in this issue:

3  Toward a meaningful way to measure whole body vibration in motor cycle riders exposed to rough surfaces

11 Using the Critical Decision Method for Incident Analysis in Mining

23 “Being” versus “Going” Native: an Account from the OHS Field

34 Frequency, incidence, observed risk and outcome performance in OHS

JOURNAL OF HEALTH & SAFETY RESEARCH & PRACTICE

Volume 2 ISSUE 2
Journal of Health & Safety Research & Practice

The JHSRP is an international publication of the Safety Institute of Australia. It is aimed at health and safety practitioners, researchers and students. The journal aims to:

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

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ISSN 1837-5030
Since the publication of the first issue of the *Journal of Health and Safety Research and Practice* and its launch by The Governor General, Her Excellency Ms Quentin Bryce AC, the editorial office has received a very encouraging number of manuscripts for review. This indicates that there is a high level of interest in a journal of this nature as well as preparedness by safety professionals and researchers alike to share knowledge and ideas and subject those to rigorous peer-review. Interest in subscriptions by libraries and individuals is growing.

One measure of success of the journal is the number of citations that articles receive in other journals. This requires widespread distribution of the journal and its articles;

Caption: The Governor General, Her Excellency Ms Quentin Bryce AC launches the JHSRP at Admiralty House, with the (then) National President Mr Barry Silburn (left), Editor in Chief Dr Steve Cowley and (then) Dean of the College of Fellows Dr Geoff Dell (right)

in this issue:

3 TOWARD A MEANINGFUL WAY TO MEASURE WHOLE BODY VIBRATION IN MOTOR CYCLE RIDERS EXPOSED TO ROUGH SURFACES

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34 FREQUENCY, INCIDENCE, OBSERVED RISK AND OUTCOME PERFORMANCE IN OHS
distribution beyond the Safety Institute of Australia (SIA) membership. Following a 6-month period of SIA member and subscriber-only access, the release of the first issue into the public domain via the internet (www.sia.org.au) assisted with this. There is evidence that a relationship exists between open access and increased citation rates (Open Citation project 2009) and the redesign of the Journal web pages that facilitate access by web crawlers has been important. Summaries of both embargoed and open-source articles are now presented to an international audience of health and safety professionals; allied professionals; researchers; and students via Google Scholar and other bibliographic database search engines.

A limitation on any journal of this nature is the availability of qualified individuals who are willing to freely give their time to undertake reviews, provide constructive criticism to authors and then review subsequent drafts. The JHSRP Editorial Board is assisting with the growth of a database of reviewers and the assistance of both board members and reviewers is very much appreciated. We are very pleased to announce the recent appointment of Dr Felicity Lamm to the board. Dr Lamm is Associate Professor and Co-Director of the Centre for Occupational Health and Safety Research at the Auckland University Technology (AUT).

In this issue of the Journal of Health and Safety Research and Practice we publish four quite diverse articles. The article by Altree-Williams challenges the way in which frequency and incidence rates are used in the reporting of injury and disease in aggregated data sets. In the previous issue of Journal of Health and Safety Research and Practice the article by Stuckey et al (2010) provided a data set that will inform research into health and safety issues surrounding light vehicle use in Australia. The documentation of meaningful and robust data sets is very important to research; to the setting of priorities for investigation and intervention; and the building of the health and safety evidence and knowledge base. In Australia, researchers’ access to data sets that may be used for assessment of risk is often limited. In particular, access to useful data from the state and commonwealth workers’ compensation databases is hampered by, among other things, differences in database structure, differences in field coding and differences in fundamental definitions of terms. There is also reluctance by some workers’ compensation agencies to either de-identify data such that it may be released to researchers or, alternatively, make release conditional to preserve anonymity. Further, the relatively small size of the databases limits their usefulness in quantifying risk associated with, for example, particular activities or items of equipment. Aggregated sets of consistently coded data are required to provide statistical power.

Perhaps, as the Australian jurisdictions work more closely together through harmonised legislation, harmonised approaches to data collection and reporting will emerge and more useful data will become available to researchers.

Dr Steve Cowley, FSIA
Editor in Chief, JHSRP


“Being” versus “Going” Native: an Account from the OHS Field

ANNABEL TEUSNER

ABSTRACT

There has been little scholarly focus within the literature on insider research in the field of Occupational Health and Safety (OHS). Despite this, there is a growing body of knowledge in other disciplines that can provide a foundation to support insider research in OHS. In particular, the benefits of insider research can present strengths and opportunities that would not otherwise exist. Whilst the constraints can be problematic, the insider researcher can minimise the impact, if adequately prepared. The aims of this paper are to examine the literature from a thematic perspective on the benefits and constraints of insider research; provide one account from the field, arising out of doctoral research, to demonstrate how the benefits and constraints were managed in that research; and provide the author’s learnings back into the literature.

Cite this article as: Teusner, A., (2010), “Being” versus “Going” Native: an Account from the OHS Field, J Health & Safety Research & Practice, (2)2, 23-33

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KEY WORDS
Insider; Methodology; Qualitative; Ethics; OHS

INTRODUCTION

An ‘insider’ is a researcher who engages in a study within a setting in which they work (Robson, 2002) or their community (Stephenson & Greer, 1981) where they are ‘complete members of organisational systems and communities’ (Brannick & Coghlan, 2007, p. 59) and have an ‘explicit research role in addition to the normal functional role’ (Coghlan & Holian, 2007, p. 5). Insider research as a methodology lends itself to use in Occupational Health and Safety (OHS) research (Galea, 2009), however, it has not been widely reported in the literature. An overview of the application and issues of validity have previously been reported by Galea (2009).

The reasons for choosing to undertake research within a familiar setting can be quite diverse. Some may employ this methodology for convenience; others may adopt it through the need to better understand the workplace or a community; or it may be chosen due to personal or professional interests. Although many OHS practitioners may conduct research within their place of employment, this work has often not been explicitly identified as qualitative research from an insider’s perspective. As such, there has been limited acknowledgment of the benefits, constraints and ethical considerations of the research process.

It is the aim of this paper to firstly; provide a thematic overview of the benefits and constraints for the use of insider research as a methodology; secondly, describe...
some of the unique experiences that the author uncovered during doctoral research in relation to studying the barriers to improving OHS in a medium sized business; and thirdly, present the integration of the author’s learnings back into the literature.

BENEFITS AND CONSTRAINTS OF INSIDER RESEARCH

In order to advance insider research in the OHS field, it is important to acknowledge the benefits and constraints from other disciplines reported in the literature. A summary of the benefits and constraints of insider research have been provided in Table 1. For each constraint identified, a benefit has also been examined.

Drawing from Table 1, eleven themes were identified from the literature concerning the constraints and benefits of insider research. These have been grouped under the headings in relation to their relevance to People, Organisation, and Insider (Galea, 2009), as presented in Table 2.

EXPERIENCES FROM THE FIELD

The use of insider research by this author yielded both benefits and constraints which were consistent with the literature as summarised in Table 1. However, the methodology also delivered benefits and imposed constraints not reported in the literature. Some of these were attributable to the different context of the research. Building on current literature (Galea, 2009), two additional themes were identified from personal experiences from the field. These were Research Design and Independent Third Party. These and other areas of difference have been presented below according to the phases of the project: Pre Data Collection; Data Collection; and Data Analysis.

PRE DATA COLLECTION

My own choice to use insider research was the need to better understand the influences that hindered improvements to OHS efforts within a manufacturing environment where I was employed. I was cautious at the onset of my doctoral research not to choose a ‘sensitive’ topic or one which may be difficult to pursue due to factors outside my control. I originally had considered conducting an action research project but during the planning stage I saw the potential for the data collection to become a burden to the organisation. Hence, insider ethnography was chosen, as the research project was culturally based; several methods are used to triangulate the data; and data could be gathered in a shorter timeframe, which would be less disruptive to the organisation. Despite changing the Research Design, the topic I chose was of great interest to me and I could see the potential benefits to the organisation and the wider community.

As with any research of this nature, approval of an Human Research Ethics Committee (HREC) was sought prior to the conduct my of research. As part of using an ethnographic approach, it was originally intended to employ three separate group meetings (with Managers, Supervisors and Process Workers) to assess the Safety Culture of the organisation, conduct interviews, use participant observations and collect company artifacts. However, it became evident during the preparation of the ethics application that an insider status greatly affected the ethical considerations of the project.

Firstly, the HREC highlighted the potential ethical risks if an insider researcher held group meetings to gain consensus for items in a typology to identify the Safety Culture of the organization. The grounds for this decision was to prevent the insider research influence individuals responding to questions in a particular way in group discussions. The basis for a group discussion was changed to a questionnaire before it was approved. This change to the Research Design was originally viewed as a constraint, although, on reflection over the research period, it was identified as a benefit because the ethical aspects of the research design were preserved.

Secondly, the HREC also identified another potential ethical risk if I approached peers within the business to ask them to participate in pilot studies, interviews or to
"being" versus "going" native: an account from the OHS field

Table 1 Summary of Benefits and Constraints for Insider Research

<table>
<thead>
<tr>
<th>Benefits of Insider Research</th>
<th>Constraints of Insider Research</th>
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<tbody>
<tr>
<td><strong>Peer Relationships</strong></td>
<td><code>· Interviewing colleagues can negatively impact on peer relationships after the study is complete, particularly in hierarchical organisations where the interviewee is more senior in status and the researcher makes errors during the data collection phase (Robson, 2002). Inequalities such as class, race, gender, age, security or condition of employment and remuneration between the researcher and the respondent may negatively impact on the relationship (Hockey, 1993; Merriam et al., 2001).</code></td>
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<td></td>
<td><code>· Challenging one's peers can also create turbulence within the workplace (Moore, 2007). Respondents may interpret follow up questioning as testing their knowledge or challenging them (Delyser, 2001) or they may respond in such a way to avoid offending the researcher; try to impress them with their responses; provide responses that they think the interviewer is seeking (van Heugten, 2004) or filter out responses (Hockey, 1993).</code></td>
</tr>
<tr>
<td></td>
<td><code>· Ambiguity can result from occupying the role of researcher, friend or both (Hockey, 1993) which may influence relationships during and after the study is complete. In some circumstances, peers may ignore requests from the researcher due to familiarity (Ravitch &amp; Wirth, 2007).</code></td>
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<td><code>· Conducting research upon peers can also result in professional scrutiny by the respondents, yet ethical considerations are directed at informants only (Hockey, 1993).</code></td>
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<td><code>· Respondents may become hostile or antagonist towards the researcher, the project, and / or the project's sponsors and make it difficult for data collection (Hockey, 1993).</code></td>
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<td></td>
<td><code>· Confidentiality can also be a very sensitive issue when researching peers, particularly as the researcher has no control over respondents which engage in the research process and then publicly communicate their own views (Hockey, 1993).</code></td>
</tr>
<tr>
<td><strong>Trust and Rapport</strong></td>
<td><code>· Informants share a greater trust and rapport with the insider researcher that may not otherwise be negotiated (Bonner &amp; Tolhurst, 2002; Merriam et al., 2001; Ravitch &amp; Wirth, 2007).</code></td>
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<td></td>
<td><code>Challenges exist when assuming a researcher stance, particularly in ethnographic studies when a researcher feels uncomfortable spying on colleagues or participants feel they are being spied on (Hannabuss, 2000).</code></td>
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<tr>
<td>Benefits of Insider Research</td>
<td>Constraints of Insider Research</td>
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<tr>
<td><em>In</em></td>
<td><em>Out</em></td>
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<tr>
<td><strong>Trust and Rapport</strong>* (cont.)</td>
<td><strong>Access</strong></td>
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<tr>
<td><em>They</em></td>
<td><em>Access is more easily granted to the insider researcher (Braithwaite, Cockwill, O’Neill &amp; Rebane, 2007; Roth, Shani, &amp; Leary, 2007; Stephenson &amp; Greer, 1981), data collection can be less time consuming with greater flexibility with regard to interview times (Mercer, 2007) and there is no need to travel far (Robson, 2002).</em></td>
</tr>
<tr>
<td><em>In</em></td>
<td><em>The insider can adopt new roles as bestowed upon them by their community to fit their circumstance to allow them to undertake research with minimal impact (Hayano, 1979; Stephenson &amp; Greer, 1981).</em></td>
</tr>
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<td><em>Out</em></td>
<td><em>Initial consent may have been granted at the start of a project, however, as the project progresses, research material may be obtained without full knowledge or understanding from participants, in the form of observations or company documentation, which can have ethical ramifications particularly if sensitive information is not appropriately managed (Braithwaite, Cockwill, O’Neill &amp; Rebane, 2007).</em></td>
</tr>
<tr>
<td><strong>Organisational Politics</strong></td>
<td><strong>Invisibility</strong></td>
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<td><em>Insider researchers have an understanding of an organisation’s power struggles and politics that they can work in ways that are in keeping with the political environment without compromising the research or their future career (Coghlan, 2007).</em></td>
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<td><em>The ability for the insider to blend in to the surroundings and be virtually invisible enables the research setting to have minimal disruption (Hockey, 1993).</em></td>
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<td><em>The insider may have initial consent but may not have informed consent (Hockey, 1993).</em></td>
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Table 1. Summary of Benefits and Constraints for Insider Research (cont.)
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<thead>
<tr>
<th>Benefits of Insider Research</th>
<th>Constraints of Insider Research</th>
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</thead>
<tbody>
<tr>
<td><strong>Pre-undertstandings and Familiarity</strong></td>
<td><strong>The insider researcher must guard against assuming a taken-for-granted approach towards the informants’ meanings, languages and concepts. In this regard, they may not explore areas that could have different interpretative ideas (Minichiello, Aroni, Timewell, &amp; Alexander, 1995).</strong></td>
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<tr>
<td>The insider researcher has intimate knowledge of the context of the organisation or community and understands the formal (outwardly expressed) and informal (internally expressed) approaches taken (Coghlan &amp; Brannick, 2005).</td>
<td>The insider researcher may have difficulty crossing departmental, functional or hierarchical lines in order to gain relevant data which supports the necessary epistemic reflexivity required to be aware of other perspectives (Coghlan &amp; Brannick, 2005).</td>
</tr>
<tr>
<td>An insider understands how the system really works, who to approach and can have immediate ‘street credibility’ (Robson, 2002, p. 382) to support the process to get things done (Roth, Shani, &amp; Leary, 2007).</td>
<td>Common practices may be easily overlooked for their significance and there can be a difficulty in recognizing patterns because of their familiarity, resulting in a failure to record important cultural material (Stephenson &amp; Greer, 1981).</td>
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<tr>
<td>The insider’s level of knowledge and insight can be used to direct the focus of the research into areas that can most profitably address the problem and aid the greater community (Fuller &amp; Petch, 1995).</td>
<td>Preconceived notions about colleagues may also compromise the ability to see more objectively the possibilities for building new kinds of interactions and dynamics (Ravitch &amp; Wirth, 2007).</td>
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<td>Preunderstandings of personalities can provide the researcher with a guide on whom, how and when to approach people within an organisation or community to discuss research related material, particularly on sensitive issues (Ravitch &amp; Wirth, 2007).</td>
<td>The researcher’s views may not be as widespread and may be one possible perspective (Hayano, 1979). Preunderstandings may also interfere with the interviewer not questioning the informant sufficiently to explain prior shared experiences (Kanuha, 2000).</td>
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<tr>
<td>An insider has the ability to use different methods to triangulate or cross-check information, so that the informant’s subjective view is examined in more detail taking into account other possible sources of bias and the insider’s own analysis and interpretation (Edwards, 2002; Minichiello, Aroni, Timewell, &amp; Alexander, 1995).</td>
<td>The insider researcher may not sufficiently nurture and guide the informants through the research process (Hockey, 1993) due to their over familiarity of the research setting.</td>
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<td>An absence of a culture shock as described by Hammersley and Atkinson (1983) can be advantageous as the insider researcher is quite familiar with their surroundings (Hayano, 1979; Hockey, 1993).</td>
<td>There is a potential for a tug of war between loyalties, allegations on behavioural matters and the predicament of having more than one focus (Brannick &amp; Coghlan, 2007) which can lead to ethical issues (Jarvis, 1999). Insider action researchers may encounter role confusion, role conflict and role overload when holding dual roles (Coghlan &amp; Holian, 2007).</td>
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</table>

**Table 1 Summary of Benefits and Constraints for Insider Research (cont.)**

<table>
<thead>
<tr>
<th>Dual Role</th>
<th>When the perceived roles and identities of the insider researcher emerge, there is an opportunity to open up new sources of information and insights (Stephenson &amp; Greer, 1981).</th>
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<tr>
<td></td>
<td>There is a potential for a tug of war between loyalties, allegations on behavioural matters and the predicament of having more than one focus (Brannick &amp; Coghlan, 2007) which can lead to ethical issues (Jarvis, 1999). Insider action researchers may encounter role confusion, role conflict and role overload when holding dual roles (Coghlan &amp; Holian, 2007).</td>
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<tr>
<td>Benefits of Insider Researcher</td>
<td>Constraints of Insider Research</td>
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<tr>
<td>Emotional Distancing Issues</td>
<td>During the research process, the insider may experience emotional issues (Ohnuki-Tierney, 1984) which may interfere with data collection due to overwhelming emotions from personal reflections due to the closeness of their understandings of the topic and their informants (Kanuha, 2000).</td>
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<td>If there is sufficient distance kept between both the personal and intellective self, then the contribution can be significant because of the insider’s intimate knowledge of their own culture (Ohnuki-Tierney, 1984).</td>
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<td>Interview and Recording Skills</td>
<td>The researchers own behaviour can have a major influence on the willingness of participants to talk freely (Robson, 2002). Further, personal hostility may be encountered during the interview process from individuals who view the research process with a degree of antipathy (Hockey, 1993). This may not only impact on the process during the research but after the research process has ended.</td>
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<td>Most research practitioners have suitably developed interviewing and data recording skills which have tapped into nurturing a rapport with clients for extracting information, focusing on an agenda and discriminating between relevant material and background noise. They also are accustomed to working with sensitive issues and highly confidential material (Fuller &amp; Petch, 1995) which may not be as highly developed in an external researcher.</td>
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<td>Holistic View</td>
<td>Practitioners conducting insider research can be blinded by their own workload and have difficulty seeing the wider standpoint (Fuller &amp; Petch, 1995).</td>
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<td>The insider researcher is often able to perceive a holistic view rather than a narrow perspective and can have the skills to make an assessment about what is practicable and realistic to the study, with consideration of the resources and time required (Fuller &amp; Petch, 1995).</td>
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<td>Economic Efficiencies</td>
<td>Practitioners may have to make adjustments as the research process has a different focus and agenda from that of practice (Fuller &amp; Petch, 1995) which can have implications on time, money and other resources.</td>
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<td>· The insider’s knowledge can save time as the researcher can seek out avenues for information that outsiders may not have access to or that may take many months to emanate (Hockey, 1993; Robson, 2002).</td>
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<td>· They may also be able to recognise patterns more readily so that the cultural and personal meanings of patterns can be readily understood, which reduces time during analysis and interpretation (Stephenson &amp; Greer, 1981).</td>
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complete the questionnaire, as prospective participants may find it difficult to refuse the request. Consequently, an independent third person (approved by the University Department Head) was used to approach company employees. At the time, some of the employees thought this requirement was excessive and felt it unnecessary. However, the requirement for an Independent Third Party was later viewed as a benefit to the research process due to the preservation of ethical considerations.

In both cases, the HREC did not only consider the ethics of my study, but also the inherent bias and provided advice how best to reduce it. Although a few authors have discussed matters of validity concerning insider research (Rooney, 2005; Brannick & Coghlan, 2007; Alvesson, 2003), it is an area that warrants further consideration.

Participant observations were not included among the methods for data collection as there were unique ethical issues that needed to be considered. It was the original intent to work on a packing line within the factory for a few months and be part of the work environment to better understand the needs of the Process Workers and Supervisors. As a requirement of ethical considerations for conducting participant observations, consent would have to be sought from every individual in the room. However, as there were numerous casual workers, maintenance crews, visitors and Management coming and going on a daily basis, this was not practical.

In an attempt to overcome this issue two approaches were considered: the use of signage to advise anyone entering the room that research was being undertaken; and to contact the contract hire labour companies to advise them of the project, which they could relay to their employees working on the site. However, after consideration, it was recognised that if one person declined to be observed then the observations could not be undertaken. In this case, it was decided that insider knowledge could still contribute to triangulating the data from interviews, company records and the questionnaire and hence, the participant observation component of the project was removed. Initially, this was perceived as a constraint, however on reflection this was viewed as a benefit to the Research Design for ethical reasons.

Prior to the start of the project and as part of the ethics application, a letter was sought from the employer to gain support for the research project. The Managing Director of the organisation was very supportive of the project and provided a letter outlining full cooperation. This was seen as a benefit to the research process, however, it was also recognised that responsibilities were also being placed back on me with possible expectations of the collection and use of data. In this context, it was important that the organisation be kept up to date during the data collection process to ensure that they were aware of the nature of documents that were being drawn for research purposes and that there had been no breaches of Trust and Rapport which may result in Organisational Politics.

Interestingly, Moore (2007) described the prime reason for support of his insider research from the Chief Executive of the non-profit organisation he was employed was trying to keep him happy to secure his continued commitment, rather than learn from or engage with any outcomes from the research. This later created tensions which resulted in Moore resigning due to the organisational politics when he discussed his research findings.

<table>
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<th>Table 2 Framework for Insider Research</th>
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<tr>
<td><strong>The People</strong></td>
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<td>Peer Relationships</td>
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<td>Trust and Rapport</td>
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At the preliminary stages of setting up the interviews, I initially planned to interview participants off site and outside work hours to preserve confidentiality. However, all of the respondents requested that their interviews be conducted at the worksite and during work hours (for their convenience). Accordingly, I followed through with this request, but did arrange an interview room that was in a remote location on site. The convenience of having the interviews conducted on site during work hours was considered a benefit, particularly in light of access arrangements. The convenience of not having to travel and greater flexibility regarding interview times was recognised by Mercer (2007), although no details were reported about the interview process.

DATA COLLECTION
During the interview process, two different, but unique scenarios unfolded. The first involved an interviewee that was quite passionate about the problems encountered when trying to improve the safety of the workplace. This person had often discussed with me (as part of my role as OHS Manager) the problems faced when attempting to implement safety measures. However, once this person had a recorder in front of them and was being asked questions in line with a semi-structured format, they appeared to be subdued by the process and were not able to freely express themselves, as they had done in the past, despite wanting to discuss their concerns (which was raised by the informant after the interview). I recognised this apparent change of demeanour and was able to change the strategies being used, by asking them to provide examples familiar to them and probing them further on areas that they had discussed in the interview, in order to draw out relevant information yet still keep within the boundaries of the ethics requirements. This insider knowledge allowed for the Interview and Recording Skills to be modified and was considered a benefit to the research process in order to gain a greater insight into the participant's perceptions. Humphrey (2007) described a situation during her insider research where she had interviewed an informant and then provided the transcript for them to review. Later, the informant indicated that they felt panicked as they had relayed sensitive and controversial information to the insider researcher that they would not have disclosed to an outsider. They negotiated a compromise where some of the material would be used in its original form and other areas would be retained in a disguised form.

The second scenario was concerned with a participant who had agreed (through a third person) to be part of the research process despite having had professional conflicts over safety issues with me (as part of my role as OHS Manager). At the start of the interview process, I read from the Plain Language Information Statement in accord with HREC requirements. The interviewee quickly interrupted and stated that it was not necessary to read from the Plain Language Information Statement as they trusted that I would not misuse the information in any way. Despite their insistence I still had to continue with this requirement. Fortunately, the participant was able to acknowledge my professionalism and ethical standards, rather than focus on prior distractions. This Trust and Rapport, which had been acquired from longstanding workplace relations, had been carried over into the interview process and was also recognised as a benefit to the research process. Edwards (2002, p. 77) highlighted the difficulties encountered when conducting interviews with colleagues of long-standing and close relations. He found that during interviews the participants could digress and ask sensitive questions outside the research programme due to the trust and rapport and he acknowledged that the ‘researcher also adopts a position which carries with it personal and organisational repercussions depending upon the response.’

In any ethnography, data collection can be an onerous task, particularly when there is a multitude of information to collect from various triangulation methods. Although
participant observations were not part of my project, I was required to collect company records. Initially, the process of collecting company records became overwhelming as there were so many documents that could be collected in the research process. However, the judgment of what should be included was narrowed down to three criteria:

- Relevance to the research topic;
- Ease of availability; and
- Contribution to the underlying discussion.

Further, there was an additional challenge as a number of documents had been produced (e.g. OHS plans, reports, policies, procedures, risk assessments, registers); approved (e.g. schedules, training requirements, procedures, forms); ordered; (e.g. signage); and displayed (e.g. policies, safety messages, audit schedules) by me (as part of my role as OHS Manager). Rather than considering the Preunderstandings and Familiarity as a conflict of interest, reflexivity methods as described by Robson (2002) were employed as part of a broader perspective to examine the information in light of the research topic.

During the interviews, many of the participants saw this was an opportunity to express their views and believed that the research project would drive solutions to their OHS concerns with immediate focus. This however, was not the focal point of the research. The participants were unable to distinguish that I had Dual Roles as an insider researcher and OHS practitioner, which became both a constraint and a benefit. Firstly, the expectations of the participants were that OHS issues that had been outstanding for some time (due to organisational issues) would be addressed quickly. This became a constraint as items were unable to be addressed immediately. Despite this, issues were raised that had not previously been discussed within the organisation and were acknowledged for their priority. This was viewed as a benefit and was examined outside the research process. Delyser (2001, p. 10) presented an intriguing picture of the dual role of insider researcher and staff member at a State Historical Park where ‘through my embodied presence, and through my role as part of the community – an insider and a researcher – I experienced new and ever evolving versions of the mythic West as they were created in place’. She described how she unwittingly helped create and be part of the mythology she was studying as she lived and worked in an historic community.

**DATA ANALYSIS**

Data analysis was a reflective process to establish what was being conveyed by the participants and whether there had been any information in the literature to support this. At the same time, any biases that I had during the data analysis needed to be considered to prevent the data from being tainted and threaten validity and trustworthiness. A number of approaches were incorporated into the project to reduce this in line with four key questions on insider research validity posed by Rooney (2005). In addition, I completed the same Safety Culture Questionnaire that the participants completed and responded to the interview questions myself and placed the results adjacent to the other participants’ results in order to be transparent about my perceptions. I viewed this as a benefit to the research process as I was aware of my Preunderstandings and Familiarity and had openly presented my position.

From my experiences in the field, not only had the themes drawn from the literature regarding benefits and constraints differed slightly in the context of my research project, there were also two new themes that had surfaced. The choice of Research Design can either be a constraint or benefit for the insider and requires careful consideration prior to undertaking a project. Further, the need for an Independent Third Party was particularly useful to assist with the preservation of ethical considerations.
CONCLUSION
Although there has been little acknowledgement of the constraints and benefits to insider research in the field of OHS, there is a body of knowledge in other disciplines that can be used as a foundation for knowledge. OHS research can have a different orientation compared with other disciplines, and it is for this reason that there is a need for further contribution to the body of knowledge. Two additional themes that can be incorporated into the Framework for Insider Research were drawn from the field through OHS research and were presented in this paper: Research Design and Independent Third Party. This is of particular importance, considering that the benefits of insider research can enhance the experience and provide depth and meaning to the interpretation of data. However, whilst the constraints can complicate and obscure the process, having foresight can allow for any hurdles to be managed out of the research process.

ACKNOWLEDGEMENTS
I would like to thank Professor Dennis Else and Associate Professor Jim Sillitoe in the development of this paper.

REFERENCES


Toward a meaningful way to measure whole body vibration in motor cycle riders exposed to rough surfaces

JOHN F CULVENOR1
GARY FOSTER

ABSTRACT
Motor cycles are used in the many occupations in Australia such as agriculture, courier services, postal delivery and police and results in exposure to whole-body vibration. Whole-body vibration exposure can be measured on the motorcycle seat, however, it can be expected that riders will sometimes lift themselves clear of the seat. The measurement on the seat only is therefore likely to be inaccurate. The aim of this study was to discover the relationship between seat-measured exposure and actual exposure. Vibration was measured simultaneously on the seat and on the rider for a range of terrain types. The results revealed that when riding on the seat that vibration dose values within about 10% of each other can be obtained by measuring vibration at the seat and on the rider. The results indicated that lifting clear of the seat increases seat vibration and decreases rider vibration. When lifting clear of the seat, the differences noted are large and indicate that the alternative method of measurement, on the rider, would be more meaningful. The small sample sizes in this study means that it is only indicative. However, it points toward the development of more meaningful analysis of whole body vibration caused by motorcycle riding.

INTRODUCTION
Motorcycles are used in the many occupations in Australia. These include agriculture, courier services, postal delivery, police, etc. Vibration in motorcycle riding presents an interesting case regarding assessment of whole body vibration. Motorcycle riding is mainly a seated activity in these occupations. The Australian Standard covering whole-body vibration is Australian Standard 2670.1-2001, Evaluation of Human Exposure to Whole Body Vibration. Whole-body vibration exposure for a motorcycle rider can be measured on the motorcycle seat, which is the normal location for whole body analysis of a seated position. However, for off road, rough road or occasional severe bumps such as speed bumps and kerbs it can be expected that riders will sometimes lift themselves clear of the seat. The measurement on the seat is therefore likely to be inaccurate in that it would overestimate the vibration exposure for two reasons: 1. lifting off the seat will cause the motorcycle seat to vibrate more thus increasing the measured values; and 2. when the rider lifts clear of the seat the rider’s spine is not directly exposed to the vibration of the seat. The aim of this study was to discover the relationship...
between seat-measured exposure and actual exposure.

Published research concerning vibration and motorcycle riding has focused on hand-arm vibration with the exception of one recent study on whole body vibration (Chen and others 2009). These studies have been in the postal delivery setting (e.g. Tominaga 1994; Tominaga 1995; and Yokomori and others 1986; Matsumoto and others 1986), agriculture (e.g. Anttonen and others 1995) and police (Mirbod and others 1997). None of these report on whole body vibration. Chen and colleagues (2009) studied whole body vibration on scooter style motorcycles. However, they rode only on paved roads and deliberately avoided or slowed down if encountering potholes manhole covers, humps or uneven surfaces. Among other vibration examples Lewis and Griffin (1998) report a measured vibration dose value for a mountain bike. Lewis and Griffin note that “...the posture of the rider and forces applied to the body at the seat may make this an inappropriate application of this standard” (1998, p. 923). Generally, whole body vibration studies on motorcycle riding do not seem to be very prominent among published research.

The study of whole body vibration in a range of other equipment such as tractors and construction machinery is better reported. Table 1 shows a list of vibration dose values from: Mansfield 2001; Cann and others (2003); Chen and others (2009) and Lewis and Griffin (1998). The table shows the sampling time and measured vibration dose value (VDV). The VDV value listed itself can be confusing as it needs to be considered together with the sampling period which varies according to the test methods. To make comparisons, a one hour VDV has been listed. The various equipment and conditions can then be compared on a level footing.

Table 1 Vibration dose values of various equipment

<table>
<thead>
<tr>
<th>Equipment/condition</th>
<th>Source¹</th>
<th>Sample time (min)</th>
<th>VDV (m/s¹.⁷⁵)</th>
<th>1hr VDV (m/s¹.⁷⁵)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bicycle off road on rough tracks</td>
<td>1</td>
<td>1</td>
<td>16.45</td>
<td>45.8</td>
</tr>
<tr>
<td>Wheel loader</td>
<td>2</td>
<td>20</td>
<td>31.7</td>
<td>41.7</td>
</tr>
<tr>
<td>Power boat (14m) in sea at state 3, 35-40 knots</td>
<td>1</td>
<td>1</td>
<td>11.81</td>
<td>32.9</td>
</tr>
<tr>
<td>Military tank, commander’s seat cross country at 30 km/hr</td>
<td>1</td>
<td>1</td>
<td>9.79</td>
<td>27.2</td>
</tr>
<tr>
<td>Off-road dump truck</td>
<td>2</td>
<td>20</td>
<td>17.2</td>
<td>22.6</td>
</tr>
<tr>
<td>Four-wheel drive ambulance at 40km/hr</td>
<td>1</td>
<td>1</td>
<td>7.83</td>
<td>21.8</td>
</tr>
<tr>
<td>Car on unmade surface at 20 km/hr</td>
<td>1</td>
<td>1</td>
<td>7.43</td>
<td>20.7</td>
</tr>
<tr>
<td>Scraper</td>
<td>2</td>
<td>20</td>
<td>14.9</td>
<td>19.6</td>
</tr>
<tr>
<td>Scooter type motorcycle on paved rural road at max 55km/hr</td>
<td>4</td>
<td>8hrs</td>
<td>28.1</td>
<td>16.7</td>
</tr>
<tr>
<td>Forklift truck on mixed hard surfaces</td>
<td>1</td>
<td>1</td>
<td>5.92</td>
<td>16.5</td>
</tr>
<tr>
<td>Skid steer – mini</td>
<td>2</td>
<td>20</td>
<td>11.6</td>
<td>15.3</td>
</tr>
<tr>
<td>Inflatable power boat (8m) in seat at state 3, 40 knots</td>
<td>1</td>
<td>1</td>
<td>4.99</td>
<td>13.9</td>
</tr>
<tr>
<td>Backhoe</td>
<td>2</td>
<td>20</td>
<td>9.81</td>
<td>12.9</td>
</tr>
<tr>
<td>Skid steer – regular</td>
<td>2</td>
<td>20</td>
<td>9.64</td>
<td>12.7</td>
</tr>
</tbody>
</table>
Table 1 Continued

<table>
<thead>
<tr>
<th>Equipment/condition</th>
<th>Source</th>
<th>Sample time (min)</th>
<th>VDV (m/s$^{1.75}$)</th>
<th>1hr VDV (m/s$^{1.75}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulldozer – large</td>
<td>2</td>
<td>20</td>
<td>9.01</td>
<td>11.9</td>
</tr>
<tr>
<td>Ride-on power trowel</td>
<td>2</td>
<td>20</td>
<td>8.81</td>
<td>11.6</td>
</tr>
<tr>
<td>Crawler loader</td>
<td>2</td>
<td>20</td>
<td>8.71</td>
<td>11.5</td>
</tr>
<tr>
<td>Bulldozer – small</td>
<td>2</td>
<td>20</td>
<td>8.56</td>
<td>11.3</td>
</tr>
<tr>
<td>Vibratory compactor</td>
<td>2</td>
<td>20</td>
<td>8.16</td>
<td>10.7</td>
</tr>
<tr>
<td>Compactor</td>
<td>2</td>
<td>20</td>
<td>7.86</td>
<td>10.3</td>
</tr>
<tr>
<td>Grader</td>
<td>2</td>
<td>20</td>
<td>7.25</td>
<td>9.5</td>
</tr>
<tr>
<td>Bus in city with speed humps</td>
<td>1</td>
<td>1</td>
<td>2.79</td>
<td>7.8</td>
</tr>
<tr>
<td>Excavator</td>
<td>2</td>
<td>20</td>
<td>5.76</td>
<td>7.6</td>
</tr>
<tr>
<td>Variable reach forklift</td>
<td>2</td>
<td>20</td>
<td>5.73</td>
<td>7.5</td>
</tr>
<tr>
<td>Dockside crane – loading operations</td>
<td>1</td>
<td>1</td>
<td>2.46</td>
<td>6.8</td>
</tr>
<tr>
<td>Car on bumpy potholed road at 15km/hr</td>
<td>3</td>
<td>0.5</td>
<td>2.0</td>
<td>6.6</td>
</tr>
<tr>
<td>Forklift</td>
<td>2</td>
<td>20</td>
<td>3.35</td>
<td>4.4</td>
</tr>
<tr>
<td>Car on highway at 100km/hr</td>
<td>3</td>
<td>0.5</td>
<td>1.16</td>
<td>3.8</td>
</tr>
<tr>
<td>Mobile crane</td>
<td>2</td>
<td>20</td>
<td>0.92</td>
<td>1.2</td>
</tr>
</tbody>
</table>

$^1$Reference 1 = Lewis and Griffin 1998; Reference 2 = Cann et al. 2003; Reference 3 = Masfield 2001; Reference 4 = Chen et al. 2009

METHODS

Vibration measurements were made with two Larson Davis HVM 100 monitors and PCB Model 356B40 ICP triaxial accelerometers housed in a rubber seat pad. The operator sits on the seat pad which is orientated to measure vibration in the vertical direction (z-axis), the horizontal side to side direction (y-axis) and horizontal forward to backward direction (x-axis).

The instruments were calibrated to the rated sensitivity of the accelerometer.

Measurements were made simultaneously on the seat and directly on the rider. One ICP triaxial vibration sensor was placed on the motorcycle seat. The measurement and analysis were carried out according to methods described in Australian Standard AS 2670-2001. A seat-pad accelerometer was connected to the rider in the vertical position so that the x-axis became the z-axis on the accelerometer seat pad. This is an unconventional technique and a method of attachment had to be devised. It was not practical to fix the accelerometer directly to the rider. The rider wore a miner’s belt threaded through the belt-loops. The pad was lodged in the rear strap of the belt, and then taped to the belt and to the pants. The accelerometer was therefore firmly fixed to the rider’s pants. However, there was the potential for movement between the pants and the rider. The data recorders were in a pannier and the rider’s shirt pocket.

Given the arrangement of accelerometers, the x-axis of the rider accelerometer was compared with the z-axis of the seat accelerometer. These would be directly comparable if the accelerometers were positioned exactly at right angles. This was only approximately the case as the riders posture would vary according to riding conditions, stature and posture. For the above reasons there is likely to be some difference between the vibration recorded by the two instruments.

To gain some knowledge about the vibration recorded by the two positions,
a number of trials were performed with the rider remaining in the seat. This enabled an assessment of whether the two accelerometers were recording similar values. After this was performed, the rider repeated a range of conditions, lifting out of the seat when striking bumps.

The motorcycle used was a 110cc agricultural motorcycle. According to the motorcycle’s odometer reading it had travelled 1658km. Tyre pressures were set at 32psi at a service station. The rider was a 51 year old male with 11 years experience. The rider’s self-reported height and weight were 157cm and 64kg.

Examination of various terrain conditions was made using the dual-accelerometer arrangement:
- Smooth surface (underground car park);
- “Square” shaped kerb;
- “Roll top” kerb;
- Rough unmade rutted soil.

In each case measurements were made while the rider either:
- Remained in seat; or
- Lifted out of the seat when encountering a jolt.

Vibration levels were assessed with the Basic Evaluation Method of AS 2670.1-2001 using the root mean square (RMS) acceleration levels and the Additional Evaluation Method using the vibration dose value (VDV) method. The vibration dose value is a fourth power method that is sensitive to jolts and jars. The RMS acceleration applies to more continuous vibration exposures that do not include a high proportion of jolts and jars. The VDV has been shown to correlate with perception of discomfort when exposed to vibration including shocks (Mansfield and others 2000).

\[
\text{AS 2670-2001 (Clause 6.3.3)} \quad \frac{\text{VDV}}{a_w T^{1/4}} = 1.75
\]

Where VDV = vibration dose value for duration of the measurement.
\(a_w\) = average weighted r.m.s acceleration level.
\(T\) = duration of measurement in seconds.

The informative section of AS 2670.1-2001 provides guidance on vibration exposure duration that could lead to adverse health effects mainly concerning back pain and damage to the spine. A ‘caution zone’ is set out for classifying vibration exposures that lie between specified vibration limits depending on the exposure duration. The VDV caution zone is between a VDV value of 8.5 and 17 m/s\(^{1.75}\).

However there is no universal agreement about the indicator levels. For instance, AS 2670.1-2001 indicates that the methodologies of the previous standards were protective and suggests that the data based on alternative measures (such as VDV) be collected to obtain information on the dose-effects relationship. These relationships are not well known. “Unfortunately, no-one appears to have carried out an epidemiological study where the prevalence of high acceleration events was considered” (Sandover 1998, p. 931). The limits themselves are contained within informative annexes to the Standard. The Standard is therefore a guide to the measurement of vibration exposure but not a guide to the limits that would apply.

RESULTS

Comparison of seat vibration and rider vibration when riding on the seat

With the rider remaining on the seat, vibration was measured simultaneously on the seat and on the rider for a range of terrain types. Speeds were all low as would be the case when negotiating rough surfaces. The connection of the accelerometer to the rider was as good as could be achieved under the circumstances but was acknowledged to be less than perfect. For this reason an examination was made of the comparative vibration dose values when the rider remained on the seat.

Table 2 shows the results of simultaneous measuring of vibration dose value on the rider and on the seat when riding on the seat. The rider/seat VDV ratio indicates
the magnitude of the VDV measured at the rider compared to the magnitude of the VDV measured on the seat. The values are normalised to one hour. This is to place varying measurement times on an equal footing, for comparison with the one hour VDV values shown in the introduction for other types of equipment, and gives a sense of the VDV that could be experienced in an extended period of very rough conditions.

Under ideal conditions riding in the smooth underground car park there was very low vibration and a very close match between the VDV measured on the rider and that measured on the seat with the figures being only 1% different. The vibration dose values (for a one hour activity) for the other activities are in the range of 19-26 m/s\(^{1.75}\), thus being comparable to activities such as off-road car driving, a dump truck, etc as measured other vibration research and shown in Table 1.

The average figures for the comparison of the vibration measured at the rider versus that at the seat for all rides were as follows indicating that the two methods were measuring close to the same values (with 100% being perfect):
- Traditional kerb: 88%
- Rough soil offroad: 100%
- Roll-top kerb: 103%
- Smooth ride: 101%

The methodology of attaching an accelerometer to the rider is not a standard one. It is also acknowledged that the fixing of the accelerometer was not perfect although it was quite firmly attached to a belt and clothing. These points noted, while potential movement of the accelerometer independent of the rider probably occurs to some degree it does not appear to be a significant issue as the vibration measured by the two accelerometers is similar. Further, given that spinal injury is the major concern, it makes sense to measure vibration as close as possible parallel to the spine rather than perpendicular to the seat. For these reasons, and bearing in mind some caution owing to the customised and experimental nature of the measurements, there seems to be good reason to examine the rider vibration data when off-seat.

Table 2 Difference between vibration measurement on the rider and on the seat when riding on the seat

<table>
<thead>
<tr>
<th>Ride descriptions</th>
<th>Length (min)</th>
<th>Seat VDV (m/s(^{1.75}))</th>
<th>Seat 1hr VDV (m/s(^{1.75}))</th>
<th>Seat rms (m/s(^{1.75}))</th>
<th>Rider VDV (m/s(^{1.75}))</th>
<th>Rider 1hr VDV (m/s(^{1.75}))</th>
<th>Rider rms</th>
<th>Rider/Seat VDV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smooth surface (one trial)</td>
<td>2</td>
<td>1.82</td>
<td>4.3</td>
<td>0.40</td>
<td>1.84</td>
<td>4.3</td>
<td>0.33</td>
<td>101%</td>
</tr>
<tr>
<td>Repeated ride over “roll top” gutter 6/minute</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial1</td>
<td>1</td>
<td>6.56</td>
<td>18.3</td>
<td>1.01</td>
<td>6.99</td>
<td>19.5</td>
<td>1.27</td>
<td>107%</td>
</tr>
<tr>
<td>Trial2</td>
<td>1</td>
<td>7.28</td>
<td>20.3</td>
<td>1.17</td>
<td>7.18</td>
<td>20.0</td>
<td>1.35</td>
<td>99%</td>
</tr>
<tr>
<td>Trial3</td>
<td>1</td>
<td>6.9</td>
<td>19.2</td>
<td>1.15</td>
<td>7.16</td>
<td>19.9</td>
<td>1.38</td>
<td>104%</td>
</tr>
<tr>
<td>Average</td>
<td>1</td>
<td>6.93</td>
<td>19.3</td>
<td>1.11</td>
<td>7.11</td>
<td>19.8</td>
<td>1.33</td>
<td>103%</td>
</tr>
<tr>
<td>Repeated ride over square kerb 9 times over two minutes (one trial)</td>
<td>2</td>
<td>11.4</td>
<td>26.7</td>
<td>1.21</td>
<td>10</td>
<td>23.4</td>
<td>1.38</td>
<td>88%</td>
</tr>
</tbody>
</table>

Rough soil

<table>
<thead>
<tr>
<th>Ride</th>
<th>Length (min)</th>
<th>Seat VDV (m/s(^{1.75}))</th>
<th>Seat 1hr VDV (m/s(^{1.75}))</th>
<th>Seat rms (m/s(^{1.75}))</th>
<th>Rider VDV (m/s(^{1.75}))</th>
<th>Rider 1hr VDV (m/s(^{1.75}))</th>
<th>Rider rms</th>
<th>Rider/Seat VDV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial1</td>
<td>1</td>
<td>8.53</td>
<td>23.7</td>
<td>1.4</td>
<td>9.68</td>
<td>26.9</td>
<td>1.76</td>
<td>113%</td>
</tr>
<tr>
<td>Trial2</td>
<td>1</td>
<td>10.5</td>
<td>29.2</td>
<td>1.59</td>
<td>10.1</td>
<td>28.1</td>
<td>1.90</td>
<td>96%</td>
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<tr>
<td>Trial3</td>
<td>1</td>
<td>8.57</td>
<td>23.9</td>
<td>1.09</td>
<td>7.86</td>
<td>21.9</td>
<td>1.59</td>
<td>92%</td>
</tr>
<tr>
<td>Average</td>
<td>1</td>
<td>9.34</td>
<td>26.0</td>
<td>1.36</td>
<td>9.4</td>
<td>26.2</td>
<td>1.75</td>
<td>100%</td>
</tr>
</tbody>
</table>
Riding Vibration When Lifting Clear of the Seat Over Bumps

As discussed, riders adapt to rough conditions by lifting clear of the seat. Table 3 shows the results of trials where the rider lifted clear of the seat over bumps. The measurements shown were made on the rider and on the seat.

It can be seen that the motorcycle itself vibrates significantly more when the rider is clear of the seat yielding 1hr VDV values in the range 30-50 m/s^{1.75}. The VDV for the seat are much greater than those for the seat as shown in Table 2 when the rider stayed on the seat. The reason would be that damping effect provided by the rider was now not present.

When lifting clear of the seat, the measurements of vibration of the rider show results that are much lower than the simultaneous measurement of vibration of the seat. These values are for 1hr VDV in the range 12-16 m/s^{1.75}. The comparisons are based on repeated rides over the same terrain and show the off-seat VDV was between 24% and 47% of the measured VDV at the seat as illustrated in Table 3 and Figure 1.

Table 3 Specific task/terrain vibration riding out of the seat over bumps

<table>
<thead>
<tr>
<th>Ride descriptions</th>
<th>Length (min)</th>
<th>Seat VDV (m/s^{1.75})</th>
<th>Seat 1hr VDV (m/s^{1.75})</th>
<th>Seat rms (m/s^{1.75})</th>
<th>Rider VDV (m/s^{1.75})</th>
<th>Rider 1hr VDV (m/s^{1.75})</th>
<th>Rider rms (m/s2)</th>
<th>Rider/Seat VDV %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repeated ride over continuous “roll top” gutter 5/minute</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial1</td>
<td>1</td>
<td>11.9</td>
<td>33.1</td>
<td>1.44</td>
<td>5.84</td>
<td>16.3</td>
<td>1.00</td>
<td>49%</td>
</tr>
<tr>
<td>Trial2</td>
<td>1</td>
<td>12.5</td>
<td>34.8</td>
<td>1.58</td>
<td>5.68</td>
<td>15.8</td>
<td>1.05</td>
<td>45%</td>
</tr>
<tr>
<td>Trial3</td>
<td>1</td>
<td>12.3</td>
<td>34.2</td>
<td>1.52</td>
<td>5.85</td>
<td>16.3</td>
<td>1.03</td>
<td>48%</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>12.2</td>
<td>34.0</td>
<td>1.51</td>
<td>5.79</td>
<td>16.1</td>
<td>1.03</td>
<td>47%</td>
</tr>
<tr>
<td>Repeated ride over square kerb 9 times over two minutes</td>
<td>2</td>
<td>21.8</td>
<td>51.0</td>
<td>1.91</td>
<td>5.39</td>
<td>12.6</td>
<td>0.93</td>
<td>24%</td>
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<tr>
<td>Rough soil</td>
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<td></td>
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<tr>
<td>Trial1</td>
<td>1</td>
<td>9.87</td>
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<td>1.62</td>
<td>4.26</td>
<td>11.9</td>
<td>0.96</td>
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<tr>
<td>Trial2</td>
<td>1</td>
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<td>41.5</td>
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<td>14.5</td>
<td>1.23</td>
<td>34%</td>
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<tr>
<td>Trial3</td>
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<td>15.7</td>
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<td>2.43</td>
<td>5.48</td>
<td>15.3</td>
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</tr>
<tr>
<td>Average</td>
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<td>14.1</td>
<td>37.5</td>
<td>2.02</td>
<td>4.98</td>
<td>13.9</td>
<td>1.17</td>
<td>35%</td>
</tr>
</tbody>
</table>
CONCLUSION

Off-road vehicle use is known to yield high vibration measurements. Whole body vibration research in motorcycle use has not been widely reported. One of the reasons for this may be the difficulty in obtaining realistic measurements. Attachment of an accelerometer to the seat will be reasonable in the case of seated riding. This would be applicable in most road-based use, however when encountering speed humps, kerbs, etc the rider may lift them self clear of the seat. In the case of off-road use this practice will be more common. The lifting of the rider could be expected to increase the vibration of the seat but decrease the vibration exposure of the rider. Thus measurement at the seat will probably be an overestimate of the actual exposure.

This exploratory study yielded two important indicative outcomes. Firstly, the results revealed that vibration dose values agreeing within about 10% by measuring vibration at the seat and on the rider can be obtained. Thus measurement of vibration on the person was indicated to be reasonable method. Secondly, using the direct measurement technique, the results indicated that lifting clear of the seat increases seat vibration and decreases rider vibration. The differences noted are large and indicate that the alternative method of measurement, being directly on the rider, would be more meaningful. The small sample sizes in this study means that it is only indicative. However, it points toward the development of more meaningful analysis of whole body vibration caused by motorcycle riding.

REFERENCES


Figure 1 Comparison of z-axis vibration dose values (1hr VDV m/s^{1.75}) measured on the seat and the rider when lifting out of the seat over various surfaces.


Using the Critical Decision Method for Incident Analysis in Mining

TIM HORBERRY1
TRISTAN COOKE1

ABSTRACT
After incidents have occurred in any high hazard work environment, undertaking detailed investigations to help learn lessons for the future is a priority. Part of such an investigation often involves obtaining an incident narrative by means of an interview with the operators involved: the accuracy and comprehensiveness of this process is vital. The Critical Decision Method (CDM) is a structured and in-depth interview process that can be used to elicit information from operators about their decision-making and problem-solving processes during incidents. Following CDM’s successful use in other industries, it was hypothesised that capturing and analysing information on equipment-related mining incidents and the operators’ decision making around these incidents would result in valuable extra information compared to the most commonly used investigation technique in mining. The CDM was adapted to the mining context, and data were collected from operators involved in previous incidents at two coal mine sites. The main findings of the research supported the anticipated beneficial use of CDM, and showed that it is a useful tool to ‘get in the head’ and better understand the mindset of the personnel involved in incidents. The method is of increasing value with more complex incidents. The research also found that CDM uncovered important details not in current incident investigation reports: such information could have key benefits to help fully understand and learn lessons from the incident. Further work with this technique to integrate it into future incident investigations is strongly recommended, so achieving more detailed and operator-centred accounts of such incidents.

INTRODUCTION

WHAT IS THE CRITICAL DECISION METHOD?
The Critical Decision Method (CDM) is a structured interview process that can be used to elicit information and knowledge from experienced operators about their decision-making, understanding and problem-solving processes during non-routine critical incidents (Crandall, Klein and Hoffman, 2006). The method involves the use of ‘probe’ questions to uncover the kinds of knowledge on which decisions are based, and the technique allows interviews to shift operators’ thinking from operational and general accounts of an incident into more descriptive retelling of their problem solving processes during the critical incident.

The Critical Decision Method builds on the earlier Critical Incident Technique that was first developed during World War II that was applied in a variety of situations through the study of near misses (Flanagan, 1954). Going beyond the Critical Incident Technique in terms of a more structured and detailed method,
the CDM is often found to be effective in revealing expert’s knowledge, especially tacit knowledge, reasoning, sense-making and decision strategies (Crandall, Klein and Hoffman, 2006). Although it relies in part on memory, it has been argued that experts mostly have clear memories of salient or unusual safety-related incidents (Crandall, Klein and Hoffman, 2006). Previous work has examined CDM in other fields such as nuclear power, aviation and medical error, especially to identify perceptual and cognitive needs for aiding decision making, and to investigate incidents by reconstructing and understanding how operators made sense of the situation they were faced with (Klein, 2008).

INCIDENT INVESTIGATIONS AND OPERATOR NARRATIVES

Traditional incident investigation techniques deal mainly with the identification of a sequence of events hoping to identify unsafe acts or conditions: that is, what happened (Doytchev and Szwillus, 2009). Some go beyond looking at causal analysis to identify the relationship between incident events and the breakdown of any controls; how it happened (Simpson, Horberry and Joy, 2009). However, it has been suggested that newer techniques are required to better understand what factors influence and predispose the decisions of mining equipment operators (Horberry, Burgess-Limerick and Steiner, 2010). Innovative investigation techniques are needed to help understand the incident, and decisions, from the perspective of the person making those decisions to give an appropriate representation of why the incident occurred. They would be particularly useful in real world situations where people made critical decisions that significantly contributed to the occurrence or prevention of an incident. The CDM is perhaps the most commonly used and researched method here. For example, Tichon successfully used CDM to elicit knowledge from train drivers, finding significant numbers of environmental cues, actions to be taken and possible errors (Tichon, 2007). It assumes that people were attempting to make sense - sensemaking - of the information and situation at hand (Klein, 2008).

Therefore, this part of the research reported here aims to understand the incident, and decisions, from the perspective of the person making those decisions: why it happened.

Decisions in Complex Sociotechnical Systems are often made using tacit or inert knowledge; knowledge that persons have but never previously explicitly considered or expressed (Simpson et al, 2009). Therefore, simply asking operators what they were thinking at the time of an incident is unlikely to be enough. Therefore, in complex situations, knowledge has to be specifically elicited from the persons involved.

To the knowledge of the authors, no systematic investigation of CDM has been undertaken in mining. Perhaps the closest study to apply something similar in the minerals industry was performed by Dal Santo (2005). Her work investigated ground control (that is, rock fall prevention) decisions made by mining engineers working in underground mines. Two of her main findings were the importance of situation assessment (that is, the ability of mining engineers to be able to ‘read the ground’) and how the characteristics of decision making changed not only with experience, but also with motivation, expectation and specific hazard knowledge. The key focus of Dal Santo’s work was improving the design of ground control education and training; it appeared that CDM and related approaches could be of considerable benefit in understanding ground control decisions in mining, and developing better training based on this understanding.

In sum, CDM is seemingly well suited to understanding incidents related to mining equipment from an operator-centred perspective, where the decisions of the
operators in a complex work environment are often linked to causing, or preventing, accidents and incidents.

SCOPE OF THE RESEARCH
Following CDM’s use in other occupations, it was envisaged that capturing and analysing information on mining equipment related critical incidents and the decision making around these incidents would result in valuable new information for the industry; the overall goal was therefore to investigate if CDM could provide such information. One particular aim was to establish if CDM revealed additional important information about operator decision making and sensemaking compared to current incident investigation methods.

METHOD

PROCEDURE: CDM-MINING

PROCESS DESCRIPTION
The research employed a ‘classic’ CDM method (as outlined by Crandall, Klein and Hoffman, 2006), adapted where required to the mining context (e.g. in the terminology used). The CDM interview process was undertaken by two researchers; one primarily an interviewer and one primarily a note-taker. The interviewee was expert in the work domain (i.e. an experienced mining equipment operator) but who had previously been involved in an incident. The interview took up to two hours; it took place in an office that was largely free of interruptions.

The CDM process used in this research occurred in four stages (also known as ‘sweeps’), with a series of structured probes to re-construct the incident. The multiple ‘sweeps’ were made to progressively deepen understanding of the challenges faced and strategies employed by decision makers to cope with the situational and environmental demands of the mining domain.

Sweep 1: Incident Identification and Selection. This stage focused on selecting an appropriate incident which would benefit from greater understanding. It was required that the interviewee must have been a decision maker or ‘doer’ in the incident.

A review or screening of multiple incidents was often required in order to find one that was appropriate for the purpose of this research. Once an appropriate incident has been identified the interviewee was asked to give a brief account of the story from start to end. They often needed to be guided through the process and kept on track by not talking about other aspects that were not relevant to the purpose of this work. Notes were taken whilst the interviewee talked to provide the ‘bones’ for the subsequent Sweeps.

Sweep 2: Timeline Construction and Verification. This sweep of the incident aimed to gain a clear structure of the incident that was refined and verified with the interviewee. During this sweep the initial account of the incident was expanded. It began with a merge from Sweep 1 where an interviewer repeats what they have recorded with any additional comments or corrections by the interviewee. So the interviewee was encouraged to correct faults and add relevant information to ensure the account was consistent, accurate and appropriately detailed.

The researchers then constructed a timeline of the incident in relevant chunks: distinct actions, occurrences or decisions. The timeline constructed was visible to the interviewee - using a whiteboard or large pieces of paper. Following construction of the timeline, the critical junctures, or decision points, where a situation could have been understood several ways or altered were identified by the interviewers. Following this, the CDM moved to the next Sweep.

Sweep 3: Deepening Understanding. In this Sweep, the researchers attempted to understand the interviewees’ sensemaking of the situation. It followed previous CDM researchers’ recommendations who stated
that it needs to:

...get inside the experts head and see the world through his or her eyes... What is the story behind the story? Based on the first two steps (the researchers) know what happened... but what did (the interviewee) know, when did they know it, how did they know, and what did they do with what they knew? (Crandall, Klein and Hoffman 2006, 78-79).

To gain this information the researchers reviewed the critical junctures again, asking the interviewee a series of deepening probe questions. The probes used depended on the event but were generally aimed at determining the information available in the incident, the meaning of this information as interpreted by the interviewee and the thoughts and issues they provoked. At this stage the interviewee usually gave a rich understanding of the event, though occasionally, they may have been unable or unwilling to share their experiences. A regular pitfall was for participants to drift to generalisations and, whilst this might reflect their experience, skills and knowledge, it was important that the interviewee gave information on the selected incident.

**Sweep 4: “What if” Queries.** The last Sweep involved the interviewers posing a number of hypothetical changes to the event in the form of ‘what if’ questions. The participant was asked how their responses might have altered, or the outcome might have changed, if the situation was slightly different (such as, if an experienced operator was involved rather than an inexperienced one). This was to gain a deeper understanding of the experience, skills and knowledge of the interviewee. It was also useful in seeing if the information gained could be generalised.

**DATA COLLECTED**

Before data collection, the research was approved by the University of Queensland’s Human Ethics Committee. Ten CDM interviews were then successfully completed at two surface coal mines in Central Queensland, Australia. The interviews were conducted with mining equipment operators who had various levels of experience.

In addition to purely analysing the data for the ten incidents, in six of these events a formal local site incident investigation had previously taken place using the standardised Incident Cause Analysis Method (I-CAM) (De Landre and Gibb, 2006). I-CAM is the most commonly used incident investigation method in Australian mining; it is based on James Reason’s models of organisational accident causation (Reason, 1997) and Jens Rasmussen’s skill/rule/knowledge model of human error (Rasmussen, 2005). I-CAM provides a classification system for various local or latent factors that may be involved in an incident (De Landre and Gibb, 2006). The CDM results were compared to these existing incident reports, in particular examining where CDM added additional insights.

It should be noted that there was a time gap between the original I-CAM investigation and the CDM data collection. This could be viewed as a potential limitation as the interviewees have time to rationalise their incident accounts. However, previous work by Crandall, Kline and Hoffman (2006) found that interviewees generally had reasonably accurate memories of incidents, often several months later (being similar to the maximum length between the I-CAM investigation and the CDM data collection). Despite this, further work to undertake CDM data collection during an actual incident investigation would help verify the obtained results.

**RESULTS**

The main findings obtained for the incidents examined at the mines are summarised in Table 1.
<table>
<thead>
<tr>
<th>#</th>
<th>Incident description</th>
<th>Main Incident Notes from CDM</th>
<th>Main CDM Findings and Key Decisions</th>
<th>Compared to I-CAM</th>
<th>Additional findings compared with I-CAM</th>
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</table>
| 1  | Uncontrolled drop of shovel bucket, so colliding with a reversing haul truck. | · Interviewee was operating a shovel and loading haul trucks when there was an uncontrolled drop of the bucket.  
· At the time a haul truck was backing under the shovel. The bucket dropped just before the haul truck was under the shovel but it could not stop before reversing into it.  
· Had the drop happened later it could have fallen into the tray of the haul truck.  
· There is a tendency for the bucket to 'drift' downwards if not actively pulled back. This might have caused the operator to pull back on the lever when the bucket fell, rather than pressing the emergency stop button.  
· Operator noted that a fault error displayed on the screen that he had not previously seen, and was not in the instruction manual. | · There is a tendency for the bucket to 'drift' downwards if not actively pulled back. This might have caused the operator to pull back on the lever when the bucket fell, rather than pressing the emergency stop button.  
· Operator noted that a fault error displayed on the screen that he had not previously seen, and was not in the instruction manual. | YES              | · The I-CAM report does not note how the driver attempted to halt the bucket.  
· Error message that the driver claims to have seen is not noted.  
· It also has only a very short description of the incident and one word answers to I-CAM questions, which would make it difficult to ascertain a pattern should a similar event reoccur.                                                                                                                                           |
| 2  | Rollover of bulldozer whilst pushing/ cleaning overburden (top soil) | · Interviewee was a trainee bulldozer driver pushing back overburden alongside a trainer operator.  
· The trainer was working on the overburden in another bulldozer and paying only little attention to the trainee.  
· At the point of the rollover he was working in a ‘cut’ directly next to the trainee and creating a lower level.  
· Trainee was attempting to reverse straight back, but was actually going at an inaccurate angle and the vehicle fell into the trainer’s ‘cut’. | · The lack of awareness by the trainee that he was not reversing in a straight line was a key cause of this incident.  
· Factors increasing the likelihood of this error included the limited rear vision, the lack of light (night shift) and perceived pressure to keep up with the trainer’s pace.  
· The trainer’s lack of intervention (e.g. by radio communication) in this was also a key cause.  
· Additionally, having another bulldozer working in close proximity created the conditions (i.e. the ‘cut’) where the bulldozer could roll. | YES              | · The supervision of the trainee was the key factor noted in the I-CAM and the practice of having a trainer work next to a trainee was ceased.  
· Key factors relating to the error reversing appear to have been overlooked or not identified, such as the low lighting, perceived time pressure and lack of vision out of the cab.                                                                                                                               |
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</table>
| 3  | Fire at a fuelling station | · The fire occurred at the fuelling station when the interviewee was working as an offside (helper) to a fuelling serviceman.  
· Sometime after connecting a ‘wiggins fitting’, which automatically fills the fuel station using the engine of the pump, both participants noticed that fuel was spraying out of the top of the fuel station.  
· This fuel landed on the top of the turbo of the refuelling truck and caught fire immediately, at which point both the serviceman and the interviewee fled the area and a large fire ensued. | · The serviceman attempted to cancel pumping using the control system, indicating that an emergency stop was not fitted or available.  
· Vehicle movement was isolated using the park break. In another case this might have prevented the vehicle being moved which would have stopped the fuel hitting the fire.  
· There was no protection/barrier between the hot engine and the fuel exiting. | YES | · The I-CAM noted a corrective action was fit a ‘deflector’ on the fuel tank to assist in preventing fuel heading in the direction of the pumping vehicle. Additionally, a cover was placed over the engines.  
· The difficulty in cancelling the fuel flow, and the emergency stop, was not noted.  
· The potential issue of unengaging park brake isolation in an emergency was not addressed. |
| 4  | Drove Haul Truck with Dump Tray Up and Striking the Reject Bins | · Whilst working as a haul truck driver the interviewee noticed that after dumping a load and driving away from an area whilst the tray descended the truck was able to shift up to second gear and pass 8km/h without an alarm sounding.  
· Shifting up gears should be prevented automatically and an alarm set off if the truck passes 8km/h without the tray fully descended.  
· The driver called maintenance to notify them of the issue. After some time they notified him that an electrician was available and to park the truck up.  
· The driver did this on his way collect a load from the reject bin; an overhead chute which transfers waste from the process plant into the truck.  
· The electrician worked on the issue, thought it was solved, and sat in dicky (spare) seat to catch a ride to the maintenance shed.  
· Driver forgets to pull lever to take tray down, the alarm does not sound and the upright tray strikes the reject bin. | · The reject bin is surrounded by ‘idiot balls’: large balls on wire that would normally be contacted before entering the area of the reject bin if a tray is in the upright position. However, the park up bay that the driver selected was past these idiot balls.  
· The electrician felt he had fixed the issue of the lack of tray alarm, but this was not tested or the test was accidently missed.  
· Other than the tray alarm, there may have been a display showing the driver that the tray was in the upright position.  
· The alarm may actually have been working but the truck not at 8km/h before striking the reject bin.  
· The driver and the electrician knew each other and were friendly. They may have been distracted whilst chatting leading to the above oversights. | YES | · The I-CAMs corrective actions were re-enforce the need for walk around inspections, the installation of sacrificial devices close to the reject bin to prevent collisions.  
· The I-CAM did not note that the roadway was designed such that a park-up bay was past the ‘idiot balls’.  
· I-CAM did not investigate how the driver may have missed pulling the lever to flatten the tray. However, the CDM found it was probably because he usually does not pull the lever at start-up and preformed his usual start-up movements whilst talking to the electrician. This could probably be prevented by having an audible tray up alarm on start-up. |
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<tr>
<td>5</td>
<td>Rollover of troop-carrier</td>
<td>· Rollover occurred on a 10% grade ramp. Just prior to the rollover a water truck had watered one side of the ramp. · Driver was moving off the ‘tough’ road and skidded when one side of the vehicle hit wet but hard and slippery clay. · Vehicle had 4-wheel-drive but was engaged in 2 wheel drive at that time.</td>
<td>· The watering of the ramp was an important primary causal factor. Subsequently, the judgement of the road conditions and speed was an important causal factor in the rollover. · This was, potentially, more likely by the type of vehicle and non-engagement of 4WD.</td>
<td>Results of I-CAM reported by interviewee, but not confirmed in writing.</td>
<td>· Main result of the I-CAM was to re-write watering policy on ramps, changing from continuous to spot watering. · Input of troop carrier factors appears overlooked: such as speed, driver judgement and the engaging 4WD.</td>
</tr>
<tr>
<td>6</td>
<td>Collision between bulldozer and grader</td>
<td>· A grader, driven by the interviewee, was parked in a line of trucks waiting for a shovel load, meaning that the grader could not move significantly. · The bulldozer that was cleaning up the face where the shovel had been backed to within 10-20m of the grader. At this time the grader operator radioed the bulldozer operator and at the same time the bulldozer moved forwards. · The bulldozer involved had limited rear vision and significant noise, which can mask radio calls.</td>
<td>· The grader operator perceived that the bulldozer operator had heard him because of the timing of change in direction. But this turned out to be a coincidence. · The lack of vision and significant noise, in the bulldozer was a significant cause of the collision. · The design of roadways and vehicle separation may have also played a role.</td>
<td>Results of Investigation reported by interviewee, but not confirmed in writing.</td>
<td>· The interviewee noted that the investigation attributed the cause of the accident to be primarily due to lack of confirmation that a radio call had been heard. · The CDM investigation found that the incident was much more complex, and continued radio calls by the interviewee was unlikely to have prevented the collision.</td>
</tr>
<tr>
<td>7</td>
<td>Engine Fire in Digger</td>
<td>· Machine was an older model with existing issues. · Operators stated that the engine was ‘surging’ during driver ‘hot seat’ change. · At this stage, a general/informal inspection was conducted for ‘something out of the ordinary’. · However, a driver would not necessarily know the specific cause for surging- it is up to the judgement of the operator to notify maintenance.</td>
<td>· Driver of equipment must informally check equipment in the field, making judgements on the seriousness of issues. This is solely based on their experience and instinct. · The communication between equipment operators can be key to identifying if smoke is abnormal and the presence of fires in their early stage. (Continued)</td>
<td>No. No I-CAM available</td>
<td></td>
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<tr>
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| 7  | Engine Fire in Digger   | · Operator continued to operate the equipment after the fire began, as it was at the rear of the machine and not visible to the driver. He was notified of smoke by a haul truck driver.  
· In this case he manually pressed the fire-suppression. Usually operators would not press the fire suppression unless they saw flames, as it was known to be costly. Newer equipment automatically sets off fire suppression on smoke/fire detection. | · The high financial cost of falsely pressing the fire suppression system does influence the operator’s decision to engage the system. | No. No I-CAM available |                                        |
| 8  | Loss of control of haul truck down a ramp | · The loss of control took place on a wet ramp in rainy conditions. The operators had been discussing the conditions, and whether they warranted ‘parking up’.  
· Loss of control took place when vehicle was unloaded it descending the ramp on approximately the 30th run of the day.  
· Usually a slip is more likely when descending unloaded, and whilst a driver may notice some issues when ascending loaded they are generally committed to an entire run once loaded.  
· The road was ‘cambered, seemingly encouraging higher speeds to the interviewee driving the truck. | · The judgement of when rain causes the roads to become dangerous is a key decision made by the team. This decision is not black and white and would have external influences, such as production pressure/competition.  
The misjudgement of safe speed, set by the auto-retarder, down a ramp was a key cause of the accident worthy of further investigation.  
The roadway design, with a ramp that included a banked corner, could have also been a cause of the accident. | No. Investigation was not conducted. Incident prior to site I-CAM use. |                                        |
| 9  | Decision Making of Maintenance when Haul Truck Engine shows Low Horse Power | · This interview regarding how a maintenance manager would typically address the issue of ‘low horse power’ on a haul truck.  
· The interview revealed that the maintenance checks followed more of a ‘trial and error’ pattern than absolute diagnosis of the problem.  
· As maintenance managers have their KPI as ‘availability’ this tends to mean that cheaper and shorter options are tested first. | · Generally the driver would be told to continue using the truck until a mobile ‘breakdown’ unit can attend. In this case the mobile breakdown unit usually checks for blow/leaking hoses.  
If this is not found the oil and air filters are replaced, even if no obvious issues are noted, as this is cheap. (Continued over page) | No. Not a specific incident. |                                        |
Table 1 continued: CDM findings for the ten coal mining incidents

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<tr>
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</table>
| 9  | Decision Making of Maintenance when Haul Truck Engine shows Low Horse Power | (Continued from previous page)                                                            | Occasionally, air filters and oil filters have been changed multiple times by alternate shifts due to poor communications.  
· It is then left to the operator to note if the problem has been 'fixed' or 'not fixed'; which is not a totally objective judgement and operators have been known to have different opinions.  
· Only when these field options have failed is the truck brought in for maintenance where cheaper options are trialled (e.g. replace injectors) before more expensive options (e.g. turbo).  
· Hierarchical expenditure approval caps reinforced this situation. For example, fitters can approve up to $2,000 of expenditure, but need to go to their supervisor for higher expenditure who is, in turn, must go higher for approval of expenditure over $4,000. | No. Not a specific incident. |                                                |
| 10 | Missing Alignment when Reversing Haul Truck to Shovel for loading | · This interview regarding the general issues with alignment of the haul truck when backing into a shovel.  
· The interviewee (a driver) was asked to describe in detail how this task is typically achieved. | · The driver used a number of 'tricks' and cues when reversing. This included using just the left mirror, past tracks of haul trucks, horn or radio from the shovel operator to correct positioning.  
· If the first truck to reverse to a particular position of the shovel lines up poorly there is a tendency for future drivers to use their tracks as a guide and repeat the mistake.  
· The reversing camera is not very useful in lining up correctly but may help the driver pick up any rocks dropped by previous drivers.  
· The glare from the sun in the side mirror, causing the driver to lose vision of the shovel for a short time, was thought to be the most common cause of lining up incorrectly. | No. Not a specific incident |                                                |
To illustrate more findings from the process, one of the incidents (‘Drove Haul Truck with Dump Tray Up striking Reject Bin Chute’) is used as the example. A flowchart of the incident is show in Figure 1 below. This shows the major stages of the event (in text boxes and the identified key decision points (as rectangles- after boxes 3, 6, 11 and 13).

For these key decision points, the decisions made were further explored. In terms of the content of this examination, examples of what the deepening probes found in Sweep 3 (but not noted in the I-CAM incident investigation) included:

- The driver had rarely previously started the truck with the tray up.
- “Idiot Balls” (large colourful balls on wires that gave an overhead warning when a vehicle was over-height) were placed around the mine, but the park up bay was past the last idiot ball
- The display for tray up was only visual.
- The display was possibly obscured/made less conspicuous by sun glare
- The driver was talking to the electrician during the drive.
- No visual feedback on tray from the driver’s position

Similarly, example findings from the “What if” inquiries (Sweep 4) that were not noted in the previous I-CAM investigation report were:

- An audible signal might have alerted the driver to the fact the tray was up.
- If the driver was not friendly with the electrician he may have noticed the tray (due to him being partially distracted by their conversation).
- If the park up bay was further from the reject bin or the road conditions were better, the driver would have reached 8km/h and set off the tray up alarm.

**DISCUSSION AND CONCLUSIONS**

The use of the CDM technique in the analysis of mining equipment incidents has shown that the knowledge elicited can provide a rich, operator-centred narrative, also it can provide valuable ‘extra’ information compared to the most frequently used incident analysis method in Australian mining (e.g. I-CAM). By focusing on the key decision points for operators, and unpicking the cues, information, goals, prior experience and related probes, the research was able to obtain a much deeper description of the incident event than the standard narratives used in much of the minerals industry today.

For example, the current investigation technique of the incident involving a road grader and a bulldozer (#6 in the results list) found that breaching procedures and not establishing radio contact between operators was the primary ‘cause’ of the accident. Therefore, a reminder to operators to follow procedures about radio contact was the sole action taken to prevent a repeat collision. However, the CDM identified that the background noise of the
bulldozer and the hearing protection worn by the operator meant that it was likely that the operator could not hear the supplied radio and positive radio contact could not be established in this situation if repeated.

Overall, four key points can be concluded from the obtained results.

1. **Mining equipment incidents are regularly complex**

The CDM revealed many of the incidents related to mining equipment to be complex in nature involving the alignment of a number of events and the failure of numerous barriers of defence, often triggered by local atypical conditions. This aligns well with the James Reason model of the dynamics of organisational accident causation (Reason, 1990 & 1997) and supports the view that CDM should be a valuable tool to add to complex incident investigation. For example, in the above-reported incident where a bulldozer struck a grader, the immediate causes of unsafe acts involved the parking of the grader and loss of situational awareness by the bulldozer operator. However, upstream the local workplace factor of the design of traffic flow on site and the organisational factor of production pressure made the unsafe acts more likely to result in an incident.

2. **CDM increases in value with incident complexity**

In general, the CDM interview process was able to establish a good understanding of the incident in most applications. In complex situations, the interview was successful not only in establishing the story of what happened, but also the critical decisions made and the operator’s sensemaking related to these decisions. With less complex events, involving simpler decisions the first two stages of the CDM were helpful in establishing the circumstances surrounding the incident. However, if the decisions made were relatively straightforward using obvious environmental cues then the deepening and ‘what if’ probes did not add significantly to the understanding of the event.

For example, the latter stages of CDM for the fire in the digger example (#7 in the results list) did not gain significant information because the cue of smoke and the action of pressing the fire suppression system was not a complex decision. In contrast, the incident where a haul truck lost control whilst descending a ramp at first appeared to be a simple case of excessive speed for the conditions. However, further probing in the CDM found the decisions were significantly more complex, such as the complex team decision on judging when wet weather makes conditions too dangerous.

3. **CDM uncovers important details not in site investigation reports**

Upon reviewing the incidents it was obvious to researchers that the CDM interviews often identified information not contained in the I-CAM report. For example, in the incident where an overhead chute was impacted by a haul truck with the tray in the upright position (#4 in the results list), large colourful balls on wires (‘idiot balls’) were set below the height of the chute were located surrounding the area. These serve as height indicators for drivers, similar to chains on low bridges or entering suburban car parks. They would have usually been contacted before the chute if a tray was in the upright position. However, a designated park up position for the haul truck was located past these balls. In this park up location the operator raised the tray for a maintenance task and either forgot to lower it or did not notice that it had failed to lower before driving towards the reject bin. The location of the park-up bay and the idiot balls were not included in the incident investigation. Therefore, the provisional conclusion is that using the CDM method could assist in the data gathering for I-CAM style investigations by asking more probing questions and building a rich incident narrative. However, as a note of caution, the fidelity of the original I-CAMs is unknown, so the gaps revealed might be in part due to not fully comprehensive I-CAM investigations.

4. **Site culture and hindsight needed to be managed**

During a number of interviews it appeared
that a site culture affected the interviewee’s perspective of the incidents. Specifically, the interviewees generally appeared reluctant to consider the influence of a system and more likely to blame the actions of people, including their own. They were often heard to use phrases like ‘I should have’ or ‘he should have’ and drift into generalisations about what was required by a specified procedure.

In one case the participant noted that he and another participant shared the blame for a collision by not establishing positive radio contact when, in fact, it is likely that the radio system was unusable in the situation. This reflects Dekker’s ‘Bad Apple Theory’ of human error where failures are introduced into a system due to unreliable persons and corrected by tightening procedures (Dekker, 2006). Therefore, occasionally it was difficult to get employees to investigate alternatives as they tended to use phrases like ‘that would never happen’. This was especially where investigations had already been undertaken and the findings had been widely disseminated.

RECOMMENDATIONS FOR FUTURE RESEARCH

Overall, by focusing on decision making in real mining environments, it is contended that this research successfully modified and applied the CDM technique to this domain, and further work to now integrate it into incident investigation processes is strongly recommended. Additionally, the potential to apply CDM proactively is an attractive topic for future research. In this vein, work is being completed with an underground gold mine by the authors to test the technique’s use when introducing new equipment (such as collision detection systems) to proactively risk assess their benefits and possible drawbacks from an operator-centred perspective.

ACKNOWLEDGEMENTS

The work contained in this paper was undertaken as part of a research contract (C18025) with the Australian Coal Association Research Program (ACARP). The ACARP industry monitor and the mine sites who participated in this work are thanked.

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Frequency, incidence, observed risk and outcome performance in OHS

STEPHEN ALTREE-WILLIAMS

ABSTRACT
Of the two parameters used to document case rates in the national OHS statistics, it is frequency rate (rather than incidence rate) that directly equates to the quantitative injury (safety) risk model in which injury (safety) cases are characterised as discrete events occurring randomly in the continuum of work-time.

Incidence rate is the preferred rate measure for disease (health) cases because such outcomes are influenced by both the individual’s occupational exposure profile and their endogenous, societal and non-work exposure characteristics.

It is established that the incidence rate parameter may show significant bias (i.e. systematic error) as a measure of disease (health) observed risk and outcome performance because it is independently influenced by the average duty cycle of employees (as well as by risk). Benchmarking the incidence rate parameter eliminates this bias and provides a more accurate measure of observed risk and outcome performance. Importantly, this understanding reduces the OHS outcome data requirement to two variables: cohort case numbers (separated by injury case and disease case) and total cohort work-hours.

The natural characteristics of observed risk and outcome performance in relation to OHS are presented with clarifying examples. The distinction between absolute and relative outcome performance is discussed. The value of these concepts (and their quantitative documentation through appropriate frequency and incidence rates) to the continuing challenge to improve OHS performance is emphasised.

INTRODUCTION
From the beginning of the post-Robens era in Australia, the need for adequate occupational injury and disease case rate data was recognised (SIA, 1984). The scheme to collect such OHS outcome data was implemented by the new National OHS Commission after due consultation with jurisdictions, business, unions and the OHS professional associations. Under this scheme, each serious OHS case (NOHSC, 2004) was registered as a discrete event at the individual workplace and, in accord with compulsory workers’ compensation laws and the defined National Data Set (NOHSC, 1987), relevant case information was submitted for analysis and collectively published in an effort to fulfil the key technical needs (Foley, 1997).

National case number data together with frequency and incidence rate estimates were published on an ad hoc basis for 1986-87 (NOHSC, 1993) and onwards, with data for 1991-92 being the first based on the National Data Set. Australian OHS outcome statistics are now available through the NOSI statistical database (Safe Work Australia, 2010a) and the current series of annual publications that provide outcome data by jurisdiction (WRMC, 2010) and by industry/occupation (Safe Work Australia, 2010b). The NOSI database is a particularly valuable resource because it documents the submitted OHS case numbers by
a wide range of industry, occupation and occurrence sub-classifications.

This data collection scheme has been successful in producing an overall picture of Australia’s OHS outcome performance (Safe Work Australia, 2010a,b; WRMC, 2010). The data show a substantial rate of fatality and serious OHS case generation, with the latter having steadily decreased by jurisdiction, by industry division (ABS/SNZ, 1993) and by occupation major group (ABS, 1997) over the two decades of data collection. Consistently different rates of serious OHS case generation (within the general trend of improvement) have been documented between industry divisions and also between occupation major groups.

**FREQUENCY AND INCIDENCE**

Interestingly, both frequency and incidence are used to measure the observed ‘OHS case’ rate in the Australian national OHS statistics. The frequency and incidence parameters are numerical properties of the work environment under study (expressed in terms of the rate of case generation). Frequency rate documents cases per million work-hours while incidence rate records cases per thousand employees and are defined as follows,

\[
\text{Annual OHS case frequency rate} = \frac{\text{number of new OHS cases in the cohort for the fiscal year}}{\text{workhours completed by the cohort during that year}} \times 1000000
\]

\[
\text{Annual OHS case incidence rate} = \frac{\text{number of new OHS cases in the cohort for the fiscal year}}{\text{number of employees in the cohort during that year}} \times 1000
\]

Such a practice of using two parameters to provide a value for a numerical property of a population is rather unusual. Each parameter gives a different value for the case rate, not surprisingly because the frequency measure assesses cases per unit work-time while the incidence measure assesses cases per unit employee. But why use both parameters? And, perplexingly, why does each parameter document a different percentage change in national OHS outcome performance through time? (Safe Work Australia, 2010b, pages 20, 23)

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.

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 2010c).

Occupational safety professionals have always preferred the frequency parameter (Standards Australia, 1976), fundamentally because it directly equates with the injury (safety) risk model where occupational injury cases are characterised as discrete events occurring randomly in the continuum of work-time. Once control over a gross energy source is lost, any person unfortunate enough to be exposed will be injured as a result of that single traumatic event (Wigglesworth, 1972).

Occupational medicine and para-medical professionals have always preferred the incidence parameter because occupational disease outcomes result from the cumulative effect on the individual person of repeated or long-term exposure to an environmental factor in the workplace as mediated by the non-work endogenous, societal and exposure characteristics specific to that person (AIHW, 2010). Safe Work Australia (2010c) uses incidence rate exclusively in its Occupational Disease Indicators publication and notes that the ‘non-work’ influences “lead to considerable under-reporting of occupational diseases through the workers’ compensation system”. This observation, of course, is another reason for the separation of injury (safety) cases and disease (health) cases in the assessment.
Frequency, incidence, observed risk and outcome performance in OHS

of risk and performance because the former are free of this bias.

INCIDENCE RATE BIAS
The incidence parameter itself can also be a source of significant bias (i.e. systematic error) in the assessment of observed risk and outcome performance, as Wooden and Tulsi (1989), Foley (1997) and the National Data Set (ASCC, 2008; page 15) have noted. The extent of the bias is determined by the average work-hours of the employees in the cohort. A simple example will illustrate this point. Agricultural workers may put in 60-hour weeks or the 60 work-hours/week may be covered by part-time workers each doing 12-hours a week. The case frequency rate (like the work environment observed risk and outcome performance) will be the same under both regimes but the incidence rate in the former situation will be five times that of the latter. Thus, incidence rate can be a biased measure of work environment observed risk and outcome performance - it will exaggerate the observed risk when employees do significant ‘overtime’; it will underestimate the observed risk when the cohort has a significant part-time worker component.

Note that if the ‘employees’ measure used in the incidence rate equation is ‘full-time equivalent (FTE) employees’, then this bias disappears and the two parameters become directly proportional. For example, where FTE is defined as a 35-hour workweek with four total workweeks of absence per year,

\[ \text{incidence rate} = 1.7 \times \text{frequency rate} \]

This issue of bias inherent in the incidence rate parameter is illustrated in Table 1, where incidence and frequency data for the same cohort in current national statistics (WRMC, 2010; Safe Work Australia, 2010b) are expressed as a ratio.

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>Industry</th>
<th>Occupation</th>
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</thead>
<tbody>
<tr>
<td>NSW</td>
<td>1.7</td>
<td>1.9</td>
</tr>
<tr>
<td>Vic</td>
<td>1.65</td>
<td>2.3</td>
</tr>
<tr>
<td>Qld</td>
<td>1.65</td>
<td>1.95</td>
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<tr>
<td>SA</td>
<td>1.65</td>
<td>1.95</td>
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<tr>
<td>WA</td>
<td>1.7</td>
<td>2.05</td>
</tr>
<tr>
<td>Tas</td>
<td>1.6</td>
<td>1.95</td>
</tr>
<tr>
<td>NT</td>
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<td>1.35</td>
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<tr>
<td>ACT</td>
<td>1.65</td>
<td>1.35</td>
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<td>1.95</td>
</tr>
<tr>
<td>Australia</td>
<td>1.7</td>
<td>1.8</td>
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</table>

Table 1 OHS case incidence rate/frequency rate ratio for 2006-07 national data, Australia, for cohorts by jurisdiction (WRMC, 2010), by industry and by occupation (Safe Work Australia, 2010b)

The data in Fig. 1 show that for 2006-07 all state, territory and national jurisdictions had an incidence rate/frequency rate ratio that is close to the ‘35-hour workweek’ value of 1.7. This is not unexpected given the Australian context and the size and diversity of the economy of each jurisdiction. It is noted, in passing, that Northern Territory had the lowest fraction of part-time workers of all the jurisdictions for 2006-07 (ABS, 2007).

Data are also available for 2006-07 of the actual average weekly hours worked by all employees (both full-time and part-time) in
An understanding of the expected form of the scatter plots in Figure 1 can be developed as follows. From the frequency rate and incidence rate equations above, it follows that,

\[
\frac{\text{incidence rate}}{\text{frequency rate}} = \frac{\text{annual total workhours}}{\text{no of employees} \times 1000}
\]

It is noted,

\[
\text{annual total workhours} = \frac{\text{no of employees} \times \text{no of weeks worked per year} \times \text{average weekly hours worked}}{1000}
\]

so,

\[
\frac{\text{incidence rate}}{\text{frequency rate}} = \frac{\text{no of weeks worked per year} \times \text{average weekly hours worked}}{1000}
\]

which, for a cohort with a total of four weeks a year absence from work, transforms to

\[
\text{average weekly hours worked} = \frac{1000}{48} \times \frac{\text{incidence rate}}{\text{frequency rate}}
\]

and thus, the expected general form of the scatter plots in Figure 1 would be a straight line extending through the origin with slope \(1000/48 = 21\).

These observations provide strong evidence that the ‘employee’ measure used in the Australian national OHS data represents actual numbers of persons employed (be that work overtime, full-time or part-time) rather than ‘full-time equivalent’ corrected data.

However, as already noted, there is a broader perspective on the use of incidence rate. The risk of an ‘occupational’ disease outcome for an individual may not be determined solely by their work environment risk but can also be influenced by non-workplace factors associated with the person’s endogenous, societal and non-work exposure characteristics (AIHW, 2010). Thus, for matters pertaining to occupational disease, it is important to track persons (i.e. ‘employees’) rather than ‘work-hours’ and so it is appropriate that incidence be used as the rate measure for the occupational disease(health) domain. This point is reinforced by the observation (Safe Work Australia, 2010c) that the non-work influences on an individual tend to encourage the sufferer’s participation in the public health system and, hence, produce an under-reporting bias in occupational disease case numbers in the national OHS statistics.

**BENCHMARKED INCIDENCE RATE**

As noted, this inherent bias (i.e. systematic error) in the incidence rate parameter (depending on the duty cycle of the employees in the cohort being observed) can be eliminated by using ‘full-time equivalent, FTE, employees’ for the ‘employees’ measure in the incident rate equation.

An alternative approach can also be used. If a ‘benchmark’ definition is given to ‘full-time equivalent’, the unbiased incidence rate can be calculated directly from the frequency rate amplified by the appropriate constant of proportionality. As has been noted, frequency rate and incidence rate are related as follows,
which, for a cohort of full time equivalent (FTE) employees working a ‘benchmark’ 35-hours per week with a total of four weeks a year absence from work, becomes

\[
\text{incidence rate} = \frac{\text{no weeks worked per year} \times \frac{\text{average weekly hours worked}}{1000}}{x \text{ frequency rate}}
\]

\[
\text{incidence rate} \ [\text{BM}] = \frac{48 \times 35}{1000} \times \text{ frequency rate}
\]

\[
\text{incidence rate} \ [\text{BM}] = 1.680 \times \text{ frequency rate}
\]

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

This alternative approach of using incidence rate [BM] eliminates the incidence rate ‘duty cycle’ bias and, importantly, it also gives a more accurate measure of observed risk and outcome performance. Benchmarking is the only way the use of incidence rate will provide a rational performance comparison between different workplaces (or different years) with potentially different worker duty-cycles. A simple point; but fundamental if progress is to be made in quantitative outcome performance assessment.

The incidence rate [BM] approach also provides another important practical advantage. Only two variables now need to be collected to obtain frequency rate and incidence rate: cohort case numbers (separated by injury cases and disease cases) and total cohort work-hours.

Intuitively, cases and work-hours has always seemed to be the way the work environment risk should be. The consideration of the natural characteristics of frequency and incidence now shows that, indeed, this is the way it is.

**OBSERVED RISK AND OUTCOME PERFORMANCE**

Frequency rate or incidence rate documents the observed risk for a cohort over a defined period of time, generally over one year. For the reasons mentioned in this paper and discussed more fully elsewhere (Altree-Williams, 2010), it is important to document specific observed risk data for each of the natural domains of occupational injury(safety) and occupational disease(health).

Observed risk for occupational disease (health) cases is proportional to exposure. If the workplace chooses to reduce risk using the control strategy of reducing the duty cycle (and exposure) of each employee by increasing employee numbers - as, for example, is done for some radiation or lead environments - then the incidence rate [BM] will directly reflect this reduction in risk via a reduction in the observed case numbers for the cohort. In contrast, the non-benchmarked incidence rate will show a large erroneous decrease in ‘risk’ via the increase in non-benchmarked employee numbers that is then used in the incidence rate equation. If in doubt, ponder the agriculture worker regimes illustration already provided.

The significant improvement in the accuracy of the observed risk for a work environment that comes with the use of incidence rate [BM] is illustrated in Table 2. The table documents, for occupational disease (health) domain cases, both the non-benchmarked incidence rate results (Safe Work Australia, 2010b) and the incidence rate [BM] results (calculated directly from the published frequency rates in Safe Work Australia, 2010b) for the two major cohorts in the Australian workforce that exhibit the greatest incidence rate bias – the mining industry and the occupation of elementary clerical, sales and service worker. The results given in Table 2, for the five years 2002-03 to 2006-07, indicate that the effect of the incident rate bias has been to over-estimate the observed disease (health) domain risk for the mining industry by around 37% and to underestimate this risk for the elementary clerical, sales and service worker occupation by around 32%.

The incident rate bias would have a similar, but inverse, effect on absolute outcome performance assessment. In absolute terms, the rate of serious occupational disease (health) case generation in the elementary clerical, sales and service worker occupation is now observed to be surprisingly close to the rate of generation.
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Table 2 Comparison of non-benchmarked incidence rate (Safe Work Australia 2010b) and incidence rate [bm] for occupational disease(health) domain cases: mining industry and elementary clerical, sales and service worker occupation, Australia, 2002-03 to 2006-07.

<table>
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<th></th>
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</thead>
<tbody>
<tr>
<td>Mining industry</td>
<td>14.7</td>
<td>13.65</td>
<td>12.3</td>
<td>9.5</td>
<td>10.0</td>
</tr>
<tr>
<td>Incidence rate [bm]</td>
<td>10.5</td>
<td>9.95</td>
<td>8.95</td>
<td>7.05</td>
<td>7.3</td>
</tr>
<tr>
<td>Elementary clerical, sales and service worker occupation</td>
<td>5.85</td>
<td>5.9</td>
<td>5.9</td>
<td>5.1</td>
<td>5.1</td>
</tr>
<tr>
<td>Incidence rate [bm]</td>
<td>8.45</td>
<td>8.7</td>
<td>8.5</td>
<td>7.45</td>
<td>7.55</td>
</tr>
</tbody>
</table>

Note: Case numbers for the occupational disease(health) domain cases, as defined in Table 1, were obtained from the NOSI database (Safe Work Australia, 2010a) using the Mechanism of Incident major group and sub-group.

of such cases in the mining industry.

For relative outcome performance assessment for a particular cohort (i.e. the %change in observed rates for the cohort through time) both processes give effectively the same result; presumably because the employee duty cycle in each cohort remained reasonably constant through these five years. Incidence rate [BM] documents an outcome performance improvement for the occupational disease(health) domain over the five years for the mining industry of 30% (compared to non-benchmarked incidence rate improvement of 32%) and for the elementary clerical, sales and service worker occupation of 11% (compared to non-benchmarked incidence rate improvement of 13%).

The question of performance, of course, has a number of dimensions. Case rates provide a direct measure of observed risk and are an important element in outcome performance. There are at least two other performance measures that also need to be more fully developed and more effectively applied to the challenge of improving OHS performance, defined, observable, ‘reasonably practicable’ regime from the OHS legislation relevant to the cohort.

CONCLUSION

The challenge to substantially improve OHS performance still confronts the Australian community. The tripartite commitment brings the cooperative resources of government, business and unions to this important endeavour.

This potential for effective prevention action will be enhanced by the availability of both national and local workplace OHS statistics that document outcomes in ways that match the natural characteristics of frequency, incidence, observed risk and outcome performance considered in this paper.

From this perspective, it is concluded that the following practices should be used in the documentation of OHS outcome data:

a) Separate documentation (case numbers and rates) is used for occupational injury cases and for occupational disease cases.

b) The frequency rate parameter is used for occupational injury cases only and as the measure for occupational injury (safety) observed risk and absolute outcome performance.

Relative occupational injury (safety) performance for a cohort is assessed by the %change in the frequency rate parameter for the cohort through time.

c) The incidence rate [BM] parameter
is used for occupational disease cases only and as the measure for occupational disease (health) observed risk and absolute outcome performance. Relative occupational disease (health) performance for a cohort is assessed by the % change in the incidence rate [BM] parameter for the cohort through time.

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