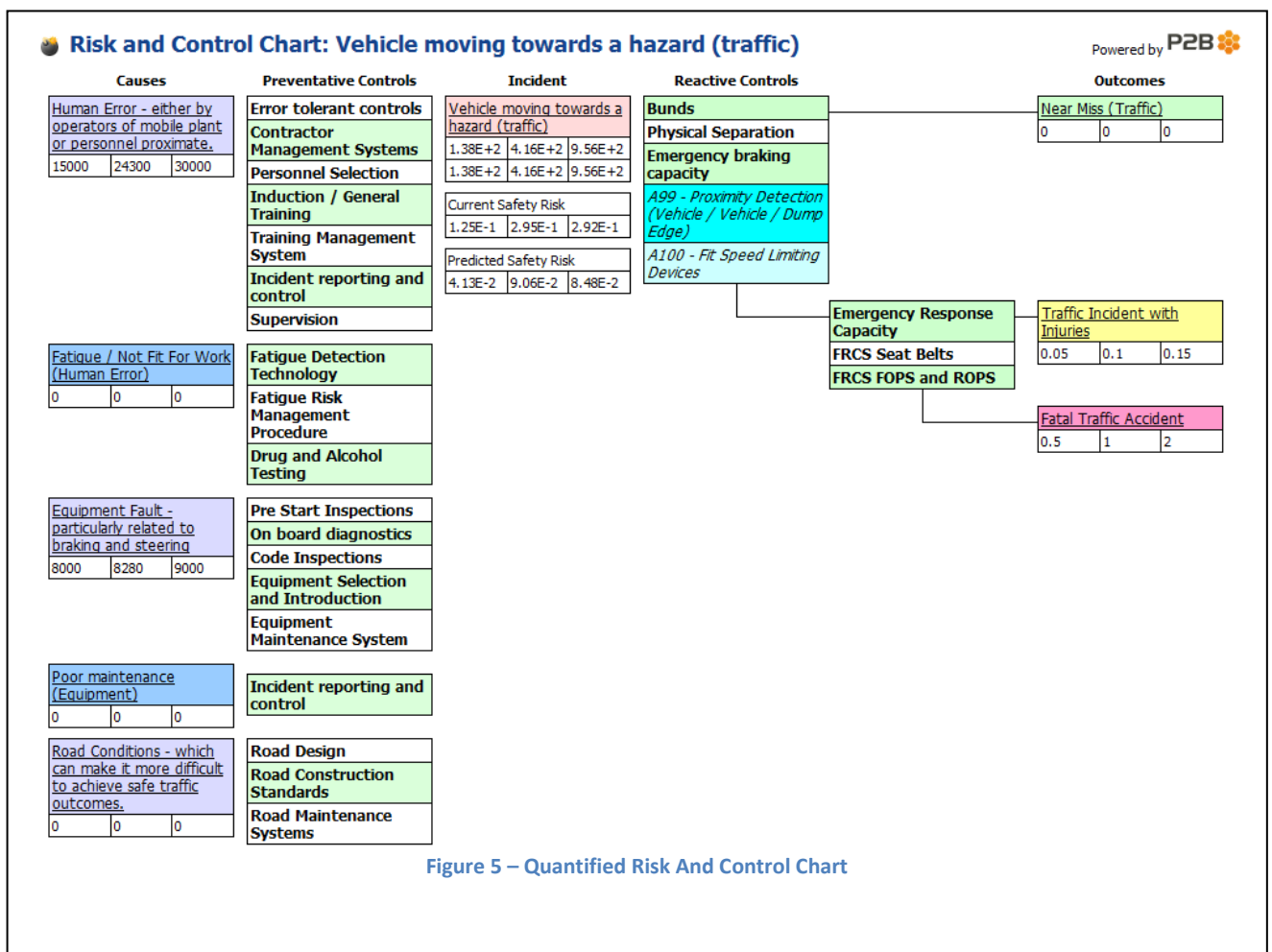


Figure 5 – Quantified Risk And Control Chart

Again – for completeness the highlighted³ threat of poor maintenance has been included in the sample chart used for this paper.

Finally the Work Environment cause of Road Conditions is presented – although no quantification of this threat was attempted – as this would “double count” the frequency. Human Error includes the failure to take account of road conditions in decision making – although this has been specifically analysed (by SP Solutions for their clients) and the controls identified included here for completeness.

There is also logic applied to the application of controls for the quantified causes. And this is included in the second “column” of the chart where each cause is matched to one or more controls.

For Human Error there is the capacity for the machinery being operated to “withstand” an inappropriate decision / command and not lead to an incident. The control of Error Tolerant Controls reflects this capacity.

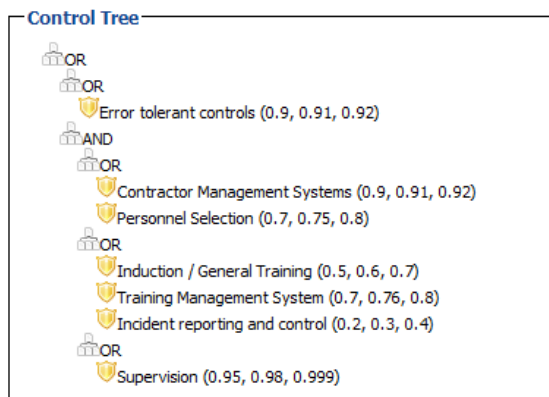


Figure 6 – Logical Application of Controls for Human Error

Figure 6 above presents the logical arrangement (and selected reliability data) of the controls. It shows that either the control arrangements or the combination of the Right People with Appropriate Skills to apply correct Methods who are adequately monitored and supervised can successfully limit the frequency of an item of mobile plant moving towards a hazard.

The reliability values are also ranged – and these values have been drawn from published data (various references). These align with Probabilistic Risk Analysis results^{viviii} that indicate multiple, redundant, system controls can reduce the frequency of incidents due to human error.

Similarly for Equipment the controls noted are those that make sure the site uses the right equipment that is appropriately checked and maintained. The logic for this combination of controls is presented in Figure 7 below.

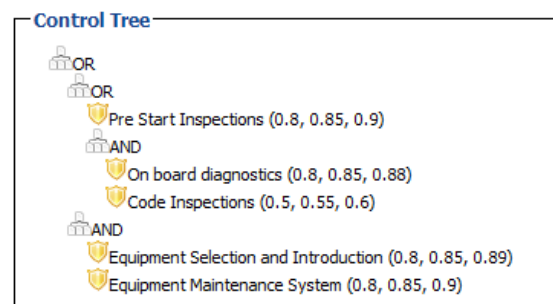


Figure 7 – Logical Application of Controls for Equipment Fault

In the third “column” of the chart the incident is presented. The “top event” in a mobile equipment related event is where a vehicle is moving towards a hazard. In this column in Figure 5 above there is also some data on risk – which will be explained in the discussion section later in this paper.

Columns four and five show the reactive controls – presented as two layers of protection.

In the first layer the ability to stop or a physical restraint (such as bunds or distance to a hazard) lead to a near miss type event (the outcome shown in the sixth column of the chart). The italicised items are potential devices which limit the speed and proximity of the mobile plant to hazards.

These are also arranged logically – as shown in the following figure.

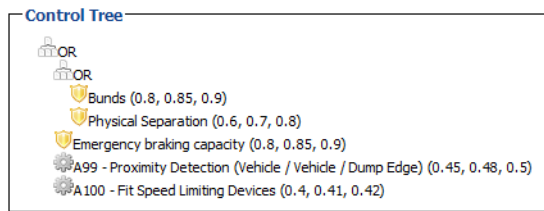


Figure 8 – Control Logic – First Layer of Protection

Again – the reliability data are based on a credible spread of values from published (and analysed) sources – and the outcome frequencies (i.e. the number of near misses) reflect the Author’s analyses of operating mines.

The second layer of protection is invoked when there is sufficient energy in the collision to cause harm – and the action of first aid / emergency response and restraint devices / protection can act.

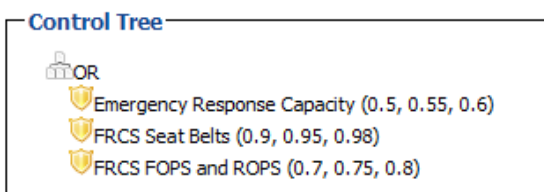


Figure 9 – Second Layer of Protection Controls

The final column of the Risk and Control Chart (RCC) shows the outcomes that can result and the consequence of these occurring.

The values selected are based on loss of life – with an allowance made for impairment at the Traffic Incident with Injuries Outcome. This indicates that major accidents have a one in ten chance (ranged from one in 20 to one in 8) of leading to a fatality equivalent.

Similarly the worst case outcome – of a fatal traffic accident is ranged from a 50% chance of survival to a multiple fatality.

Quantified Risk Discussion

The values shown in Figure 5 are not intended to be accurate – although the indicated current safety risk of 2.95E-1 gives a probability of loss of life at one death every three years – which is aligned with NSW’s accident history. The value in constructing a

model is that it allows some comparisons to be drawn.

These can be seen in the values assigned to the italicised items in the first layer of protection (Reactive Controls). The values chosen for reliability are very conservative – that is their potential for working is basically presented as 50/50.

Even with this relatively poor control effectiveness – the implementation of Proximity Detection (and Speed Limiting Devices) can have a significant impact on fatality outcomes – with a prospective lowering of fatalities from one in three years to less than one in ten years.

What this means is that more of the hundreds of traffic incidents which occur in our operations each year will lead to a near miss outcome.

This appears plausible – as with the controls uniformly applied the state’s fleet will be moving consistently at nominated speeds and will have automated braking (or other appropriate response) when approaching a hazard.

So – how good do our people have to be?

With the current controls (assuming no speed or proximity detection and response) – we’re asking them to achieve a reliability equivalent to a high functioning electronic device to avoid fatalities. This is where none of the 40,000⁵ opportunities for an incident to occur will be realised.

We could relieve them of a lot of the “pressure” to consistently avoid incidents by having better reactive controls in place – and devices which limit the speed of collision and avoid moving towards a hazard could achieve this.

⁵ Taking the maximum values for human error and equipment faults combined.

A Word of Caution

This paper is not intended to be definitive and the author has had to make a number of (hopefully reasonable) assumptions to generate quantitative values for loss of life for the state's surface mobile (coal) fleet. The model itself is reasonably simple – and represents a summary of the more extensive models prepared for some of SP Solutions' clients.

The main value to be gained when you reflect on this paper is that of considering what you are planning to implement in light of the broader suite of causes and controls. Putting your controls in a Risk and Control Chart (RCC) format can help your thinking on how controls inter-act. This in turn should lead to better fleet acquisition / modification decisions and improve your operation's outcomes – hopefully avoiding a fatal loss.

Acknowledgements

The Author would like to thank the Department – in particular Steve Bentham – for the opportunity to share our innovative approach to risk analysis.

Also – there is a clear recognition of the seriousness of this issue. The author has sadly witnessed first hand the terrible loss to mine staff / workers and families of workers where the absence or failure of defences has led to a fatality – and hopes that attendance at (and implementing the right outcomes from) the seminar will reduce the fatality rates in our industry.

ⁱ MacNEILL, Patrick – Overview of Project. *Internet Hosted Report*. NSW Department of Industry and Investment – Fatality Data Base. April 2008 <http://bit.ly/SPS-Ref001>

ⁱⁱ GIBB, Gerry – Incident Cause Analysis Method (ICAM). *ICAM Basic Investigator Course*. SafetyWise Solutions. 2009.

ⁱⁱⁱ NSW Department of Industry and Investment. Summary of NSW Coal Statistics. *Internet Hosted Report*. NSW DI&I. <http://bit.ly/SPS-Ref002>

^{iv} SME Mining Engineering Handbook. Volume 2. 1995. Pg 1395 Table 14.1.6.4 Coal Haulage Distances.

^v Australian Government, Geosciences Australia. Mineral Resources, Mines and Processing Centres. *Internet Hosted Data*, Accessed Jan 2011. <http://bit.ly/SPS-Ref003>

^{vi} Anonymous. Risk Management (Bow Tie Entry). Wikipedia. Accessed Jan 2011. <http://bit.ly/SPS-Ref004>

^{vii} Anonymous. Human Reliability. *Wikipedia Reference*. Accessed January 2011. <http://bit.ly/SPS-Ref005>

^{viii} REASON, James – Human Error. *Cambridge University Press*. ISBN 0 521 31419 4. 1990