Fatigue and Safety in Mining – A Distraction

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Abstract This paper addresses the contribution, or otherwise, of fatigue to personal damage on mining sites in Australia. It does not address personal damage involving travel to work or off-site road accidents e.g. transport of equipment to and from sites. The story which would be told with respect to fatigue and its contribution to traffic accidents in the public sector would be quite different to that which will be suggested for the mining industry.

Fatigue is a much discussed subject, particularly in the last decade. It occupies a significant space in many mining conferences, Codes of Practice, newsletters etc.

In addition, Government legislation places requirements on employees and employers with respect to fitness, duty of care etc. There are Alerts issued which reinforce the fatigue issue. Essentially, there is a complex set of "drivers" which result in an organisation's available resources being strongly directed towards fatigue management. However, should the expectation of effective fatigue management be one of a change in the pattern of personal damage from work on mining skips? Perhaps effective fatigue management has longer term implications for health and societal improvements?

This paper will suggest that effective fatigue management will not have any noticeable reduction in future occupational safety (versus health) associated with on-site work-related damage. At best it will produce minimal gains.

Introduction

The subject of fatality is an emotive one. People may quickly and inappropriately attribute fatigue as a causative factor to personal damage but the critical questions which must be asked are – to what extent is fatigue a factor in personal damage? and what are the types of situations in which it plays a part?

In answering these questions, one must be very mindful that the paper is not addressing those 1-2 hour driving periods which may occur in a high speed environment (100-120km/h) at the start of a shift roster or the end of a 12-13 hour working day. Motor vehicle crashes and fatigue involvement is a different discussion.

What does the literature say?

There is a great deal written on fatigue and its relationship to incidents. There are papers that deal with fatigue / on-highway driving and fatigue / aviation[1 2 3] which are very specific areas of study. However, there are many documents that make the tenuous link between fatigue and occupational health and safety. For example, one press release[4] states "*it also found the work hours averaging between 42-60 hours per week obviously impacted on OH&S and the industry had few, if any, measures in place to manage the effects of fatigue and other hazards created by 12-hour rosters.*"

Other quotes are as follows.

An ABC news story[5] states *"Work has resumed at a number of coal mines in Queensland's central highlands after being shut down for seven hours amid safety concerns.*

The Construction, Forestry, Mining and Energy Union (CFMEU) issued a directive just before 6:00am (AEST) yesterday to stop work at all BMA sites, claiming the company's fatigue management standard represented an unacceptable level of risk to workers".

A NSW Government Fact Sheet[6] states *"fatigue causes an increased likelihood (risk) of incidents because of tiredness and lack of alertness. Fatigue may result in a slower reaction to signals or situations and affect the ability to make good decisions and adapt to a constantly changing environment like mining. Consequently the human error component of incidents is increased along with the risks to health and safety."*

It is true that fatigue may slow reaction times but are these statements essential to the pattern of damage?" The next section of the paper will attempt to answer this.

A Mining Australia article titled "Waking up to Driver Fatigue"[7] states – *"Worker fatigue is one of the most crucial safety issues in the mining industry, particularly for heavy equipment operators.*

According to a study published in 2007 by Caterpillar Global Mining, Viewpoint, perspectives on modern mining, up to 65% of truck haulage accidents in surface mining operations are directly related to operator fatigue."

Another document, Road Safety on Mine Site[8] states as follows.

"The introductory article by State Mining Engineer Martin Knee in this issue of MineSafe is a timely reminder of the importance of a proactive 'safety culture'. In the past few months, Resources Safety has received several requests for information about road safety on mine sites. Some safety and health officers are concerned that, despite the best intentions of most of the workforce and the implementation of a variety of controls to address road safety issues, some people are ignoring workplace safety requirements or forgetting hard-learned lessons.

Part 1 of this topic concentrates on fatigue and restraint use – two of the four key behavioural issues associated with crashes (speed and alcohol are the other two)."

Another document promoting mine safety[9] discusses hours of work and fatigue, making the linkage in the mind of the reader between hours worked and safety. Under the heading "Shiftwork and Performance" it states:

"There is evidence that shiftwork affects production and safety."

However, the discerning reader would see that the remainder of the paragraph under "Shiftwork and Performance" discusses that which is known with respect to highway truck drivers, fatigue, crash exposure and the critical 2.00am to 5.00am period.

"Studies have shown increases in the number of accidents during the night shift particularly between 2.00am and 5.00am. Jobs that require concentration and alertness are most affected by night work. A number of studies have shown that in jobs such as train and truck drivers, switchboard operators and meter readers, the number of errors increase and the speed at which the job is performed decreases when performed in the early hours of the morning. Again these performance effects occurred almost invariably during the period 2.00am to 5.00am."

Therefore, one could discern from the literature published that there is a strong linkage made between fatigue and mining injuries and, hence, organisations respond with time, money and effort in response to this association. It would be true to say that fatigue / incident linkages do exist in the transport industry which is a much higher energy environment. Fatigue associated with extended hours of work may well have effects on the longer term health of a person and implications for the overall emotional health of a family. Fatigue management is necessary, but concern arises when such management is completed in the belief it will reduce site-based personal damage.

Frameworks of Thinking

To determine the contribution of fatigue to personal damage at work, several frameworks of thinking are required e.g.

Framework 1. the Pareto Principle;
Framework 2. classes of personal damage;
Framework 3. energy damages;
Framework 4. taxonomies (pattern analysis of personal damage)
Framework 5. appropriate models;.

Framework 1 – Pareto Principle

With respect to the Pareto Principle, it is the 80/20 Rule or the rule of the critical view. Essentially, a little produces the most. This is as true in managing occupational health and safety as it is in managing the geological aspects of a mine or the maintenance of mining equipment. The Pareto Principle has linkage to the notion of classes of damage.

Damage to people can be usefully classified as –

Class I – permanent
Class II - temporary, full recovery)
Class III - minor irritation.

Framework 2 – Classes of Damage

Class I, permanent alteration of life, includes fatal and non-fatal. Non-fatal damage includes an upper level where the person does not return to work and a lower level where the person returns to work in a limited capacity, time or skill.

The Pareto Principle states that one of those three classes of damage costs the mining industry and Australian society the most. With respect to all work in Australia, the question is answered by reviewing three snapshots of damage to people from work published by the Industry Commission[10] (1995), the National Occupational Health and Safety Commission[11] (NOHSC 2004) and the Australian Safety and Compensation Council[12] (ASCC March 2009). The three studies gave the 'baseline estimates of economic costs' (ASCC 2009) for the years 1992-93, 2000-01 and 2005-06. NOHSC (2004) also estimated the cost equivalent of 'pain, suffering and early death'.

Table 1 summarises relative costs (in terms of Class I, Class II and Class III damage) of the three snapshots. An assessment for 2005-06 with pain, suffering and early death is included.

Table 1 Percent distribution of the quantity of personal damage (All Industries)

	Without pain, suffering and early death costed			***With pain, suffering and early death costed***	
	1992-93	***2000-01***	***2005-06***	***2000-01***	***2005-06***
Class I Fatal	1.5	3.5	3.3	**6.5**	**6.2**
Class I Non-fatal	80.5	88.5	88.0	**90.0**	**90.2**
Class II	18.0	8.0	8.7	**3.5**	**3.6**
Cost $ billion	**$20**	**$34.3**	**$57.5**	**$82.3**	**$141.9**
2000-01 Goods and Services Exports $132.8 billion					

Figure 1 shows the relative cost of Class I, Class II and Class III work-related damage for 2000-01 and 2005-06.

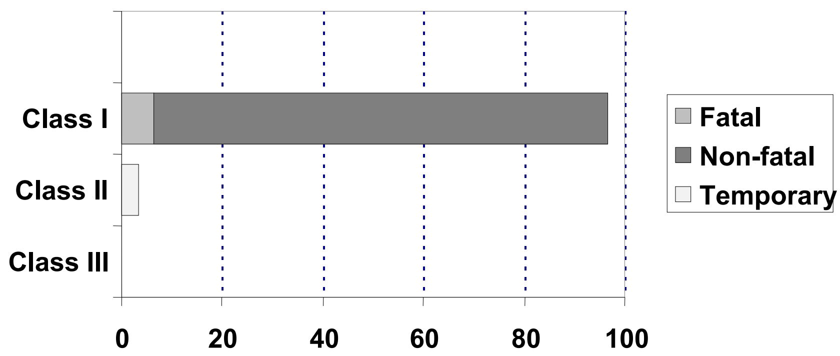

Figure 1 Personal Damage for Class I, Class II and Class III as a percentage of cost – 2000-01 and 2005-06

The proportion of costs for Class I and II damage over the years 2000-01 and 2005-06 is given in Table 2.

Table 2 Proportion of Costs 2000-01 and 2005-06 (All Industries)

2000-01	**2005-06**
6.5% Class I Fatal 90.0% Class I Non-Fatal 3.5% Class II	6.2% Class I Fatal 90.2% Class I Non-Fatal 3.5% Class II

Occupational Health & Safety is essentially a Class I problem.

Table 3 shows the daily and yearly experience of Class I damage in 2005-06.

Table 3 Number of Class I Damage Cases in 2005-06 (All Industries)

	Per Day	***Annual***
Class I Fatal	7*	2603
Class I Non-fatal	175	64,000

* (1 traumatic fatality; 6 deaths attributed to occupational disease)

In 1992-93 and 2000-01, the Class I Non-fatal per day figures were 137 and 134. Between 2000-01 and 2005-06, the workforce increased by 12% (ASCC) while the 134 Class I Non-fatal per day increased to 175, an increase of 30%.

It is quite clear that Class I non-fatal permanent damage is the Pareto, or critical, level of damage with respect to costs, whether measured in pain, suffering or impairment. Fatalities are much rarer events and cost significantly less but present sovereign risk to not only the person killed but also to surviving members of the organisation if they were to be prosecuted. However, what is the contribution of fatigue to site-based Class I damage (fatal and non-fatal). A proportion of off-site road fatalities in a high speed environment may involve fatigue. Approximately 40% of all traumatic fatalities from work in Australia involve travel to work or transport on public roads.

<u>Framework 3 – Energy Damages</u>

In 1961, Gibson[13] developed the notion that damage to living organisms was produced by an energy exchange.

"Man ... responds ... to the flux of energies which surround him – gravitational and mechanical, radiant, thermal, chemical. Some limited fields and ranges of energy provide stimuli for his sense organs; others induce physiological adjustments; still others produce injury ...

Injuries to a living organism can be produced only by some energy interchange. Consequently, a most effective way of classifying sources of injury is according to the forms of physical energy involved. The analysis can thus be exhaustive and conceptually clear. Physical energy is either mechanical, thermal, radiant, chemical or electrical."

Based on Gibson's work, the aetiologic 'agent' of injury can be clearly conceptualised as the type of energy which went outside tolerable limits of the susceptible structure. To pursue the previous example: thermal energy is the agent of burns; electrical energy is the agent of electrocution, and; gravitational energy is the agent of a fall injury. Moreover, the susceptible person in each case will suffer injury or disease based on a certain threshold being exceeded (e.g. tissue resistance to heat flow or electric current).

Gibson produced a preliminary classification of energy types. The energy-damage concept was advanced significantly by renowned American epidemiologist, William Haddon Jr[14] who summarised the conceptual basis for injury as follows:

"A major class of etiologic phenomena involves the transfer of energy in such ways and amounts, and at such rapid rates, that inanimate or animate structures are damaged. The harmful intersections with people and property of hurricanes, ear5thquakes, projectiles, moving vehicles, ionizing radiation, lightning, conflagrations, and the cuts and bruises of daily life illustrate this."

Geoff McDonald[15] strongly embraced the energy concept and developed a classification system for damaging energy exchanges. In their broadest terms, they can be classified as Human, Gravitational, Vehicular, Chemical, Thermal, Electrical, Radiation, Noise etc. Damage to people can be classified by the nature of the damaging energy. This allows for the development of taxonomies (pattern and analysis)

<u>Framework 4 - Taxonomies</u>

When one completes a pattern analysis of damage to people on the basis of the damaging energy, it is found that the Pareto principle (or, 80/20 Rule) applies i.e. 20% of the available energies produce some 80% of the damage. Research in the 1980s[16] clearly shows that the Pareto energies with respect to Class I non-fatal permanent damage are Human, Gravitational and Vehicular. InterSafe has completed research in a wide range of industries (2009) (e.g. A Study of Personal Damage in the W.A. Mining Industry[17], W.A. Construction Study[18]) which reinforces the hypothesis that these remain as the critical energies with respect to non-fatal permanent damage.

The Pareto Chart illustrated in Figure 2 applies.

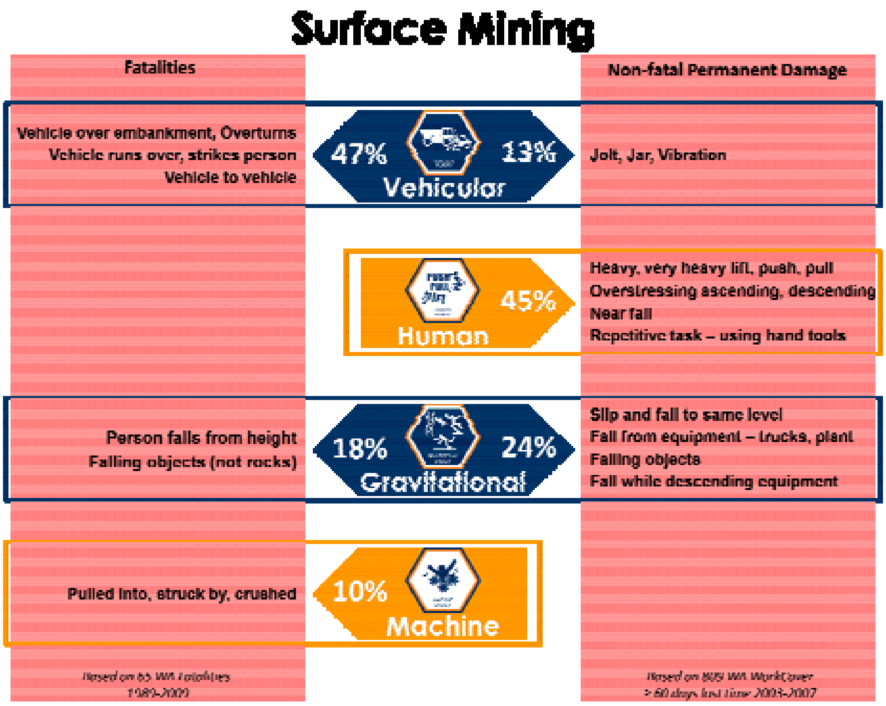

Figure 2 W.A. Mining Industry Data (Fatalities 1989-2009) (>60Days 2003-2007)

Therefore, one could conclude, based upon this line of thinking, that there must be a strong management focus on Human, Vehicular and Gravitational energies with respect to non-fatal permanent damage and a strong focus on Gravitational and Vehicular energies with respect to single fatalities if the size of the problem is to reduce. Fires, floods, explosions and structural collapse are the major descriptors of multiple fatality outcomes.

<u>Framework 5 – Appropriate Models</u>

Having established those energies which are of interest, it is necessary to have an appropriate model when thinking about damage. The scientific process involves modelling, hypothesis forming and testing. Taxonomies, or pattern analyses, show the relative importance of the different energy types. The Pareto Principle allows us to be properly focussed on that which permanently damages.

To understand the phenomena, we must go to the scientific processes of modelling and hypothesis forming and testing. A model is a conceptual frame of reference for the guiding of observations, describing and analysing the observations and preparing solutions.

A hypothesis is simply a testable proposition e.g. all green apples are sour. It is possible to test this proposition by eating a range of different of types of green apples. When new information is provided, e.g. a sweet Granny Smith apple, it is necessary to modify the hypothesis.

In the world of understanding damage, when damaged people are interviewed with respect to their damage, they are describing their hypothesis. That hypothesis is organised against a model intrinsic to the person and that model is often not understood by the person describing the situation. When the incident description is finally written, it is also a hypothesis. As the complexity of incidents increases so does the potential for multiple hypotheses.

Current investigative models have their origins in the generic classifications of “egocentric” or “ergonomic”. There are other generic classifications, e.g. sociosomatic, in which damage is seen as a symptom of society. Egocentric models abound and have their own language and propositions. For example, egocentric models hypothesise that 88% of accidents, or some variation to that percentage, are caused by human error. They have their own language of ‘cause’ (prime, root, main), ‘unsafe acts’, ‘unsafe conditions’, ‘error’ etc.

If one considers for a moment the notion of ‘unsafe’, any model that requires the listing of ‘unsafe acts’ and ‘unsafe conditions’ compels the observer to make an observation (e.g. with respect to observed human behaviour), and weigh that observation against their own internal values continuum of safe/unsafe. They then must make a value judgement and write down their perception of unsafe. This is totally unscientific.

What if the solution is to be found in the very notion of safeness? A classic example of this is the design of tractors in which people were being and continue to be run over because the access platform allows access in front of the rear wheels. When one examines the tractor from an ‘unsafe’ perspective, it becomes highly unlikely that the absence of a platform in front of the rear wheels will be recognised. This is borne out historically.

An ergonomic model will use a different set of words that maximise meaning and minimise the emotional component of “affect”. It is, therefore, useful to consider damage in terms of factors that were either essential to the final observed damage, contributory to that damage (i.e. increased the likelihood of a damaging outcome but were not essential) or simply an observation.

An example of essential and contributory factors would be as follows. A man is severely injured when jolted and jarred as a passenger in an underground man transporter. The lack of vehicle suspension would be essential. The presence of a pothole would be essential. The speed of the vehicle would be essential. The hole submerged in water would be essential. The time of the incident i.e. 10 hours into the shift may be “contributory” or not essential i.e. just an observation. The person was on the ninth day of a 10-day roster (contributory or just an observation?).

This section of the paper has attempted to set in place the necessary frameworks of thinking to make an informed judgement with respect to fatigue

Discussion

When the author completed studies of patterns of personal damage in the NSW and Queensland underground and open cut mining industries, in conjunction with Mr Geoff McDonald in the 1990s[16], the pattern of damage is the same as that which currently exists for the WA mining industry. In the 1980s, it would be difficult to argue the role of fatigue in the pattern of personal damage.

The point is that when damage occurs and involves Class I non-fatal permanent damage (the critical issue), it is difficult to attribute fatigue to a pattern of damage which is remaining relatively unchallenged over a very long period i.e. 1980-2000s.

What the author observes is strong egocentric control measures being applied to the pattern of Class I non-fatal damage which involves human, gravitational and vehicular energies. Those egocentric control measures are reflected in Table 4.

Table 4

Energy	Sub-group	Dominant Egocentric Control Measure
Human	Over-exertion	Were you lifting correctly?
Gravitational	Falls to the Same Level	Watch where you are walking
Gravitational	Ascending/Descending access systems	Use three points of contact
Vehicular	Jolt/Jar	Drive to conditions

The author would suggest that fatigue management policies and practices will not alter this pattern of Human, Gravitational and Vehicular energies at the non-fatal level and that the current and strongly egocentric control measures of Table 4 (e.g. lift correctly) will also do little to alter the size of the Class I non-fatal damage problem.

When one investigates individual incidents, be it in the 1980s, 1990s or 2000s, over-exertion tasks (Human Energy) require redesign of the task. People falling to the same level (Gravitational Energy) requires that the under-foot walking surface be addressed. Incidents involving access systems on fixed and mobile plant requires more stringent design criteria to be applied. The jolt/jar problem (Vehicular Energy) will be resolved through significantly enhancing the ride quality of vehicles (the longer term solution) and the road condition (the shorter term solution).

When one shifts to the pattern of single fatalities which strongly involve Vehicular and Gravitational Energy, it is very difficult to find comprehensive investigations of those incidents which are discerning of whether the factors in the incident are essential, contributory or not essential. Observations about an incident can be listed as “causes” and yet the “observations” are simply observations. They are neither essential nor contributory. For example, a single vehicle loss of control occurs at 8am and it is observed that the person only had an a 9-hour formal break (9pm – 6am) whereupon “fatigue” is listed as a cause but the person, upon questioning, says he was alert with no micro-sleeps etc. etc.

Having discussed the pattern of Class I non-fatal damage (remember that Class I non-fatal is the Pareto issue with respect to cost), let’s move our attention to single fatalities.

Figure 3 is a pattern of single fatalities for vehicle energy on sites in the surface W.A. mining industry.

It strongly shows the pattern of heavy vehicles over embankments, overturning and running over people but under-represents heavy vehicles driving over light vehicles and killing the occupant (3 cases in 36 years, 1 in last 20 years). One would suggest that if fatigue were a common essential factor across the range of heavy vehicle accidents on sites there would not be such a variation in the pattern of the taxonomy. It is suggested that heavy vehicles over embankments e.g. trucks will be managed through addressing other critical issues e.g. dropping short at a tip head, bund height, bund integrity, quality of lighting, drainage etc and will not be influenced by an effective fatigue management policy.

Similar observations can be made for other vehicle interactions in the taxonomy of Figure 3.

The reader must be sensitive to drawing their own conclusions about fatigue and damage by saying “in my experience.....”; “I know of a situation.....”. Your experience is valid only in the context of a much larger experience/exposure base. It takes approximately 15,000 person years of exposure in the mining industry for a fatality outcome from any energy source. A workforce of 60,000 could be expected to experience 4 fatalities on average per year (maybe 3, maybe 5 in a particular year). Therefore, we must look to the taxonomies to understand what is happening and not happening, gain insight into the relative importance of different energies and use appropriate models and frameworks of thinking in arriving at our conclusions.

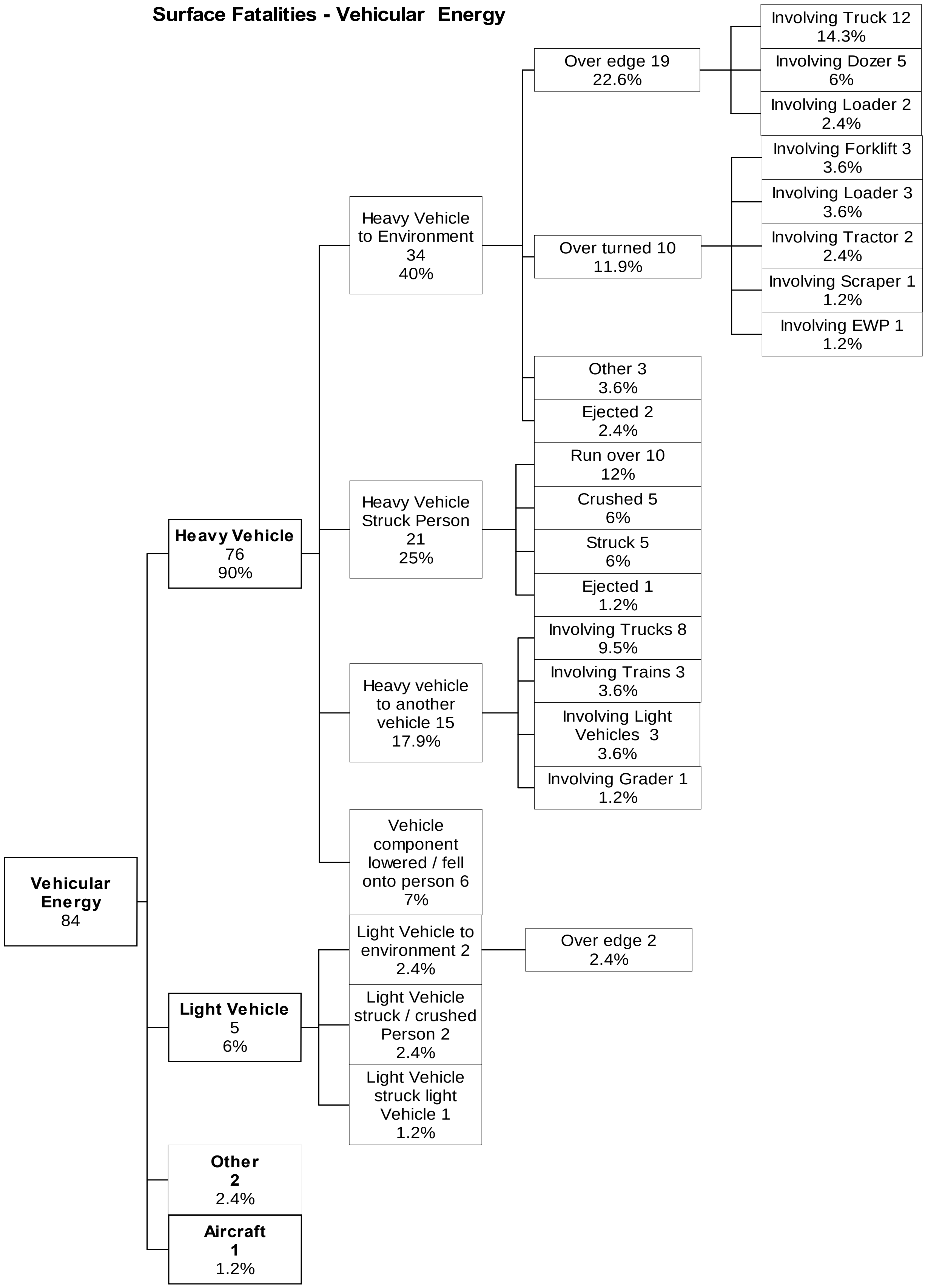

Figure 3 Surface Fatalities 1970 – 2006, Vehicular Energy

Summary

This paper has attempted to convey some framework of thinking which, when combined with what is actually occurring in the mining industry, would suggest that directing a substantial proportion of available resources to fatigue management should not create the expectation that the pattern of Class I damage (both fatal and non-fatal) will be altered significantly.

The author agrees that fatigue can play a role in off-site vehicle-related accidents. It can play a part in the long term health of people but it is when fatigue is correlated with occupational safety that the correlation becomes tenuous. Management of a mining company should be cognisant of where the Pareto levels of damage exist, the energies that produce them, the phenomena involved and aim to achieve the greatest reduction in damage for the available financial and human resources.

Off-site road fatalities in a 100+kph speed environment can drive an on-site fatigue management focus. There is a need to ensure people entering into that high speed environment are not fatigued. Don't expect fatigue management to significantly alter the on-site Class I damage.

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