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- Share information about solutions to health and safety problems;
- Encourage intellectual debate around propositions for improvements in practice.

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Prevention-focussed consideration of case in OHS

STEPHEN ALTREE-WILLIAMS

ABSTRACT
A consideration of the natural characteristics of causation in OHS has identified three functional domains into which OHS cases should be routinely separated for the purposes of statistical evaluation and prevention action. These domains are the OCCUPATIONAL INJURY(SAFETY) domain, the OCCUPATIONAL DISEASE domain, and the PUBLIC HEALTH INFLUENCE domain.

The separation of OHS cases by these three domains and the reporting of their separate rate data have the potential to greatly enhance the effectiveness of prevention initiatives because of the substantially different contribution to outcome within each domain made by factors such as hazard, hazard energy, exposure profile through time, individual susceptibility, and public health influence.

Such a separation should also be valuable for researchers using analysis of variance and hypothesis testing to objectively document the influences responsible for the OHS performance difference between industries (or occupations). It is also noted that the three domains align with the associations of OHS professional disciplines, the membership of which provides a valuable resource of ethically committed individuals whose technical knowledge within their discipline has been formally accredited through education, practice and certification benchmarks.

INTRODUCTION
The first sentence in the discussion paper produced by the Interim National Occupational Health and Safety Commission (INOHSC, 1984) articulates the essential focus of the OHS discipline on causation-directed prevention,

“In developing a national strategy for occupational health and safety there can be but one goal – the recognition, measurement and control of the causes of occupational injury and disease.”

Safe Work Australia’s mission statement is similarly direct and focussed on prevention (WRMC, 2010),

“The vision of Safe Work Australia is Australian workplaces free from injury and disease. Its mission is to lead and coordinate national efforts to prevent workplace death, injury and disease in Australia.”

The reason for this primacy is stark enough: the Australian workforce suffers hundreds of traumatic fatalities each year together with hundreds of thousands of serious injuries and diseases (Safe Work Australia, 2010a,b,c; WRMC, 2010), the majority of which have the potential to be prevented under the ‘reasonably practicable’ performance criterion of current OHS legislation.

In coming to an understanding of the way prevention initiatives can be most effectively implemented, it is valuable to consider the question...
of the natural characteristics of causation in OHS.

OHS CASE

Occupational ‘health and safety’ literally encompasses two independent natural domains: injury(safety) and disease(health).

A safety issue involves acute or short-term impact from an environmental factor of high energy. In occupational injury(safety) cases, the uncontrolled high energy is associated with the workplace and the injury occurs to a person on exposure (Wigglesworth, 1972).

Disease(health) issues come to the fore when the exposure to the environmental factor is of a lower energy, where chronic or longer-term occupational exposures may produce a disease in an individual depending on the person’s work exposure profile and on the non-work endogenous, societal and exposure characteristics specific to that person (AIHW, 2010; Safe Work Australia, 2010d).

The National Data Set (NOHSC, 2004) recognises the natural difference between these two domains,

Section 2.12: Occupational injury - . . . . "result of a single traumatic event . . . . where there was a short or non-existent latency period . . . ."

Section 2.13: Occupational disease - . . . . "result of repeated or long-term exposure to an agent(s) or event(s) . . . ."

and, while including both domains in the sole category of ‘case’ that is counted,

Section 2.5: “The statistical unit of enumeration is the case. A case is any new workers' compensation claim made by, or for, a worker.”

it does achieve functional separation of the case numbers for the two domains in its Mechanism of Incident occurrence classification (ASCC, 2008a), as summarised in Table 1. It is the Mechanism of Incident classification that captures the essentials of incident causation and, hence, provides the relevant data for considerations on prevention.

This is an essential separation. Occupational injury(safety) and disease(health) domains are different in their nature, in their causal determinants,

Table 1 OCCUPATIONAL INJURY(SAFETY) domain and occupational disease(health) sub-groups in the Mechanism of Incident classification of the National Data Set (ASCC, 2008a)

<table>
<thead>
<tr>
<th>Mechanism of Incident Major Group</th>
<th>Sub-groups comprising OCCUPATIONAL INJURY(SAFETY) domain</th>
<th>Sub-groups relevant to occupational disease(health)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 Falls, trips and slips of a person</td>
<td>01, 02, 03</td>
<td>nil</td>
</tr>
<tr>
<td>1 Hitting objects with a part of the body</td>
<td>11, 12, 13</td>
<td>nil</td>
</tr>
<tr>
<td>2 Being hit by moving objects</td>
<td>21, 22, 23, 24, 25, 26, 28, 29</td>
<td>27</td>
</tr>
<tr>
<td>3 Sound and pressure</td>
<td>31, 38</td>
<td>32, 39</td>
</tr>
<tr>
<td>4 Body stressing</td>
<td>nil</td>
<td>41, 42, 43, 44</td>
</tr>
<tr>
<td>5 Heat, electricity and other environmental factors</td>
<td>51, 52, 57, 58</td>
<td>53, 54, 55, 56, 59</td>
</tr>
<tr>
<td>6 Chemicals and other substances</td>
<td>61, 63, 64</td>
<td>62, 69</td>
</tr>
<tr>
<td>7 Biological factors</td>
<td>nil</td>
<td>71, 72, 79</td>
</tr>
<tr>
<td>8 Mental stress</td>
<td>nil</td>
<td>81, 82, 84, 85, 86, 87, 88</td>
</tr>
<tr>
<td>9 Vehicle incidents and other</td>
<td>91, 92, 93</td>
<td>98, 99</td>
</tr>
</tbody>
</table>

NOTE: Case numbers by Mechanism of Incident sub-group are available from the NOSI database (Safe Work Australia, 2010a).
in the outcomes of their bodily impact, in their risk assessment, and in the control strategies and practices that the workplace needs to apply to minimise the risk from the work environment and, thereby, to improve the workplace’s OHS outcome performance (Altree-Williams et al., 1998). Although there is an obvious regulatory commonality between these two domains (both can cause severe bodily dysfunction, both exist within the workplace) such administrative scope should not extend to reporting OHS case data as a collective whole whereby information on causation is blurred and the on-going drive for improved OHS performance is potentially impeded.

**PREVENTION-FOCUSED OHS CASE DOMAINS**

A further insight arising from the consideration of case causation is the recognition that, for disease(health) cases, the boundary between occupational health and public health causation is sometimes less than clear. Safe Work Australia (2010d) notes that, for occupational disease cases these non-work influences tend to encourage a person’s participation in the public health system and, hence, produce an under-reporting bias in occupational disease case numbers in the national OHS data. This is one point. But there may also be an insight from this observation that is relevant to the understanding of case causation in the occupational disease(health) domain.

The diffuseness between occupational health/public health influences is likely to vary considerably depending on the specifics of the case. For example, an outcome from ‘exposure to non-ionising radiation’, if non-ionising radiation is clearly identifiable with the person’s work environment, is not likely to have a significant non-work causation.

### Table 2 OCCUPATIONAL INJURY(SAFETY), OCCUPATIONAL DISEASE and PUBLIC HEALTH INFLUENCE domains in the Mechanism of Incident classification of the National Data set (ASCC, 2008a)

<table>
<thead>
<tr>
<th>Mechanism of Incident Major Group</th>
<th>Sub-groups comprising OCCUPATIONAL INJURY(SAFETY) domain</th>
<th>Sub-groups comprising OCCUPATIONAL DISEASE domain</th>
<th>Sub-groups comprising PUBLIC HEALTH INFLUENCE domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 Falls, trips and slips of a person</td>
<td>01, 02, 03</td>
<td>nil</td>
<td>nil</td>
</tr>
<tr>
<td>1 Hitting objects with a part of the body</td>
<td>11, 12, 13</td>
<td>nil</td>
<td>nil</td>
</tr>
<tr>
<td>2 Being hit by moving objects</td>
<td>21, 22, 23, 24, 25, 26, 28, 29</td>
<td>27</td>
<td>nil</td>
</tr>
<tr>
<td>3 Sound and pressure</td>
<td>31, 38</td>
<td>32, 39</td>
<td>nil</td>
</tr>
<tr>
<td>4 Body stressing</td>
<td>nil</td>
<td>nil</td>
<td>41, 42, 43, 44</td>
</tr>
<tr>
<td>5 Heat, electricity and other environmental factors</td>
<td>51, 52, 57, 58</td>
<td>53, 54, 55, 56</td>
<td>59</td>
</tr>
<tr>
<td>6 Chemicals and other substances</td>
<td>61, 63, 64</td>
<td>62</td>
<td>69</td>
</tr>
<tr>
<td>7 Biological factors</td>
<td>nil</td>
<td>71, 72</td>
<td>79</td>
</tr>
<tr>
<td>8 Mental stress</td>
<td>nil</td>
<td>nil</td>
<td>81, 82, 84, 85, 86, 87, 88</td>
</tr>
<tr>
<td>9 Vehicle incidents and other</td>
<td>91, 92, 93</td>
<td>nil</td>
<td>98, 99</td>
</tr>
</tbody>
</table>

**Note:**
1. Case numbers by Mechanism of Incident sub-group are available from the NOSI database (Safe Work Australia, 2010a).
2. The minor category variations from the above in earlier editions of the Mechanism of Incident classification relevant to the NOSI case years used were appropriately allocated in the generation of the data in Fig. 1.
whereas an activity common to both work
and non-work environments - such as body
stressing - could possibly have a significant
non-work contribution to its causation
(AIHW, 2008). In a similar way, ‘long-term
contact with chemicals or substances’ that
are part of the individual’s work activities is
less likely to have a non-work contribution
to causation than a condition common
to the general population such as mental
stress (AIHW, 2008).

Table 2 shows the results of a further
separation of the sub-groups in the
occupational disease(health) section of
Table 1. The result of this bifurcation
is to generate the two domains of the
disease(health) sub-groups as shown in Table
2: the OCCUPATIONAL DISEASE domain

Table 3  Prevention-focussed match of Mechanism of Incident group or sub-group (ASCC, 2008a) to the
technical knowledge expertise of the OHS professional disciplines

<table>
<thead>
<tr>
<th>Mechanism of Incident Domain</th>
<th>Mechanism of Incident Group or Sub-group</th>
<th>OHS professional discipline primarily relevant to prevention</th>
</tr>
</thead>
<tbody>
<tr>
<td>OCCUPATIONAL INJURY(SAFETY) domain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0  Falls, trips and slips of a person</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>1  Hitting objects with a part of the body</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>2 (less 27) Being hit by moving objects</td>
<td>A, B</td>
<td></td>
</tr>
<tr>
<td>31 Exposure to a single sudden sound</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>38 Explosion</td>
<td>A, B</td>
<td></td>
</tr>
<tr>
<td>51 Contact with hot objects</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>52 Contact with cold objects</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>57 Contact with electricity</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>58 Drowning/immersion</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>61 Single contact with chemical or substance</td>
<td>A, B, D</td>
<td></td>
</tr>
<tr>
<td>63 Insect and spider bites and stings</td>
<td>A, D</td>
<td></td>
</tr>
<tr>
<td>64 Contact with poisonous parts of plant or marine life</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>91 Slide or cave-in</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>92 Vehicle incident</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>93 Rollover</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>OCCUPATIONAL DISEASE domain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27 Exposure to mechanical vibration</td>
<td>B, D</td>
<td></td>
</tr>
<tr>
<td>32 Long-term exposure to sounds</td>
<td>B, D</td>
<td></td>
</tr>
<tr>
<td>39 Other variations in pressure</td>
<td>B, D</td>
<td></td>
</tr>
<tr>
<td>53 Exposure to environmental heat</td>
<td>B, D</td>
<td></td>
</tr>
<tr>
<td>54 Exposure to environmental cold</td>
<td>B, D</td>
<td></td>
</tr>
<tr>
<td>55 Exposure to non-ionising radiation</td>
<td>B, D</td>
<td></td>
</tr>
<tr>
<td>56 Exposure to ionising radiation</td>
<td>B, D</td>
<td></td>
</tr>
<tr>
<td>62 Long term contact with chemicals or substances</td>
<td>B, D</td>
<td></td>
</tr>
<tr>
<td>71 Contact with, or exposure to, biological factors of non-human origin</td>
<td>D, B</td>
<td></td>
</tr>
<tr>
<td>72 Contact with, or exposure to, biological factors of human origin</td>
<td>D, B</td>
<td></td>
</tr>
<tr>
<td>PUBLIC HEALTH INFLUENCE domain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4  Body stressing</td>
<td>C, D</td>
<td></td>
</tr>
<tr>
<td>8  Mental stress</td>
<td>C, D</td>
<td></td>
</tr>
<tr>
<td>59 Exposure to other and unspecified environmental factors</td>
<td>contingent</td>
<td></td>
</tr>
<tr>
<td>69 Other and unspecified contact with chemical or substance</td>
<td>B, D</td>
<td></td>
</tr>
<tr>
<td>79 Contact with, or exposure to, biological factors of unknown origin</td>
<td>D, B</td>
<td></td>
</tr>
<tr>
<td>98 Other and multiple mechanisms of incident</td>
<td>contingent</td>
<td></td>
</tr>
<tr>
<td>99 Unspecified mechanisms of incident</td>
<td>contingent</td>
<td></td>
</tr>
</tbody>
</table>

KEY:  
A. Safety Institute of Australia, www.sia.org.au  
D. Australasian Faculty of Occupational and Environmental Medicine, www.afom.racp.edu.au

NOTE:  
1. All OHS professional disciplines, including Australian College of Occupational Health Nurses www.acohn.com.au, can contribute in the technical implementation of prevention practices for all disciplines.  
2. The skills set of managers/supervisors includes the OHS of 4 – Body stressing and 8 – Mental stress.  
3. More specialised technical disciplines exist within the general scope given above; for example, the Australasian Radiation Protection Society, www.arps.org.au
and the PUBLIC HEALTH INFLUENCE domain, where the latter domain contains those disease(health) sub-groups in which non-work contribution to case causation becomes increasingly possible.

This further separation has significant functional value because the OCCUPATIONAL DISEASE domain,

a) thereby becomes largely free of under-reporting bias due to the sufferer’s participation in the public health system,

b) encompasses those environmental factors of greatest potency and potential for societal alarm (such as chemicals, radiation and biological agents).

This fuller separation of OHS case into the domains given in Table 2 also matches reasonably well with the technical knowledge expertise of the OHS professional disciplines, as tabulated in Table 3. Associations of OHS professionals by technical discipline naturally developed during the twentieth century. Such a fit is useful for prevention action because the membership of the various OHS professional associations provide a valuable resource of ethically committed individuals whose technical knowledge within their discipline has been formally accredited through education, practice and certification benchmarks.

FREQUENCY RATE AND INCIDENCE RATE [BM]
The frequency rate and incidence rate [BM] parameters provide a direct measure of the work environment’s observed risk and outcome performance for the case domain etc. under consideration (Altree-Williams, 2010). It is noted that both parameters measure of the same characteristic – observed risk of the work environment – in a similar way that the mass of an object can be equally documented through the use of kilograms or pounds. Conventionally, frequency rate documents cases per million work-hours and is used for the OCCUPATIONAL INJURY(SAFETY) domain (and its associated Mechanism of Incident groups), while incidence rate [BM] records cases per thousand FTE employees and is used for the OCCUPATIONAL DISEASE domain and the PUBLIC HEALTH INFLUENCE domain (and their associated Mechanism of Incident groups) as summarised in Table 4.

A practical problem arises when interpreting Australian national OHS data because the documented incidence rates (WRMC, 2010; Safe Work Australia, 2010a,b) are not corrected for the average employee duty cycle in the cohort and, hence, the assessment of the observed risk of the work environment derived from the published incidence rate data is biased by the extent of the deviations of the work cohorts from a defined ‘benchmark, [BM]’ employment duty cycle, such as ‘full-time equivalent’ (Wooden & Tulsi, 1989; Foley, 1997; ASCC, 2008b). Fortunately, the problem is easily overcome because the two parameters are simply related (Altree-Williams, 2010). If the employee duty cycle is benchmarked at ‘full-time equivalent, FTE’ (defined as 35 work-hours per week; 48 weeks worked per year), then for a one-year period of observation, incidence rate [bm] = 1.680 × frequency rate.

The incidence rate [BM] so calculated records cases per thousand FTE employees. Thus, incidence rate [BM] data free of the

<table>
<thead>
<tr>
<th>Prevention-focussed OHS case domain</th>
<th>Appropriate case rate parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>OCCUPATIONAL INJURY(SAFETY) domain</td>
<td>frequency rate</td>
</tr>
<tr>
<td>OCCUPATIONAL DISEASE domain</td>
<td>incidence rate [BM]</td>
</tr>
<tr>
<td>PUBLIC HEALTH INFLUENCE domain</td>
<td>incidence rate [BM]</td>
</tr>
</tbody>
</table>
duty-cycle bias can be obtained for a cohort working any pattern of hours from the frequency rate data of that cohort by the use of the above equation. The incidence rate [BM] data reported in this paper (in Fig. 1b,c) have been obtained by this method using the relevant frequency rate reported in the national OHS data (Safe Work Australia, 2010a,b) for the cohort of interest.

It is noted, in passing, that the proportionality constant in the equation above is dependent on the benchmark conditions chosen (work-hours per week; total weeks worked per year; period of observation) and can be directly calculated for any chosen benchmarking specification (Altree-Williams, 2010).

OBSERVED RISK BY CASE DOMAIN
The Australian national OHS outcome data (Safe Work Australia, 2010a) are shown in Fig. 1 for the three prevention-focused domains in Table 2 expressed using the appropriate case rate measures given in Table 4. A number of industry divisions (ABS/SNZ, 1993) are included and their annual case rate data are shown for the five year period 2002-03 to 2006-07, inclusive.

The annual case rate data through time for the various Australian industry divisions given in Fig. 1 show a number of interesting features.

Consistency. For all domains, the case rate for any one industry (or Australia collectively) is consistent through time, within a general trend of decreasing work environment observed risk over time.

Difference. There is a substantial (and consistent) difference in case rate - and, hence, in observed risk - between industry divisions. An employee in the agriculture, forestry & fishing industry was ten times more likely to suffer a serious occupational injury (Fig. 1a) than an employee in the finance & insurance industry.

Hazard Ranking. The observed risk matches that ‘expected’ from the industry’s hazard ranking in Fig. 1a (OCCUPATIONAL INJURY(SAFETY) domain) and Fig. 1b (OCCUPATIONAL DISEASE domain) but not in Fig. 1c (PUBLIC HEALTH INFLUENCE domain).

For the OCCUPATIONAL INJURY(SAFETY) domain case rates, shown in Fig. 1a, the observed risk ranking of ag,for,fish > construction = manufacturing > mining > Australia > retail > education > financial would not be unexpected, but the mining industry’s good outcome performance ranking for this domain is noted.

For the OCCUPATIONAL DISEASE domain case rates, shown in Fig. 1b, the observed risk ranking of mining >
construction = manufacturing > Australia > ag,for,fish > education > retail > financial is, again, intuitively reasonable except perhaps for the good outcome performance ranking of the agriculture, forestry and fishing industry for this domain.

For the PUBLIC HEALTH INFLUENCE domain case rates, shown in Fig. 1c, the observed risk for industries of quite diverse hazard ranking (e.g. construction, ag,for,fish, retail, mining, education) are, somewhat counter-intuitively, found to cluster within a narrow range of values.

Case Numbers. The majority of case numbers occur in the OCCUPATIONAL INJURY(SAFETY) domain and in the PUBLIC HEALTH INFLUENCE domain. For the OCCUPATIONAL DISEASE domain, cases are relatively small in number and thus the case rates obtained will be significantly less precise. It can be noted, in passing, that quantified input performance measures (Standards Australia, 2001a,b; Victorian WorkCover Authority, 2002) are particularly important for evaluating performance in the OCCUPATIONAL DISEASE domain.

As illustrated by the data in Fig. 1, the separation and documentation of OHS case and case rate data according to the prevention-focussed case domains given in Table 2 is of potential value to stakeholders faced with the continuing challenge to improve OHS performance in Australia. Such a separation should also be important for researchers looking to extend the pioneering work of Wooden (1998) by using analysis of variance and hypothesis testing to objectively document the influences responsible for the performance difference between industries (or occupations). Importantly, such separated data are readily obtainable for the cohorts included in the national OHS outcome data (Safe Work Australia, 2010a,b) using the methods described in this paper.

CONCLUSION

There remains a pressing need to reduce the hundreds of traumatic fatalities and hundreds of thousands of serious injuries and diseases generated each year in the workplaces of Australia.

The separation of OHS cases by the three domains compatible with the natural causations of OHS case (namely, the OCCUPATIONAL INJURY(SAFETY) domain, the OCCUPATIONAL DISEASE domain, and the PUBLIC HEALTH INFLUENCE domain) and the reporting of their separate rate data, as illustrated in this paper, has the potential to greatly enhance the effectiveness of this endeavour because of the substantially different contribution to outcome in each domain made by factors such as hazard, hazard energy, exposure profile through time, individual susceptibility, and public health influence.

From the perspective of prevention, it is noted that these three domains (and their component Mechanism of Incident groups and sub-groups) naturally align with the associations of OHS professional disciplines in Australia whose members provide a valuable resource of ethically committed individuals whose technical knowledge within their discipline has been formally accredited through education, practice and certification benchmarks.

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performance in OHS. J Health & Safety Research & Practice, (2)2, 34-40.


Safe Design in Construction: Perceptions of Engineers in Western Australia

DR MICHAEL BEHM & DR JOHN CULVENOR

ABSTRACT
In 2008, WorkSafe Western Australia and the Western Australia Commission for Occupational Safety and Health developed and implemented a Code of Practice for the Safe Design of Buildings and Structures to provide guidance for construction designers in meeting safe design regulations.

Design engineers were surveyed and participated in focus groups to evaluate the Western Australia construction industry’s perspective on the new code of practice and to understand the effects of construction safety in design.

The research concluded that engineers generally believe the regulations and code of practice are sensible and almost all believe construction worker safety and health is being positively impacted. Furthermore, the research indicates that the regulations and code of practice have made a positive impact on the design engineers’ duty of care, thinking, and actions towards affecting the safety and health of construction workers.

The work was carried out to understand the effects in Western Australia and also to inform the current National Institute for Occupational Safety and Health (NIOSH) Prevention through Design approach and a long-term strategy to adoption in the United States.

INTRODUCTION
SAFE DESIGN IN CONSTRUCTION
Influences on the eventual safety and health outcomes during a construction project are multifaceted and vast. The design of a construction project can have an influence on the safety and health of workers involved throughout the project’s life cycle including during construction, operation, maintenance, refurbishment, and decommissioning. In recent years design has become a focal point of researchers and regulators.

This paper addresses the question of how design engineers conceptualise their role in the sphere of what is known as ‘safe design’ Specifically the inquiry is concentrated on the construction industry in Western Australia and the messages for programs in other places such as that of the National Institute for Occupational Safety and Health (NIOSH) in the United States.

In 2007, NIOSH set forth a Prevention through Design (PtD) initiative in the United States. At the same time the United Kingdom revamped its Construction Design and Management (CDM) regulations (for background and literature reviews on this topic see Aires et al (2010), Breslin (2007), Behm (2005), and Driscoll et al (2005)). The material available on safe design stresses why it is useful and what people should do in order to get it done. Methods are being developed to assist in the process of safe design such as the CHAIR process (WorkCover NSW 2001) and more recent tools (e.g. Gengolells, et al.) including those arising from the building sector (Fleming, et al. 2007).

The initiatives have been driven by the occupational health and safety community including regulatory
bodies. However it is intended that a different group put these ideas into action; being the design and engineering community. What we know little about are the conceptual underpinnings of people like engineers who are supposed to engage in this process and how this affects their response. We do not know if they are interested in this topic, whether they see it as part of their role or whether the process useful for them.

Fadier (2003) postulates that at one time it was the job of an engineer simply to make things work. However, to achieve better safety throughout product lifecycles, or in construction and, more specifically, the built environment and its lifecycle, it is recognised that the role is a much bigger. How the abilities of engineers can be harnessed to this effect raises a number of questions such as the conceptualisation of design, the possibilities for integration of safety in design, the prediction of human actions downstream of design decisions and design methods (Fadier 2003). These questions tackle the concepts that underpin the work of engineers and their response. Their way of thinking really is key to whether the benefits that those in the occupational health and safety arena envisage can actually be delivered and by what means.

One recent approach that attempts to shape the thinking and actions of the design community including engineers is a recent Code of Practice for Safety Design in Western Australia. This instrument and the response of the design community is the subject of this paper.

THE WESTERN AUSTRALIA CONSTRUCTION INDUSTRY SAFE DESIGN DUTIES

Since its inception, the Western Australia Occupational Safety and Health Act 1984 has included specific “upstream” duties in the construction environment. The duty of designers of buildings and structures is as follows (s23(3a)):

“A person that designs or constructs any building or structure, including a temporary structure, for use at a workplace shall, so far as is practicable ensure that the design and construction of the building or structure is such that —
a) persons who properly construct, maintain, repair or service the building or structure; and
b) persons who properly use the building or structure, are not, in doing so, exposed to hazards”.

These duties however did not feature in the original sub-ordinate Occupational

<table>
<thead>
<tr>
<th>Thinking generally, when designing an “item” (structure, machine, material, process, tool, work system, etc), it is a designer’s responsibility to design/allow for...</th>
<th>Rank</th>
<th>Mean</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Making the item reliable, e.g. avoiding structural failure, overbalancing, breakdowns, overheating, etc)</td>
<td>1</td>
<td>4.85</td>
<td>0.362</td>
</tr>
<tr>
<td>The item’s purpose - e.g. capacity, power, size, output</td>
<td>2</td>
<td>4.75</td>
<td>0.588</td>
</tr>
<tr>
<td>Information that will be needed to use the item safely</td>
<td>3</td>
<td>4.67</td>
<td>0.478</td>
</tr>
<tr>
<td>Access for workers who repair or maintain the item</td>
<td>4</td>
<td>4.65</td>
<td>0.533</td>
</tr>
<tr>
<td>How safe the item will be to manufacture/build</td>
<td>5</td>
<td>4.33</td>
<td>0.859</td>
</tr>
<tr>
<td>Keeping the design to budget</td>
<td>6</td>
<td>4.17</td>
<td>0.675</td>
</tr>
<tr>
<td>How the item will be refurbished</td>
<td>7</td>
<td>4.07</td>
<td>0.797</td>
</tr>
<tr>
<td>Eventual users/workers who don’t have their mind on the job</td>
<td>8</td>
<td>3.82</td>
<td>1.130</td>
</tr>
<tr>
<td>What will happen with the item when it is no longer needed</td>
<td>9</td>
<td>3.65</td>
<td>1.027</td>
</tr>
<tr>
<td>Workers/users who take short cuts when using the item</td>
<td>10</td>
<td>3.33</td>
<td>1.207</td>
</tr>
<tr>
<td>Uses to which the item could be put other than the original purpose</td>
<td>11</td>
<td>3.12</td>
<td>0.992</td>
</tr>
</tbody>
</table>

Table 1. Total Design engineers’ response

Based on Likert Scale, 5 = Strongly agree through 1 = Strongly disagree
Safety and Health Regulations 1996. It is evident in discussions with the coordinating body in Western Australia (The WA OSH Commission as described later) that over recent years it was recognised that although the provisions in the Act had been in place since inception, they were not well understood by the duty holders. In 2007 the Regulations were amended to introduce specific safe design duties. Under Division 12 the regulations now detail the responsibilities of the following: clients (consult with the designer/main contractor regarding worksite safety); designers (provide a hazard report to the client); and contractors (record hazard report information and prepare occupational health and safety management plans, obtain or prepare safe work method statements for high risk work and monitor compliance).

The Regulations were based on a model developed in Australia at a national level. In 2005 the National Occupational Health and Safety Commission (now Safe Work Australia www.safeworkaustralia.gov.au) developed a National Standard for Construction Work. Safe Work Australia is a non-regulatory Australian national institution.

The National Standard followed recommendations of the 2003 Royal Commission into the Building and Construction Industry that concerned safe design in the construction industry. The National Standard is non-regulatory. However its development established the state of knowledge at the time and provided a basis for regulation by the jurisdictions such as Western Australia. The National Standard covers: duty holders including clients, designers, people in control of construction projects and construction sites and people engaged to undertake construction work; hazard identification and risk assessment.

Table 2. Comparison of consulting firm and community forum respondents – designers’ responsibility (as percentages)

<table>
<thead>
<tr>
<th>Thinking generally, when designing an “item” (structure, machine, material, process, tool, work system, etc), it is a designer’s responsibility to design/allow for ...</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Mean</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Making the item reliable, e.g. avoiding structural failure, overbalancing, breakdowns, overheating, etc</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>4.81</td>
<td>0.457</td>
</tr>
<tr>
<td>The item’s purpose - e.g. capacity, power, size, output</td>
<td>95</td>
<td>0</td>
<td>0</td>
<td>4.71</td>
<td>0.938</td>
</tr>
<tr>
<td>Information that will be needed to use the item safely</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>4.75</td>
<td>0.264</td>
</tr>
<tr>
<td>Access for workers who repair or maintain the item</td>
<td>90</td>
<td>5</td>
<td>0</td>
<td>4.81</td>
<td>0.052</td>
</tr>
<tr>
<td>How safe the item will be to manufacture/build</td>
<td>86</td>
<td>5</td>
<td>0</td>
<td>4.48</td>
<td>0.409</td>
</tr>
<tr>
<td>Keeping the design to budget</td>
<td>85</td>
<td>0</td>
<td>0</td>
<td>4.10</td>
<td>0.283</td>
</tr>
<tr>
<td>How the item will be refurbished</td>
<td>90</td>
<td>10</td>
<td>0</td>
<td>4.33</td>
<td>0.037</td>
</tr>
<tr>
<td>Eventual users/workers who don’t have their minds on the job</td>
<td>81</td>
<td>5</td>
<td>14</td>
<td>4.05</td>
<td>0.115</td>
</tr>
<tr>
<td>What will happen with the item when it is no longer needed</td>
<td>67</td>
<td>24</td>
<td>9</td>
<td>3.90</td>
<td>0.104</td>
</tr>
<tr>
<td>Workers/users who take short cuts when using the item</td>
<td>62</td>
<td>24</td>
<td>26</td>
<td>3.43</td>
<td>0.410</td>
</tr>
<tr>
<td>Uses to which the item could be put other than the original purpose</td>
<td>47</td>
<td>29</td>
<td>24</td>
<td>3.38</td>
<td>0.087</td>
</tr>
</tbody>
</table>

TOP – Large Design and Construction Consulting Firm (N=21)
BOTTOM – Community Forum (N=19)
processes; high risk construction work; and construction project health and safety management plans.

The National Standard employs the principles of practicability and the hierarchy of control (discussed below). The safe design features incorporated in the 2007 changes to the Western Australian Regulations were drawn from the National Standard. The Regulations have since been supported by the 2008 Code of Practice for Safe Design of Buildings and Structures. The Code of Practice is advisory in nature. Its purpose is to provide guidance to assist duty holders to understand and perform their obligations:

“This code of practice applies to all workplaces in Western Australia covered by the OSH Act. It is intended to assist those involved in designing buildings or other structures to meet the requirements of the OSH Act and the Occupational Safety and Health Regulations 1996 (the OSH Regulations). In particular, this code of practice aims to:

• explain the legal obligations applicable to a person who is in control of, or who may have influence over, the design of a building or structure; and
• provide guidelines for ways in which these obligations can be met by providing practical guidance on ways of maximising the safety of the design”

The Code of Practice uses discussion and examples to explain the ideas behind safe design. The case is made for safe design, terms are defined and principles are outlined. The Western Australia (WA) Act, Regulations and Code of Practice are now seen (Breslin 2009) as a set of comprehensive construction safety in design instruments in Australia because of the requirements on all stakeholders (clients and designers as well as constructors) and due to the code of practice which explains the requirements.

The broader context of Australian Occupational Safety and Health (OSH) legislation

For an international audience to better understand the Western Australian regulations, it is helpful to place these in the broader context of Australian OSH legislation. This is necessary in two ways; firstly that the concepts in occupational health and safety regulation can vary from those that underpin building regulation and from occupational health and safety regulation in the other places such as the United States.

Within Australia the approach to occupational health and safety legislation has been to follow that found in the United Kingdom (Johnstone 2004). This style of legislation followed the transformational changes that stemmed from the review in the United Kingdom beginning in 1970 and

Table 4: Comparison of consulting firm and community forum respondents – opinion on regulations (as percentages)

<table>
<thead>
<tr>
<th>Thinking about the WA construction safe design regulations</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Mean</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>I know my obligations</td>
<td>81</td>
<td>14</td>
<td>5</td>
<td>3.95</td>
<td>0.134</td>
</tr>
<tr>
<td></td>
<td>47</td>
<td></td>
<td>14</td>
<td>3.53</td>
<td></td>
</tr>
<tr>
<td>The regulations are sensible</td>
<td>81</td>
<td>19</td>
<td>0</td>
<td>3.95</td>
<td>0.042</td>
</tr>
<tr>
<td></td>
<td>37</td>
<td>47</td>
<td>14</td>
<td>3.42</td>
<td></td>
</tr>
<tr>
<td>I worry about being fined or prosecuted</td>
<td>14</td>
<td>38</td>
<td>48</td>
<td>2.62</td>
<td>0.075</td>
</tr>
<tr>
<td></td>
<td>42</td>
<td>26</td>
<td>32</td>
<td>3.21</td>
<td></td>
</tr>
<tr>
<td>The regulations are making a positive impact on</td>
<td>67</td>
<td>33</td>
<td>0</td>
<td>3.76</td>
<td>0.074</td>
</tr>
<tr>
<td>construction worker safety and health</td>
<td>44</td>
<td>44</td>
<td>12</td>
<td>3.33</td>
<td></td>
</tr>
<tr>
<td>The regulations unfairly target my profession</td>
<td>0</td>
<td>14</td>
<td>76</td>
<td>2.19</td>
<td>0.403</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>26</td>
<td>63</td>
<td>2.42</td>
<td></td>
</tr>
<tr>
<td>Safe design was driven by good practice rather than</td>
<td>0</td>
<td>21</td>
<td>0</td>
<td>3.90</td>
<td>0.795</td>
</tr>
<tr>
<td>legislation</td>
<td>11</td>
<td>26</td>
<td>11</td>
<td>3.79</td>
<td></td>
</tr>
</tbody>
</table>

TOP – Large Design and Construction Consulting Firm (N=21)
BOTTOM – Community Forum (N=19)
concluding in 1972 with the report titled Safety and Health at Work known as the Robens’ Report after the Chair, Lord Alfred Robens (Committee on Safety and Health at Work 1972). The regulation of health and safety had developed from the times of the industrial revolution. This approach dealt with notable concerns as they arose leading to large body of prescriptive standards. The Committee found that a new system needed to move away from externally imposed health and safety solutions toward a self-regulated model. They wrote that the “…traditional approach based on ever-increasing, detailed statutory regulation is outdated, over-complex and inadequate.” (at para 452). They envisaged legislation that would enliven creativity within industry. Recommendations to achieve this change were put into effect with the 1974 United Kingdom Act and later by similar legislation in the Australian jurisdictions which continues today.

PROMOTING A DESIGN PHILOSOPHY THROUGH THE HIERARCHY OF CONTROL

The Australian occupational health and safety law promotes creative thinking in the development of safety solutions. The Western Australian Act begins this theme in its objects where it lists one of the seven objects of the Act as being: “…to reduce, eliminate and control the hazards to which persons are exposed at work”2. The elimination of hazards requires a creative approach (for a discussion see Culvenor 1997a,b). Many and perhaps most hazards at work are part of the production processes. The hazards are intrinsic to what is happening in the workplace. Often they were put in place deliberately in order to perform a function. The aim to eliminate hazards therefore often runs counter to decisions taken in the past. This objective challenges the status quo. Given hazards are often and perhaps mostly in place to serve a function, their elimination...
requires a new way of getting the job done. This requires a creative effort. From this effort there is potential not only to solve the safety problem but to create a better way of working; perhaps more effective, more productive, cheaper or easier.

The hierarchy of control is set out in various places throughout the Western Australian regulations as it is in other Australian jurisdictions. The hierarchy of control is intended to cause an examination of any problem with a view to prompting more reliable solutions. The model is drawn historically from studies of occupational hygiene by founders in the field such as Alice Hamilton (1929). The model aims to draw attention from easy, “quick fixes” such as rules and procedures and personal protective equipment to more fundamental adjustments of the hazard levels built into a system. The low order solutions (administrative and personal protective equipment) aim at gaining a higher level of control over behaviour and increasing personal resistance to hazards within a work system. The higher order solutions aim to gain control of a work system. The low-order solutions essentially aim to ameliorate the impact of a system with known weaknesses. This is necessary and useful but the limitations must be understood. These low-order solutions have no potential to generate anything particularly new or innovative or fundamentally change the work. If the attention to rule-following or use of personal protective equipment falters or is ineffective then the hazards remain. This kind of solution is a reactive and rule-following approach focused on failures at the very end of the chain (construction site) rather than the contributing circumstances (design).

In contrast, the high-order solutions tend to be the domain of those who control the design of a work system, not those who control behaviour within a work system. Through the enactment in legislation of the hierarchy of control, the primacy of the high-order solutions is recognised. The high-order solutions present a great opportunity. They demand a high level of thinking that can result in changes to the system. The hierarchy of control model as far as construction safety is concerned therefore encapsulates the philosophy of safe design. Rules, procedures, and personal protective equipment abound on construction sites. This environment is the outcome of site managers attempting to gain control over hazards that are contained within the construction process. To gain control of the system rather than within the system, we need often to look beyond site management to site planning, programming, construction methods, materials choices, etc. This is aimed at better safety. However the benefits of rethinking a material choice, work process, design detail, and so on might be much more diverse. A simpler design may result, or a more durable material may be found, potential clashes in the work schedule may be identified and removed, etc.

**METHODS**

**OBJECTIVES**

The objectives of this research endeavour were

<table>
<thead>
<tr>
<th>Thinking about your work over the last year and perhaps a recent job or project</th>
<th>Answer to “The regulations are sensible”</th>
<th>N</th>
<th>Mean</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clients were interested in safe design</td>
<td>Did not agree</td>
<td>16</td>
<td>3.81</td>
<td>0.054</td>
</tr>
<tr>
<td></td>
<td>Agree</td>
<td>24</td>
<td>4.29</td>
<td></td>
</tr>
<tr>
<td>I have done extra training about safe design.</td>
<td>Did not agree</td>
<td>15</td>
<td>3.13</td>
<td>0.080</td>
</tr>
<tr>
<td></td>
<td>Agree</td>
<td>24</td>
<td>3.63</td>
<td></td>
</tr>
<tr>
<td>I used the 2008 WA Code of Practice</td>
<td>Did not agree</td>
<td>13</td>
<td>2.31</td>
<td>0.015</td>
</tr>
<tr>
<td></td>
<td>Agree</td>
<td>24</td>
<td>3.33</td>
<td></td>
</tr>
<tr>
<td>I have the proper formal education to implement safe design.</td>
<td>Did not agree</td>
<td>16</td>
<td>2.94</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>Agree</td>
<td>24</td>
<td>3.92</td>
<td></td>
</tr>
</tbody>
</table>
to evaluate the Western Australia construction industry’s perspective on the 2007 additions to the Regulations and 2008 Code of Practice, understand the impacts that construction safety in design practice has on the work of professionals, identify the impact that these changes have had on the industry in general. These objectives were both within the local context and in order to appreciate lessons for application of similar ideas in other places such as the NIOSH Prevention through Design program. To meet this objective, a written survey and focus group interviews were undertaken in October 2009, just a little over one year after the Code of Practice was released and two years since the 2007 safe design features were added to the Regulations.

**DATA COLLECTION AND ANALYSIS**

In order to meet the research objectives, a written survey was developed and administered to the study participants. Following the survey, a focus group forum was held in which qualitative information was discussed. The authors gave an overview of the NIOSH PtD approach in the U.S. and the objectives after the survey and before the forums. A script of questions were posed in an open forum style discussion asking about the participants’ background and experience with safe design, organisational and individual impacts of safe design, barriers and enablers, impacts on practice, and the future perspectives.

Three groups participated in the research: WorkSafe Western Australia and WA Commission for OSH (n=15); design and OSH professionals at a large design and construction consulting firm in Perth (n=35); and a community forum on safe design which was advertised by WorkSafe and Engineers Australia (n=30). The study was conducted in Perth, WA and therefore was limited by its geography not including other areas of Western Australia. Participants were not randomly selected but were self selected likely based on their interest in the code of practice and safety through design.

The survey was in the form of a 5-point Likert scale (strongly agree through strongly disagree). All dependent variables were tested for normality using the Kolmogorov-Smirnov Test procedure which compares the observed cumulative distribution function for a variable with a specified theoretical distribution, in this case a normal distribution. None of the dependent variables were normally distributed. Thus, nonparametric analyses (Mann-Whitney) were utilised. Means are provided within the tables of results to give the reader an indication of the results numerical value.

**DEMOGRAPHICS COMMUNITY FORUM**

Thirty participants attended the Community Forum held in the evening at the Perth offices of Engineers Australia. Twenty-one valid surveys were returned. The Community Forum was communicated by WorkSafe Western Australia and Engineers Australia. Nineteen participants were design engineers or who listed with design engineering experience and three were OSH professionals; one listed previous design engineering experience and was currently an OSH professional. The design engineers reported a range of experience between 2 and 40 years with an average of 18.94 years of experience. The

### Table 7: Respondents who agree the regulations are sensible compared with those who did not agree the regulations are sensible – opinion of WA regulations

<table>
<thead>
<tr>
<th>Thinking about your work over the last year and perhaps a recent job or project</th>
<th>Answer to “The regulations are sensible”</th>
<th>N</th>
<th>Mean</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>I know my obligations</td>
<td>Did not agree</td>
<td>16</td>
<td>2.94</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>Agree</td>
<td>24</td>
<td>4.29</td>
<td></td>
</tr>
<tr>
<td>The regulations are making a positive impact on construction worker safety and health</td>
<td>Did not agree</td>
<td>15</td>
<td>3.27</td>
<td>0.047</td>
</tr>
<tr>
<td></td>
<td>Agree</td>
<td>24</td>
<td>3.75</td>
<td></td>
</tr>
<tr>
<td>The regulations unfairly target my profession</td>
<td>Did not agree</td>
<td>16</td>
<td>2.63</td>
<td>0.015</td>
</tr>
<tr>
<td></td>
<td>Agree</td>
<td>24</td>
<td>2.08</td>
<td></td>
</tr>
</tbody>
</table>
design engineers reported a variety of primary construction projects, the most being heavy civil (N=7) followed by mining, residential, commercial, and industrial. The Community Forum respondents came from a variety of firm based on size, with the most being over 1000 employees (N=7) followed by small firms less than 9 employees (N=4) with the remaining being somewhere in the middle.

LARGE DESIGN-CONSTRUCTION FIRM
Thirty-five participants attended the large design and construction consulting firm’s forum, with twenty-five valid surveys returned. Three client representatives attended the forum with one returning a survey. Twenty-one of the respondents were design engineers; they reported a range of design experience between 2 and 30 years with a mean of 15.5 years. The company has a focus on safe design and that is clear from their website which states, “Safety in Design is one area where we can use safety to gain a market edge and differentiate ourselves from our competitors”.

WORKSAFE WESTERN AUSTRALIA / OSH COMMISSION
Fifteen participants attended the focus group held at WorkSafe. Twelve of the attendees were regulators and three were on the OSH Commission. One of the Commission’s attendees was a union OSH representative; the other two were OSH professionals.

RESULTS
Perceptions of design responsibilities
Participants were asked to respond to the statement, “thinking generally when designing an “item” (structure, machine, material, process, tool, work system, etc), it is a designer’s responsibility to design/allow for ...” with eleven potential responsibilities. This question provides insight into designers’ thinking when

<table>
<thead>
<tr>
<th>How has each of the following changed as a result of implementing safe design on projects?</th>
<th>Decrease (%)</th>
<th>No Change (%)</th>
<th>Increase (%)</th>
<th>Increase (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design costs</td>
<td>0</td>
<td>14</td>
<td>76</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>26</td>
<td>68</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>20</td>
<td>73</td>
<td>8</td>
</tr>
<tr>
<td>Construction costs</td>
<td>13</td>
<td>29</td>
<td>29</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>16</td>
<td>63</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>23</td>
<td>44</td>
<td>23</td>
</tr>
<tr>
<td>Design duration</td>
<td>0</td>
<td>35</td>
<td>60</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>32</td>
<td>63</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>33</td>
<td>62</td>
<td>15</td>
</tr>
<tr>
<td>Construction duration</td>
<td>10</td>
<td>67</td>
<td>10</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>47</td>
<td>21</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>57</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Construction quality</td>
<td>0</td>
<td>28</td>
<td>62</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>36</td>
<td>32</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>32</td>
<td>48</td>
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</table>
|                                  | 2            | 5             | 73           | 18           

Table 8: How has design and construction changed due to safe design? (as percentages)

Top – Large Design and Construction Consulting Firm (N=21)
Middle – Community Forum (N=19)
Bottom – Totals
it comes to the various competing variables during the design phase. Responses for all 40 design engineers from both the community forum and the large design and construction consulting firm are ranked in Table 1. Table 2 shows the percent agreement among the two groups and provides a statistical comparison for each question.

Designing for reliability and purpose ranked highest. Designers are also thinking about ‘build-ability’ and safety. Encouragingly design objectives such as information for safe use, access, safety in manufacture/construction and refurbishment are all not far behind reliability and purpose and yield average levels of agreement around the issue of keeping a design to budget. Poorer agreement however is found as the time frame is extended (e.g. refurbishment and end-of-life) and in relation to non-ideal use (users/workers who don’t have their mind on the job, taking short-cuts or adaption for alternative uses). The analysis revealed a statistical difference in thinking about how safe the item will be to manufacture/build; the large firm engineers are in stronger agreement than the community forum engineers (p=0.049). There is also a difference on the issue of how the item will be refurbished. The large firm engineers are considering that part of their duty more so than the community forum members (p=0.037), although the figures in both cases are reasonably high.

EXPERIENCES WITH SAFE DESIGN

Questions were asked about experiences with aspects of safe design over the previous year. While the previous bank of questions were philosophical, these questions targeted actual experiences with all prefaced by “Thinking about your work over the last year and perhaps a recent job or project...”. The purpose was to tap into experiences since the adoption of the Code of Practice. The results are shown in Table 3.

Design engineers in the large design and construction consulting firm agreed more than the attendees of the community forum that client/s took the lead on safe design (p=0.002) and that clients were interested in safe design (0.040). This could be an indication that their focus on safe design as a market strategy is making its way to their clients. Designers at the community forum believed that safe design was more about paperwork than making design changes compared to the large firm (p=0.047) although they still overall disagreed with the statement (z=2.37). Overall, the good news is that designers are seeking to make an impact on construction worker safety and health rather than creating risk assessment files that may not be utilised. We also analysed the variables based on the number of years of design experience using 15 years experience as a cut-off point. The only interesting variable that emerged was that designers with 15 or more years of experience disagreed more than designers with less than 15 years of experience that safe design was more about paper work than making design changes (p=0.053). Although they both disagreed with the statement, this might indicate that designers with more experience see safe design more within their overall duty of care compared to newer designers.

VIEW OF THE REGULATIONS

Questions were asked about views of the regulations. These are shown in Table 4. Design engineers in the large design and construction consulting firm believe the regulations are more sensible when compared to the community forum attendees. (p=0.042). They also believe that the regulations are making a positive impact compared to the community forum attendees. (p=0.042). They also believe that the regulations are making a positive impact compared to the community forum attendees. (p=0.042). They also believe that the regulations are making a positive impact compared to the community forum attendees. (p=0.042). The designers generally agree that safe design was driven by good practice rather than by legislation, and disagree with the statement that the regulations unfairly target their profession.

ARE THE REGULATIONS SENSIBLE?

Questions were asked about the participant’s views of the regulations. We utilised the statement “thinking about the WA safe design regulations, the regulations are sensible” as a categorising variable. Two categories were created; one for those who
agreed with that statement, and the other for those who did not agree (i.e. they were neutral or they disagreed). The purpose was to explore whether people who are in agreement that the regulations are sensible were different in their thinking compared to those who do not agree. Several significant results were found and are highlighted in Tables 5 – 7. We also included those results that approached p=0.05 to give the reader an idea of the breadth of the responses. Those who agreed that the regulations are sensible are designing for other aspects and thinking about safe design in a more proactive manner that those who did not agree with the sensibility of the regulations. One potential explanation is that the respondents who agree with the regulations’ sensibility are simply more agreeable to all questions. This is certainly a strong possibility. However, other plausible explanations exist. Consider that not all variables were significant; ten of the 27 variables showed significance at or below the p=0.05 level. During the research the large design firm discussed examples of how individual designers made design changes thinking about construction worker safety that positively impacted cost, schedule, productivity and other business measures. These comments paralleled the survey responses in that those from the large design and construction consulting firm believed more strongly that the regulations are sensible when compared to the community forum attendees (p=0.042). These two observations could be linked. The business focus on safe design of itself and/or the subsequent practice of safe design could strengthen a belief that safe design regulations are sensible.

THE OUTCOMES OF SAFE DESIGN
The final bank of questions is shown in Table 8. These questions sought views on changes in construction variables due to implementing safety in design practices on projects. Responses were the categories of decrease, no change, increase and don’t know. The results for the large firm and community forum are separated. The clearest views are found in the areas of design costs and duration and safety, quality, and productivity. There are strong views that design cost and duration have increased as a result of safe design activity. The result of this effort is thought to be in the areas of worker and end-user safety, worker productivity, and construction quality. Total project costs, depending on the magnitude of the design and construction costs, could be less and is an area to evaluate in the future. Clients and developers will be interested in this analysis.

WORKSAFE VIEW
The regulators that participated (N=12) believe the regulations are sensible ( =4.00) and that they are making a positive impact on construction worker safety and health ( =4.00). The obligations on design professionals for safe construction design have been in the WA Act since 1986. It is only since the Regulations and Code of Practice were developed in 2007-2008, that the regulators moved to enforce the legislation. WorkSafe also commented that the Code of Practice has helped establish a consistent message about the various parties’ roles for safe design in construction. When asked about enforcement logistics, the regulators said they would not knock on a design professionals’ door or utilise public bid notifications to enforce the regulations on designers. Rather, they would work through the contractors on construction sites and make a determination if it was necessary to backtrack into the design work.

DISCUSSION
THE REQUIRED INPUT AND USEFUL OUTPUTS OF SAFE DESIGN
A majority of the participants believe that design duration and costs have increased. This impact is an input into the safe design process. It should be expected. On the construction site, most believe that safe design has improved both worker productivity and worker safety. There are some who feel that construction costs have increased but construction duration has not changed. Most believe that construction quality has improved and that the safety of the end users has been improved. The strongest views are found in the level of agreement that the safety
of the construction workers and end users has improved. These are the key goals. With these key aspects there is overall a positive mood reflected in the views on matters such as job quality.

A POSITIVE MOOD WAS EVIDENT
Generally there seemed to be a positive mood about the philosophy and general practice of safe design. A large majority of designers say that in the last year they have made decisions that improved safety for construction workers (83% agree). They say that safe design works best with a collaborative approach (89%), that clients have been taking the lead (85% agree) and that they are comfortable in their role (79%). They do not believe that safe design is just a paperwork exercise (5% agree). Of course these were people interested enough in the topic to attend the forum hence they are not necessarily representative of the broader construction community. A few comments illustrate this result:

“Code of practice helps with the learning process about safe design.”

“From an asset owner’s point of view the code of practice helped establish what they had wanted for some time.”

“If you bring in operators into the design then you achieve a better result.”

“In my experience the engagement of the operator and maintainer has been relatively easy because they are usually the client. Their involvement is useful. However the builder is not usually known. So some extra process is needed to engage and perhaps pay (is the client happy to pay?) for someone to provide that input.”

Examples of changes mentioned included:
“... tilt up construction design perhaps done better”;
“...simple things like trying to remove confined spaces, provide spaces for chemical storage, etc”

The reasons are speculative but the possible factors for the positive mood could include the following. Safe design in Australia has developed as a matter of good practice rather than regulation – regulation is now underpinning good practice. The consultation period associated with the code of practice in Western Australia should be relevant in building support for safe design. Furthermore the broader Australian experience has enjoyed the benefit of the process having been previously implemented in the United Kingdom.

A TRICKLE-DOWN EFFECT
It has been a matter of policy in Australia to build safe design knowledge and practice through a trickle-down effect. The topic of safe design was introduced in a discussion paper (Durham et al 2002). Subsequent recommendations of the Royal Commission into the Building and Construction Industry (Cole 2003) were to use the purchasing power of publicly funded building and construction projects to influence safe design practice. Royal Commissioner Cole (para 170) wrote:

“Two considerations at least point to the value of the Commonwealth assuming the obligations of a model client in terms of occupational health and safety. The first relates to its substantial contribution to the industry as a client, directly or indirectly. Any occupational health and safety initiatives on Commonwealth projects inevitably will have direct and flow-on effects for the industry. The second – and perhaps the most significant – consideration is that by attending to its own projects, and to those that it is in a position to influence, the Commonwealth can lead by example. It can demonstrate that real gains can be made, not simply by prescribing the conduct of others, but by practical demonstration of method and result.”

The regulator in Western Australia likewise believes that working with the
bigger players and industry associations is the best approach at present – the big players will then influence the smaller players. An example of the influence of clients and of changing recognition of safe design was relayed at the WA OSH Commission forum. An inspector at the forum said that in the 1980’s an attempt was made with the designers of a large public building about the future difficulties of cleaning a glass roofed atrium. The discussion at that time gained no traction. A mobile elevating platform is now used which is an expensive and awkward solution in a public area. By contrast a story was related about the current development of a new hospital. The regulator contacted the client (government) who responded favourably and since there has been useful consultation between the architects, users and operators. This process it seems was initiated by the client. It can certainly be argued that this should be happening without prompting. The point however, was that the environment today meant that a small input at the right level met with useful action. This is a significant change from the 1980’s. Today the regulator can point toward a specific regulation which gives the suggestion a reference point. Furthermore the stakeholders in the project today have an awareness of the topic built up through a lengthy consultation period over the introduction of the code of practice and therefore understand the process. Evidence of this can be noticed in the responses of designers at the large consulting firm to those at the engineers’ community forum. The designers from the larger firm experienced clients that were (a) more interested in safe design and (b) taking the lead on safe design.

A WAY OF THINKING
The participants recognised some safe design aspects such as the provision of instructions and consideration of safe manufacturer and maintenance - but only it seems with ‘proper’ use. Distant factors (reuse) and perceived misuse are less well supported. However this is probably changing over time. We are hampered by a lack of baseline perceptual data, however the following comment was made at the community forum:

“An accident happened recently where a person fell 15 floors to their death after a plastic chair on which they were standing collapsed and they fell over a balcony (due to the location of a light). The problem could have easily been averted by a light fitting on the wall which any good designer should know about today.”

In this designer’s opinion the vision of the designer should now extend to the effects on users throughout the life of the structure – such as the people changing the light bulbs. Breslin (2007) discusses this balcony lights design issue in more detail. The reference to what a good designer should know “today” seems to indicate that perhaps in the not-too distant past a designer may have not taken this into account. In this person’s view it seems that perceptions are changing for the better in terms of safe design.

RESPONSE TO REGULATION
Most people think that the regulations are sensible (60% agree). This is not an overwhelming majority but most others are neutral (33%) which may be because they are not familiar with the legislation. Further those who do not agree that the regulations are sensible are also less inclined to agree with responsibilities like designing for eventual workers who might not have their mind on the job (p=0.001), workers or users who might take short cuts (p=0.005), and what happens when the item will no longer be needed (p=0.050) Hence the uncertainty about the value of the regulations is correlated with views about safe design philosophy. We are therefore more likely to gain support for and engagement with regulatory approaches if the philosophy and reasoning is understood.

WHAT DOES IT MEAN – AN OPPORTUNITY FOR CREATIVITY
Overall, the results show that, in general, design engineers in Western Australia agree with and support the construction safety and health through design concept. Design engineers in the large firm gave a more
favourable response but this is likely due to the emphasis within that firm on this ideology as a market differentiation or driver. For example, one engineer described his involvement with a telescopic column canopy for service stations. This idea was developed by thinking about construction worker safety and seeking to minimise work at height. By developing a hydraulic lifting process, the canopy could be constructed quicker and with less cost.

“The results from this particular innovation have been very encouraging; the total man hours required to work at height on canopy installations has been reduced by 95 per cent, almost eliminating the need to have workers exposed to risks associated with such work. The telescopic column canopy has also reduced the critical path of a construction timeline of a site by seven to 10 days on average.”

By focusing on worker safety, the engineer was able to create a win for safety and a win for cost and schedule. It demonstrates the innovation and creativity that can develop when a designer focuses on something outside their original sphere of expertise. Another example provided was that of communicating design hazards in a steel column placement where large columns had to be installed within an existing building. The engineer communicated a method for the constructors to clamp and bolt the column into place. Additionally, the engineer communicated the potential hazard of high wind and specified a maximum wind speed which should not be exceeded during construction. This example demonstrates the duty of care logic and how it carried over to means and methods of construction. In the United States, such means and methods would typically be left to the constructor without input from the design team. A frequent barrier listed by designers in the U.S. to implementing the design for construction safety and health concept is that of means and methods being solely the constructors’ responsibility (Gambatese et al 2005). We brought up the question during the focus group discussion of whether the role of design has changed. The designers brought up their duty of care frequently in the discussions stating that it is within their duty to consider construction workers and build-ability. The duty of care is not new and appears to be generally accepted that construction workers are included within that duty of care.

CONCLUSIONS
The regulations and code of practice for safe design of buildings and structures in Western Australia have made a positive impact on design engineers’ thinking and actions towards positively affecting the safety and health of construction workers. Designers are generally innovative and creative professionals. New innovative and creative thoughts have emerged by focusing on construction site safety and health. These design changes can sometimes impact more traditional construction business measures, such as quality, cost, and schedule in a positive way.

The design engineers were found to be generally supportive of the concept. They are not only willing to provide information to constructors regarding hazards and risk arising from and identified in the design phase but are actively seeking to make design changes that will positively affect construction safety and health. In other words, they are not simply conducting risk assessments and design reviews in a check-the-box manner. Rather, they have integrated creative thinking to construction safety just as they would any other project goal. This ideology is best summed up by a quote from the large design and construction consulting firm’s website:

“Understand how innovation can eliminate risks rather than just mitigate it, during project construction.”

For jurisdictions seeking to diffuse the construction safety and health through design concept, such as the U.S. NIOSH through their PtD initiative, several recommendations were generated from this research.

First, the proper environment is needed
to ensure a positive mood among the design community. Western Australia has the benefit of a long history involving the duty of care concept, which design engineers have largely bought into that this duty includes construction worker safety and health. NIOSH's approach within PtD seeks to positively impact education, practice, research, and policy and appears to be a proper long-term strategy to create the positive mood and momentum for diffusion within the design community. The proper environment for concept adoption must be created before regulations are sought.

Secondly, the trickle-down concept is appealing. The early adopters and champions of new concepts, such as construction PtD, can provide demonstration projects and case studies so that the design industry can learn about the methods that work and do not work. Incorporating the construction safety and health through design concept into large government projects would be a method to demonstrate effectiveness to the larger industry. Linking the construction safety and health through design concept to sustainable and green construction would be another method to introduce the concept to the industry.

Thirdly, the relationship between the construction safety and health through design concept and construction project business measures should be researched more thoroughly. Understanding the concept's impacts and limitations in business terms will aid the design community and the construction industry to identify enablers and barriers to safe design.

Lastly, this research highlights that innovation and creativity can sometimes be stimulated by focusing on construction site safety and health. Finding the win-win situations and understanding how the processes that enable such innovation and creativity are keys to overall adoption. The strength of association between a view that the regulations are sensible and other metrics was also notable. Which comes first here—the conceptual understanding—or belief in the value of the regulations has not been established.

The broad conversation and promotion of safe design in Australia has a longer history than the regulations. It seems likely then that a strong conceptual understanding in this case has led to acceptance of the regulations. For instance the development of the Code of Practice was a process involving community consultation over a number of years. The approach of building support for the concepts and practices first and then underpinning these with regulatory instruments would therefore be indicated. Jurisdictions considering methods to adopt construction safety and health through design should not rush into a regulatory approach; rather, this research demonstrates the benefits of a cooperative effort which can ultimately benefit workers and business value.

There are several areas for future research as a result of this study. Our research did not include architects and this is a limitation of the findings. A larger study should include architects as well as design engineers. Additionally, other geographic areas of Western Australia should be included in the scope. While this research serves as an indication of the impact the regulation and code of practice has had, a future study utilising a web-based survey among the Western Australia design community would be useful. During the study, several examples of the concept in practice were provided. It would be useful, especially for the practical implementation of construction safety and health through design concept, to document case studies that in turn could be used to educate and spur innovation amongst the design community.

Overall, Western Australia provides an excellent opportunity to learn about the concept of construction safety and health through design and how regulation and a code of practice can reinforce the philosophy and practice of safe design. Follow-up research to evaluate the effects of the code of practice on the Western Australian construction industry safety and health metrics should be conducted. Jurisdictions seeking to revise or develop regulations in the area of designing for construction safety and
health should consider evaluating Western Australia’s approach.

ACKNOWLEDGEMENTS
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REFERENCES


**Determining industry response to the Construction Induction Training in WA**

**DR SUSANNE BAHN1**  
**DR LLANDIS BARRATT-PUGH2**

**ABSTRACT**  
This paper presents the results of a 2010 study on the effectiveness of the Construction Induction Training in WA (previously known as the “Blue Card”). The findings indicate that the commercial construction sector values the development of the Construction Induction Training, are supportive of the mandatory nature of the training and believe that the training has not only increased their personal safety awareness but has contributed to a positive improvement in the safety culture on construction worksites. There was strong support for a refresher Construction Induction Training course on a regular basis to inform workers of legislation changes and to present changing construction processes. This is evidence of a positive shift in safety culture that was not apparent in 2007 when Bahn (2009) identified considerable resistance to the introduction of mandatory ‘Blue Card’ training from the industry. At that time participants were strongly opposed to the safety awareness training. They were unsupportive of the compulsory nature of the training and considered the Blue Card would simply become an additional legislative hurdle financially burdening the industry, producing little measurable gain. In addition the idea of a refresher course was considered unnecessary. Data collected for the study includes a survey distributed to 669 members of the Master Builders Association of which only 25 responses were returned, and thirty semi-structured interviews with clusters of supervisors, OH&S Managers, and employees at five commercial construction sites, and key industry stakeholders. This paper specifically focuses upon the issues encountered in collecting statistical data from this cohort.

**The Construction Induction Training**  
Worksafe Western Australia (WA) took a step towards improving the safety culture in the construction industry in WA by introducing a mandatory safety awareness induction, the ‘Blue Card’ in 2006/07, for all construction workers. The aim of the Blue Card was to ensure that all construction workers had minimum training in general site safety including working at heights, working in confined places, general lifting, and working with hazardous materials before they worked on any construction site. The Blue Card was additional training that did not replace company, site specific, or job role inductions. In 2009, there was a move to replace the state Blue Card with a national training program ‘Construction Induction Training’ or commonly referred to as the ‘White Card’) that ensured a minimum safety standard for all construction workers in Australia. The reasoning behind this move was that the previous Blue Card was only valid in WA and did not reflect the need for more universal and transferable national competencies. The state Blue Card required renewal and re-training every 3 years, however the Construction Induction Training provides workers with a statement of attainment for a unit of competency (CPCCOHS1001A) within the construction industry training package CPC08 and thus does not require any further reassessment (CPSISC, 2011). The CPC08 is the national training package for the construction industry and provides and range of nationally endorsed qualifications for construction employees from the basic Certificate I level, all the way...
through to Vocational Graduate certificates at level 7 in the Australian Qualification Training Framework (AQTF). Thus, the Construction Induction Training course complies with the AQTF framework and specifies a set of competency elements that guide the delivery and assessment of the training and places the successful trainees with a credit towards further industry qualifications. Registered Training Organisations (RTOs) determine how to deliver the elements of competency to the participants, requiring them to develop their own course design and supporting training materials. Some RTOs indicated in the study interviews that to deliver all the required elements effectively would require more than a day’s training for most employees to achieve competence. However, the Construction Induction Training course varies in length considerably between training providers. Some providers train the Construction Induction Training face-to-face in a day-long course, while others operate over 3-4 hours, with some RTOs achieving course delivery and assessment in an hour. Some RTOs deliver the training and assessment online.

SAFETY CULTURE
The actions of individuals within organisations influence most industrial accidents that occur (Hopkins, 2005). Individuals are strongly influenced by what they perceive to be the expected, or expedient, safe work practices of the workplace. They are influenced by the safety climate/culture that surrounds them which consists of both formal practices and informal learning from watching and imitating others. Guldenmund (2000) suggests that safety culture and safety climate in organisations are in fact the same positivist construct that can be understood as a sphere with three layers. At the centre of the sphere is the basic assumptions held by the organisation (the way we do things around here): the culture. The middle layer of the sphere is the safety climate: the values and attitudes of the organisation regarding safety. The outer layer of the sphere is the artefacts: the accidents/incidents, PPE, safety posters, etc. We base our understanding of organisational safety culture on this holistic view.

Martin (1992) recommends that in order to promote a safety culture organisations need to introduce organisational behaviour change models and initiatives. The Construction Induction Training is one example of a safety behaviour initiative designed to modify work practices and the subject of this research. However, a good safety culture does not mean there will be no incidents at all, but that if these occur they will be responded to openly and considered a learning opportunity (Reiman & Oedewald, 2002). A study conducted in 2002 (Prussia, Brown and Willis, 2003) with workers in a high-hazard industry found that the convergence of supervisor and worker attitudes towards safety created a good safety climate. This is supported by the 2005-08 study conducted by Bahn (Bahn & Barratt-Pugh, 2009) in the civil construction industry that found that the value managers placed on safety led to the level of safety culture in the workplace. Other research found that safety culture is determined not only by employee/manager commitment, but by ability, leadership and the communication styles of management that are supported by the participation, competency, training, behaviour and attitudes of the individual employee (Farrington-Darby, Pickup, & Wilson, 2005; Glendon & Stanton, 2000; Guldenmund, 2000). The literature is mainly focussed on safety culture and climate but is limited on the effectiveness of training in the construction industry. However, safety culture and training are not independent of each other in the workplace. Those that place a value on safety often place a higher priority on training. Marsh, Robertson, Phillips, & Duff (1995) believe that cognitive clarification and increased commitment should contribute to increased safe behaviour and productivity; and employees should have a clearer idea of what they are expected to do and more reasons for wanting to do it well. The Construction Induction Training is designed to provide workers in the construction industry with basic safety awareness and provides examples of safe work practices within a safe work culture.
RESEARCH DESIGN
This study was designed as a case study of the Construction Induction Training intervention within the commercial sector of the industry in two phases; a survey to stakeholders; and semi-structured interviews with stakeholders. Each phase gathered evidence that informed the construction and focus of the subsequent stage in an iterative fashion. The study also developed through an action learning approach (Stringer, 1999), collecting data and reviewing the findings collaboratively with a reference group established for this study. Members of the reference group were made up of representatives of Worksafe WA, the Construction Training Fund, the Master Builders Association, the Housing Industry Association, the Australian Workers Union, the Construction Forestry Mining and Energy Union and Edith Cowan University. The reflections on the data collected both informed the subsequent data collection, and also developed recommendations to fine-tune the current practice of the Construction Induction Training. Table 1 depicts the sample for the study.

Table 1: The Sample

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<td>Incident Statistics</td>
<td>Tabulation and segmentation of Commercial Construction sector records from Worksafe WA for the previous 6 years – Pre and during the Construction Induction Training scheme.</td>
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<td>Questionnaire</td>
<td>Distribution to the complete Master Builders Association Membership of 669 CEOs and supervisors - 25 returned completed.</td>
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<td>Semi-Structured Interviews</td>
<td>23 interviews with clusters of supervisors, OH&amp;S Managers, trained employees at two commercial construction sites. 17 were conducted as telephone interviews and 6 as face-to-face.</td>
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<td>7 interviews with representatives of peak/key bodies: Construction Training Fund, Worksafe WA, Master Builders Association, Housing Industry Association, two unions, and a Registered Training Organisation. 6 interviews were conducted as telephone interviews and 1 as face-to-face</td>
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<td>1 focus group with representatives from the Training Accreditation Council.</td>
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Three key research questions drove the study. Having experienced the Construction Induction Training in the construction industry during the past 3 years in WA:
1. How effective has the training been for the industry?
2. How effective have the training practices been for the industry?
3. How has the training impacted upon organisations and safety in the industry?

THE FINDINGS

Quantitative data
The response rate to the survey was a mere 4%, with only 25 completed questionnaires from a mail out to nearly 700 potential participants in two separate distributions. As researchers we were naturally concerned at the low response rate and argue that this is an indication that online questionnaires are not supported by a participant group that is particularly manual in their work practices, site based, in temporary and changing accommodation, and not regularly working with computers. However, even with the low response rate saturation of responses was reached and the key issues emerging from the responses were aligned with and validated by the interviews that followed the questionnaire phase of the study.

Nearly all of the completed surveys (21) were from companies operating in the commercial sector; with only a few in the civil sector (1) and in the housing sector (3). Most of the respondents (18) conducted...
work in the Construction Induction Training, and two remaining undecided. The evidence indicates that generally the respondents did the time allocated to the survey training was adequate. However, this is an interesting finding in that the time taken for RTOs to deliver the training varies from one to all day training. It appears that without comparisons, respondents are happy with what they are receiving.

The respondents were asked if they perceived that after their staff completed the Construction Induction Training there was a measurable benefit to their business. The majority (17 participants) agreed with this statement, with a further 3 participants strongly agreeing and the remainder simply undecided; therefore the vast majority (20 participants) of those surveyed perceive the Construction Induction Training to be of value to their businesses. This is evidence that the level of acceptance to improvements in safety culture is greater than was apparent in 2007 when Bahn (2009) identified considerable resistance to the introduction of mandatory 'Blue Card' training for workers.

The respondents were asked whether they believed that the Construction Induction Training assisted their business by reducing incident rates. Nearly all of respondents believe that the Construction Induction Training assisted their business by reducing incident rates.

The evidence indicates that generally the respondents perceived the Construction Induction Training to be of value to their business. This is evidence that the level of acceptance to improvements in safety culture is greater than was apparent in 2007 when Bahn (2009) identified considerable resistance to the introduction of mandatory 'Blue Card' training for workers.
However, there were some minority cynical views of the training of respondents did not; with the supporting statement:

• [I]Often wonder if some people on site have attended a safety training course, they have the relevant card but make basic breaches on site.

Respondents were asked to comment on the extent they believed that the Construction Induction Training contributed adequately to basic safety awareness, as a first stage, prior to site-specific and job-specific training. Twenty of the responses were positive and included statements such as:

• Training at this level helps bring the focus onto safety issues before they arise.
• It is only basic training but it does give the employee a head start when continuing that training.
• It gives a broad overview of risks likely to be encountered on site - especially good for people new to the industry.

However, additional comments such as those following indicate that those working in the industry for many years (‘old hands’) may be less influenced by the training; and that some staff do not see the value in the training or indeed absorb the training due to its compulsory nature.

• Training seems to work better on novices in the industry, the “old hands” think they know it all and tend to treat training as an encumbrance rather than a benefit.
• As the cards are a pre-requisite to working on a construction site, some employees obtain the card but do not appreciate the course content; the site management are continually required to remind them of basic safety issues.

The respondents were asked to suggest improvements that could be made to the Construction Induction Training. Responses included making the course more detailed for ‘different skill levels’; providing more emphasis on the ‘responsibility of individuals for front line safety’; and providing ‘more stringent testing’. One respondent suggested that the Construction Induction Training would be more effective if the course was conducted on site. Other responses included specific course content such as a lack of knowledge of their staff in understanding Job Safety Analysis and that this section of the course could be expanded upon; and that some of the test questions were ambiguous. One respondent suggested renewal of the Construction Induction Training should remain at every three years rather than life accreditation. Finally, one participant made the following comment about the online delivery and assessment of the Construction Induction Training:

• NO ONLINE testing as this can be sat by anyone.

Three quarters of the respondents indicated that they had used a number of different training providers to deliver Construction Induction Training to their staff. Some respondents had used the MBA training; others the Construction Skills Training and others had utilised online training due to the ‘logistics of their operations’.

The respondents were asked to indicate from six responses what they looked for when choosing a training provider. Figure 2 illustrates their responses. Most of the respondents (18) indicated that the location of the classroom for training delivery was important, while about half (11) indicated that the cost of the training was a factor. A third of the respondents indicated that class start time influenced their choice of training provider, while a half indicated that the length of the training influenced their choice, with just one respondent suggesting the length of the course should be increased from two hours to four. Respondents who chose face-to-face and online delivery indicated that having these options influenced their choice of training delivery and both groups were equally satisfied with their choices. However, one respondent commented that for those companies operating in regional areas that ‘online courses are a lifesaver for our business’. An additional comment was made by one respondent in that there were issues
of availability of the courses run by training organisations which limited when they could enrol their prospective staff.

Figure 2: Influences in selection of a Construction Induction Training provider

QUALITATIVE DATA
The interview data was gathered from more than 30 semi-structured interviews with construction managers and managers responsible for the organisation of training and certification. The interview data responses were consistent through the diversity of perspectives on the focal issue and confirmed the emerging themes of the survey findings. The interview data revealed that in general participants were happy with the course content of the Construction Induction Training. Most participants acknowledged that the course is safety awareness training and is the first step to a deeper site-specific induction that does not replace the need for further training.

• I think it’s good, you know obviously you can’t teach everybody everything they need to know in 3 or 4 hours but it does get the guys to think a little bit and covered a lot of the important aspects of working on site. I think the contents pretty good.

• I found it to be a very informative course and I do honestly believe that it should be a minimum requirement for anyone working on a construction site.

The most valued section of the training was the information on duty of care. It was stated by some participants that this was the only forum in which they were exposed to the OSH legislation and they appreciated the chance to be informed of current requirements.

• When it’s being delivered it is basically focussing on the duties of care. People often still don’t understand that.

However, some participants felt that the content was delivered at too high a level and should be catered to participant abilities for the construction audience. This was particularly an issue for non-English speaking participants, where understanding could be limited due to the use of complicated language.

• I think one of the issues we’ve got is the delivery of 457 workers into the state and their English is not good.

In addition the quality of the assessments was questioned by many, indicating that they were ineffectual, as ‘those who paid passed’.

• I felt the course content for the White Card didn’t go into the detail that the Blue Card did.

• If I had any criticism of the Blue Card courses it’s I would say that the questions at the end are possibly just a little bit too easy. I don’t know of anybody who’s failed the Blue Card course. Multiple choice and a lot of the questions are pretty obvious.

The majority of those interviewed were unaware that the Construction Induction Training is now a unit of competency. This is partly due to the unit of competency only coming into effect since the transition from the Blue Card in September 2008/09. Participants suggested that if the significance of the accreditation was emphasised there would more support for the Construction Induction Training and the training might hold a higher value within the construction industry. Participants suggested changes to the Construction Induction Training content and these included: practical assessments, provision of standardised supporting materials, and additional emphasis placed on the unit of competency statements of attainment.
• We’ve just got to do the bloody thing and don’t care if it has a certificate or not.
• Most workers may just want the card, however RTOs also don’t understand what a statement of attainment is now that it’s a unit of competence. The Blue Card didn’t have a statement of attainment; it’s only with the White Card.

Construction Induction Training is delivered in WA in face-to-face and online modes. Generally participants believed that the face-to-face delivery mode was the preferred option as it allowed interaction between trainer and participant. However, the mandatory requirement of the Construction Induction Training resulted in resistance from workers, particularly those who had been in the industry for some time. For these workers their intrinsic knowledge of the industry enabled them to pass the Construction Induction Training online and receive accreditation with a minimum of engagement with the training, and loss of production. For those working in remote areas in WA the online mode provided easy access and accreditation. However, the data indicates that there are issues of certification by deception, where other staff complete the training for those with limited language or English skills, or where certification is required immediately. In contrast some companies are opposed to the quality of the online delivery and assessment and do not accept accreditation through this method of training. Despite the introduction of a national system this study has uncovered instances of such as WA workers moving interstate having completed the Construction Induction Training online and yet have not had their training recognised in another state.

• The issue we have with doing it online is we don’t know the person holding the card actually went through the course online and answered all the questions. You know anybody on his computer at home to do it for you online and we would never know but if you’ve got to go in there yourself, that’s not so easy. That’s the only reason why, we can’t be sure that person has actually done it themselves.
• I believe we did have problem with the training delivery. Firstly the online option I know a lot of the contractors we used had done that online option and I believe there is an issue out there with non English speaking employees someone can complete the online training for them and giving them the cards so they can get access on site, that is probably one of the major issues on site at the moment.

The commercial construction sector has embraced the move to national Construction Induction Training even though in 2010 OHS in Australia is still regulated by a number of different individual state OHS Regulations, supporting the Federal OSH Act (1985). The Construction Induction Training addresses OHS content with a particular focus on duty of care. This aspect of the legislation is consistent across the state jurisdictions with the main difference being the levels of fines for a breach. Most in the industry believe the Construction Induction Training provides enough content to make the participant aware of their duty of care and this is of paramount concern in the industry. The levels of fines are viewed as secondary. However, the industry is generally opposed to one-off training of the Construction Induction Training. The participants were very vocal about the need to refresh the Construction Induction Training as a means of revisiting the content, informing staff about legislative changes and checking up on continued competency. Changes to OHS legislation are occurring (national harmonisation of OSH Acts and Regulations) and the Construction Induction Training is positioned as a suitable forum that could be used to inform the industry. The construction industry has a transient workforce with workers moving in and out of the industry that it appears would benefit from localised refresher programmes.

The data indicated that most participants believed the mandatory Construction
Induction Training had made a positive effect on workplace safety. Almost all participants agreed that their workplace had increased safety awareness and that the Construction Induction Training along with other safety inductions specific to their individual workplaces attributed to a safer culture. Generally participants held the belief that the Construction Induction Training had increased their personal safety awareness. Those that did not hold this belief were long-term workers in the industry. However, even though these long-term construction managers did not believe the Construction Induction Training had increased their safety awareness as individuals, these same respondents were convinced that refresher training was essential for maintaining safer workplaces.

DISCUSSION
Occupational Health and Safety research often involves collecting statistical data; for example lost time injury data informs much research in the field. Keeping this in mind we designed the study to gather data from three sources: injury statistics specific to the commercial construction sector, a survey and semi-structured interviews. In issuing the survey to 669 Master Builders Association members we expected a large volume of completed data, especially since we had designed the survey together with the enthusiastic study reference group and it was accessible online. We planned to validate the survey data with the interviews and drill down into specific issues. When we achieved a response rate to the survey of a mere 4% after issuing the survey twice to the MBA membership we were indeed relieved that we had designed the study with a mixed methodology. Access to the participants to conduct interviews was extremely unproblematic with most interviewees keen to talk about their experiences with the Construction Induction Training. We came to the conclusion that workers who are site based and manual are reluctant to complete online questionnaires as this may not be a tool they are familiar with and access to computers on site may be limited. The lessons learned from this study include the recognition that collecting data in a traditional quantitative way needs adjustment when researching this cohort and that mixed methods studies or purely qualitative data collection may be more abundant and rich sources of data.

The study findings, taken predominantly from the interview data, indicate that the commercial construction sector values the development of the Construction Induction Training, and are supportive of the mandatory nature of the training. We acknowledge that there may be a possibility of positive bias in the survey responses in that those with a favourable disposition toward the training are more likely to reply. However, our findings indicate that the respondents believe that the training has not only increased their personal safety awareness but has contributed to a positive improvement in the safety culture on construction worksites. There was positive support for a refresher Construction Induction Training course on a regular basis to inform workers of legislation changes and to present changing construction processes. This is evidence of a positive shift in safety culture that was not apparent in 2007 when Bahn (2009) identified considerable resistance to the introduction of the mandatory ‘Blue Card’ training from the industry. At that time participants were strongly opposed to the safety awareness training. They were unsupportive of the compulsory nature of the training and considered the Blue Card would simply become an additional legislative hurdle financially burdening the industry, producing little measurable gain. In addition the idea of a refresher course was considered unnecessary. These attitudes appear to have disappeared, and this mandatory approach to learning may be part of the cultural shift.

The main criticism of the course delivery focussed upon the assessment process. Although 50% of respondents used the online training delivery of the Construction Induction Training because of its easy access and availability, there were suggestions that the online assessment of the Construction Induction Training is open to misuse. Participants expressed the views that there
is no guarantee that a person holding the Construction Induction Training Card is necessarily the same person who completed the training online. It is these concerns that have resulted in some RTOs and companies moving to a policy of only accepting face-to-face training modes for the Construction Induction Training. Some participants have suggested that a requirement to complete a practical assessment would alleviate the issue of obtaining Construction Induction Training certification by deception. These issues of the validity of simulated training and learning experiences and the use of online assessment to bridge the tyranny of distance are challenges for the industry to build upon what appears to be a cultural change. A mandatory approach appears to have been embraced by the industry.

CONCLUSIONS
The review of the introduction of pre-site mandatory training in the commercial construction industry indicates that there is a broad acceptance of benefits of the initiative across by the managers surveyed and that it has become an embedded feature of the industry safety culture. The change from the local Blue Card to the national Construction Induction Training programme has raised some anomalies in the industry that may require further policy investigation. The Construction Induction Training is significantly different in three ways from the previous Blue Card: it is based on a National competency, it is an accredited unit of the AQTF (a part of the CPC08 Training Package) and it does not require tri-annual refresher courses as it awards trainees a statement of attainment that is a lifelong competency. There remains a concern about online delivery and its adherence to quality standards compared to face-to-face methodology; particularly the training assessment. Overall, stakeholders indicated that the introduction of mandatory pre-site safety training has been a significant driver in moving the safety culture of the industry forward.

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INTRODUCTION
Miners are constantly exposed to a range of hazards which have the potential to cause serious injury or fatality. These hazards include fire, underground explosions, toxic gases, geotechnical hazards, and working in close proximity to mining equipment such as haul trucks, continuous miners, shuttle cars. Equipment related safety hazards include collisions, being caught between moving equipment parts, as well as exposure to energy sources such as electricity and high pressure fluids (Burgess-Limerick & Steiner, 2006).

Effort has been sensibly devoted to eliminating hazards and reducing risks through implementing design controls. However, it has been recognised in mining (Schofield et al, 2001), as in other industries such as aviation (Helmreich & Foushee, 1993) and rail (e.g. McInerney, 2005), that there will always remain the potential for miners to make skill-based or rule-based errors. For example, failure to perceive a hazard is consistently identified as contributing to injuries and fatalities (Kowalski-Trakofler & Barrett, 2003). In addition, another integral aspect of improving mine safety has been an increased focus on ensuring that employees and contractors are competent to perform their duties, and trained in the actions to take if an unplanned event with adverse safety consequences occurs.

A Review of Virtual Reality as a Medium for Safety Related Training in Mining

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ABSTRACT
A common problem for high risk industries such as mining is how to provide effective safety related training. Virtual reality simulation offers the opportunity to develop perceptual expertise, perceptuo-motor skills, and cognitive skills such as problem-solving, and decision-making under stress, without exposing trainees or others to unacceptable risks. This review examines the evidence for the effectiveness of virtual reality as a medium for safety related training in mining.

Evidence exists to demonstrate the effectiveness of virtual reality as a medium for safety related training in a range of other industries (e.g. training perceptuo-motor skills of pilots, surgeons, and drivers of a range of vehicles; maintenance inspection tasks; spatial awareness for specific locations; and improved decision making under stress). However, no satisfactory systematic evaluation of performance changes, or transfer of learning, has been undertaken in mining contexts, with almost all previous evaluations restricted to usability of the simulation and subjective trainee responses. Where performance changes as a consequence of training have been assessed, the evaluations have utilised poor evaluation designs, and very small numbers of trainees. A large scale, systematic, evaluation of the outcomes of safety related training via virtual mining environments is required to inform future practice.

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A review of traditional training methods used in mining (Churchill & Snowden, 1996, cited by Schofield et al, 2001) suggested a number of potential problems, including:

“...rote learning of information is the most common technique used by trainers with the same sets of training media being used from year to year. Many teaching methods present too much material, too rapidly, with little or no opportunity for worker involvement.

Trainees frequently fail to attend to the problem at hand, often dividing their attention between what is going on at the front of the classroom and interpersonal interactions with those around them. ...

Skill degradation is an important issue. When the hazards of a mine environment are combined with the issue of skill degradation, the need for realistic training becomes paramount.” (p. 154)

Schofield et al (2001) proposed that virtual reality simulation offered the opportunity to improve safety related training in mining, suggesting that “the capacity to remember safety information from a three-dimensional computer world is far greater than the ability to translate information from a printed page” (p. 155).

There is no doubt that virtual reality simulation offers the opportunity to develop both perceptuo-motor skills, and cognitive skills such as problem-solving, decision-making and hazard perception, without exposing trainees or others to unacceptable risks. This strategy has been employed in other hazardous industries such as aviation, rail, health and defence.

For example, Blickensderfer et al. (2005) provide a historical review of the development of simulation in pilot training. Considerable evidence exists to demonstrate the effectiveness of virtual reality in this domain (e.g. Lintern et al, 1990; Biocca & Delaney, 1995; see Hays et al, 1992 for a meta-analysis; and Carretta & Dunlap, 1998 for a review). While flight simulators have been consistently demonstrated to result in skill acquisition by pilots, the effectiveness of the training is strongly influenced by the task to be trained and the amount and type for training provided. Simulators have been found to be more effective for training take-off, approach and landing than for other flying tasks. Landing skills, and instrument flying learned in a simulator, has also been shown to transfer to the real task (Hays et al, 1992; Pfeiffer et al, 1991).

Similarly, strong evidence exists to demonstrate that learning of surgical skills may be achieved in virtual environments (e.g. Issenberg et al, 2005; Gurusamy et al, 2008), and evidence also exists which demonstrates that virtual reality simulations is effective as a means of training drivers of cars (Fisher et al, 2002; Roenker et al, 2003; Uhr, 2004), trucks (Parkes & Reed, 2006; Strayer et al., 2004) snow plows (Kihl & Wolf, 2007; Masciocchi et al, 2007), and emergency vehicles (Lindsey, 2005) in terms of both safety related behaviour, and fuel efficiency. Evidence also exists to suggest that virtual environments can be used to improve the hazard awareness of novice drivers (Fisher et al, 2006; Pollatsek et al, 2006) and motorcyclists (Liu et al, 2009).

Evidence is available to suggest that an immersive virtual environment is an effective training medium for aircraft maintenance inspections (Barnett et al, 2000; Vora et al, 2002). The performance of naval fire-fighters in wayfinding around a ship during a subsequent exercise was found to be improved (fewer wrong turns) by rehearsal in a virtual environment (Tate et al, 1997), suggesting that spatial awareness for specific locations may be learned in a corresponding virtual environment.

The development and evaluation of virtual environments for training in decision-making under stress has a strong empirical basis provided by the military. In 1998 the US Office of Naval Research
completed a seven-year research project focusing on decision-making under stress (TADMUS) (Cannon-Bowers & Salas 1998). Rather than focusing on skills development, the focus here is on ensuring that performance does not deteriorate under stressful conditions, hence - Stress Exposure Training (SET) (Driskell & Johnston, 1998). Stress Exposure Training has been demonstrated to transfer to performance in novel environments (Driskell et al, 2001), and has been adopted as a standard training tool in Defence.

THE USE OF VIRTUAL ENVIRONMENTS FOR SAFETY RELATED TRAINING IN MINING

The potential for improved safety suggested by Schofield et al (2001) and others (e.g. Bise, 1997; Filigenzi, et al, 2000; Wilkes, 2001) has been embraced by the mining industry, and virtual reality simulation is beginning to be adopted. Kizil (2003), for example, suggests that “There is no doubt that the use of VR based training will reduce these injuries and fatality numbers” (p. 569). This conclusion may be premature.

The general difficulty with evaluating the effectiveness of training in a virtual environment is that it is first necessary to measure performance of the skills being trained, before and after, training. An initial evaluation question would be: how does final performance compare to baseline measures? That is, did performance improve following exposure to the training? A second evaluation question might be: how does performance after exposure to training in the virtual environment compare to performance following conventional training methods, or real world practice?

These are important questions, however, the true test of the effectiveness of training, whether in a virtual or physical environment, is whether the skills learned transfer to different contexts and situations (Bossard et al, 2008). This is a difficult topic to address empirically in many contexts, and this is especially so for safety-related training because of the hazardous nature of the contexts.

A range of equipment simulators including dozers, draglines, haul trucks, shovels, continuous miners, longwall and roof bolters are available from commercial vendors with others under development. While reports of their use are available (e.g. Williams et al, 1998; Wilkes, 2001), no systematic performance evaluations could be located. One exception was a conference paper by Swadling & Dudley (2001) in which operators’ performance while driving a virtual simulation of a remote Load-Haul-Dump LHD vehicle (VRLoader) was compared with the operators’ subsequent performance during driving the remote LHD. The simulation was found to be an effective training tool, and performance on the simulation was predictive of subsequent performance while driving the remote LHD.

A jackleg drill simulation (MinerSIM) aimed at training new operators (Dezelic et al, 2005; Hall et al, 2008; Nutakor, 2008) has been constructed. MinerSIM consists of a web tutorial, and a virtual reality simulation which allows trainees to install rock bolts in a virtual environment. The simulation provides exposure to both normal, and abnormal situations. The only evaluation results available to date are preliminary results of a usability assessment of the web tutorial component.

Based on the results of evaluations of equipment operation in other domains, it is likely that equipment simulators will be effective in assisting trainees develop the perceptuo-motor expertise required to operate the equipment, and that this will reduce the real world practice necessary to achieve competent operation. This has potential safety benefits for both the trainee, and others located in the vicinity of the equipment.

A virtual conveyor belt safety training program has also been described (Lucas, 2008; Lucas et al., 2007, 2008; Lucas & Thabet, 2007, 2008). The simulation consists of an instructional module, and a task-based training module in which
the trainee completes assigned tasks. Both desktop, and immersive versions, have been described. The development of the simulation, and a usability evaluation has been reported.

A similar application was described by McMahan et al (2008) in which training in pre-shift inspection for haul trucks was provided in both desktop and immersive virtual environments. The training included a “virtual tour” which introduced the information necessary to conduct a pre-shift inspection (parts to be inspected and explaining defects). The trainees then completed a virtual inspection, and were shown a simulation of the potential consequences of overlooking defects.

McMahan et al (2010) reported an evaluation of the effectiveness of this training in terms of the retention of information after using the virtual reality simulation, by administering a knowledge assessment test before and after using the simulation. While a significant improvement in knowledge was found following the training, the evaluation design was flawed and an order effect cannot be excluded because all participants performed the knowledge assessment test twice. A comparison of the effectiveness of the desktop version to the CAVE version, and to conventional “powerpoint” presentation was also reported (N=9, 10 & 10 respectively). Again, although no significant differences in knowledge retention were found, the statistical power of the comparisons was very low, and the conclusion drawn (that the methods were equally effective) is very likely erroneous.

The ability to detect and identify hazards has been another target for training in virtual environments (e.g. Filigenzi et al, 2000; Orr et al, 1999). Squelch (1997; 2001) provided hazard awareness training via desktop virtual reality. A comparison with traditional training methods was attempted for two groups of 30 miners. While the trainees reported that they preferred the virtual reality training, no quantitative comparison between two training media was possible.

Denby et al (1998) similarly trained mine operators in hazard identification and hazard avoidance using a desktop virtual haul truck, processing plant walkthrough, and underground fire and explosion, however no evaluation was reported other than trainee reactions. Schafrik et al (2003) provided reconstructions of accidents using desktop virtual reality to “emphasise the significance of unsafe acts” as a method for influencing safety culture, although no evaluation was undertaken.

Training in hazard identification has also been extended to include procedural information. For example, van Wyk (2006, van Wyk & Villiers, 2009) trained underground mine workers in hazard recognition and correct safety procedures using desktop virtual reality and reported “positive results in South African context” although no results were provided. Stothard et al, (2008) similarly aimed to improve understanding of hazards, procedures and processes. A survey of 51 trainees was undertaken to assess psychological characteristics of the trainees and their reaction to the simulation (immersive tendency and presence), however no evaluation of the understanding gained was reported.

Desktop virtual reality training for miners has been of interest for some years, with one of the earlier desktop applications being to educate mine workers on the hazards of mining, and in safe evacuation routes and evacuation procedures discussed in the previous section (Orr et al, 1999). More recently, the use of gaming technology is gaining popularity with a number of training alternatives based on this technology appearing in the area of mines safety training. NIOSH offers desktop virtual reality based training in underground coal mine map reading.

The program “Mine Navigation Challenge” was built using a first person shooter computer game engine and is designed for new miners. Trainees can practice using skills trained while
navigating through a simulated mine. To successfully complete the tasks, trainees count cross-cuts, go through man doors and find belt crossovers. It is reported that the game was tested in new miner classes at three training locations as it was being developed. This field testing, however, conducted in 2007 appears to be limited to a qualitative survey provided to trainees and instructors. Questions gauged the degree to which trainees liked or enjoyed the session, what parts of the course they liked best and if they would like computer-based sessions in future training (NIOSH, 2009).

The Queensland-based Mining Industry Skills centre (MISC) has also focused on serious-games with project CANARY (MISC, 2009). It is described on the MISC website as ‘an industry first serious-game based training tool.’ This project offers a suite of PC-based training scenarios which have been built using the game engine Virtual Battle Space 2, an engine previously used by the Australian military to run defence-specific scenarios for Australian and international forces pre-deployment. The hazard awareness scenario is designed to be used in a facilitator-led classroom and depicts a mine site workshop in which a clean-up needs to be performed while identifying key hazards and applying tagging and isolation processes. No underground scenarios are available. No evaluation of its use in the mining sector could be located.

Very limited research exists regarding the effectiveness of serious games for training miners. Private companies developing serious games either do not evaluate their product in applied settings or do not release publicly in-house evaluations of their products (Mallet & Orr, 2008). The military, both in Australia and overseas, but most notably in the United States, are investing significantly in what is still to a large degree an experimental use of this technology. There may be value in such applications, however much military research is not accessible to researchers working in civilian industries. Clearly those developing computer-based scenarios for training miners should be devising associated evaluations (Mallet & Orr, 2008).

CONCLUSION
There are promising results derived from other domains which indicate that virtual environments can be effectively used for safety related training, at least in some situations. These results suggest that there is potential for virtual environments to be effective in the minerals industry. However, other than evaluations of usability, or the subjective impressions of trainees, there has been little systematic evaluation of the effectiveness of virtual environments as a training medium in the minerals industry. Where evaluations have been undertaken, the designs were poor, and the sample sizes very small. A large scale, systematic, evaluation is warranted.

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